The influence of self-relevant information on attention and memory

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Abstract

Attention and memory can increase the saliency of information in accordance with task goals (Driver, 2001; Pashler & Sutherland, 1998; Reinecke, Rinck, & Becker, 2006; Vuilleumier, 2005). Self-relevance of stimulus materials may be an important factor, both in attention and memory. However, there is, as yet, no clear consensus on the mechanisms underlying this. For example, it is unclear if the benefit of self-relevance on attention and memory is because of positive emotional value linked to the self or if self-relevance and emotion are two separate processes. This thesis independently assessed the contributions of self and emotional processing on attention and memory.

The experiments use a modified version of a paradigm developed by Sui, He and Humphries (2012). These experiments arbitrarily assigned visual information as being self-related or not self-related. Furthermore, the emotional valence of these stimuli is also varied. The studies explored whether the emotionality and self-relevance influence memory for the presented materials and whether they do so independently or interactively. The studies explored the effects of emotional self-relevance on attention and memory using a combination of behavioural and neurophysiological methods. The findings of this thesis support previous research on the benefits of self-relevance, on both attention (Sui, He, & Humphreys, 2012; Sui, Sun, Peng, & Humphreys, 2014; Wang, Humphreys, & Sui, 2016) and memory (M. A. Conway & Dewhurst, 1995; Kelley et al., 2002; Klein & Kihlstrom, 1986). The results also showed that emotion has similar effects on attention and memory as self-relevance does.

This thesis has shown that the underlying processes of self and emotion are distinct (*Experiment 1)*. However, this thesis has also shown in a novel way that emotional self-relevant information is processed more efficiently than either emotion or self-

relatedness alone (*Experiment 2)*. In other words, self-relevance and emotion can interact and together increase the saliency of emotional self-related memories (*Experiment 6)*. The results also revealed that, though self-related information is processed faster and more efficiently, this was only in terms of the faster rate of learning for self-related information compared to other-related information. When given enough repetitions, non-self-related information can achieve a similar level of memorability, given sufficient exposure (*Experiment 3*, and *Experiment 4)*. Nonetheless, the richer information linked to self-related events means that all things being equal, such information will tend to produce more stable memories over time (*Experiment 5)*, which results in faster forgetting of other-related information compared to self-relevant information.

These findings are further supported by the Electroencephalogram (EEG) research of this thesis. In particular, early N100 responses were found to be enhanced for self-related items during the matching task. In memory, the late positive parietal components linked to recollection were more enhanced for self-related information also. Overall, the EEG results support the suggestion that self-related information has attentional priority and, consequently, is encoded into memory more efficiently than other-related information.

Fundamentally, this thesis has shown that attention prioritises self-relevant information over information unrelated to the self. Moreover, it showed that self-relevance interacts with emotion, and in doing so ensures enriched and therefore, more salient memories. This thesis is the first to show that prioritised (emotional) self-relevant information is recalled more often as well, when compared to information unrelated to the self. The importance of this interaction between emotion and self-relevance is discussed in terms of potential broader clinical benefits for people suffering from memory impairments.

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Review of Self & Emotion

"For whatever we lose (like a you or a me)
it's always ourselves we find in the sea." (E. E. Cummings, 1958).

Aims of the Thesis

The above quote from 'Maggie and Milly and Molly and May' by E. E. Cummings (1958) is a light-hearted poem reflecting on how our identity shapes what we see. The author of this thesis takes the more literal meaning: no matter what we do, we always look for things relevant to ourselves and our goals. The question of how people process information relevant to ourselves; how it affects attention and memory, is the core subject of this thesis.

The work in this thesis takes a *neurocognitive* approach. The core question concerns the sensory input from our surroundings and how this information is attended to and later retrieved from memory. Information in our environment is rarely of equal importance to us. Depending on the context, certain types of information will often stand out (i.e. is more salient to us) whereas other information is less distinct. Many factors influence the saliency of perceived information.

For instance, physically contrasting stimuli will stand out from other stimuli. An example of this would be a red letter amongst black letters, like the red letter T in this sentence (Treisman & Gelade, 1980; Wolfe, 1994). Also, some information is directly relevant because it is potentially rewarding (Libera & Chelazzi, 2006; Seitz, Kim, & Watanabe, 2009), more threatening (Mathews & MacLeod, 1994), or merely novel or unexpected (Posner, Snyder, & Davidson, 1980). As could be gleaned from the first paragraph, events and things related to the self are one way to potentially increase the saliency of information. Furthermore, perceived information is rarely devoid of emotion, and as will be explained later, emotion too can increase the saliency of perceived information. For this reason, this thesis will examine the relationship between self-related processing and emotion.

The principal aim of this thesis is to investigate *the influence of emotional self-relevant information on attention and memory processes*. This thesis uses a cognitive (neuro) scientific approach involving analysis of behavioural and EEG data. This data is derived from a series of experiments that manipulate the self-relevance and emotional content of presented stimuli.

The next few paragraphs will first try to operationally define what is meant by 'self' and 'emotion', in how they are used in the context of this thesis. In order to turn these concepts into measurable and easily manipulable entities, it is necessary to give a rather narrower definition of these terms than how they might be thought of in every day vernacular speech. This chapter will then review relevant literature on the influence of self and emotion on attention and memory. Finally, this chapter will state the research questions of this thesis, and provide an overview of how the subsequent chapters will address these research goals.

Self-relevant information

Self-relevant information is the crucial concept of this thesis. It refers to information vital to one's identity (e.g. one's face, or name) as opposed to information not relevant or inessential to one's sense of self (e.g. a stranger's face, someone else's name). However, this is an inadequate definition. It largely defines the concept in terms of what it is not, rather than what it is. To get a proper definition of self-relevance we first need to tackle the question of what is meant by 'self'. This is arguably one of the slipperiest and most abstract terms in Psychology, yet at the same time the sense of self is something which is part of everyday experience. Therefore, this section will explain how cognitive psychology has tried to define the notion of self and how this thesis specifically considers the notion of self and its arguable different manifestations.

Cognitive psychology has often tried to define the 'self' in terms of the sense of ownership or self-as-object (Brown, 2014; James, 1890; Kim & Johnson, 2010; Northoff, 2011; Sui & Gu, 2018). This thesis follows in this tradition.

To define 'self' in this way concurs several advantages. It is something which is easily both measured (by asking people if they view something belongs to them) and experimentally manipulated (by telling people that something belongs to you). This is also a very ubiquitous definition: Every person will have experienced a sense of ownership over something, one which is not shared with others. 'Other' in this case can be convenient defined as being everything that is neither the self nor part of the self and is the opposite of the self. The notion of 'other' provides a natural comparison condition from which to judge the effects of self in cognitive processing.

It should be noted that this operational definition avoids any kind of theoretical claim about what the self is. Before we turn to this in detail the discussion here will first give a flavour of the complex and different ways in which 'self' has been characterised in Psychology. Two distinct ways the 'self' has been described are the 'self as identity'; and the 'self as an object'. Indeed, this division led James (1890) to suggest the use of 'I' and 'me' as labels which differentiate between the two elements. Evidence suggests that this distinction between 'I' and 'me' is not just a mere linguistic one, but a distinction between two 'types' of self. Brown (2014) provided the example of the statement: "I see me". Here, the 'I' is part of your identity, an awareness that you see something. The 'me' in this context is that which is seen as an object of your attention. It illustrates the self as our awareness that we exist separately from others, and capable of our own will ('I'), and the self as an object in our attention and memory ('me'). However, the way the self as an object is studied in psychology wildly differs and a further operationalisation of the concept is needed.

When a person is talking about themselves, they talk about their 'me'. For example, you can recount what you have been doing today and how you are feeling. Recounting your day or feelings would not only require an awareness that you exist separately from others ("I"), but you would need to be able to see yourself as an object ("me") in order to describe what happened to you. Furthermore, if someone asked who you are, you would be able to describe yourself using traits and characteristics you believe comprise your identity. James (1890) made a distinction between several types of selves that make up the 'me': *the social self; the material self; and the spiritual self.* These three concepts will be briefly explained below.

The social self is a perspective of self in terms of how others identify us. It is argued that it is the social self which is the driving force which leads to specific behaviours of what is socially acceptable. The social self tends to involve an individual in relation to other things or people. For instance it can be the "me" as a father or mother, as a student, a friend, as a member of group or even a nation. With each social identity, it is argued, comes a different self (Hornsey, 2008). For example, the way people behave is different when they are just a friend, compared to when they are a father[1].

The material self is often expressed using the pronoun ' mine' or 'my' and focusses on the body or the extended self (Rosenberg, 1979). For example, people talk about "my body", or "my house". Brown (2014) makes an interesting point in highlighting James' (1890) work on how possessions can become a part of the self and are incorporated into the self. Often the value of an item is not its intrinsic worth but how important it is to its owner.

[1] Social self or social identities is attempted to be explained by Social Identity Theory (SIT, Turner & Oakes, 1986). The main tenet of SIT is that there are multiple selves that influence behaviour. The social identity is derived from a group or groups a person identifies with. A complete review of SIT is beyond the scope of this thesis. See Rupert Brown, (2000) for an extensive of SIT.

The material self is argued to be linked closely to the notion of a *spiritual self*. This latter concept is the total sum of everything we view as being "my" or "mine", without it being a physical entity or social identity. In other words, the spiritual me are the things we think about ourselves, how we feel, and what we think we can do. For example, people talk about "my" skills, feelings, interests, motives, traits, opinions, and so forth. Brown (2014) refers to these spiritual selves as personal identities.

It is generally viewed that these distinct types of 'selves' do not exist in isolation but together form a single coherent self. This is reflected by the narrative self (Gallagher, 2000; McAdams, 1996). The narrative self is considered to be a natural consequence of being a fairly intelligent user of language. Language is a fundamental part of who we are. Through language, we can connect all our experiences and thoughts over time. In doing so, it is argued, we create our sense of self. Episodic memory (discussed in more detail later) is vital to create this narrative self. With episodic memory, we remember events that happened to ourselves and use the different 'stories' to form one coherent (possibly partly fictional) narrative of the self (Gallagher, 2000). The narrative self explains how the self is defined by merging our spiritual, social and material selves into one entity. However, the narrative self is almost a side-effect from the interaction between our general language skills and our episodic memory. Moreover, in episodic memory events related to the self are already conveniently stored for us to create our narratives. How then is it first determined when something is self-related? Potentially this means that a more simple or primitive form of self must exist also.

This 'primitive' form of the self is referred to as the minimal self and is not concerned with self-reflection or storytelling such as elaborate narratives. The minimal self is closely associated with the material self. It differs in being more focussed with the here and now and is not concerned with time or conscious awareness. The minimal self is the immediate sense of self that is not just the domain of intelligent life (Gallagher, 2000). With the minimal self, an individual can know if they are responsible for the sensory consequence of an action ('I moved my arm') or if the sensory consequence is initiated by someone, or something, else. This is called the *sense of agency* (Blakemore, Wolpert, & Frith, 2000). Knowing that it is your arm that moves is a sense of ownership (material self), which is achieved via a comparison of a predicted state with an intended state, allowing attenuation of self-generated sensory signals.

In healthy individuals, the difference between agency/ownership and the minimal self would probably be negligible (Gallagher, 2000). However, the two things can dissociate under some circumstances. If observers misattribute agency and ownership then the process can go wrong. This can lead to unusual perceptions. For instance a person might still claim that his arm is moving but he is not doing the moving (loss of the sense of agency), or a person might claim that he is moving the arm but that it is not his arm (Spence et al., 1997). This dissociation shows that it is possible to disrupt the process of forming a 'me' and that a minimal self does not require an elaborate narrative.

The type of self that is of most interest to this thesis, is the primitive minimal self. However, how the minimal self and the narrative self are connected is by-and-large an open question in the existing literature. However, Sui and Humphreys (2015b) see the self as a 'hub' that binds together different pieces of information from different sources and modalities. In this way, the 'integrative self' of Sui and Humphreys might be ideally placed to connect the primal minimal self with the self-reflecting qualities of the narrative self. This is precisely what a recent paper by Sui and Gu (2018) suggested. The authors propose a neural framework of the self as an object, built on the idea of an integrative self. This neural network of the self will be explained in more detail later in this chapter. Briefly put, the neural network on processing the self as an object consists of three major components: a core self-system involved in internal self-related information processing and other-related judgements; a cognitive control system related to processing external information; and a salience node which is related to the processing of emotional and reward stimuli. These three nodes are interconnected and together process information related to the self.

To summarise, the self as studied in this thesis will reflect processes associated with the 'minimal self'. As will become apparent in the paragraphs on attention and memory, the minimal self can be studied by linking stimuli to inherently self-related items. Examples of these are one's face or name, or by linking items to the self via instructions or making self-judgements (e.g. by telling the participants they own the items). The aim is to compare the influence of self-related items with the influence of items not related to the self (e.g. the memorability of self- versus other-related items).

A second key concept in this thesis to be operationalised is emotion. The next section introduces the notion of emotion from a Psychological perspective, and how it is considered in this thesis. The main reason for including emotion as a topic of study is that previous research has attempted to explain self-relevant information processing as an emotional process (Brédart, Delchambre, & Laureys, 2006; McNeill, 2000). Information relevant to the self is rarely without emotion in natural settings. However, research has shown that emotion and self are two separate processes, which will be illustrated later. The experiments described here aim to further examine the role between emotion and the self in attentional and mnemonic processing, albeit with the self as the main topic of interest. Emotion will be briefly explained and operationally defined in the next subsection.

Emotion and Emotional information

Emotion is either a temporary state elicited by a specific event or thought which is temporary or emotion is a trait which is long lasting and can describe an individual's tendency or nature (Cattell & Scheier, 1961; Izard, 2013). This thesis considers emotions temporary states that can last for a few moments and are not traits in the sense that it defines an individual. Furthermore, there is a distinction between positive and negative emotions.[2] Research describes positive or negative emotions in terms of positive or

[2] Traditionally it is argued there are six basic emotions that people can recognise: surprise; happiness; sadness; fear; disgust; and anger (Ekman & Friesen, 1975). These six basic emotions were identified in two literature reviews on emotion (Ekman & Friesen, 1975; Fridlund, Ekman, & Oster, 1987), which focussed on identifying separate emotional facial expressions. These reviews found that regardless of culture, there is an agreement across observers that these emotions are reflected in distinct facial expressions.

negative 'valance'. Of course, emotions do not just vary in valence. For instance, emotions also differ in intensity, a component of emotion referred to as 'arousal' (Kensinger & Corkin, 2004). The emotional strength of a stimulus can vary per individual and situation but can be always be described in terms of valence and arousal. Furthermore, depending on the valence (either positive or negative), the same emotional information can affect people differently (Chen & Bargh, 1999).

For example, in their experiment Chen and Bargh (1999) asked participants to classify emotional words as quickly as possible by pulling a lever backwards (towards themselves) for perceived positive words and a push the lever forward (away from themselves) if the participants believed the word was negative. For half of the participants these instructions were reversed. The results showed that participants were affected differently by positive versus negative emotions. Pulling the lever backwards towards oneself was facilitated for positive words compared to pulling the lever backwards for negative words. Similarly, participants were faster in pushing the lever away from themselves with negative words when compared to positive words. Chen and Bargh (1999) concluded that positive and negative words let to automatic approach and withdrawal behaviour respectively. This does not imply that that positive emotion is more salient to the self. Generally, negative stimuli are more important than positive stimuli when considering a pure evolutionary perspective. Naturally, potential harmful stimuli are very salient especially when if they can be potentially threatening or/and are goal relevant. Furthermore, the strength or arousal of the emotion is more determining in directing our behaviour than valance alone (Mather & Sutherland, 2011). Emotional information is relatively quickly processed (roughly between 200 – 300ms with emotional words Kissler, Herbert, Peyk, & Junghofer (2007)) and evaluated on how self-relevant the emotional stimulus is (Sander, Grandjean, & Scherer, 2005). When information is more easily linked to the self, then positive emotion is likely to be favoured over negative information (Herbert, Junghofer, & Kissler, 2008; Herbert, Kissler, Junghöfer, Peyk, &

Nonetheless, there is no complete consensus on the basicness of emotions (See reviews: Kreibig, 2010; Scarantino & Griffiths, 2011). However, this debate, is beyond the scope of this thesis.

Rockstroh, 2006). This is possibly because positive information is more in line with one's self-image or how an individual would describe themselves when compared to negative information (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Mezulis, Abramson, Hyde, & Hankin, 2004; Taylor, 1991). However, negative information remains salient and can still be favoured over positive information when positive and negative information are equally related to the self (Herbert, Pauli, & Herbert, 2010). This link between emotions and self-related information will be discussed in more detail later in this chapter.

In short, in this thesis the emotional valence of presented stimuli will be used to explore the effect on attention and subsequent memory of these stimuli. The stimuli used in this thesis are words (nouns or traits) that have a positive or negative valence with high arousal levels to maximise the influence of each emotion. This will allow a comparison of positive or negative valence words with neutral stimuli, which are stimuli that fall between positive and negative valence and have low arousal levels.

The next part of this chapter will review existing relevant research on emotion and the self. As will be discussed in the subsequent two sections, emotional and self-related information can attract attention and influence memory. However, depending on the situation, the influence of emotion and self-relatedness might not be beneficial per se (Levine & Pizarro, 2004; Mather & Sutherland, 2011). Because of the importance of the concept of attention to this thesis, the next section will explore this concept. This is followed by linking self-relevant information processing to attention and how emotion can impact this process. After the section on attention, the subsequent section explains how (emotional) self-relevant information impacts memory.

Attention

Humans perceive their surroundings using their senses. However, in most cases there is too much information coming from the different sensory apparatus of the brain for the brain to process all at once. For example, in an experiment using guinea pigs and naturalistic images, researchers found that the amount of visual information sent by the retina is estimated to be around 875,000 bits per second (Koch et al., 2006), which when translated to humans roughly equals 10 million bits per second. Consequently, the brain needs to be selective in processing only a subset of the information that the senses are receiving (Neisser, 1976; Vuilleumier, 2005). In cognitive psychology, this process of selectivity is referred to as *attention*[3] (Sperling, 1960; Von Wright, 1968). One phenomenon which attests to the selectivity of attention is *inattentional blindness* (Mack & Rock, 1998). The inattentional blindness paradigm presents observers with an unexpected stimulus under conditions in which they are performing a difficult visual tracking task. The primary finding is that when required to perform the tracking task, observers typically fail to consciously register the unexpected object that would otherwise to be easily perceived.

One of the most ubiquitous examples of inattentional blindness is the 'invisible gorilla' experiment (Simons & Chabris, 1999). In its typical setup participants look at a video of individuals from two distinct groups passing a ball around. The participants are told to count the number of times a player from a specific team (identified by wearing white or black shirts) passes the ball. However, at some point a man in a gorilla suit walks through the scene. Interestingly, 50% of the participants do not report seeing a gorilla, those tracking the players wearing white shirts are least likely to see it. As the gorilla is unexpected and not relevant to one's current goal, people tend not to consciously perceive the gorilla. In other words, since the participants' attention was fixed on counting the number of passes, events outside their focus of attention did not get detected, despite being very obvious. Those observers tracking the white shirts seem particularly to miss the gorilla because they are selectively prioritising things on screen which are a different colour to the gorilla. Therefore, attention is one way to select a subset from a wealth of information available to an individual, and information that is not attended to is less likely to be noticed. Directing our attention depends on the saliency of information. Briefly put, this selection of information by the brain is determined by the inherent

[3] An extensive review of attention is beyond the scope of this thesis. Please refer to the reviews of Driver (2001); Pashler and Sutherland (1998); and Yantis (2000) for a more in depth discussion on attention.

salience of an event (Gibson, 1966) or through existing knowledge (Bruner, 1957; Gregory, 1970). This distinction between the stimulus or data-driven control of attention and goal-directed control of attention is respectively referred to as *bottom-up* and *top-down* processing. Via attention an individual can focus on one event whilst ignoring others, filtering out unimportant information that is not relevant to one's current goal.

With bottom-up processing is meant that a stimuli can be prioritised attentionally regardless of the current goals or intent of the individual. This can be true for stimuli containing unexpected or abrupt movement. However, as soon as one is searching for a specific target then the process is no longer purely bottom-up, and is arguably driven by the goals of the individual. This top-down process suggests that selection of stimuli is dependent on the current goals of the individual and is called the contingent capture hypothesis (Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994). In the now classic spatial cueing paradigm, Folk, Remington, and Johnston (1992) showed a cue which is directly followed by a target on four potential target locations (valid 25%). If the target was defined with a specifc caracteristic (e.g. look for a red dot), and a cue was defined by the same characteristics, particpants would respond faster on valid trials (i.e. the cue appeared in the same location as the target). There would be no difference between valid and invalid trials if the cue was not defined by the same characteristing as the target. These results showed that a top-down process influenced the allocation of attention . In this paradigm participants would prioritise the characteristics of the target and the attention is therefore directed to any stimuli that matched that characteristic (e.g. cue defined with red dots and a red dot as a target). Stimuli that do not share the specific characteristic of the target would then be ignored (e.g. cue defined with a shape, and a a red dot). In other words, the goal of the particpants (e.g. find the red dot) influenced the allocation of attention. Although this research shows that attention is not purely a bottom-up process, neither is it a purely top-down process as very salient stimuli will attract the attention regardless of one's will (Belopolsky, Schreij, & Theeuwes, 2010; Theeuwes, Olivers, & Belopolsky, 2010). Previous research has provided two separate neural networks related to top-down and bottom-up attentional processing (Giesbrecht, Woldorff, Song, & Mangun, 2003; Kastner, Pinsk, De Weerd, Desimone, & Ungerleider, 1999). In their review, Corbetta and Shulman (2002) link a goal-directed system to a neural network involving the dorsal parietal cortex (dPC), intraparietal sulcus extending dorsomedially to the superior parietal lobule (SPL) and anteriorly to the postcentral sulcus) and frontal cortex (frontal eye field), and can be referred to as the dorsal attention network (DAN). It is suggested that a right lateralised neural network consisting of the temporoparietal and ventral frontal cortex (VFC) is involved in stimulus driven attention.

Bottom-up and top-down driven processes often interact in directing our attention. (Yantis, 2000). For example, studies have found that suddenly appearing stimuli capture one's attention automatically, i.e. bottom-up stimulus-driven direction of attention (Folk et al., 1992; Jonides & Yantis, 1988). However, if participants are asked to look for a target and that target is reliably cued then a sudden onset of a non-target stimulus in the visual field does not automatically attract one's attention (Yantis & Jonides, 1990). This suggests that top-down attentional control inhibits the bottom-up capture of attention that would otherwise occur. Rarely in cognitive psychology is the participant not given some form of 'top-down' task instructions. These instructions will always influence the way attention is allocated to the task. Similarly, the stimuli themselves will always have attention-grabbing properties which direct attention in a bottom-up manner. For instance the onset of a word or any other kind of object will tend to grab attention in an involuntary manner. Therefore no study is ever entirely free from bottom-up or top-down attentional processes. The (bottom-up) salience of stimuli is often influenced by their behaviour relevance as defined in the given task (e.g. street signs for a lost person) and some forms of contingency can be a permanent aspect of attention processes due to genetics (e.g. spiders) and learning (Corbetta & Shulman, 2002). This means that the salience of an object can be increased via a top-down process outside the awareness of the observer. It is for this reason that there is some overlap in the underlying neuro mechanisms between top-down and bottom-up processing. Research suggests that the lateral intraparietal cortex and the frontal eye field are involved in both top-down and bottom-up information processing (Bichot & Schall, 1999; Wolfe, 1994).

Naturally, some sensory information is very salient regardless of current behavioural relevance and will automatically attract attention (e.g. sudden movement). By directing one's attention to suddenly new behaviour-relevant information, one becomes aware of important information outside one's current attentional focus. Corbetta and Shulman (2002) link specifically the right lateralised temporoparietal junction (TPJ) and the ventral frontal cortex (VFC) to the disengagement and subsequent reorienting of attentional focus from current to new highly relevant information. In this scenario, the TPJ and VFC are seen as a "circuit-breaker" that interrupts ongoing attentional focus.

Focussing one's attention is the most efficient way of ensuring that what is focussed on remains in our consciousness so that we can mentally process the information. It also allows us to block competing signals and prevents us getting distracted by minor occurrences (e.g. distracting bottom-up noise). As with the invisible gorilla example, it is not guaranteed that other events will not automatically attract your attention (after all, 50% of the participants do notice the gorilla). It is important to remain aware of our surroundings and potential opportunities and threats therein.

Self-relevance and attention

Arguably, one way that the brain might use to prioritise visual information is in terms of self-relevance. It seems to make logical sense that information related to the self would be more important than information that is not self-associated. Therefore the brain may have an intrinsic tendency to preferentially select self-relevant information over other kinds of information when they are presented in competition. Indeed, there is some experimental data to support this. For example, when looking for a specific face, people are much faster in detecting the target face if that face is their face, or reject their face as not being the target (Tong & Nakayama, 1999). Furthermore, research has shown that one's name has a lower threshold for recognition and is, therefore, more salient (Moray, 1959; Shapiro, Caldwell, & Sorensen, 1997; Treisman, 1960). Naturally, self-relevant information extends beyond one's name and face, as any item that is important to the self is self-relevant. For example, the work of Treisman and Gelade (1980) has been highly influential in shaping the research interests of the author of this thesis, and whenever the name *Treisman* appears on a list his attention is automatically directed to it (i.e. it pops-out), even when not actively searching for it. In other words, self-relevant information easily grabs our attention. As this anecdote illustrates, it seems a person can potentially learn and form associations between items and the self. This will be the main focus in the next few paragraphs as the influence of self-related information on attention will be discussed in more detail, using relevant literature.

The *self-priority* effect occurs when self-relevant information draws our attention over other potentially competing information. In this thesis, the term self-priority is used when describing the prioritisation of self-related information over other information for attentional processes. When studying the self-priority effect, self-relevant stimuli are needed. Most studies research the self-priority effect using highly familiar stimuli, such as names and faces (Alexopoulos, Muller, Ric, & Marendaz, 2012; Cherry, 1953; Shapiro et al., 1997; Tong & Nakayama, 1999) since our names and faces are highly self-relevant stimuli.

Your name is a highly familiar and self-relevant type of stimulus which can be hard to ignore (Moray, 1959; Wood & Cowan, 1995). In an article revisiting the well-known *cocktail-party effect* (Cherry, 1953), A. R. A. Conway, Cowan, and Bunting (2001) applied a dichotomous listening task where participants had to listen and repeat the information presented in one ear while ignoring the information presented to the other ear. The participant's name was inserted into the message presented to the irrelevant ear. Interestingly, A. R. A. Conway et al. (2001) also measured the working memory capabilities of the participants. The results showed that participants with a lower working memory capacity were less able to ignore one's own name when presented in the irrelevant ear, whereas participants with higher working memory capabilities were better able to inhibit the distracting information presented in the irrelevant ear.

Besides names, one's face is also highly familiar. In a study on self-relevance and faces by Keyes and Brady (2010) participants were presented in their left or right (or both) visual field with faces of either themselves, a friend or a stranger. Furthermore, half of the faces were inverted. The participants were asked to judge as quickly and as accurately as possible, which of the three faces were present (self, friend, or stranger). Their results suggest that there is an advantage for one's face compared to the face of a stranger or a friend, even if the faces are inverted. The familiarity of the faces lead to a more 'robust' representation of one's face. This, in turn, enabled faster responses to one's face compared to the faces of a friend or stranger, especially if the faces were inverted.

Another study using faces as stimuli found that one's face is difficult to ignore (Brédart et al., 2006). In this experiment, participants had to decide as quickly as possible if the name shown on screen was their own or a classmate's. At the same time, a face would flank the name and would either be congruent with the name or not. The faces could be the participant's face, a classmate's face, or a professor's face from their course. The results showed that participants did respond slower for incongruent trials when the participant's face flanked a name. The authors give two main possible explanations: first, your face is very emotionally important and previous research has linked strong emotional reactions when looking at one's face (Brédart et al., 2006; McNeill, 2000); second, like the study by Keyes and Brady (2010), the authors believe that the familiarity of your face leads to a robust visual representation that quickly grasps the attention.

In a more recent series of experiments, Alexopoulos, Muller, Ric, and Marendaz (2012) investigated the effect of the self-relevance of names by looking at automatic attentional capture using a peripheral cueing task. In their first experiment, the authors briefly presented an orientating cue, which was followed by a target. This cue can be valid and correctly precede the target on the target's location, or the cue is invalid and does not correctly predict the location of the target. The target, in this case, was an 'O' amongst 'Qs' in a four-point grid. The cue was the participant's name; the name of a different participant; no cue; or some filler (e.g. a series of Xs) not related to their conditions. The accuracy and reaction time data revealed that the difference between valid and invalid trials was greater when the cue was the participant's name, compared to using a different name. In other words, there was a greater cueing effect when using one's name. This could indicate that one's name is more salient when compared to a different name.

In their second experiment, using subliminal orientating cues, the authors replicated the results from their first experiment. However, in this second experiment, a 33ms reduction of the orientating cue was applied, which was followed by a mask for 100ms. The aim was to make it unlikely that participants would be consciously aware of the cue. Despite presenting the cues outside of conscious awareness, the results replicated the findings of the first experiment (a greater cueing effect of one's name compared to a different name), although for reaction time only. This indicates that self-relevant information (the participant's name) not only captures attention but can do so automatically, without conscious effort from the participant. It is possible that the high familiarity of one's name is increasing the saliency of the stimulus allowing for faster (automatic) processing of the participant's name, compared to a stranger's name.

However, based on their third experiment, Alexopoulos et al. (2012) offer an alternative explanation for their findings. This experiment added a go/no-go element to their setup of the second experiment. The number of target locations was halved and would now only appear at either the left or right side of the screen. Also, the cue could now consist of four possible names: one's own, a same-sex acquaintance (but not a close friend), and two same-sex names (unfamiliar to them) from a predetermined list. Participants had to respond as quickly as possible if the target was present ('O') and not respond if the target was absent. The results replicate their previous experiments by finding a larger cueing effect for one's name compared to other names, including the acquaintance name. However, no significant difference was found between the neutral names and the acquaintance names. Therefore the authors cautiously claimed that familiarity could not fully explain their findings as they found a larger cueing effect for the participant's name when compared to the acquaintance's name. However, it is possible that one's name is still more familiar than an acquaintance's name. Nonetheless, if familiarity is the main factor underlying the observed results, the cueing effect should have been significantly different between the acquaintance and neutral names conditions.

Finally, in their fourth experiment, the Alexopoulos et al. (2012) showed that attention to one's name is not only automatic and unconscious but uncontrollable as well. For this experiment, they used an anti-saccade task. Participants were now instructed to actively inhibit inappropriate responses to the cue (i.e. do not look at the cue), while the target would always appear on the opposite side of the cue and consisted of an arrowhead pointing to one of four directions (left, right, up, down). Participants had to decide as quickly as possible the direction the target was pointing. The results show that the participants were less accurate when the cue was their name, showing that attentional control to your name is hard to control.

As mentioned earlier in this introduction, A. R. A. Conway et al. (2001), found that participants with sufficient cognitive resources seemed to be more able to inhibit the orienting toward one's name. Nonetheless, the visual presentation of one's name in the experiment of Alexopoulos et al. (2012) was sufficiently distracting to impact task accuracy, which was claimed to be an automatic, and hard to control process. If self-related stimuli like names are indeed salient enough to grab the attention in a hard to control manner automatically, why would sufficient cognitive resources prevent an effect of self-relevance?

The main difference between the two tasks is when attention needs to be applied to perform the task correctly. In the dichotomous listening task by A. R. A. Conway et al. (2001), attention was always fully on the information presented to the relevant ear meaning no switch in attention is required. Since continuous listening to the correct ear is relevant to one's current goal, the bottom-up interference of your name can be inhibited by top-down directed attention to ensure goal achievement. In experiments one to three by Alexopoulos et al. (2012), it was not possible to continuously focus on one location. Since the cue is task-relevant, an initial orientation towards the cue is expected and followed by an anti-saccade movement to the target. However, it seems that switching away from self-relevant information is more delayed when compared to switching away from a name which is not relevant to the self. The study by Alexopoulos et al. (2012), is very interesting in the sense that it highlights the role of self-relevance without using familiarity to explain the effect (albeit with caution). The authors summarised the effect as being automatic, or in other words, unintentional, unconscious and uncontrollable (Moors & De Houwer, 2006).

Most of the literature mentioned thus far discusses the self-prioritising of information that potentially is highly familiar (names and faces). This allows for a possible confound of familiarity as it is a possibility that the familiarity of the stimuli influences the self-priority effect. Some recent work has addressed this potential confound by using a paradigm in which self-relevant and irrelevant information can be defined on-line in the task itself.

Sui, He, and Humphreys (2012) used a perceptual matching paradigm which linked simple geometric shapes to an arbitrarily assigned label that could either be yourself, a familiar other, or an unfamiliar other. In a series of experiments, Sui et al. (2012) used reaction times (RTs) and accuracy to measure if there was any self-prioritisation when linking the self to a specific geometric shape. In their first experiment, participants learned to associate a label (best friend's name, yourself or stranger) with each shape (square, triangle or circle). A small pre-test instructed the participants that: "[best friend's name] is a circle; you are a square; and a stranger is represented by a triangle." The geometric shape was presented above a fixation cross in the middle of the screen, and presented underneath the label was the fixation cross. The task was a perceptual matching task where participants had to judge as quickly and accurately as possible if the label and shape matched with the rule provided in the instructions. For example, in a matched trial the participant could be presented with a triangle and the label 'stranger' underneath or a square paired with the label 'yourself'. In this case the participant would have to respond with a 'yes, it matches' by clicking one of two buttons. In a non-matched trial, the label 'yourself' could be paired with a circle or triangle. Their results show that associating the self to geometric shapes did indeed result in a self-priority effect. Specifically, participants were more accurate at responding to trials where the geometric shape was paired to the self, compared to trials where the geometric shape was linked to a familiar-other and stranger. For RTs they found a difference between self and the other labels and between familiar-other and unfamiliar-other. The RTs were faster for familiar-other compared to unfamiliar-other, and the RTs for self was faster than both familiar- and unfamiliar-other.

What is interesting about this study by Sui et al. (2012) is that the familiarity of the stimulus is no longer a relevant factor as it was in the studies using names and faces as stimuli. The stimulus was a completely arbitrary assignment of self to a particular geometric shape. There is no *a priori* greater familiarity with any one geometric shape over any other. The faster responses to the familiar other over unfamiliar other can therefore not wholly be explained by familiarity but by self-relevance also. In a series of follow-up control experiments, Sui et al. (2012) replicated their findings of a prioritising effect of self-related information on attention. The unfamiliar 'other' label was replaced with the neutral word 'none' and the authors replaced for the familiar other label (the name of one's best friend) with the word 'mother'. Since the concept of 'mother' is, presumably for most people, a highly familiar other, the authors were interested to see if the self-priority effect would be maintained. Their results revealed that the self and familiar other conditions were responded to faster and more accurately than the neutral label condition. Despite the highly familiar non-self control label of 'mother', the self label still led to more accurate and faster responses on the matching task, showing that even with the supposedly increased familiarity of 'mother', the self-priority effect remained intact.

Using an adaptation of the paradigm mentioned above, Wang, Humphreys, and Sui (2016) investigated the gains and costs in switching from or to self-associations. For example, in one experiment the authors switched the label pairings of self-circle to self-triangle, friend-square to friend-circle, etc. This means that participants were trained to associate specific shapes to self, friend, and stranger labels only to be forced to switch and form new associations between specific shapes and self, friend, and stranger labels in the second half of the experiment. In the first half of the experiment, the participants would learn to associate labels with geometric shapes. However, unlike the earlier experiments where participants had to judge if the label-shape pair was correct, the three labels appeared underneath the shape at the same time and the participant had to select the correct one. For the second half of the experiment, the label-shape pairing would change (the participants were informed of this change), and the paradigm was more akin to the original experiment. However, the presentation of the label and shape would not be simultaneous. After a fixation cross, the shape would appear, followed by a blank screen, then the label, and finally a blank screen again during which participants had to judge if the shape-label pairing was correct.

Like the previous experiments, their results showed an apparent self-priority effect for the first half of the experiment. The correct label for the geometric shapes linked to the self was selected more often than the geometric shapes linked to a friend or a stranger. For the second half of the experiment, the authors found that new self-shape associations were forming faster than the new friend- and stranger-shape associations. However, on the mismatch trials for the former self-shapes associations, participants made more mistakes and were slower in responding. Furthermore, in a correlation analysis, the authors discovered that the participants who showed a greater self-priority effect for new shape-labels pairs would show a cost in the mismatch trials for the previous self-shape association. The authors argued that self-associations could either be a benefit or a cost in a task, depending on whether the participants are learning new self-associations or old ones need to change.

This conclusion is consistent with the results from Alexopoulos et al. (2012) mentioned earlier: the binding of self is automatic and beyond one's control. In the study by Wang et al. (2016), undoing the binding of a previous self-shape pair was more difficult when the instructions changed. Moreover, the authors conclude that self-association leads to stronger binding in memory, referring to Rogers, Kuiper, & Kirker (1977) who showed that self-association enhances the binding of different memory components, which can then be retrieved more accurately. This will be further explored later in this chapter.

In several other experiments using variants of the matching paradigm, Sui et al. demonstrated both the robustness and ubiquity of the self-priority effect. The authors went on to show the self-advantage when the stimuli are degraded (experiment four; Sui et al., 2012), when the size of the shape changes (Sui & Humphreys, 2015a), and when self-relevant information is expected or not (Sui et al., 2014). Crucial to the perceptual matching paradigm is the use of geometric shapes that are not overly familiar or at least the different shapes are equally familiar. However, as Woźniak and Knoblich (2019) pointed out, the linking of the self to an arbitrary geometric shape might not be the only factor driving the self-priority effect in this paradigm. The labels used (e.g. 'yourself', 'stranger') might potentially create a self-priority effect on the matching trials. Like one's name, labels related to the self are known to lead to a self-priority effect (Tacikowski & Nowicka, 2010; Zhou et al., 2010). In order to investigate the effect of the labels on the self-priority effect, Woźniak and Knoblich (2019) used an adaptation of the perceptual matching task by substituting the labels with unfamiliar symbols, and the geometric shapes were replaced with unfamiliar faces. This new 'no-label' perceptual matching task was then compared with the original version. Their results showed a clear self-priority effect in both the 'label', and for the 'no-label' perceptual matching task using unfamiliar faces. Furthermore, the strength of the self-priority effect found in the 'no-label' paradigm correlated with the strength of the self-priority effect of the original 'label' paradigm. Therefore, the authors concluded that the prioritisation of self-related stimuli during the matching trials could not be explained by a self-priority effect driven by the labels. As such, the association of the self to an arbitrary and unfamiliar stimuli is the only remaining explanation of the self-priority effect found in the perceptual matching paradigm.

The perceptual matching paradigm, originally developed by Sui et al., (2012), produces a robust perceptual self-priority effect. However, this paradigm uses stimuli at pre-attended locations. Therefore the role of attention on the self-priority effect (as measured by the perceptual matching paradigm) remains unclear.

A variation of the perceptual matching paradigm was employed by Sui, Liu, Mevorach, and Humphreys, (2013). They interpreted their result as suggesting that self-related information processing is modulated by an attention control network. In this experiment, participants were required to select a target amongst distractors. Similar to the original perceptual matching paradigm, participants learned to associate self, other, and friend to a respective geometric shape. However, in this experiment, participants had to respond to local-global shapes. Global-local shapes were first introduced by Navon (1977). In this classical paradigm, participants were presented with compound stimuli where a large 'global' letter was made out of smaller 'local' letters. The global and local were either the same (e.g. a large 'E' made out of smaller 'Es'), or they would be dissimilar (e.g. a large 'E' made out of smaller 'Hs'). Generally the conclusions of this paradigm are: there is a global precedence effect where participants identify the global shape faster than the local shape; when the global and local shapes are not the same participants respond slower, which is called the interference effect; and there is an inter-level interference effect as there is a larger interference effect when identifying local shapes when compared to global shapes (Gerlach & Poirel, 2018).

In case of the experiment by Sui, Liu, Mevorach, and Humphreys, (2013),these local-global shapes were a combination of two shapes (e.g. small squares forming the outline of a circle). One local-global shape was displayed per trial and participants had to respond by pressing one of three buttons, indicating which label matched the local-global shape (e.g. self, other, friend). Participants either had to make a global shape/label judgement or a local shape/label judgement. Furthermore, the shapes could either be globally salient or locally salient. A shape was locally salient if the local shapes were contrasted with red and white. A shape was globally salient if the local shapes were blurred and were the same (red) colour. Their results showed that self-related, salient distractors distracted from low salient targets, regardless of whether the target was the global shape or the local shapes. For example, a participant could be presented with a global square, and the participant had to match the global shape to a label. The local shapes would interfere with this process if the local shapes were salient, associated with the self, and if the global low salient shape was associated with a distant other. They also found increased brain activation when self-related distractors were combined with a non-self targets, related to top-down suppressive control via the left intraparietal sulcus. Based on these results, the authors conclude that self-related information can actively alter attention by modulating the saliency of stimuli.

Humphreys and Sui (2016) proposed the self attention network (SAN) in an attempt to explain how the neural mechanisms involved in self-prioritising stimuli and attention interact. In this network the authors link the vmPFC to self-related processing together with the left posterior superior temporal sulcus (LpSTS), where the vmPFC provides top-down modulation to the LpSTS and can work independently from the attention network. In this view, irrelevant self-related information needs to be actively suppressed by the attention network (Sui et al., 2013). The ignoring of a high salient distractor over a lower salient target has been linked to the IPS (Mevorach, Hodsoll, Allen, Shalev, & Humphreys, 2010) which, as previously mentioned, is part of the attentional network. Using the vmPFC as the mechanism that prioritises self-relevant information, the SAN uses a separate self-mechanism distinct from the typical attention network. The vmPFC top-down modulation primes the attention network via the LpSTS to respond quicker to self-related stimuli.

Humphreys and Sui (2016) showed that it is possible that self-related responses are made without involving the attentional network, but the attentional network would be needed for more complex situations. Their research has shown that damage to the LpSTS results in a hyper-self-bias, which is possibly due to a lost capacity to sufficiently judge complex potential self-related information, whereas strong self-related responses remain unimpaired. Furthermore, the authors assume that due to the connection between the vmPFC and LpSTS, the vmPFC must receive input from the sensory areas earlier than the visual associative areas. Although, there is some evidence suggesting that self-modulation takes place at later, e.g. response selection or memory encoding, stages (Stein, Siebold, & van Zoest, 2016). The SAN consists of three major parts: 1) the attention network, seen as a general top-down control, with a focus on IPS and the dorso lateral prefrontal cortex (dlPFC); 2) self-representations via the vmPFC; and 3) Bottom-up communication via the posterior superior temporal sulcus (pSTS).

In the model, the network is proposed to revolve around the interactions between a general-purpose top-down attentional control, a self-representation network, and a bottom-up orienting function which together guide our behaviour towards self-related information. The self-representation modulates top-down attentional processes towards self-relevant information. Bottom-up information directly orientates attention towards self-relevant information but can be inhibited by top-down attentional control. For example, the self-representation network can prime the bottom-up orientating function to be sensitive to self-related information. Humphreys and Sui (2016) give the example of the perceptual matching task where participants link a specific colour to the self. In this case, the self-related colour is primed in the bottom-up orienting function by the self-representation network, resulting in the faster detection and processing of the self-relevant colour. Furthermore, the top-down attentional control can similarly modulate the self-representation network. This creates a loop which results in further attentional enhancement of self-relevant information (see Figure 1).

Figure 1 has been removed from this thesis due to copyright restrictions

Figure 1. The Self Attention network (SAN). The solid arrows show excitatory connections and the dotted arrows show inhibitory connections. This network displays a top-down attentional network and a bottom-up network sensitive to self-related information. The self-representational network is involved with self-related information, and the excitatory connection between the bottom-up orientating function helps prime self-related information, which generates the self-priority effect in attention (adapted from Humphreys & Sui 2016).

Other studies have found other brain areas involved in processing self-relevant information. Most notably the perigenual anterior cingulate (pACC) for the self and the posterior cingulate cortex (PCC) and the precuneus (PC) for distant other related information (Denny, Kober, Wager, & Ochsner, 2012; Fox, Bzdok, Murray, Debban, & Eickhoff, 2014). These studies do however look at higher levels of self which are more in line with the conceptual self, which involves more complex processing such as psychological representations of the self and is more linked to social cognitive processing (M. A. Conway, Singer, & Tagini, 2004).

The preceding paragraphs have illustrated how attentional processes have been claimed to be influenced by self-related information, resulting in a self-priority effect. From the above, it can be determined that most items are not inherently important to the self, but through experience will be. Even a randomly assigned colour shows that something that starts without any inherent importance to the self becomes part of the self via a simple instruction. As part of the self, the colour becomes salient enough to draw our attention automatically.

As mentioned at the beginning of this thesis, self-related information is expected to involve emotion. Indeed, some research attempts to explain the prioritising effects of the self purely in terms of emotional processing (Brédart et al., 2006; McNeill, 2000). Certainly, emotion does influence attention; there is evidence going back at least as far as the 1940s demonstrating this (Bruner & Postman, 1947), and more recent work has described numerous conditions under which emotion and attention interact (Mather & Sutherland, 2011; Vuilleumier, 2005). However, emotion and self-relevant information processing are two separate processes. Therefore, in the subsequent paragraphs about attention, the influence of emotion and attention will be reviewed, and how this is linked to the self.

Emotional information and attention

Besides the self, one of the other ways to select information is the emotional value of an event or item. Manipulation of emotional valence is known to affect the saliency of information (Neisser, 1976; Öhman, Flykt, & Esteves, 2001; Reinecke et al., 2006; Sperling, 1960; Von Wright, 1968; Vuilleumier, 2005). The automatic capture of attention by increasing the salience of information through fear-eliciting stimuli is an example of how bottom-up information can direct and influence our attention. The next few paragraphs will focus on the effects of emotional information on attention, and this section on attention will end with linking emotion and self together.

Phelps, Ling, and Carrasco (2006) demonstrated the pervasiveness of emotional information on perception. They showed that, in addition to the attentional aspects, emotion could alter the perception of a stimulus. Participants were presented with either neutral or fearful faces using a discrimination paradigm. After a blank inter-stimulus interval (ISI), four Gabor stimuli were displayed, and the contrast of these Gabor patches was manipulated. One of these Gabor stimuli was a tilted target, and the other three were distractors. The participants had to report the orientation of the Gabor target. Their results showed that if the Gabor patches were preceded by a fearful face, the participant's sensitivity to contrast -as measured by the Gabor discrimination task- increased when compared with neutral trials. This result indicates that emotion can alter the way the stimuli are perceived. In a follow-up experiment, Phelps et al. (2006) used mostly the same experimental setup, but with a few crucial changes. Instead of presenting the neutral or fearful faces in the centre, the faces were additionally displayed in the periphery, preceding the target location (or on all four Gabor stimuli locations as a baseline condition), and drawing the attention to the location of the target Gabor stimuli. As expected, the mere presentation of any stimuli near the target location increased contrast sensitivity, but more so for the fearful faces than the neutral faces. Furthermore, fearful faces increased contrast sensitivity regardless of location, but if the fearful face preceded the target location the contrast sensitivity increased even further, i.e. location and emotion increased contrast sensitivity separately, but this effect was greater when both coincided. Therefore, emotion not only influences early visual perception, it affects attention also. This is because the elicited transient attention with a fearful face (cue) increased contrast sensitivity more than when fearful faces were displayed on all four locations.

This role of emotion on attention is demonstrated further by *the emotional Stroop* task (Ray, 1979; Watts, McKenna, Sharrock, & Trezise, 1986; Williams & Broadbent, 1986;

Williams, Mathews, & MacLeod, 1996). A classical and often used technique in attention research is the well-known *Stroop task* (Stroop, 1935). With this task participants are traditionally shown different words, of which the font-colour would vary. The task of participants is to say the colour of the ink aloud. Research found that participants are slower to report the ink colour aloud (as shown by an increase in reaction time) when the meaning of the actual word would describe a different colour. For example, saying the colour 'red' when you see the word 'Car' is less effortful than naming the green ink-colour of the word 'Red'. The reason for this is an interference of the semantic meaning of the word which clashes with the naming of the ink-colour. This clash is most likely caused by parallel processing of the relevant ink-colour and irrelevant semantic meaning of the word (MacLeod, 1991; Stroop, 1935).

In the emotional variation of the classical Stroop task (Stroop, 1935), the participant still has to name the ink colour of the word. However, instead of using words incongruent to the ink-colour (e.g. 'green' in a red ink-colour), emotional words were used. Like the mismatch between word meaning and ink-colour, negative words often lead to delayed reaction times compared to positive or neutral words. This is often explained as an attentional bias towards negative (threatening) words, and this attentional bias enables better detection of potentially threatening stimuli. This focus on the emotional meaning of the words reduces available resources needed to identify the colour (Wells & Matthews, 1996; Williams, Mathews, et al., 1996).

The comparison made in an emotional Stroop task is different from a traditional Stroop task since there is no conflict in the semantic meaning of a word and the naming of the colour font. The font colour of 'purple', does not conflict with the word 'table' and this is the same for neutral or negative words (e.g. 'Table' versus 'Plague'). This difference means that the effects found with the emotional Stroop task are potentially not related to selective attention as measured by the original Stroop task. The effect found could reflect a more threat-driven automatic slow-down of active processes as a result of a defence mechanism that responds to threatening stimuli. This is in contrast to the assumed post-attentive process underlying the traditional Stroop effect (Algom, Chajut, & Lev, 2004; Öhman et al., 2001). Although in both paradigms it is the automatic process of reading the words which cause the slowing down of the colour naming and there has been some evidence to suggest the emotional words are even more automatically processed and more easily interrupts other ongoing activities (McKenna & Sharma, 1995).

Emotional Stroop effects are a clear indication that emotion has an impact on our cognitive processes. It shows that, at least for negative information, an automatic and uncontrollable influence of emotion draws our attention towards goal-irrelevant information and disrupts, or conflicts with, ongoing attentional processes. However, as the next paragraph will show, this influence over our attention processes is not a negative relation per se.

The influence of emotion on attention was also demonstrated by Öhman, Flykt, and Esteves (2001). With a range of experiments, the effect of fear-relevant versus fear irrelevant search task with distracters was investigated. The authors found that indeed people direct their attention towards threatening stimuli and that if the target was a fearful stimulus, it was found quickly regardless of location. Furthermore, an increase of distractors did not influence threatening stimuli but did increase the detection time for non-threatening stimuli. Their results suggest that threatening stimuli were found faster regardless of one's goal because threatening stimuli enjoy a default evolutionary goal-relevance for fear-relevant stimuli, as such fearful stimuli like snakes and spiders would automatically become goal relevant (Mogg & Bradley, 1998).

Based on the above paragraphs on emotion and the self, it is clear that both potentially influence our attention. However, it is possible that emotion might interact with self-related information in different ways depending on the valence. For example, some evidence has suggested that positive emotions can widen visual attention, whereas negative emotion does not (Fredrickson, 1998; Wadlinger & Isaacowitz, 2006). This *broadening of attention* appears to facilitate the detection of self-relevant information, as found by Grol, Koster, Bruyneel, and De Raedt (2014). In this experiment, the participant had to detect a target presented in the periphery while observing a label in the centre of the screen. The label could either be 'ME' or 'LR'. The word 'Me' referred to the participant and 'LR' referred to the initials of an unknown stranger. Interestingly, no effect of self was found in this experiment. However, in their second experiment a positive mood was induced by having the participant vividly recall a positive memory. This induction of a positive mood resulted in attentional broadening as expected, but this broadening was greater for the self-related information when compared to information related to a stranger.

It appears that positive mood increased the likelihood of detecting a self-relevant label. It has been documented that people tend to attribute positive events to themselves and negative events to something or someone else (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Taylor, 1991). For example, Mezulis, Abramson, Hyde, and Hankin (2004) conclude in an extensive meta-analysis that individuals link success to their characteristics but failure as unrelated to their characteristics. Emotions seem to have strong connections with the self, as individuals tend to describe themselves in positive traits (Alicke, 1985), even to the point of nullifying the self-priority effect in face recognition when asked if a negative trait describes the participant (Ma & Han, 2010).

However, several studies have shown that emotion alone does not explain the attentional advantage for self-related stimuli (Gutchess, Kensinger, Yoon, & Schacter, 2007; Leshikar, Dulas, & Duarte, 2015; Stolte, Humphreys, Yankouskaya, & Sui, 2016). For example, in the study by Stolte et al. (2016) the perceptual matching task of Sui et al. (2012) was used to see if there was a relationship between the self-bias and the positive emotion bias. First, the authors used the standard matching task version, as described earlier in this text. This is followed by a second matching task where the words "you", "friend", and "stranger" were replaced by images of happy, neutral and sad faces. The standard matching task showed a typical self-priority effect, and the second emotional matching task shows an advantage for positive faces. The authors found no correlations between the personal label matching and emotional matching tasks despite the similarities between the two tasks. Although emotion and the self are both prioritised, the finding of Stolte et al. (2016) suggest that independent processes support the self and emotion.

So far, in this thesis, the focus has been on attention and how self-related information together with emotion influences our attentional processes. As discussed above, Self-related and emotional information often leads to improvements in the detection of relevant information (especially when relevant to our goals) and allows individuals to faster process information from our surroundings from which there are many competing signals. This increase in attention of emotion and self-relevant information carries beyond our initial detection and processing of that information. Information that is attended to more tends to be memorised better, compared to information that is attended to less (Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996).

Memory

A further question concerns the role of any putative effects of self and emotion on episodic memory. In the previous sections, the importance of the self in directing our attention was discussed. As was alluded to by Wang et al. (2016), information related to the self does not only draw our attention; it influences our memories also (Rogers et al., 1977). In the simplest term, memory is the consequence of learning which is stored in the brain for potential later retrieval. This term does, however, require some further elaboration, as not everything is learned at the same pace, and similar events are not remembered equally (Cowan, 1988).

Evidence has shown that memory is not a unitary entity. Rather it is fractionated into several different processes. A typical distinction is usually between *short-term/working memory* (STM) and *long-term memory* (LTM) (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965). The differences between these two are mainly defined in terms of capacity limits and time course. Short-term memory and working memory are often used interchangeably in the literature, but it is generally agreed that STM is the temporary storage of incoming information (up to a few minutes). The concept of working memory emphasises the active nature of STM processes in terms of the maintenance and manipulation of encoded information over short periods, and the role of STM processes in the retrieval of information from long-term memory (Baddeley, Hitch, & Bower, 1974).

Long-term memories are memories that are retained for longer than a few minutes, up to a lifetime. There are two distinct versions of long-term memory: *declarative* and *non-declarative memory* (Tulving, 1985). Non-declarative memory is often implicit, in the sense that people are not consciously aware of the memories. These memories contain skills, habits, and conditioned responses. Nevertheless, in specific cases, we can make ourselves aware of the memories.

Declarative memories contain knowledge of events and facts. These are referred to as *episodic memory* and *semantic memory*, respectively (Tulving, 1983). Declarative memories are more explicit than non-declarative memories. Semantic memory is general knowledge about the world and objects. For example, semantic memory is the memory of what a house is what parts of the house are called, and the purpose of a house. Episodic memory contains events related to ourselves, e.g. you know how you felt when you bought a house and when you first moved in[4]. When discussing memory in this thesis, it generally refers to declarative memory.

However, how are these memories created, and how are they connected in declarative memory? The example above shows that semantic knowledge can be connected with episodic memory to create meaningful events from a specific time. In semantic memory, an item, like a chair, is represented by the concept of a chair. Furthermore, linked to the concept of a chair is knowledge of its different parts. Each of these parts exists independently, like the concept of a chair, but are also bound together in memory. Binding in memory helps recall by grouping individual features that belong

[4] For a more detailed review of the memory systems in the brain see Squire (2004).

together (Gronlund & Ratcliff, 1989; M. K. Johnson, 1996; Opitz, 2010). This is not limited to the perceptual qualities of the concept 'chair', but concepts about its use would be bounded to it as well, and other objects closely associated with a chair. Whenever you try to memorise the word chair, each of the bindings connected to the concept of 'chair' will be strengthened. The more bindings and the stronger these bindings are, the stronger the memory of a concept becomes, and this, in turn, facilitates later retrieval. In episodic memory, a chair is still a chair. Furthermore, the bits of information representing the concept of 'chair' now has bindings with yourself like 'your favourite chair'. Linked to your favourite chair are memories of events such as buying the chair and of sitting on the chair reading an engaging book. Other more abstract examples are the memories of 'home' which is a concept that is slightly different for everybody. A house is not a home, but the concept of 'home' is bound with a specific house, family members, and events occurring there. This idea of binding into memory is essential in this writing. This thesis revolves around the suggestion that situations involving the self and emotions can affect the strength of the bindings between different pieces of information. Naturally, this binding into memory is facilitated via underlying neurophysiological processes.

To-be-remembered information needs to be first encoded. Generally, incoming information needs to be interpreted so that an internal representation can be constructed, using already existing knowledge. This is then followed by the binding of the internal representation into a lasting trace, which, when retrieved, leads to the recollection of the original event (Tulving, 1983). According to Paller and Wagner (2002), these two processes are linked to prefrontal plus posterior cortex (PFC), and medial temporal lobe (MTL), respectively. Exactly which regions of the prefrontal cortex are involved in encoding is dependent on the type of the to-be-remembered information and depth of processing (Otten & Rugg, 2001).

Any memory will have different multiple internal representations making up the full event. It is thought that the MTL structures the hippocampus, perirhinal, entorhinal, and parahippocampal cortices are involved in linking these multiple internal representations together in a single coherent event (Squire, 1992). The regions involved in encoding are also involved in retrieving information from memory (Moscovitch et al., 2005; Petrides, 2005). Since the MTL is suggested to have a role in linking multiple internal representations into a whole and, the PFC as a stimulus and task-specific control, it makes sense that these regions are needed for the reverse process as well. Also involved in memory retrieval is the posterior parietal cortex (PPC) (Wagner, Shannon, Kahn, & Buckner, 2005). Specifically, Ciaramelli, Grady, and Moscovitch, (2008) report that retrieval success is correlated to the left side the SPL along the IPS (mostly lateralised to the left side), and part of the IPL adjacent to the TPJ. These results lead the authors to postulate that the IPL and SPL have a similar role in both attention and memory retrieval, which is the top-down and bottom-up attention to memory, respectively. That being said, there is evidence that within the PPC attention and episodic memory are anatomically separate and possibly interact competitively (Capotosto et al., 2016).

Sestieri, Shulman, & Corbetta (2017) therefore introduce a functional anatomical model of the PPC wherein perceptual attention and episodic memory are mostly supported by different mechanisms in what the authors describe as a "push-pull" relationship. Naturally, attention and episodic memory can both simultaneously be active when information from memory is used in perception. This model contains brain areas used in: perceptual attention from the dorsal attention network (mainly posterior IPS and SPL as mentioned earlier) providing top-down modulations; Angular gyrus (AG, which holds the details of retrieved information from memory); the frontoparietal control network (FPCN) (including the lateral IPS and postcentral sulcus (PoCS)); and the MTL regions which is co-activated with the memory retrieval regions and is, as mentioned, involved in encoding consolidating multiple internal representations of an event and its early retrieval.

Influencing all of this via top-down modulation is the cingulo-opercular network (CON, consisting of the dorsal anterior cingulate cortex (dACC), pre-supplementary motor area (preSMA), the anterior insula (aINS), and the frontal operculum (fO)). The

CON is mostly associated with task control, arousal, or sustained attention (Sestieri et al., 2017). The AG (retrieval) and the regions in the DAN (perceptual attention) cause mutual suppression or are top-down modulated by the CON (i.e. push-pull, Sestieri, Shulman, & Corbetta, 2010). Recollection seems to be supported by the AG, whereas familiarity is supported by the lateral IPS (J. D. Johnson, Suzuki, & Rugg, 2013; Wheeler & Buckner, 2004).

In summary, three networks of the parietal lobe are involved in memory retrieval and attention: DAN, FPCN, and the AG. Together with the PFC and the MTL these regions are involved in the attending to, encoding, consolidating, and retrieving of information. Since emotional self-relevant information influences attention and memory, these neural networks could be differentially engaged when processing self-relevant information.

Self-relevance and memory

Just as one cannot attend to everything, not all attended information can be remembered, there are cognitive capacity limits which prevent this (Cowan, 1988). Therefore the more important or salient the event, the more likely one is to remember it. If self and emotion can modulate attention, then it is not unreasonable to assume that they could also modulate episodic memory. This is particularly the case given the established links between memory encoding and attention (Awh, Vogel, & Oh, 2006; Baddeley et al., 1984; Cowan, 1998; Craik et al., 1996).

Turk et al. (2013) used a divided-attention paradigm to look at this issue. In a computer, task participants were instructed that an item belonged to either themselves or a fictional other. A colour would indicate which, and depending on the colour the participant had to put the item in their basket or the basket of the fictional other. Furthermore, a number was simultaneously displayed underneath each item, and after six items, the participant had a question which could be related to the preceding six numbers. In the divided-attention condition, participants had to remember all six numbers shown with the items, whereas for the full attention condition participants were asked to copy an arbitrary number presented on the screen after the six items. Their results showed a memory advantage for the self-owned items in the full attention task, and no such benefit was found in the divided attention task. Turk et al. (2013) interpreted these results to indicate that attention is required for detecting any benefit of self on memory, viewing self-relevant information processing as attentionally demanding, allowing for richer encoding which in turn allows for better recall.

There is indeed evidence suggesting that self-relevant information tends to be more salient and is remembered easier than information that has no self-relevance (Symons & Johnson, 1997). As mentioned earlier in this thesis, the name Treisman always catches the attention of this thesis' author. Along with capturing attention, a multitude of memories is also recalled. In this case, it is a memory of the first cognitive psychology experiment performed as an undergraduate, which was a feature integration experiment. Even though the exact details of this memory are vague, it is followed by a string of related memories all bound together by the attention drawing a self-relevant name. The next few sections will build on the example illustrated above and will focus on a scientific review on the influence of self-related information on declarative memory.

Often the effect of the self on memory is studied by comparing the effect of self- versus other-reference encoding or self-reference versus semantic encoding. The frequently found superior memory for items related to the self is called the *self-reference effect* (Rogers et al., 1977)[5]. In this thesis, a beneficial effect of self-related information during encoding or recall is referred to a self-reference effect. For example, in a self-reference versus other reference memory experiment, participants could be asked in the encoding phase if a trait word (e.g. 'friendly') describes themselves, a highly familiar other (like a friend or mother), or a distant other (often a well-known stranger, e.g. Donald Trump). In a self-reference versus semantic memory experiment, there would still be a

[5] See Symons and Johnson (1997) for an extensive review on the self-reference effect.

self-reference effect, but it would be compared with semantic processing (e.g. "Does 'friendly' mean the same as 'sincere'?").

One of the first studies to look at the self-reference effect is the study of Rogers et al. (1977). In this study, a depth of processing paradigm was adapted to include a self-reference judgement. Typically in depth of processing paradigms, two conditions are compared that are thought to differ in depth of processing, which then leads to a measurable difference in during encoding (e.g. superior recall for semantically processed words compared to structurally processed words (Craik & Tulving, 1975)). Rogers et al. (1977) used this approach to add self-referentially processed words by asking the participants if the adjectives described them (e.g. "Does the word describe you?"). The researchers found that adjectives that were processed self-referentially were recalled more accurately than words that were semantically processed. Since then, the self-reference effect using this approach has been demonstrated many times (M. A. Conway & Dewhurst, 1995; Kelley et al., 2002; Klein & Kihlstrom, 1986).

An example of a study on the self-reference effect in memory comes from a study consisting of two experiments by Leshikar, Dulas, & Duarte (2015). This study looked into the influence of self-referencing in recollection, using the paradigm based on the findings by Rogers et al. (1977). In their first experiment, Leshikar et al. (2015), looked at the effect of self-referential processing on both objective (source accuracy) and subjective (estimate of recollection) processing. This experiment presented the participants with negative and positive adjectives in a study phase which consisted of two conditions: the self condition; and the common condition. In the self condition, the participant had to judge if the adjective was describing them. In the common condition, the participants had to decide if the word was either commonly used or not commonly used. Each study phase was immediately followed up by a test phase in the form of a memory recognition task, consisting of the adjectives from the study phase plus 96 new adjectives. The test phase displayed an adjective. The participants had to decide if the adjective was either 'remembered', 'know', or 'new' as a subjective measurement. Participants would select ‘remember’ is the participants would clearly remember the word, and ‘know’ was chosen if there only was a sense of familiarity or vague recognition of the word but no clear recollection. Participants would choose ‘new’ if they did not recognise the word at all. ‘Remember’ generally reflect recollection, whereas ‘know’ reflects a feeling of familiarity with the word without recollection (Tulving, 1985). Next, the participants had to choose if the adjective was from the ‘self’ condition, the ‘common’ condition, or ‘unknown’ as a measurement of source accuracy.

The results showed that a self-referential effect was present as shown by a higher estimate of recollection and source accuracy for the self-referenced adjectives. Interestingly the results showed higher source accuracy for negative adjectives for the common condition and a higher source accuracy for positive items in the self condition. However, no self-reference effect was found for the adjectives rated as ‘know’. The authors concluded that this lack of self-reference for ‘know’ items could be because the organisational and elaborative processes enriched by the self-reference effect are not present. The feeling of familiarity for the words without recognition might not be driven by these more elaborative processes that are part of recollection.

In their second experiment, Leshikar et al. (2015), addressed the type of episodic details that are facilitated by self-referential processing by including a memory characteristics questionnaire (MCQ). The main setup of the second experiment was similar to the first experiment but the adjectives were no longer displayed on the screen and were presented in either a female or male voice instead. Like the first experiment, there was a self condition and a common condition in the study phase, which was followed by a memory recognition test phase. This test was still similar to the first experiment. However, after deciding ‘remembered’ or ‘familiar’ for the adjective, the MCQ followed. The MCQ consisted of five questions in which the participants had to decide if they recollected rich details, few details, or no details for visual details, auditory details, feelings, thoughts, and temporal order. For the temporal order question the choices were: beginning; middle; and end. After the MCQ, one final question was about source information. Participants decided if the adjective was spoken by a male or female voice.

The results not only replicate most of their findings in the first experiment (the self-reference effect most importantly) but, Leshikar et al. (2015) showed that the self-referenced adjectives resulted in higher remembered details when compared to the semantically processed adjectives, indicating that the self-reference effect in memory is facilitated via enriched perceptual and internal details. In contrast with the first experiment, the second experiment did find a self-reference effect for the words rated as 'know'. The authors theorised that the self-reference effect for the 'know' words in the second experiment was the result of the addition of the MCQ test, which prompted participants to retrieve more details of each trial before making their decision. Leshikar et al. (2015) conclude that there is no general positivity or negativity effect in memory but that the effect of valence is determined by the cognitive task a person performs at a specific time. The authors based this on their findings of an enhanced recollection for negative adjectives compared to positive adjectives. However, this was only when items were not processed self-referentially. Furthermore, only when items are processed self-referentially would this results in a positivity effect.

A different approach to measuring the self-reference effect is to compare self-judgement to judgements made about a more distant other. Similar to the research by Leshikar et al. (2015), a study using a self- other-reference memory paradigm showed a self-reference effect as well (Gutchess et al., 2007). The encoding task consisted of a series of positive and negative adjectives and the participants were asked to either judge whether the word described themselves, a familiar distant other (Albert Einstein), or was in uppercase. Via these conditions, the authors could compare deep self- versus other-reference encoding and shallow upper- lowercase encoding. For each condition (self, other, case) the participant had to make a yes/no judgement (i.e. adjective describes me; adjective describes Einstein; adjective is displayed in uppercase). An old/new recognition task followed the encoding phase. For the old/new recognition test participants had to judge whether the word shown on screen was presented during the encoding task (old), or if the word was not presented before (new). The results supported a self-reference effect, as overall more self-related words were recalled. However, there seemed to be an effect of emotion as well. In the self condition positive items were recognised more frequently than negative items. Interestingly, in the upper-, lowercase condition recognition from memory was higher for the negative items.

In the second experiment of their paper, Gutchess et al. (2007) addressed the potential benefit of familiarity by replacing the unfamiliar other (Albert Einstein) with a familiar other (a close other of the participant). Participants completed a digit and pattern comparison task and were split into a high and low cognitive resource group accordingly. The results revealed that when comparing the high and low resources group, the high resources group did show a stronger self-reference effect, suggesting that cognitive resources are beneficial to self-referencing. Overall, negative items were remembered more than the positive items, but unlike the first experiment, emotion did not interact with self, other or, case.

In their final experiment of the paper, Gutchess et al. (2007) manipulated the emotional information of their paradigm by replacing the other condition with desirability judgements based on the participant's own experience. This means that the participants still made a self-judgement if the trait described them with a yes/no response, but now they also made a judgement if the trait was desirable, and a case judgement as well. The main reason for asking for a desirability judgement was that these could contain spontaneous self-referencing (i.e. "Do I find this desirable?"), potentially extending to and further emphasising the self-reference. The authors found a self-reference effect and a better memory performance for the desirability condition compared to the case condition. Also, when comparing age differences, the younger group performed better in the self and desirable conditions when compared to the older adult group. Gutchess et al. (2007) suggest that these findings show that older adults benefit less from self-referencing when attention is directed to emotional information. The authors conclude that based on their three experiments, the self-reference effect is dependent on the availability of cognitive resources and is thus more limited in older adults. Moreover, if emotion was responsible for the self-reference effect, then the increased evaluative and emotional influence should lead to comparable memory performance between age groups.

In the third experiment mentioned above (Gutchess et al., 2007), the effect of self was explored subjectively via desirability judgements, showing that these judgements extend to the self-reference effect. In an experiment by Turk, Cunningham, and Macrae (2008), self-referenced information did not have to be processed explicitly as self-relevant to result in a self-reference effect. This experiment compared an explicit self-referential memory task with an implicit self-reference memory task. In both cases a face was depicted of either the participant or of a famous individual, pairing each face with an adjective, shown either below or above the face. In the explicit condition, the participant had to make a typical self-reference response by saying 'yes' or 'no' if the adjective described the depicted face. In the implicit condition, the participants had to respond with 'yes' or 'no' depending on if the adjective appeared below or above the face. This task was followed-up by a standard old/new recognition task. In this fashion, no explicit self-reverence judgement is made in the implicit condition, whereas a direct comparison with the standard explicit self-reference judgement was possible.

Their results showed a strong self-reference effect in the explicit condition, but although the overall score on the old/new task was lower for the implicit condition, a self-reference effect was still present in this condition. An interaction between the two conditions was also found, revealing that the self-reference effect was stronger (i.e. greater difference between self and other) in the explicit condition compared to the implicit condition. According to Turk et al. (2008), these findings are the result of the cognitive system's necessity to ensure the processing of relevant information as dictated by our goals and safety (Bruner & Postman, 1947). Via their research Turk et al. (2008) have shown that self-relevant information on its own, without any explicit self-referential processing, is already enough to ensure preferential processing, leading to improved encoding into memory. The authors suggest that this preferential treatment of self-related information could be the result of the positive affect (Alicke, 1985), where positive emotional information is associated with the self, and therefore the affective response to self-relevant items might impact memory. The authors further suggest that the automatic capture of self-related items (as discussed earlier in this thesis) leads to enhanced encoding adjectives related to the self. The authors conclude that it is likely the combination of the increased attentional capture due to the emotional nature of self-relevant information. Also interesting here is that the more robust self-reference effect for the explicit condition could be explained by the integrative self (Sui & Humphreys, 2015b, discussed earlier in this thesis). Not only does the more explicit processing of the adjectives lead to more enriched encoding (as reflected by overall better performance), this would also generate more binding to other self-related information which, in turn, facilitates later recall even more.

A different approach to the often used self versus other or semantic processing as described above is via ownership (e.g. the feeling that something belongs to you)[6]. Through ownership, the self extends to what is perceived as 'owned' (Belk, 1988, 2013). The mere ownership effect reflects this when items arbitrarily associated with the self (i.e. owned) are seen as more positive (Belk, 1988) and more valuable (Morewedge & Giblin, 2015) when compared to the same items not associated with the self. The experiment by Turk et al. (2013) on divided-attention mentioned earlier used 'ownership' by instructing participants that an item belonged to them. Also using this connection between the self and ownership, Cunningham, Turk, Macdonald, & Macrae (2008) designed a shopping experiment where the participant could "own" items. Also, a confederate (pretending to be a participant) was part of the experiment. The confederate could "own" some of the

[6] A detailed discussion of ownership is beyond the aims of this thesis, but ownership can lead to an 'immersion' of self into the perceived owned object or concept creating close associations with the self and can even become an extension of the self, see the review of Pierce, Kostova, and Dirks (2003) for more detail.

items as well. In this way, a self (participant) versus other (confederate) manipulation was created. The confederate and participant were seated at a table with two baskets. Both were explicitly told that they owned the basket nearest to them. The participants were also instructed that they should imagine having won a basket full of items. These items were represented by picture cards. The baskets were red or blue which corresponded with the picture cards which could be red or blue too. The participant then had to place each of their picture cards (which represented an item they owned) in the same coloured basket. The participant or confederate was given a card one at the time. They would not know which of them would receive a card, but they were shown the card before it was handed over. After receiving a card the participant or confederate then put the card in the correct basket depending on the colour of the card. After all the cards were handed out and divided over the two baskets, a computer based old/new memory task followed.

With their experiment, Cunningham et al. (2008) showed that items, perceived as belonging to the participant, are more often correctly recognised in the old/new task when compared to items that were possessed by the confederate. Moreover, these items were also recognised faster. This effect is evident when the participant placed the card in their basket and when the confederate placed the card in the participants' basket. This led the authors to conclude that, despite the temporary and imaginary nature of ownership, encoding into memory is affected by enhancing memory for self-related owned items. According to the authors, this is likely due to the ecological benefit of remembering items that are yours versus those that you do not own.

A study by by Kim and Johnson (2010) linked the mPFC to self-relevant objects, and subsequent memory of those objects. Their experiment had three distinct phases: first participants were shown a picture of an object and had to indicate how much they liked the object, and how much people, in general, would like the object; second, after the preference rating task the participants were asked to assign pictures of objects to either themselves or another person. After each picture was shown, a coloured dot was depicted alongside the picture. The colour indicated if the participant had to assign the picture to themselves or to another person; third, the object assignment task was followed by a memory task where the participants were again shown a picture, and this time they had to indicate if the picture had been assigned to them or another person; fourth and final phase was again a preference rating task similar to the first task, to see if "owning" an object would change their preference of said object.

Overall, the findings of Kim and Johnson (2010) show typical mPFC deactivation for items not related to the self, i.e. self-related items show more activity in the mPFC when compared to distant other but generally did not significantly differ from baseline. Participants showed greater mPFC, paracingulate, and frontal pole activation for items assigned to themselves. The authors also found greater mPFC activity for items related to the self that were accurately recalled. Lastly, the results showed a mere ownership effect, meaning that the mere act of assigning items to yourself increases the preference for that object. In this study, the mere ownership effect was again linked to greater mPFC activity. The authors concluded that self-referential processing is linked to the mPFC.

However, as mentioned by Turk et al. (2008) in the preceding section, this effect might be emotional in nature as the mere exposure effect is driven by a positive bias for owned items (Belk, 1988) Emotional processing of self-related information improves memory performance (D'Argembeau, Comblain, & Van der Linden, 2005; Kuiper & Derry, 1982; Ochsner, 2000; Sedikides & Green, 2000, 2004). This, in turn, prioritised attention to self-owned items, which with the extra attention, help encode the items into memory. In short, the rich binding between self-relevant information could facilitate memory retrieval (Sui & Humphreys, 2015b).

This rich binding between self-relevant information could refer to the interconnectedness of self and memory. This concept was the rationale behind the Self-memory system (SMS) proposed by Conway & Pleydell-pearce (2000). The self, as discussed in the SMS, is arguably a higher order of self when compared to the self discussed so far. This self pertains more to the "I" (or Identity) mentioned earlier in this introduction, than the "me" (self as an object) which is the main focus of this thesis.

However, this research has been fundamental in self-reference research, and self-related information is naturally highly dependent on one's identity in a natural setting. In order to explain the SMS, it is essential to introduce and define the concept of *autobiographical memory*.

Autobiographical memories are specific memories of events, people, and semantic facts from a person's life relevant to themselves and generally consists of three levels: lifetime periods (e.g. memories of your time at university, work, or childhood), general events (e.g. specific memories when you were playing sports, going out with friends), and event-specific knowledge usually recalled via remembering general events (e.g. winning first place, or a particular eventful outing with friends). These memories can be episodic in nature (e.g. how you felt when you started your first job) or semantic (e.g. the name of your first employer), but are always associated with the self (Anderson & Conway, 1993; Brown, Shevell, & Rips, 1986; Conway, 1992; Conway & Bekerian, 1987).

A second assumed component of the SMS is the 'working self' (M. A. Conway & Pleydell-Pearce, 2000). The working self is a control process which helps to maintain coherence between the current and future goals by modulating the creation of relevant memories (Burgess, 1996). Furthermore, the working self is influenced by conceptual self-knowledge, meaning all abstract knowledge structures which are independent of specific autobiographical events but nonetheless help define the self; and typical (culture-specific) behaviours in the environment (Conway, Meares, & Standart, 2004). Fundamental to the working self is to limit or resist goal changes, in order to maintain a coherent and stable self. In doing so, the working self can lower/increase accessibility or distort existing memories to fit more with the current goal and maintain coherence (Conway et al., 2004).

The SMS comprises of the autobiographical systems and the working self, which together generate autobiographical recollections. This would not be possible if the working self and autobiographical self were acting independently. In this sense, the SMS[7]

[7] See Conway (2005) for a full review on the SMS.

promotes self-relevant information relevant to one's goals, via the knowledge base of autobiographical information and the goal monitoring (coherence) of the working self. This promotion of self-relevant information is what could lead to the greater saliency in self- related information in memory, in other words: the self-reference effect. See Figure 2 for an overview of autobiographical memory and SMS.

Interestingly, emotion seems to either be used as a possible explanation to explain what drives the self-reference effect (S. J. Cunningham et al., 2008; Turk et al., 2008), or like the research by Gutchess et al. (2007) and Leshikar et al. (2015) have shown, emotional aspects interact with self-related information processing, but emotion alone cannot explain the self-reference effect. Similarly, the SMS (M. A. Conway & Pleydell-Pearce, 2000) is thought to be distinct from emotional processes. The SMS minimises potential disruptive effects of negative or intense emotional memories on one's goals, yet still retains access to emotional memories relevant to one's goals.

In another fMRI experiment on memory, Kelley et al. (2002) found again mPFC activity related to self-referenced words. This experiment was a trait-word experiment where participants were shown trait-words in three conditions: 1) self-relatedness to trait-word; 2) distant other-relatedness to trait-word (in this case a familiar distant other the then U.S. president George Bush); 3) control judgement (is the trait-word printed in uppercase?). After the encoding phase, a surprise recognition test followed. The results showed that participants were faster for judgements related to the self when compared to judgements related to a distant other (e.g. George Bush). The uppercase judgement in the control condition was faster than the other two conditions. The memory recognition test revealed that trait judgements related to the self were recognised faster and more accurately than trait judgements related to a distant other. The performance for uppercase judgements was worst of all (since these judgments did not require semantic processing). In their fMRI results, the recognition for trait-words did not result in any differences between distant other referenced trait words and self-referenced trait words for any of the main brain areas involved in memory. It was discovered that the mPFC was involved during self-judgements for later correctly recalled trait-words, again because distant other-judgement resulted in greater deactivation from baseline. This led the authors to conclude that the mPFC contributes to the advantage of the self-reference effect on memory. Furthermore, it is suggested that if self-referencing is the result of normal memory processes and is but an extension of these processes that this should be reflected in additional activation, which they did not find and thus they conclude that the mPFC is driving the self-reference effect. Lastly Kelley et al. (2002) hypothesize that since the greater activity of the mPFC for self-related information is not significantly different from baseline and is only different due to a greater deactivation when not processing self-relevant information, the self is not categorised as different from resting brain activity but by its similarity to resting brain activity.

Figure 2 has been removed from this
thesis due to copyright restrictions

Figure 2. Directed and generative retrieval in the Self Memory System (SMS). Replicated and adapted without permission from M. A. Conway, 2005). This figure illustrates how a cue activates existing long –term memories, either directly without being influenced by the working self, or generatively via an iterative cue elaboration involving the working self. Via the retrieval models memories are distinguished from other mental imagery (e.g. daydreams) and the elaborated cue help assist is further memory retrieval/specification.

Emotional information and memory

It has been known for some time now that emotion (like the self) influences the likelihood of later recollection (Alicke, 1985; LaBar & Cabeza, 2006; Levine & Pizarro, 2004; Mather, 2007). Many other studies involving trait-words and emotional valence find indications that the dmPFC is involved in encoding information related to the self (Fossati et al., 2004, 2014; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Qin & Northoff, 2011). Naturally, with emotion, it is well known that activity in the amygdala is linked to the processing of emotional stimuli (W. A. Cunningham, Raye, & Johnson, 2004; Herbert, Ethofer, et al., 2008; Zald, 2003). Like self-relevant information processing this is an automatic and fast process of which one does not have to be consciously aware of the emotional valence and as such activity in the amygdala does not reflect conscious emotional experience per se (A. K. Anderson & Phelps, 2002; Craig, 2008; Damasio, 1999).

An excellent example of how recalling some information from memory can be easier, is the phenomenon of flashbulb memory (Brown & Kulik, 1977). Flashbulb memories are highly detailed bits of memory for an event often emotional in nature. For example, ask any American what they were doing on 9/11, and you will likely get a very detailed report of everyday things they were doing when the terror attack occurred. Naturally, this is an extreme emotional example illustrating how certain events are more (emotionally) important to remember compared to more neutral events. However, this does not mean that these emotional memories are always correct. Research has shown that even though the memories are more vivid, this does not mean that the remembered details are accurate (Dougal & Rotello, 2007; Kensinger, 2009; Sharot, Delgado, & Phelps, 2004).

In a series of experiments, Sakaki, Fryer, and Mather (2014) used an oddball paradigm to investigate the effects of emotion on memory. For these experiments, the authors used photos with different semantic meanings on a white background, and one oddball picture on a black background. The black background ensured that the picture was an oddball. Furthermore, the pictures used as an oddball were either neutral or had an emotional value (negative or positive). The instructions informed the participants to remember either the oddball picture, the picture immediately following the oddball picture, or the picture immediately preceding the oddball picture.

The follow-up memory test showed that when the participant prioritises the picture before the oddball, they have better recognition for that picture. Moreover, if the oddball had an emotional value, the recognition for the picture before the oddball was better than if the oddball was neutral. This effect reversed when the participants had to prioritise the oddball picture, as the results showed a decrease in recognition for the word immediately before the emotional oddball when compared to the neutral oddball. Recognition decreased for the picture following the emotional oddball if these pictures were not prioritised. This decrease in recognition was reduced (but not to the point of memory enhancement) if the pictures following the emotional oddball were prioritised. This decrease in recognition inhibition was greater for negative emotions compared to positive emotions.

Sakaki et al. (2014) conclude that emotion enhanced recognition when there was a top-down priority for the to-be-remembered items and impaired recognition when not. However, this is only true if the prioritised event precedes the emotional event. No enhancement was found when the prioritised stimuli followed the emotional event.

Taken together, these studies can be understood in terms of arousal-biased competition (ABC) theory. This theory states that emotional arousal enhances processing and consolidation for high priority events over low priority events. The priority of an event is established through bottom-up perceptual salience and top-down relevance (Mather & Sutherland, 2011). In this sense, the top-down control of emotion is similar to the top-down control of the self, and the goal promoting aspect of the SMS. In the case of Sakaki et al. (2014), the emotional oddball helps strengthen the prioritised event as the participants were instructed to remember the picture before the emotional oddball. In other words, the emotion is experienced while participants are trying to remember as many pictures as possible. The emotional oddball provides the participants with the information they need (remember the picture before this oddball), and the emotion helps strengthen this top-down prioritised picture. The same could be true of anything related to the self: as soon as a specific piece of information is related to the self, top-down prioritisation increases the saliency of self-related information, which generates enriched encoding into memory. Via the self, the prioritised information binds to other self-relevant information, which in turn increases the likelihood of later recall.

How then have authors proposed that emotion and self-relevant information might interact with each other? As mentioned before people tend to see themselves positively (Alicke, 1985). Since memory is goal driven as discussed (M. A. Conway & Pleydell-Pearce, 2000), self-enhancing positive information which confirms the positive self-image is more memorable over information which is negative and would subtract from a positive self-image (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Mezulis et al., 2004; Taylor, 1991). This is precisely what previous research has found: an overall better memory for self-related positive information compared to self-related negative information (Kuiper & Derry, 1982; Ochsner, 2000; Sedikides & Green, 2004). Part of this enhancement of positive self-relevant information is thought to be the result of increased depth of encoding (Sedikides & Green, 2000). Here there is a potential overlap between the self-priority and self-reference effect. In other words, do the extra attentional resources, when processing positive self-relevant information, enable more in-depth encoding (i.e. self-reference effect)? D'Argembeau et al. (2005) researched another possible option. The influence of valence on self-relevant information was studied by comparing two memory retrieval methods.

In their experiments, participants were asked to rate a list of traits. Half of these lists contained positive trait-words (e.g. happy) and the other half negative trait-words (e.g. sad). Furthermore, half of the participants were asked if the trait-words described them, and the other half of the participants were asked if the trait-words described a famous individual the participant did not know personally. The participants were not informed that a memory test would follow. This encoding paradigm was precisely the same for two experiments. In one experiment, an old/new recognition task followed the encoding phase. In the other experiment, a free-recall task followed the encoding task. By comparing two different memory tasks which were preceded by the same encoding task, the authors could compare the effect of a memory task with retrieval cues (old/new recognition task) versus a task with no retrieval cues (free-recall task). D'Argembeau et al. (2005) suggested that there is not as much need to look for emotion and self-relevant retrieval information in an old/new recognition task since the nature of the cue (valence or self) is superseded by the cue itself. In other words, the cue by itself provides enough information for fast retrieval. The free-recall task does not offer any external cues for the participant to use. Therefore, the emotional valence and self-related information of the trait-words become more critical in enabling successful recall. Based on this, the authors predicted a greater self-reference effect for positive information when compared to negative information for the free-recall task only. For the free-recall task, their result did indeed show a self-reference effect for positive self-related words, and no self-reference effect for the negative trait-words. For the old/new recognition task, a self-reference effect was also found, but with no difference between positive or negative valence. The authors interpret these results as reflecting the difference in retrieval processes. As such, the self-reference effect is partially taking place during retrieval. The rich external cue from the old/new recognition task overshadows any influence of valence on the self-reference effect. The self-reference effect persists, but the distancing of negative trait from, or the attraction of positive trait to self-relevant information does not occur, or at least less clearly. The increased demand on internal cues on the free-recall task demonstrated the beneficial effect for positive self-related information.

In an fMRI study by Herbert, Herbert, and Pauli (2011) this link between positive and self-relevant information on memory was investigated further. Participants were presented with pleasant, unpleasant and neutral nouns and these were either paired with the possessive pronoun ‘my’, ‘his’, or a definite article ‘the’. With this set up, the authors could compare the emotional effects on self- and distant other-relevant information processing compared to neutral information. The participants were presented with one word at the time which they had to read silently, and they were told that some words would describe their emotions, some the emotions of a distant other, or just state an emotion not linked to anyone. After all words were presented, a surprise free-recall task followed. Their results showed that the amygdala and insula were active whenever emotional negative words were presented regardless of perspective, showing that negative emotions specifically activate the amygdala and insula. The amygdala activity was also increased when the participant was presented with self-relevant positive information. According to the authors, this suggests that the amygdala is involved in the processing in multiple kinds of emotions and that the amygdala is also involved in detecting personal relevance, and also supports the self-positivity bias. Furthermore, self-relevant positive nouns increased the ACC and the mPFC. As mentioned, the mPFC is linked to self-referential information processing and especially the vmPFC been linked to the evaluation of current feelings (Herbert, Herbert, & Pauli, 2011; Lee & Siegle, 2009; Ochsner, Bunge, Gross, & Gabrieli, 2002). The experiment also revealed the PCC and precuneus to be active during self-reference processing, especially if the self-related information is positive.

The above shows that emotion has an effect on how self-relevant information is processed but now during retrieval. This suggests a separate (possibly multiplicative) benefit during retrieval compared to the influence of emotional self-related information on attention and encoding processes. Lastly, beyond the emotional valence of words, emotional feelings during encoding and retrieval influence how easily one will be able to recall certain words.

The recollection of words learned while in a specific mood is easier when a person is in the same mood during recall (Bower, 1981). In the free-recall experiment, Bower (1981) had participants learn wordlist in either a happy or a sad mood. After the learning phase, the participants were asked to recall as many words as possible freely. However, the participants were induced to have a similar or different mood during recall. The results showed that when one learns words during a happy mood, one is more likely to correctly recall the words when in a happy mood as well. Similar effects were found when people learned and recalled during a sad mood. Bower (1981) explains this mood-congruent effect as each emotion binding to events with similar emotions, allowing for easier recall when the participant is in that emotional state.

Interestingly, mood-congruent recall appears to be dependent on an individual's self-knowledge base (Sakaki, 2007). People tend to recall fewer negative memories when in a positive self-related mood. However, when induced into a similar positive mood, but recalling memories not related to the self, people recall more negative words. When recalling positive words during a negative mood, similar effects are observed. Generally, people have mood-congruent recalls for self-related information and mood-incongruent recall for non-self-related information. Furthermore, with recalling more positive memories, the participant would feel more positive afterwards (Sakaki, 2007). It is not a huge leap to imagine that the words one attends to more (i.e. self-priority effect) influence the encoding of that information. This subsequently enables superior recall of that information, but the information itself (not just an encoding benefit) influences retrieval of that memory (i.e. self-reference effect).

Summary

Together, the sections on attention and memory show that emotion and self both seem to influence attention, memory encoding, and retrieval processes independently. Furthermore, it is clear that emotional valence influences self-related information differently depending on whether the information is positive or negative, although the exact nature of this interaction remains unclear. The above helps to illustrate that familiarity and emotion are not the driving force behind the self-priority effect and, to an extent, the self-reference effect. Each exerts an influence on cognitive processes on their own, but interact with each other also. In other words, it is possible that self and emotional processing do not function in isolation of each other despite being distinct systems.

Sui & Humphreys (2015b), offer a theory that self-relevant information enhances the binding of stimuli in perception (self-priority effect) and memory (self-reference effect). This allows for a more rapid detecting and processing of self-relevant information into a core self-representation. Furthermore, Sui & Humphreys (2015b) suggest that the enhanced binding of self-relevant information alters ongoing processes, which results in preferential treatment for the self-relevant information compared to information not related to the self. This same enhancement of binding self-relevant information makes re-binding of information previously linked to the self more challenging (Wang et al., 2016). In short: "*Self-reference provides a form of associative 'glue' for perception, memory, and decision making and, through this, acts as a central mechanism in information processing*" (Sui & Humphreys, 2015b, p. 719)

If the self does act as a central mechanism, then one would expect this to be reflected by the underlying neurophysiological processes. Interestingly, the mPFC, pACC, PC, PCC, pSTS, TPJ, IPL, MTL and AG are all related to what is called the default mode network (DMN), which has been implicated in multiple self-related studies (Northoff & Bermpohl, 2004; Qin & Northoff, 2011; Spreng & Grady, 2009; Whitfield-Gabrieli et al., 2009). The DMN includes cortical midline structures (CMS) as core structures and shows consistent task related de-activation, being more active at rest. The DMN is highly interconnected with other brain areas and networks. For example, there is a strong functional connection with the ACC, PCC, and a reciprocal connection with the parietal and lateral prefrontal cortex. Cognitively demanding tasks generally result in greater deactivation of the DMN (Singh & Fawcett, 2008). However, the opposite is true when the task involves self-referential processing (Mitchell, 2006).

For example, experiments by Whitfield-Gabrieli et al. (2011) aimed to identify associations and disassociations in the CMS between the self-reference network and the DMN. Like many trait word experiments, the participants were asked to judge if trait-words related to themselves and if trait-words were positive. Each trial was then followed by a resting state for ten seconds. When compared to the valence condition, the results showed an increase in neural activity for the vmPFC, dmPFC, PCC, and pACC for the self-traits condition. Interestingly during the resting phase, the CMS revealed greater activity when compared to the valence condition but not when compared to the self condition. The authors then looked to dissociate regions involved in rest and self and found that the dmPFC was more strongly activated during rest whereas the pACC, PCC, and vmPFC showed overlap between the two conditions.

Based on a meta-analysis on more studies like the one described in the previous paragraph on self- and resting state, Qin and Northoff (2011) introduce the concept of "rest-self overlap" to describe the similarities between self-related processing and the resting state in term of neural overlap (Northoff, 2015). To explain this rest-self overlap, Northoff suggests two possible explanations: 1) regardless of overlap, the self and rest states are independent of each other. Similar regions might be recruited but in different ways so that the neural activity reflects two distinct processes. This is what the author refers to as "rest-self overlap"; 2) Northoff calls his second explanation the "rest-self containment". Now the DMN not only shows overlap with self-related processes, but the neural activity also reflects the same process, i.e. the spontaneous activity during the resting state reflects self-related processing. This, in turn, means that resting state can predict if information will be processed as self-relevant or not and that stimuli that are highly related to the self do not show any differences in neural activity when compared to the resting state. Northoff postulates that this is because spontaneous brain activity in the DMN already contains self-information and thus the processing of a highly self-relevant item does not add to the already present self-related activity. Moreover, according to Humphreys and Sui (2016) the vmPFC is housing the self and via its top-down modulations to the LpSTS self-relevant information is prioritised. Furthermore, the dlPFC is part of the SAN as well, and it this relation between the vmPFC and dlPFC that Northoff (2015) suggests is one way for different networks in the brain to encode spontaneous self-related brain activity to internal or external stimuli. His reasoning behind this is that where the vmPFC shows increased activity related to the self, the dlPFC activity is weaker. Since the vmPFC is linked to the DMN and the dlPFC is linked to the control executive network (CEN), this negative correlation relationship encodes self-relatedness to stimuli, i.e. higher vmPFC activity and lower dlPFC activity equals higher self-relatedness linked to stimuli.

Also, M. A. Conway, Pothos, and Turk (2016) suggest that the self attention network (Humphreys & Sui, 2016) might be part of an overall bigger self-relevance system (SRS). The authors emphasise the inhibitory network essential in discriminating between situations that are highly self-relevant and those that are not. Via the SAN, other processes, like memory, can be influenced as the result of attentional bias. The bigger SRS suggested by the authors shares cortical networks with the SAN linked to the DMN.

In other words, the SAN model suggested by Humphreys and Sui (2016) and the rest-self containment model proposed by Northoff (2015) are very similar in their basic concept. Both suggest that the self is a separate function of the brain, and both suggest that the self-relatedness of a stimulus is determined at a low processing level of the brain. However, the SAN suggests that the self is housed in the vmPFC, linking self-relatedness to incoming stimuli earlier than the visual associative areas; whereas the rest-self containment model suggests that the self is part of the spontaneous brain activity. This means that both models agree that the self is not a higher cognitive function, but is a part of the brain's basic functioning. With the link of the vmPFC to the DMN, both models together help explain how the self modulates stimuli at the earliest level of stimuli processing, e.g. sensory cortex (incoming information) to CMS (self/not-self attribution) to lateral cortex (higher cognitive aspects such as autobiographical memory) and reverse top-down modulation. The above suggestion that the SAN is part of a bigger SRS fits well with the idea of an integrated self by Sui and Humphreys (2015). The self-reference and the self-priority effect are not two disconnected phenomena. The standpoint of this thesis is that self-relevant information influences both attention and memory systems. This is achieved via underlying cortical processes that help prioritise and bind self-relevant information together across multiple cognitive domains.

Lastly, this chapter has reviewed literature suggesting that emotion prioritises information as well (or at least as long as it is goal relevant). Furthermore, emotion and self-related information together seem to create an interaction between the two. Self-relevant information is preferably linked with positive information, and the self seems to be distanced from negative information. Therefore how emotion and self-related information interact to influence attention and memory will be the main focus of this thesis. The final section of this chapter focusses on explaining the precise aims of this thesis (and of each chapter).

Thesis aims and overview

Emotion and self-related information processing are two factors that are being used to prioritise parts from the constant stream of information confronting people in their daily lives. Emotion and self-relevance are two indicators (albeit not the only two) to help us navigate the world and quickly perceive what is possibly harmful or beneficial to our continued existence. Furthermore, their effect on memory ensures that emotional and self-relevant events can be recalled with greater ease, ensuring that past benefits or harmful situations help guide future behaviour.

However, there are several questions still unanswered: although research has indicated that emotion and self-referential processing are two separate and independent processes, it is still unclear what would happen in situations where an event is both self-relevant and emotional. In short, how do these two priority systems interact, if they interact at all? Especially if you are not judging if a positive trait describes you, which is the main modus operandi of previous research. Finally, most studies investigate the self-priority or the self-reference effects separate from each other. Therefore, it is not clear if the same emotional self-related information that influences attention (i.e. self-priority effect), also influences memory (i.e. self-reference effect).

This thesis is divided into two parts: the next four chapters describe seven experiments focussing on cognitive, computer-based, experiments. These four experiments mainly gather reaction time (RT), d-prime, and accuracy data, except *Experiment 2*, where redundancy gain models are applied to the data. In Chapters 6 through 8, behavioural data but also electroencephalogram (EEG) data is presented.

Experiment 1 (a & b) reduced the influence of familiarity by using an adaptation of the Sui et al. (2012) matching task combined with an old/new recognition task. The adaptation of the matching task involved changing the geometric shapes used in Sui et al. (2012) to words and the linking of a specific colour to the self instead of a shape. *Experiment 1a* and 1*b* were very similar, and the main difference was the use of negative nouns in *Experiment 1a* and positive nouns in *Experiment 1b*. This approach would allow the testing of emotional self-relevant information without the elaborate encoding resulting from asking the participant to judge the words in relation to themselves.

Experiment 1 (c & d) aimed to make the stimuli more self-relevant by replacing the emotional nouns with emotional trait-words. *Experiment 1c* used negative trait-words and *Experiment 1d* used positive trait-words. Like the previous two experiments, a matching task was followed by an old/new task.

Experiment 2 attempted to highlight the different influences of self and emotion further and looked into a potential redundancy gain effect of self and emotion. This was achieved by making sure that the emotional meaning of the words was processed roughly at the same time as the colour of the word (i.e. self-relevance).

Experiment 3 studied the effects of repetition on the self. The main reason for this was to examine the effect of automaticity on the self-reference effect. The standard matching paradigm was used from *Experiments 1a-1b* but was repeated three times, after which the old/new task followed.

Experiment 4 used a free recall design to look beyond memory recognition to free recall. So far, all experiments have used an old/new memory task, which naturally provides a robust external cue for memory retrieval. Since there is a potential effect on retrieval by self-relevant information, a free-recall task was used as a memory task with no external retrieval cues. Furthermore, like *Experiment 3*, there was an element of repetition, repeating the wordlist three more times. The number of words used in the free-recall task was too large and the wordlist was divided into multiple blocks. The use of multiple blocks allowed for an inspection on the effect of each repetition on the self-reference effect.

Experiment 5 is the major EEG experiment of this thesis. Like the two previous chapters, it examines the automaticity of self-relevant information processing. This was done by an intentional forgetting task where participants were instructed not to think of some words and instead try to suppress the recall of the word. For this task, participants had to learn a wordlist containing words linked to the self or a distant other.

Experiment 6 was a free-recall experiment like *Experiment 4*. This final experiment was also an EEG experiment. This experiment used positive trait-words without any repetition. The primary purpose was to examine the effect of an increased recall difficulty on the self-reference effect and examine the underlying neurophysiological processed used in the matching task.

Lastly, this thesis is concluded in *Chapter 8*. In this chapter, the results of all the experiments are summarised. Furthermore, the implications and limitations of *Experiments 1-6* are discussed, concluding with several ideas of further research.

Chapter 2:
Attention, Memory & Self

Introduction

The paradigm described in this chapter aimed to study the influence of self and emotion on attention and memory within the same participants. This was achieved by using the same stimuli for attention and memory, using a direct experimental control of self. A comparison was made between the effect of emotional self-relevant information and information related to a distant other on memory and attention.

The experiments that follow involve manipulation of the encoding of stimuli, which subsequently have to be remembered in a memory recognition or recall task. These manipulations involve the self-relevance of the stimuli. Additionally, the presented memory items themselves were chosen with qualities which are expected to influence their encoding. Specifically, the stimuli varied in their emotional valance.

The basic paradigm in this thesis involves an adaptation of the perceptual matching task of Sui, He, and Humphreys (2012). As discussed in *Chapter 1*, their paradigm linked the self and distant other to a geometric shape by instructing the participant that "you are a circle; a stranger is a triangle". Their results showed clear prioritisation of the geometric shape linked to the self. Since one of the aims of this thesis is to explore the link between the self-priority and the self-reference effect, the matching paradigm of this thesis used different coloured words - rather than shape-associations as part of the manipulation of self-relevance. Participants were told that a particular colour belonged to them.

Similarly to using shapes, using colour should reduce any influence of familiarity or differences in processing the stimuli. As discussed in the main introduction, many self-relevant stimuli have a potential confound of familiarity. Using the methods suggested by Sui et al. (2012), familiarity was separated from self-priority by using the matching task. Because of this, all stimuli could be expected to be equally familiar. Furthermore, the semantic meaning of the words varied in their emotional valance. Words were chosen to be either emotionally negative, emotionally positive, or emotionally neutral. Using words, this version of the perceptual matching task not only allowed for manipulation of emotion, but the matching task could be used as an encoding paradigm as well. The perceptual matching task was therefore followed, after a delay, by an old/new recognition task.

By arbitrarily associating a colour to the self or distant other, perspective could be linked to a word. With this adaptation of the perceptual matching paradigm by Sui et al. (2012), this study aimed to use the robust self-priority effect elicited by the perceptual matching test and link it to memory processes. This way, the possible relation between the prioritisation of self-related information via attention with a later self-reference effect in memory could be explored.

With the matching task, the effect on attention of emotional and self-relevant information can be tested. Research suggests that positive information 'broadens' attentional processing, whereas negative information 'narrows' attentional processing (Fredrickson, 1998; Wadlinger & Isaacowitz, 2006).

Another issue is the effect of negative emotions in the self. As was mentioned in *Chapter 1*, several studies have shown that it is easier to link positive information to the self compared to negative information. (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Kuiper & Derry, 1982; Mezulis et al., 2004; Ochsner, 2000; Sedikides & Green, 2004; Taylor, 1991). In other words, positive information is more approachable for the self, whereas negative information leads to a distancing of the self. Therefore the current adaptation of the matching task should allow the testing of the effect of emotion and self-relevant information on attention.

It is expected that item memory, as measured on the old/new recognition task, would be better for words related to the self compared to non-self related words. It was further expected that recognition of emotional words would be better compared to neutral words. As mentioned in *Chapter 1*, emotion and self could interact. Previous studies have explored the role of emotional self-related information (Gutchess et al., 2007; Leshikar et al., 2015). However, these studies compared positive versus negative stimuli. Therefore, it was not clear if the self-reference for negative self-related items is reduced only in comparison with positive items or reduced in comparison with neutral items or vice versa. In the study by Leshikar et al. (2015), non-self conditions were used to compare with self-related information. Arguably, the task for the non-self conditions impact different processes (e.g. is 'excited' a commonly used word?), compared to self condition (e.g. Does 'excited' describe you?), which alone could partially account for any differences observed. Therefore, this thesis will investigate the self-reference effect using the matching paradigm as an encoding task as the task for both the self and other condition would the same. The only difference would be that the self is prioritised when processing the stimuli. In other words, any benefits in recognition would likely be the result of the more efficient processing of self-related information.

The next four experiments described in this chapter varied from each other, but all were based on the matching paradigm paired with an old/new task. Mainly the next four experiments explore if there is a difference between positive and negative self-related information when compared to neutral self-related information. The first two experiments (*1a & 1b)* will use negative and positive nouns, respectively. The last two experiments (*1c & 1d)* will use negative and positive trait words. In short, this chapter will explore the relationship between the self-priority effect and a self-reference effect using emotional stimuli, which are arbitrarily linked to the self or other using colour.

Experiment 1a: The self and negative emotions

Leshikar et al. (2015) and Gutchess et al. (2007) both have shown that it is possible negative self-related words result in no, or a reduced self-reference effect. A reduced or missing self-reference effect is possibly due to the distancing of the self from negative information (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Taylor, 1991). However, as mentioned in the previous section, the studies by Leshikar et al. (2015) and Gutchess et al. (2007) do not provide an equal encoding opportunity for the non-self condition, compared to the self condition. For example, asking individuals if something relates to themselves possibly results in a much richer encoding experience compared to asking if a particular word is commonly used. The former would potentially entail a wide range of memories of experiences, beyond the mostly semantic processing of the later.

Experiment 1a of this thesis will further investigate the effect of negative self-related words on the self-reference effect. This study aims to elicit a self-priority effect and a later self-reference effect, using the same stimuli. A self-priority effect will be achieved by using an adaptation of the perceptual matching task designed by Sui et al. (2012) as an encoding task. An old/new recognition task will then follow the matching task. Therefore, a reduced self-reference effect for negative information is expected with regards to memory. In other words, participants will show reduced accuracy levels in the old/new task for other-related information compared to self-related information. Furthermore, this effect will be stronger for words with a neutral valence compared to words with a negative valence. For the matching task, it is expected that a self-priority effect precedes the self-reference effect. An interaction between perspective and emotion is expected. This interaction will be reflected by a slower RT and reduced accuracy in the matching task for other-related information compared to self-related information. This difference will be reversed for the negative words compared to the neutral words.

Methods

Participants

In total, 25 participants from Oxford Brookes University participated for course credit in the study. Five participants were removed from the data analysis because the task was not understood or due to technical issues. Of the remaining 20 participants, 18 were female, and two were male (mean age= 22.44 years, range: 18-50 years). The university ethics committee approved this study; all participants gave informed consent.

Stimuli

The stimuli used in this experiment were words with two main conditions. The first condition was the emotional value of the word; either negative or neutral. The second condition was a perspective linked to the words, which could either be 'yourself' or 'stranger'.

Two hundred and thirty words were derived using the word database given by Warriner, Kuperman, & Brysbaert (2013). This database consists of norm rating for arousal and valence, among other measures, for 13,915 English words. In the database, both valence and arousal were measured on a nine-point scale (for valence 1=unhappy, 9=happy; for arousal 1=calm, 9=excited). The ratings for arousal and valence were used in combination with word frequency ratings derived from another word database reported by Heuven, Mandera, Keuleers, & Brysbaert (2014), of which 230 of the top frequent unique words were taken (homophones and different tenses were excluded). Of these 230 words, 115 were negative (valence <3, arousal >5), and 115 were neutral (valence between 5-6, arousal <3).

These 230 words were divided into three lists: one practice list and two main lists of 100 words each. The main lists were subdivided into four sets: 25 were neutral and linked to the self (self/neutral); 25 were negative and linked to a distant other (other/negative); 25 were neutral and linked to the self (self/neutral); and 25 were negative and linked to stranger (other/negative), a similar division was made for the practice list. Therefore, this created three lists with two main conditions each: perspective and emotion. The average word-length was 5.68 letters, was matched across conditions, and the Courier New font was used for all text (size 18).

Procedure

The experiment was designed and run using PsychoPy software (Peirce, 2007). All stimuli were presented on a light grey background. Words from the matching task wordlist were presented in colour; all other texts were in white. The software was run on a pc in a darkened room on a 17" monitor running at 60 Hz with a resolution of 1280-960. All input provided by the participant was registered using a three button pc mouse. The experiment consisted of two components: an initial matching task and a later old/new recognition task in the same session.

Matching task

The matching task (see Figure 3A) was based on the perceptual matching task reported in Sui, He, & Humphreys (2012). For the experiment by Sui et al. (2012), participants had to compare one of three labels ('self', 'mother' or 'stranger'), with a geometric shape based on an earlier given rule. In the current experiment, participants had to report if one of two labels ('yourself' or 'stranger') matched with a font colour of a simultaneously presented word. For example, the participants were instructed: "You are a salmon colour; a stranger is a slate blue colour". The colours linked to stranger and self were counterbalanced across participants. In this study, the word-label pair could either match with the instruction or not match. The participant was instructed that they would be presented with a series of words, each of which would be in one of two font colours: salmon (RGB: 250, 128, 114) or slate blue (RGB: 106, 90, 205). Each of these coloured words would be presented with a label given in white ink which would state either 'yourself' or 'stranger'. The participants had to respond yes or no according to whether or not the colour of the word matched with the label presented for that trial by pressing the left or right mouse button respectively, which was counterbalanced across participants also. For instance, if a participant had been told to associate salmon with 'yourself' and slate blue with 'stranger' then they would have to respond yes if the label 'yourself' appeared with the word given in the salmon font colour and 'no' if the label 'yourself' appeared with the word in the slate-blue font colour. Half of the trials matched with the instructions and the other half did not match with the instructions.

Each trial started with a fixation cross in the centre of the screen (subtended visual angle 0.57°), which was shown for 500ms. After the fixation cross, the emotion-word and the label (subtended visual angle for both 0.57°) were presented respectively above and below fixation cross (subtended visual angle as measured from centre of the fixation cross to the top of the emotion-word or label: 1.72°). Participants had to respond 'yes' or 'no' according to whether the given pairing of stimulus and label matched with their given rule (e.g. label 'stranger' displayed simultaneously with the emotion word 'knife' in a slate blue coloured font). They were instructed to respond as quickly and as accurately as possible. All words remained on screen 2000ms irrespective of whether or not the participant responded in that time. Following the response, if the participants made an incorrect response, an auditory tone was played to inform the participant of the incorrect response. If the participant failed to respond within the 2000ms after stimulus onset, the word 'slow' would appear on the screen for 400ms after the offset of the emotion-word and label. After each trial, a blank screen ITI of random duration between 1000ms and 1500ms was presented. The matching task consisted of 100 trials and was preceded by 30 practice trials. There were two factors in this experiment, each with two levels: word-person category ('yourself', 'stranger') and emotion (neutral, negative). Equal numbers of these four factorial combinations of trial types were given. These were presented in the experiment in a pseudo-random order where each factor combination was never repeated consecutively more than three times. Participant were told to expect a memory task after the matching task. Even though this increased the workload for the matching task, this would put more emphasize on the words and not just the colour of the words. Increasing the focus on the words potentially increased later memory performance. Earlier pilots of this paradigm showed low performance on the old/new task.

Old/new recognition task

The matching task was followed by the old/new recognition task in which 200 words were presented, half of which were old words and the remaining half new words (see Figure 3B). The 'old' words were taken from the matching-task word-list (the emotion-words), and the 'new' words were taken from the second list of words described in the stimulus section. The 'new' words were matched in terms of word length, word frequency, valence and arousal with the 'old' word-list. For the old/new recognition task participants were asked to decide as quickly and as accurately as possible whether the word depicted on screen was either 'old' or 'new'. Participants were asked to respond as quickly as possible to encourage responses as a result of clear recognition and not a feeling of familiarity with the words. A word was 'old' if it had been presented in the matching task and 'new' if it appeared for the first time. Each trial began with a fixation cross in the middle of the screen, lasting 500ms, which was replaced by a word. Participants had to decide as fast and as accurately as possible if the word was 'old' or 'new' by pressing the left mouse button and the right mouse button respectively (counterbalanced across observations). The words remained on the screen up to five seconds or until the participant made a response. After each trial, a blank screen was shown for 500ms. The main task comprised of 200 trials and was preceded by five practice trials.

The 'new' and 'old' condition in the old/new recognition task was counterbalanced, i.e. the words for the matching task and the new words from the old/new task were interchanged. Participants were able to take a self-paced break after the perceptual matching task and every seven minutes during the old/new recognition task. The matching task took about 10 minutes to complete, and the old/new recognition task took about 35 minutes to complete. No data on source memory was collected. This was mainly due to practical limitations as the experiment already exceeded 35 minutes, and no a priori predictions were made on source memory and self-relatedness.

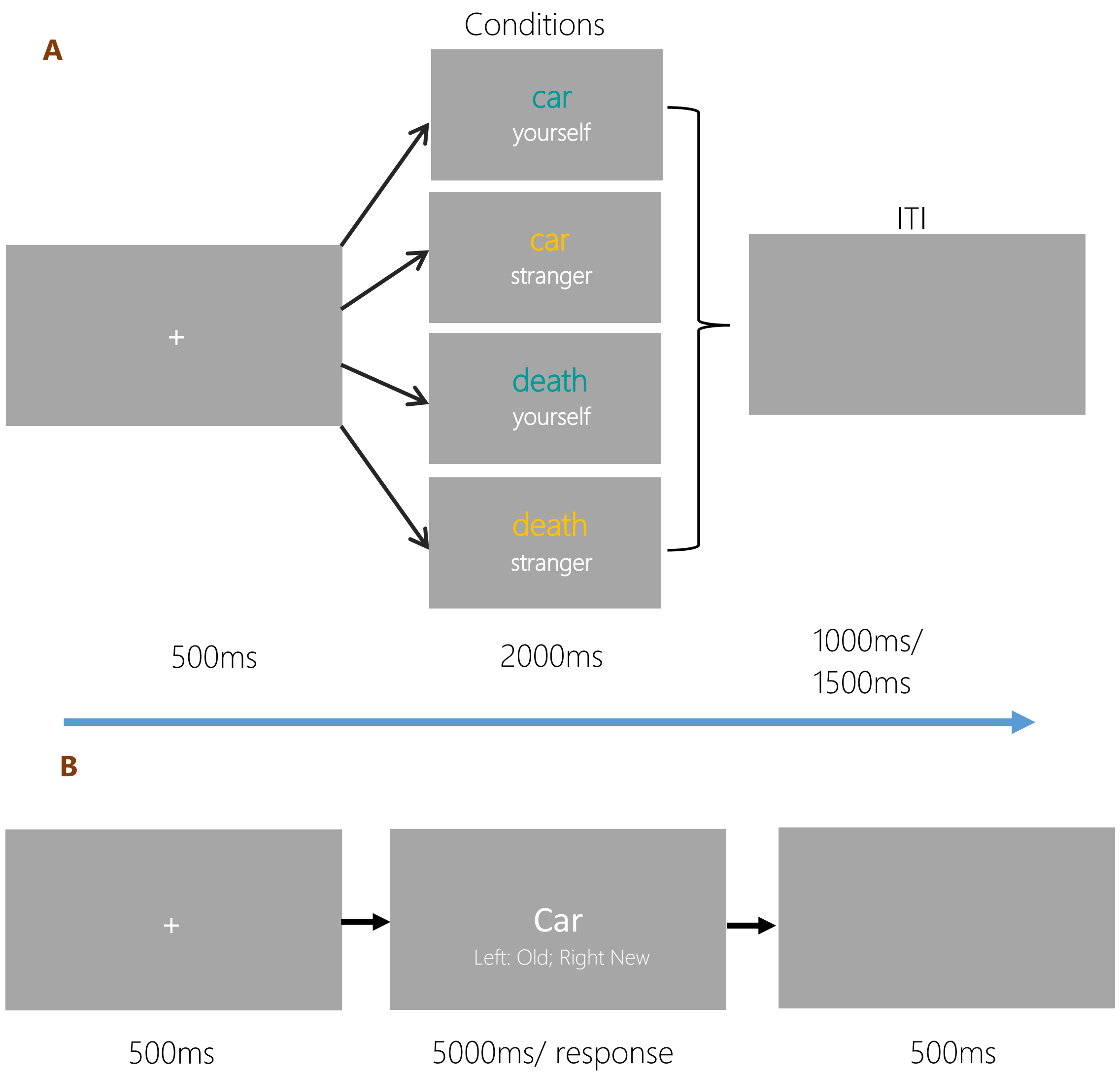

Figure 3. Procedure matching task (**A**) and old/new task (**B**), *Experiment* 1a-d.
Colours shown in this figure more closely reflect the colour used in the experiments after *1a*

Design & analysis

In this experiment, and unless stated otherwise, most analyses were performed using SPSS software (IBM Corp, 2013) by employing n-way repeated measures ANOVA of the relevant conditions. Using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), a power analysis based on the effect-sizes found in previous literature showed that the sample size for attaining sufficient power should be 20. However, due to the novel nature of this paradigm there was no precedent for accurately determining the expected effect-size. This is mainly because of the very robust findings of the matching task. For the old/new task the sample size ranges from 25 to 30 depending on the literature. A sample size of 20 was chosen as both over-powered and under-powered test are undesirable. In this experiment, a 2 (perspective[self, distant other]) x 2 (emotion[negative, neutral]) repeated ANOVA was used to analyse the data, and a Bonferroni correction was applied for multiple comparisons. The independent variable of 'perspective' consisted of two levels ('self' versus 'distant other'), and the second independent variable was emotion also with two levels ('negative' versus 'neutral'). The dependent variables were participants' responses and reaction time in milliseconds for the matching task. For the old/new task, only the proportion of correct responses were analysed. The reaction time data of the old/new task was not analysed as it is less accurate due possible fast guesses.

With the signal detection theory, it is possible to isolate a signal from noise, allowing for the measurement of a response bias by the participants. In other words, with signal detection theory, the sensitivity of detecting a true signal amidst noise or competing signals can be calculated. Using hit rates (finding something that is actually there) and false alarm rates (claiming to have found something that is not there) one can calculate a person's sensitivity to detect a signal using the d-prime (d') statistic.

With d' it is possible to separate the means of a signal from noise, and it is a sensitivity index used in signal detection theory (Macmillan & Creelman, 2004). This sensitivity index is measured by calculating the difference between the Z-transforms of the proportion of hits and the Z-transforms of the proportion of false alarms: d' = Z (Hit rate) – Z(False alarm rate). A d′ of 0 indicates that an individual cannot distinguish a signal from noise and with every increase in d′ reflect an increased capability to distinguish signal from noise. Hit rates of 100% or false alarms of 0% were assigned values of 99% or 1% respectively (Macmillan & Creelman, 2004).

Although the d′ measure is an accurate measure of one's ability to differentiate signal from noise, in the current (and subsequent) experiments, there were several issues in calculating d′. In the non-matched trials, the process of recognising an incorrectly paired label and colour is more laborious, and therefore a quick self-judgement is not possible. Furthermore, when the label and colour are not matched, it is difficult to ascertain in retrospect which aspect (label or colour) was more important in making a self or other judgement. This approach is the same for all experiments using the matching task. Throughout this thesis, the colour of the word linked to self is seen as 'self-related' for analysis purposes, but this potentially creates interpretation issues for the non-matched trials with the label of self and the colour linked to a distant other. The label 'yourself' or 'myself' might be enough to elicit self-relatedness.

For this reason, the experiments were analysed with an overall d′ rating, which, by necessity, includes the non-matched trials. However, the proportion of correct trials is reported as well, separately for the matched and non-matched trials, avoiding the potential problematic interpretation of the non-matched trials. Therefore, when discussing the proportion of correct responses, the emphasis is placed on the matched trials. Similarly, the reaction time data was split up in matched and non-matched trials and only the reaction times for the correct responses were analysed.

Results

Matching task

For *Experiment 1a* there was a significant effect of d′ for perspective (see Figure 4), $F(1,19) = 14.619$, $p = .001$, $\eta^2_p = .435$. Participants were more accurate in detecting signal from noise for the self-condition than the distant other-condition. There was no significant effect of emotion, $F(1,19) = .039$, $p = .845$, nor was there a significant interaction between emotion and perspective, $F(1,19) = 2.466$, $p = .133$. See Table 1 for an overview of all means and standard errors for the matching task.

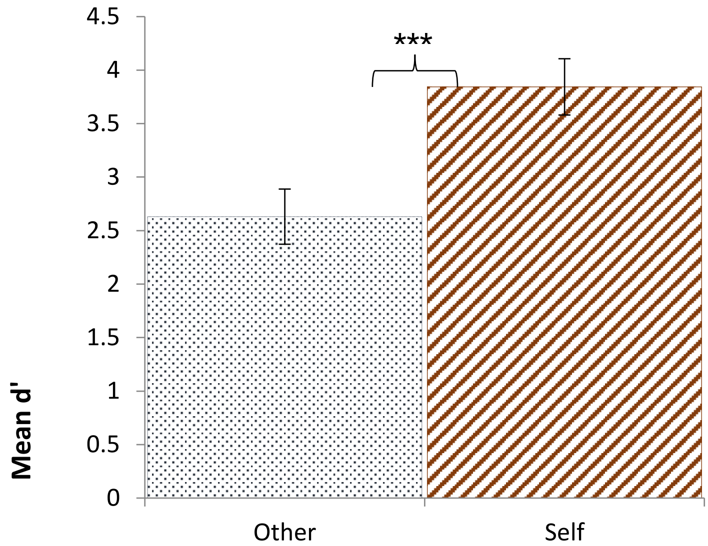

Figure 4. D' matching task, *Experiment 1a.* D' of perspective for the matching task (Error bar = standard error. * = p<.05, ** = p<.01, *** = p<.001).

Table 1. Experiment 1a, Matching task. Proportion correct responses, median RT, and d'. Standard error in parenthesis.

	Matched Trials		Non-Matched trials		d'
	Correct	RT	Correct	RT	
Self	.97 (.01)	1007.30 (31.82)	.92 (.02)	1206.65 (35.56)	3.80 (0.20)
Other	.88 (.02)	1228.61 (44.54)	.86 (.02)	1232.67 (37.29)	2.75 (0.22)
Negative	.93 (.01)	1124.50 (39.73)	.88 (.02)	1246.46 (35.86)	3.30 (0.21)
Neutral	.92 (.01)	1111.41 (33.62)	.90 (.02)	1192.86 (35.88)	3.26 (0.17)
Self/Negative	.97 (.01)	1009.57 (33.35)	.91 (.02)	1240.30 (42.63)	3.70 (0.26)
Self/Neutral	.97 (.01)	1005.03 (36.68)	.93 (.02)	1173.00 (32.88)	3.91 (0.22)
Other/Negative	.90 (.03)	1239.43 (54.44)	.86 (.03)	1252.62 (34.73)	2.90 (0.25)
Other/Neutral	.86 (.03)	1217.79 (40.62)	.86 (.03)	1212.72 (43.00)	2.61 (0.26)

When looking at the proportion of correct responses for the matching trials, there is a main effect for perspective, $F(1,19) = 13.327$, $p = .002$, $\eta^2_p = .412$ where proportion correct responses for the self-condition was higher than the distant other-condition. Again, no significant effect for emotion, $F(1,19) = 1.411$, $p = .250$, and no significant interaction between perspective and emotion $F(1,19) = .788$, p .386 were observed. For the non-matching trials there is an effect of self for the proportion correct responses, $F(1,19) = 4.754$, $p = .042$, $\eta^2_p = .200$, where self outperformed distant other. There was no effect of emotion, $F(1,19) = .462$, $p = .505$, and no interaction effect between emotion and perspective was found $F(1,19) = .418$, $p = .526$.

There was a main effect on median correct RT data for perspective, $F(1,19) = 50.883$, $p < .001$, $\eta^2_p = .728$. There was a significantly faster RT for the self condition when compared to the distant other-condition, see Figure 5A. There was no significant effect of emotion, $F(1,19) = .444$, $p = .513$, and no interaction between the two conditions, $F(1,19) = .106$, $p = .748$. The RT data showed no main effect of perspective for the non-matched trials, $F(1,19) = 1.465$, $p = .241$. However, there was a significant main effect of emotion ($F1,19) = 9.686$, $p = .006$, $\eta^2_p = .338$). Neutral words were responded to faster than the negative words, see Figure 5B. No interaction was found between the conditions perspective and emotion, $F(1,19) = .542$, $p = .470$.

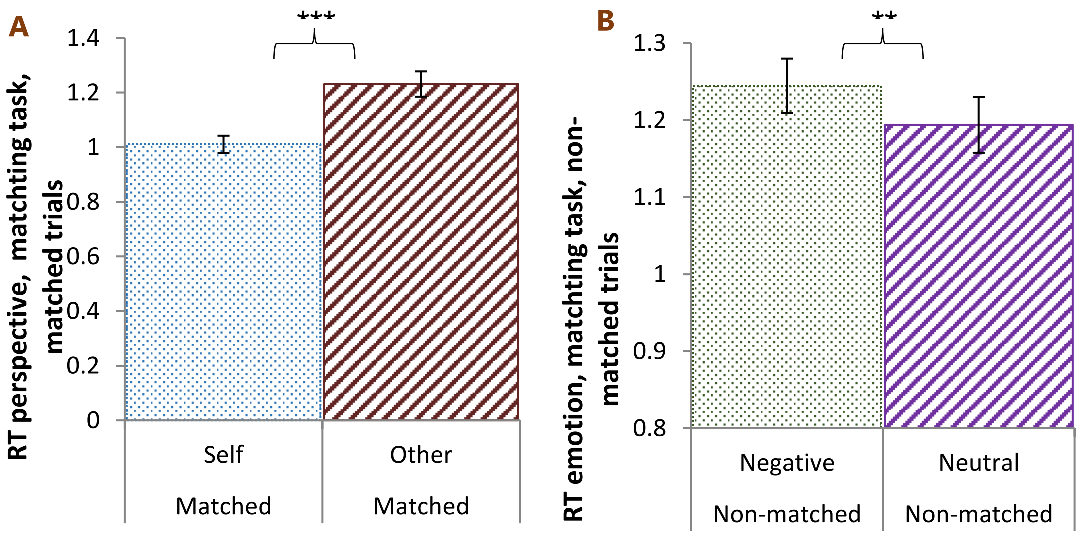

Figure 5. RT matching task, Experiment Median RT for perspective in the matched trials (**A**), and emotion for the non-matched trials (**B**) (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

Old/new task

Looking at the sensitivity data (d'), an effect emerges of perspective ($F(1,19) = 10.207$, $p = .005$, $\eta^2_p = .349$), where the d' for the self condition was higher (.925) than the distant other-condition (.775), see Figure 6A. Furthermore a main effect of emotion is revealed, $F(1,19) = 5.212$, $p = .034$, $\eta^2_p = .215$. Participants were more sensitive in detecting a signal (i.e. correctly identifying an 'old' word) for the negative trials than for the neutral trials, see Figure 6B. No interaction between the conditions of perspective and emotion was found, $F(1,19) = 1.686$, $p = .210$. Table 2 shows the means and standard error of the old/new task.

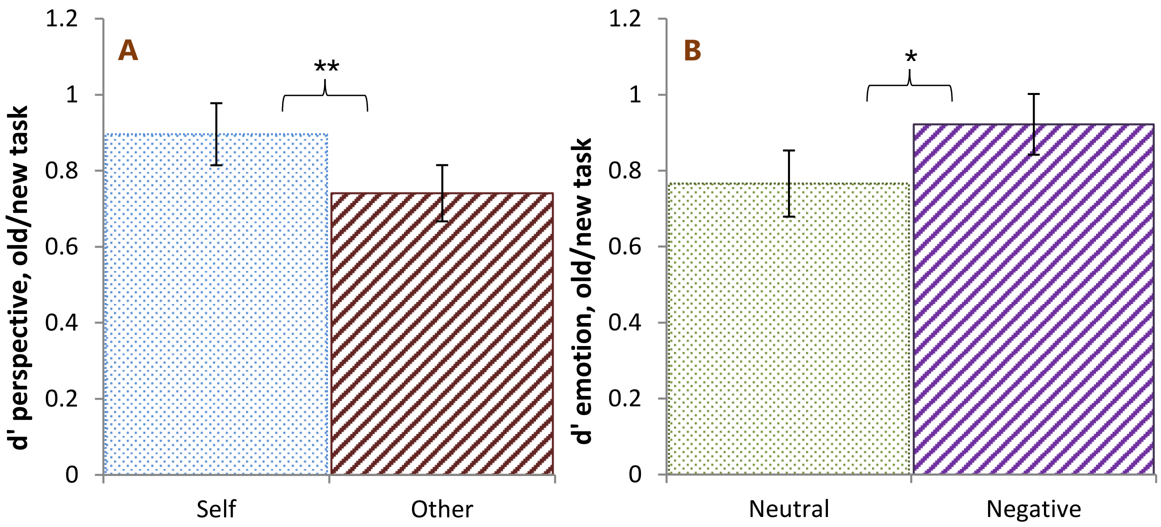

Figure 6. d' old/new task, *Experiment 1a.* d' measures for perspective (**A**) and emotion (**B**) on the old/new task, Experiment 1a. (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

Analysing the proportion correct responses for the matched trials resulted in an effect of both perspective ($F(1,19) = 6.674$, $p = .018$, $\eta^2_p = .260$) and emotion($F(1,19) = 24.721$, $p < .001$, $\eta^2_p = .565$). The mean scores revealed that the self trials resulted in higher number of correct responses compared with the distant other-trials. For the emotion condition participants correctly recognised more words from the negative trials than from the neutral trials. Again, no interaction was observed between the perspective and emotion condition, $F(1,19) = 1.699$, $p = .208$.

For the non-matched trials only a main effect was observed for the emotion condition for the proportion of correct responses: $F(1,19) = 17.384$, $p = .001$, $\eta^2_p = .478$. A closer look indicated that the negative words were recognised more often than the neutral words. No significant effect was found for perspective: $F(1,19) = 3.177$, $p = .091$, and there was no interaction between the two conditions, $F(1,19) = .048$, $p = .828$.

Table 2. Experiment 1a, old/new task. Proportion correct responses, Median RT, and d'. Standard error in parenthesis.

	Matched Trials	Non-Matched trials	D'
	Correct	Correct	
Self	.64 (.03)	.64 (.03)	0.93 (0.08)
Other	.58 (.03)	.58 (.03)	0.78 (0.08)
Negative	.71 (.03)	.67 (.03)	0.93 (0.08)
Neutral	.51 (.04)	.55 (.03)	0.77 (0.09)
Self/Negative	.71 (.03)	.70 (.03)	0.97 (0.08)
Self/Neutral	.56 (.05)	.58 (.04)	0.89 (0.10)
Other/Negative	.71 (.04)	.65 (.04)	0.90 (0.10)
Other/Neutral	.45 (.05)	.52 (.04)	0.65 (0.09)

Discussion

Self-related information does not only impact memory (Symons & Johnson, 1997) but influences the early stages of attention also (Phelps et al., 2006). By creating a new paradigm (the matching task) based on the work of Sui, He, and Humphreys (2012), it was possible to examine the early self-priority effect of attention. The matching task was followed-up by an old/new task in order to examine a potential self-reference effect in memory. Furthermore, since emotion too influences early attentional processes (Bruner & Postman, 1947) and later memory (LaBar & Cabeza, 2006) processes, the connection between self and emotion was investigated.

The results from the matching task show that via the higher proportion correct responses, faster responses and better signal detection (d′) for words linked to the self, information was prioritized when self-relevant, and these findings are in line with previous research (Sui et al., 2012, 2014; Wang et al., 2016). Therefore, it can be concluded that a self-priority effect was found in *Experiment 1a*. This shows that self-relevance influences attention. The self-priority effect was achieved by using a perceptual matching paradigm that avoided any influence of familiarity. These findings add to the robust findings of a self-priority effect using this paradigm (Sui et al., 2012, 2014; Sui & Humphreys, 2015b). The results demonstrate that our attention is drawn to self-related items in our environment over items that are not related to the self. In other words, this helps us to select relevant information from our surroundings in an automatic, efficient and fast manner.

However, the emotional valence of the words did not have a significant effect on the matched trials. Emotion was expected to influence perception and attention also. As is discussed shortly, emotion does seem to have a very clear and robust effect on the subsequent old/new recognition task. Furthermore, past research has shown the effect of processing emotion-laden information on perception and attention (decreased reaction times, Bruner & Postman, 1947; Increased contrast threshold, Phelps et al., 2006). Furthermore, emotional words are even more automatically processed than regular words (McKenna & Sharma, 1995). Therefore, it can be assumed that the emotional value of the word was processed for the matched trials, but the experimental setup of the matching task fails to highlight this effect, especially since a threat-driven slowing down of ongoing activity is expected for negative words as demonstrated by the emotional Stroop task (Algom et al., 2004; Öhman et al., 2001). A possible reason is that participants did not have to actively read the words in order to perform the matching task, i.e. participants were likely to respond as soon as they perceived the label and the colour of the emotion-word combination. This response was likely well before the word was fully processed. In the task, the words remained onscreen for two seconds irrespective of the latency of participants' responses. Since it was explicitly mentioned in the instruction that the words must be read and that people cannot help reading a word that is displayed in front of them (Logan, 1988), it can be assumed that the words were read. This insured that the fast colour processing of the word was followed by the processing of the emotional value of the word. This is further exemplified by the significant effect of emotion for the non-matching trials. Although the non-matched trials are unclear regarding self-relevance, the slower processing of the more difficult matching-judgement during the non-matched trials allowed for a measurable influence of emotion. Furthermore, Previous literature did find that emotion influences early perception and attention processes (Phelps et al., 2006). Therefore, the absence of an emotion effect in *Experiment 1a* on the matching task may be due to the nature of the task itself (a rapid matching judgement via colour recognition before word meaning processing).

In support of this, it was found that during the non-matching trials of *Experiment 1a* the overall RTs were higher than the overall RTs for the matching trials. The matching judgement during the non-matching trials was more difficult as there was a mismatch between the colour of the word and the label. This greater task difficulty possibly had the effect of increasing processing time for the non-match trials and in turn provided enough time for emotion to have a measurable effect. Because of this, negative emotion did significantly increase the RTs for the non-matching trials. Nonetheless, the exact interpretation of the non-matched trials remains problematic as the self-relatedness of the trials is unclear (i.e. the label "yourself" might already make the words self-relevant, even if matched with the colour linked to a distant other).

Despite the lack of a main effect of emotion on the matching task, there still was a measurable effect of emotion on the later memory recall task. It was found that negative words were recognised more often compared to neutral words. Therefore, emotion did influence memory processes as measured with the old/new recognition task. This indicates that emotion did potentially impact encoding and subsequent memory processes.

In order to test whether the lacking effect of emotion on the matching task was a consequence of processing time, as was argued above, a further experiment was conducted. In this experiment, an attempt was made to delay the participant's response until after the word has been read. If the lack of an effect was a consequence of limited processing time of the word, then we should expect an effect of emotion to emerge under the different task conditions of this experiment.

Where the matching task showed a clear self-priority effect, the old/new recognition task revealed a self-reference effect and an effect of emotion. Participants recognised more self-relevant words and more negative words correctly, faster, and with better signal to noise detection (d'). These results show that information related to emotionally negative events or the self are recalled more easily than neutral information or information not related to the self.

However, no interaction was found between emotion (negative) and perspective (self-related words). This appears to be at odds with earlier experiments suggesting a reduced effect for negative self-related items compared to positive self-related items (Gutchess et al., 2007; Leshikar et al., 2015). Even so, this might not be a strange finding in the sense that the enhancing effects of emotion and the enhancing effect of the self on memory are possibly two distinct processes (Stolte et al., 2016). Taken separately, these findings support the idea that emotional (negative) events are remembered more easily (Alicke, 1985; LaBar & Cabeza, 2006; Levine & Pizarro, 2004; Mather, 2007). This possibly supports the concept that emotion enhances later recollection of an item if that item is of higher priority (i.e. ABC-theory (Mather & Sutherland, 2011)). In this case, the participants were instructed that a memory task will follow the matching task. This means that the nouns were goal relevant and of high priority, which lead to greater recall for all emotional words. The emotional information is processed separately from the self-relevant information as they were not directly linked together in the matching task. Lastly, because people tend to readily associate positive events with themselves and avoid linking negative events to the self (Baumeister & Cairns, 1992; Blaine & Crocker, 1993;

Taylor, 1991), it remains possible that a reduction of self-relevance by negative information would be minimal. Previous research did find an enhancing effect of positive emotion on self-relevant information, compared to an increased effect of negative information in a non-self or semantic condition (Gutchess et al., 2007; Leshikar et al., 2015). This experiment compared self versus distant other and not self versus a semantic condition. Therefore, it is possible that negative self-related information does not lead to a reduced self-reference effect per se when compared to distant other-relevant negative information. However, a clear interaction between positive emotion and self-relevant information has been shown by previous research (Gutchess et al., 2007; Leshikar et al., 2015). Therefore, the next experiment will use positive nouns linked to the self in a similar paradigm as used in *Experiment 1a*.

Experiment 1b: The self and positive emotions

The previous experiment (*1a*) has shown a self-priority effect on attention, as measured by the matching task. However, negative emotions did not seem to impact attention. An old/new recognition task followed the matching task and revealed an effect of self on memory and separately an effect of emotion on memory. The main purpose of *Experiment 1b* is to see if positive emotions will generate similar results. Furthermore, *Experiment 1a* was adapted to delay the participant's response slightly during the matching task. This should allow for a measurable effect of emotion on the matching task. No interaction between perspective and emotion was found in *Experiment 1a*. However, opposite to negative emotions, which might cause some distancing of the self from negative events, positive events may result in a stronger self-reference effect.

Furthermore, in *Experiment 1a*, the matching task revealed no effect of emotion (an effect of emotion was only found for the non-matched trials). As discussed, this could be due to the faster matching judgement for the matched trials. Therefore an attempt is made to delay the participants' response in the matching task, which should then show an effect of emotion.

The main purpose of *Experiment 1b* is to study the effects of positive emotions and the self on attention and memory. Where negative emotion could potentially weaken the self-reference effect, positive emotions might have the opposite result. In other words, participants will be more accurate on the old/new matching task for self-related items compared to items not related to the self. However, this effect will be larger for positive words than for neutral words. With the "delay" (explained below in the methods section) to the matching task, it is likely that beyond a self-priority effect, an effect of emotion will be observed as well. This means that participants will be faster and more accurate for self-related items compared to items related to a distant other and this effect possibly interacts with emotion, i.e. the predicted beneficial effect for self-related items will be stronger for positive items when compared to neutral items.

Methods

Participants

Twenty participants took part in this study. However, screening of the data showed that three participants performed at chance level and were not included in the subsequent analysis (N = 17, mean age 22 years, range 18-59 years). All participants were female.

Stimuli

The materials were the same as *Experiment 1a* except for three changes: first, the negative valence words were replaced with positive valence words from the same word database of Warriner, Kuperman, and Brysbaert (2013) creating a list of 280 words. Half of which were neutral and the other was positive (valence > 6.0, arousal > 5); second, 40 of the 280 words were catchwords and were added to ensure that participants were reading the words during the matching trials and always described something living (e.g. 'puppy', 'dragon', 'tomato'). Third, the colours used in this experiment for the matching task were changed from 'salmon' and 'slate-blue' to 'dark-cyan' (RGB: 0, 136, 136; referred to as 'jade') and 'dark-yellow' (RGB: 183, 137, 0; referred to as 'yellow'). In *Experiment 1a*, participants referred to the salmon colour as 'pink'. Since pink can have very strong gender-specific meaning/ preference (Koller, 2008), the colour was changed.

The words were again derived from the database of Warriner et al. (2013). However this time instead of negative words, positive words (valence > 6, arousal > 5) were chosen, the neutral words chosen in the same way as *Experiment 1a* (valence between 5-6, arousal < 3). 280 words were dived into two lists of 140 words for each. These lists were then subdivided into four sets: 35 words were neutral and linked to the self (self/neutral); 35 words were positive and linked to the self (self/positive); 35 words were neutral and linked to a distant other (other/neutral); and 35 were positive and linked to a distant other (other/positive). Of each category, five of the 35 words were the catch-words. This thus created two main lists with two main conditions each: perspective, emotion, and each condition contained catch-trials (words describing something living, e.g. 'dragon', 'goat', 'girl').

Procedure

The setup is the same as *Experiment 1a*. However, there were some changes specifically for the matching task. Added to the normal procedure outlined in the methods section of *Experiment 1a*, the participants were now instructed to withhold any response if the word describes something living (i.e. the catchwords). For this experiment, the participants were instructed: "*You* are a yellow colour; A *stranger* is a jade colour." The colour linked to stranger and self was counterbalanced across participants.

Results

Matching task

The d' data for signal detection showed a significant effect for perspective: $F(1,16) = 20.886$, $p < .001$, $\eta^2_p = .566$. This difference was caused by a higher sensitivity in detecting a signal for the self-related words when compared to words linked to a stranger. No significant effect was observed for emotion: $F(1,16) = .259$, $p = .618$; nor was there an interaction between perspective and emotion: $F(1,16) = 1.208$, $p = .288$, see Figure 7. For an overview of all means and standard errors for the matching task *Experiment 1b*, see Table 3.

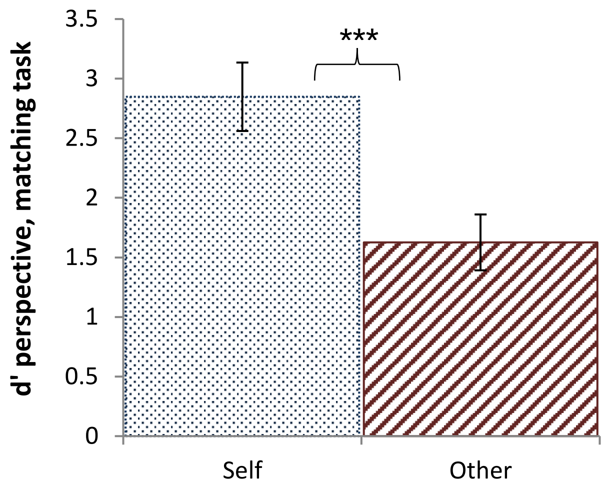

Figure 7. d' perspective on the matching task of *Experiment 1*b.
(Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

For the matched trials, the proportion of correct responses showed a similar pattern was found for perspective, $F(1,16)= 16.273$, $p = .001$, $\eta^2_p = .504$. Words linked to the self were responded to more accurately than words linked to distant other. Emotion did not show a significant difference, $F(1,16)= 2.519$, $p = .132$. There was no interaction between the conditions of emotion and perspective, $F(1,16) = 1.076$, $p = .315$.

Very similar findings were found when looking at the RT data, where the differences in median correct RT was compared for the matched trials (See Figure 8A). A main effect of perspective was found, $F(1,16)= 133.250$, $p < .001$, $\eta^2_p = .893$; The self-related words are responded faster to for the matched trials when compared to words related to a distant other. No significant result were found for emotion, $F(1,16) = .007$, $p = .936$, and no interaction between perspective and emotion, $F(1,16) = .155$, $p = .699$ (see Figure 8B).

For the non-matched trials, a significant difference for perspective was calculated for the proportion of correct responses: $F(1,16) = 5.201$, $p = .037$, $\eta^2_p = .245$. Like the matched trials, the words related to the self are responded to more accurately than the words related to distant other. Again, no effect of emotion (F(1,16) = 1.000, p = .332) was found and there also was no interaction between emotion and perspective (F(1,16) = .653, p = .432).

The RT data for the non-matched trials revealed a significant main effect for perspective, F(1,16) = 5.956, p = .027, η^2_p = .271. Words related to the self were responded to faster than words related to distant other. There was no main effect of emotion, F(1,16) = .005, p = .943. However, a significant interaction was observed between emotion and perspective, F(1,16) = 12.263, p = .003, η^2_p = .434. A further analysis of this interaction revealed that perspective had a significant effect on the neutral trials (p = .002), other/neutral trials were responded to faster than other-positive trials. Perspective had no significant effect on the positive trials (p = .780). When looking at distant other-related trials, a significant difference was found for emotion (p = .032). The other-neutral trials were responded to significantly faster than the positive words linked to distant other. There was no effect of emotion for the self-related trials (p = .102).

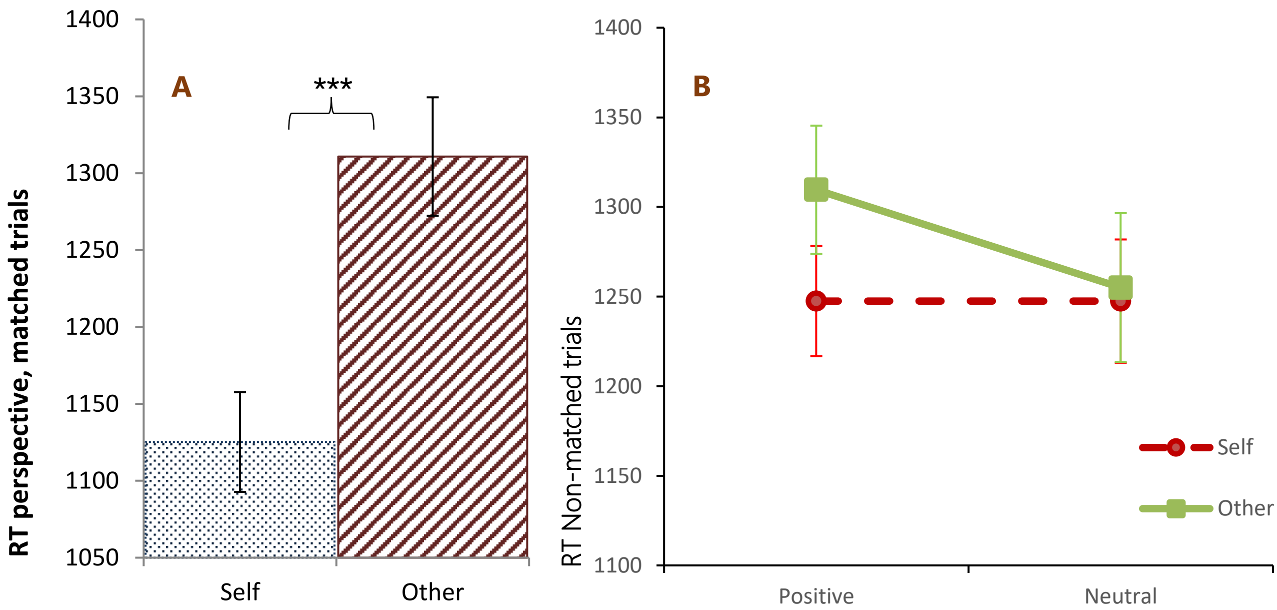

Figure 8. Median RT's Matching task, *Experiment 1b*. A) RT for perspective, matched trials. B) RT for interaction emotion and perspective, matched trials. (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

Table 3. Experiment 1b, Matching task. Proportion correct responses, median RT, and d'. Standard error in parenthesis.

	Matched Trials		Non-Matched trials		D'
	Correct	RT	Correct	RT	
Self	.89 (.03)	1121.43 (30.86)	.87 (.02)	1221.77 (29.07)	2.90 (0.27)
Other	.71 (.04)	1319.40 (37.94)	.81 (.03)	1282.29 (36.98)	1.74 (0.26)
Positive	.82 (.03)	1219.62 (37.87)	.83 (.02)	1252.82 (29.41)	2.37 (0.24)
Neutral	.79 (.03)	1221.21 (31.66)	.85 (.03)	1251.24 (35.77)	2.28 (0.27
Self/Positive	.92 (.02)	1117.24 (25.67)	.86 (.03)	1247.47 (34.40)	3.02 (0.30)
Self/Neutral	.87 (.04)	1125.62 (38.99)	.87 (.03)	1196.06 (30.75)	2.78 (0.31)
Other/Positive	.72 (.04)	1325.18 (43.03)	.79 (.03)	1255.00 (41.53)	1.71 (0.28)
Other/Neutral	.71 (.05)	1313.62 (42.17)	.83 (.03)	1309.59 (35.77)	1.78 (0.29)

Old/new task

The d' findings of the old/new task revealed two main effects: perspective $F(1,16) = 10.696$, $p = .005$, $\eta^2_p = .401$; emotion $F(1,16) = 19.773$, $p <.001$, $\eta^2_p = .553$. The d' for words related to the self (.81) were higher than words related to a distant other (.66), See Figure 9A. Furthermore, participants were more sensitive in detecting a signal for the positive words when compared to the neutral words (.81 Vs .61), See Figure 9B. No significant interaction effect between perspective and emotion was found: $F(1,16) = 1.535$, $p = .233$. See Table 4 for the means and standard errors.

The results for the proportion of correct responses on matched trials, showed significant main effects for: perspective, $F(1,16) = 6.836$, $p = .019$, $\eta^2_p = .299$; and emotion, $F(1,16) = 5.673$, $p = .030$, $\eta^2_p = .262$. Participants correctly recognized more words related to the self than to distant other-related words. The participants also recognized more positive words than neutral words, but no interaction was found between perspective and emotion, $F(1,16) = .027$, $p = .872$.

The non-matched trials only revealed a significant main effect of emotion, $F(1,16) = 14.465$, $p = .002$, $\eta^2_p = 475$. Looking closer at this significant finding, a greater proportion of correct responses were revealed for the positive words when compared to the neutral words. No significant results were found for perspective, $F(1,16) = 2.431$, $p = .139$, and there was no interaction between perspective and emotion, $F(1,16) = .2.658$, $p = .123$.

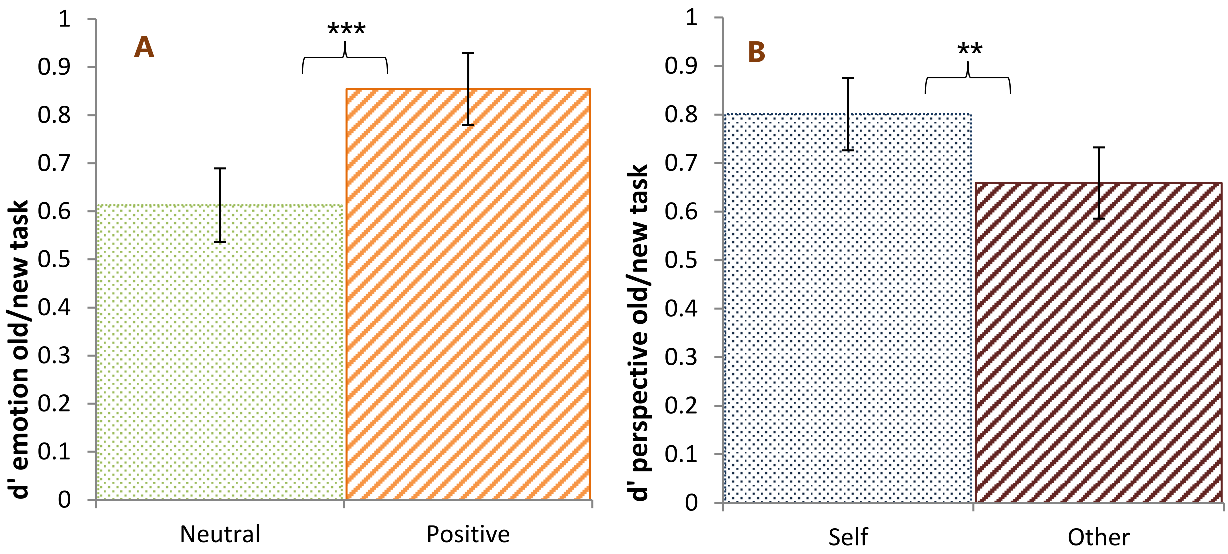

Figure 9. d' for the old/new, *Experiment 1b*. **A**) d' main effect of emotion. **B**) d' main effect of perspective (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

Table 4. Experiment 1b, old/new task. Proportion correct responses, Median RT, and d'. Standard error in parenthesis.

	Matched Trials	Non-Matched trials	D'
	Correct	Correct	
Self	.68 (.03)	.56 (.02)	0.81 (0.08)
Other	.60 (.02)	.52 (.04)	0.66 (0.07)
Positive	.67 (.02)	.60 (.03)	0.86 (0.08)
Neutral	.61 (.02)	.48 (.03)	0.61 (0.08)
Self/Positive	.70 (.03)	.64 (.03)	0.97 (0.08)
Self/Neutral	.65 (.03)	.48 (.02)	0.65 (0.09)
Other/Positive	.64 (.03)	.55 (.04)	0.75 (0.09)
Other/Neutral	.57 (.03)	.49 (.04)	0.57 (0.08)

Discussion

The main difference between *Experiment 1b* and *Experiment 1a* was the use of positive emotions instead of negative emotions. The main reason for this change was to explore if positive emotions would influence the matching task and old/new task in a similar way compared *Experiment 1a*, which used negative emotions. *Experiment 1a* showed a main effect of perspective for the matching task.

As predicted, a main effect was found of perspective for the matching task. No effect of emotion was found, despite adding catch trials. However, most participants reported that even though they understood the rule of withholding a response when the word describes something living, they would often be too late in realising that the word did indeed describe something living and would have made a response already. This can be seen in the results as in over 50% of the living condition participants responded regardless. This coincides with earlier findings that suggested that participants respond to the label and colour combination before properly processing the meaning of the word. The matching task did once again show a robust self-priority effect, showing that information related to the self is prioritised over information not related to the self. The full advantage of the self-priority effect is displayed in the greater accuracy and reaction times for the words linked to the self in the matched trials, displaying a clear self-priority effect, providing further support for the prioritising effect of self-related information. Potentially interesting, where the RTs in *Experiment 1a* were increased for the non-matching negative nouns, the non-matching trials in *Experiment 1b* demonstrated a self-priority effect for only the positive trials, with faster RTs for the positive-self trials than for the positive-distant other trials. These differences in RTs for positive emotions (faster RT for positive-self trials) and negative emotions (slower RT for negative trials) show typical preference to relate positive emotions to the self and a typical withdrawal from negative emotions (Heine, Lehman, Markus, & Kitayama, 1999; Taylor, 1991). It remains possible that the slowing down of the negative trials of *Experiment* 1 was in response to an automatic threat-driven process as typically measured by the emotional Stroop task.

However, positive emotion would not be affected by this defensive mechanism for threatening stimuli. Furthermore, the effect was different depending on the perspective.

The old/new task showed a main effect of emotion and perspective, as was predicted. However, there was again no interaction between perspective and emotion. This suggests that the self-reference effect was present for both neutral and positive words, with no significant difference between the two conditions. These findings are similar to what was observed in *Experiment 1a* with negative nouns, again lending support to the separate processing of emotional and self-related information (Stolte et al., 2016).

However, a crucial difference between the experiments of Gutchess et al. (2007), and Leshikar et al. (2015) is in how the self-reference effect is being measured or manipulated. In the experiments of this thesis, the self-reference effect is achieved via the matching task, which links the to-be-remembered information (i.e. the nouns) indirectly to the self (i.e. the colour). This way, the amount of elaboration of the to-be-remembered information is relatively the same regardless of condition. In a typical self-reference experiment, a word is linked to the self by asking the participants a yes/no question with regards to the word and themselves, for example: does the trait patience describe you? This potentially allows for more in-depth processing and encoding compared to the matching experiment where the word is not relevant to the task. Participants are warned that a memory task follows. Nevertheless, the task's pace does not allow for any in-depth encoding. The consequence of which will be further explored later. First however is the possibility that the nouns used in *Experiment 1a* and *1b* are more difficult to link to the self compared to the adjectives used in the experiments by Gutchess et al. (2007), and Leshikar et al. (2015). Therefore the next experiment will aim to replicate the current findings but with trait-words, which potentially makes the emotional words more self-relevant.

Experiment 1c: The self & negative trait-words

The last two experiments revealed that words linked to the self are more accurately recalled than words not linked to the self. However, this effect seems to be influenced equally by both positive and negative emotions. It remains possible that the emotional words in the previous experiment were not personal and therefore, less self-relevant. The current experiment aims to further influence the self-reference effect by using negative words that are more personal or closer to the self by nature. For this reason, trait-words are used in this experiment (e.g. arrogant). Since trait-words are more easily applied to the self, it is expected that negative trait words result in a greater distancing from the self (Chen & Bargh, 1999; Ma & Han, 2010). This means that negative trait words linked to the self will result in a reduced or abolished self-reference effect (Gutchess et al., 2007; Leshikar et al., 2015), compared to neutral self-related trait words.

Methods

Participants

Twenty-five participants from Oxford Brookes University participated for course credit. However, four participants were excluded from further data-analysis because two participants failed to learn the matching task and one participant performed below chance level for the old/new recognition task, and one participant was excluded due to technical failure. Of the remaining 21 participants, 20 were female, and one was male (mean age: 19.71 years, range: 18-33 years).

Stimuli and procedure

A different set of words were used as stimuli for this experiment as the words were replaced by trait words using the wordlist compiled by Dumas, Johnson, & Lynch, (2002). In this database, the ratings of likableness (1 = "would not like the person at all" – 6 = "would like the person very much") and familiarity (1 = "not familiar with the word at all" – 6 = "very familiar with the word") of the trait words are provided. Only the very familiar traits (> 3); the very negative traits (< 1.8); and neutral traits (< 4.3, >3.2) were selected.

This created a wordlist of 200 trait words and similar to the previous experiments these words were divided into two main word-lists using the exact process described for *Experiment 1a*, creating two unique lists with neutral and negative trait words. The average word length was similar across conditions (8.62). The procedure for the matching and old/new trials is precisely the same as *Experiment 1b* without the catch trials since the catch trials did not have the desired impact.

Results

Matching task

Participants were more accurate in correctly detecting a signal (d') for the self condition when compared to the distant other-condition, $F(1,20) = 4.928$, $p = .038$, $\eta^2_p = .198$, see Figure 10. Like the previous experiments no effect of emotion was found during the matching task ($F(1,20) = .074$, $p = .789$), nor was there an interaction between emotion and perspective ($F(1,20) = .022$, $p = .885$). Table 5 provides an overview of the means and standard errors for the matching task.

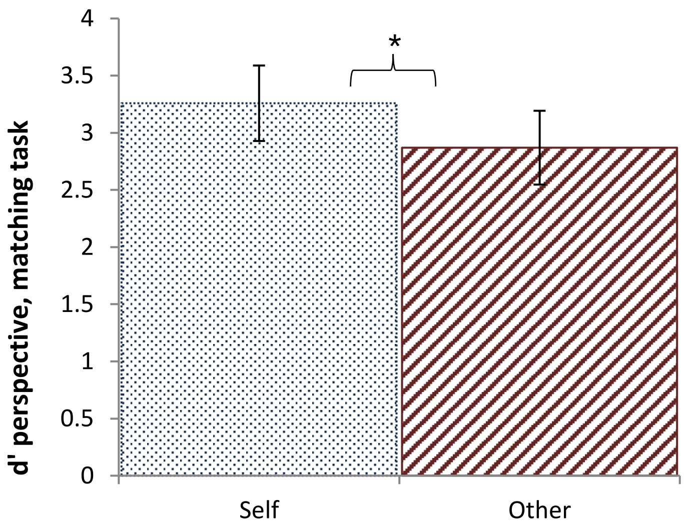

Figure 10. d' matching task, *Experiment 1c*. Mean d' for perspective on the matching task (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

The same pattern is observed for the proportion of correct responses during the matched trials. Again a main effect of perspective ($F(1,20) = 9.780$, $p = .005$, $\eta^2_p = .328$) was found as participants provided more correct responses for the self condition when compared to the distant other-condition. There was no main effect of emotion ($F(1,20) <.001$, $p = 1.00$) and no interaction between emotion and perspective ($F(1,20) = .074$, $p = .789$). For the non-matched trial no significant effects were observed: perspective ($F(1,20) = .192$, $p = .666$); emotion ($F(1,20) = .380$, $p = .545$); emotion X perspective ($F(1,20) = .192$, $p = .666$).

The most obvious benefit of the self condition was observed for the median reaction times on the matched trials correct responses ($F(1,20) = 32.818$, $p < .001$, $\eta^2_p = .621$). Participants responded faster to the words from the self condition compared to words from the distant other-condition, see Figure 11. Again, for the non-matched trials there were no main effects of emotion, perspective nor an interaction between emotion and perspective ($F(1,20)$ = respectively: 1.245, $p = .278$; .106 , $p = .748$; 1.037, $p = .321$).

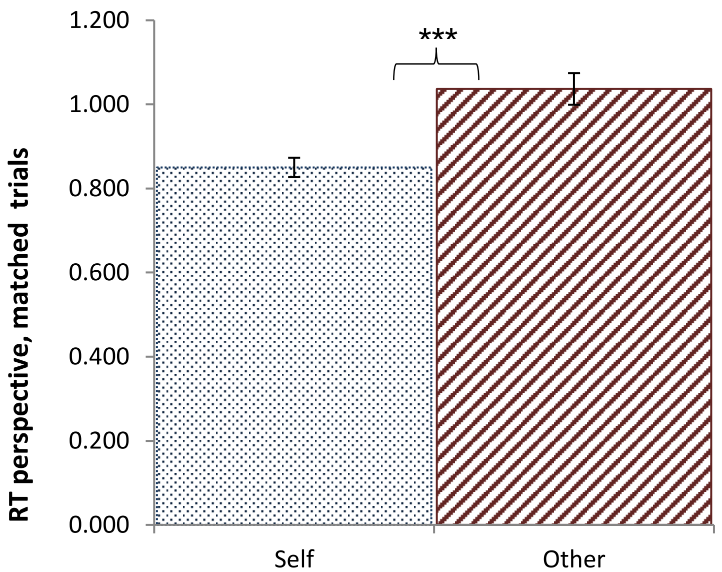

Figure 11. Median RT matching task, *Experiment 1c*. RT for perspective on the matching task, matched trials (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

Table 5. Experiment 1c, Matching task. Proportion correct responses, median RT, and d'. Standard error in parenthesis.

	Matched Trials		Non-Matched trials		d'
	Correct	RT	Correct	RT	
Self	.92 (.05)	858.01 (23.68)	.85 (.05)	1040.06 (34.56)	3.31 (0.29)
Other	.86 (.05)	1037.78 (38.45)	.86 (.05)	1045.08 (35.48)	2.90 (0.32)
Negative	.89 (.05)	938.28 (27.90)	.86 (.05)	1027.84 (29.42)	3.12 (0.27)
Neutral	.89 (.05)	957.51 (29.89)	.85 (.05)	1057.30 (42.63)	3.09 (0.33)
Self/Negative	.92 (.05)	860.30 (26.49)	.86 (.05)	1014.04 (33.45)	3.34 (0.28)
Self/Neutral	.92 (.05)	855.71 (24.25)	.84 (.06)	1066.08 (47.45)	3.28 (0.32)
Other/Negative	.86 (.05)	1016.27 (37.20)	.86 (.05)	1041.64 (34.17)	2.90 (0.31)
Other/Neutral	.86 (.05)	1059.30 (43.44)	.86 (.05)	1049.52 (39.48)	2.89 (0.37)

Old new task

Two main effects were found for the old/new task with the d' measurement (see Figure 12A): perspective ($F(1,20) = 5.828$, $p = .025$, $\eta^2_p = .226$), where the d' of self was higher when compared to distant other; and emotion ($F(1,20) = 15.722$, $p = .001$, $\eta^2_p = .440$), where the d' was higher for the negative emotions than the neutral emotions, see Figure 12B. There was no significant interaction effect, $F(1,20) = 1.336$, $p = .261$. See Table 6 for an overview of the means and standard error for the old/new task.

For the proportion of correct responses, a distinction could be made again for the matching and non-matching trials. For the matching trials, two significant effects were found. A main effect was found for emotion ($F(1,20) = 9.508$, $p = .006$, $\eta^2_p = .322$) where participants correctly recalled more negative words compared to neutral words. No main effect was observed for perspective ($F(1,20) = 1.907$, $p = .183$). However, perspective and emotion were found to significantly interact ($F(1,20) = 4.915$, $p = .038$, $\eta^2_p = .197$). A further inspection revealed that there was no significant effect of emotion when only looking at the words from the self condition (p = .057), but there was a clear significant effect of emotion for the words from the distant other-condition (p = .002). Participants responded more accurately for the negative words related to a distant other compared to distant other-related neutral words. Furthermore, an effect of perspective was only found for the neutral words (p = .032). Participants correctly judged more neutral words as old for self-related words, than distant other-related words. No difference was found between self- and distant other-related negative words (p = .571), See Figure 13.

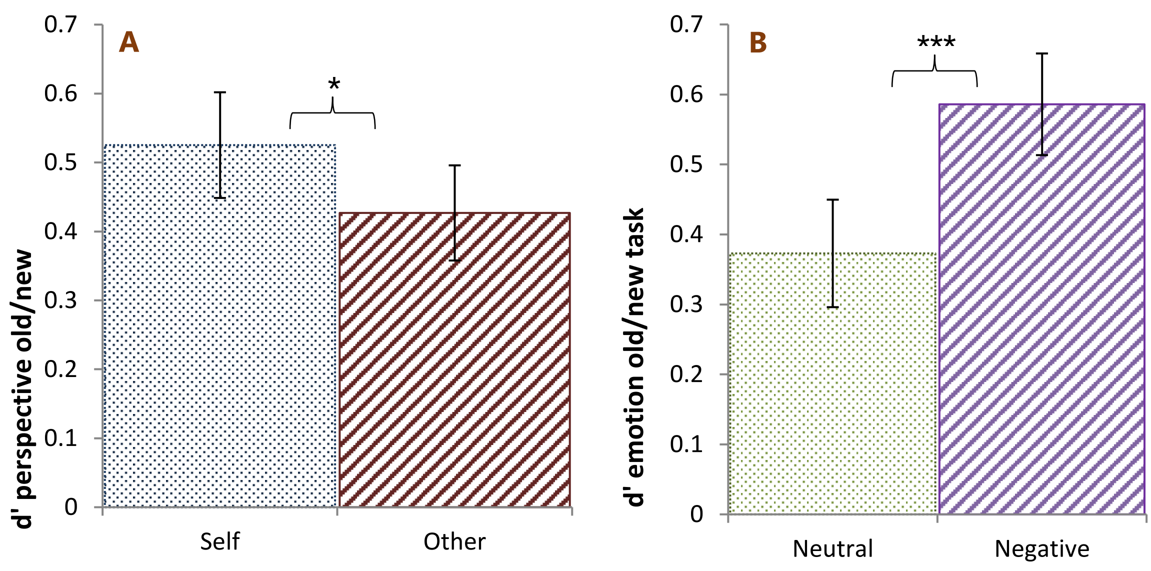

Figure 12. d' old/new task, *Experiment 1c.* d' of perspective on the old/new task (**A**) and d' of emotion on the old/new task (**B**) (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

For the non-matching trials there was no interaction between perspective and emotion (F(1,20) = .286, p = .599), nor was there a main effect of perspective (F(1,20) = 1.827, p = .192). Only a main effect of emotion (F(1,20) = 6.761, p = .017, η^2_p = .253) was observed, where negative words were recalled more often than neutral words.

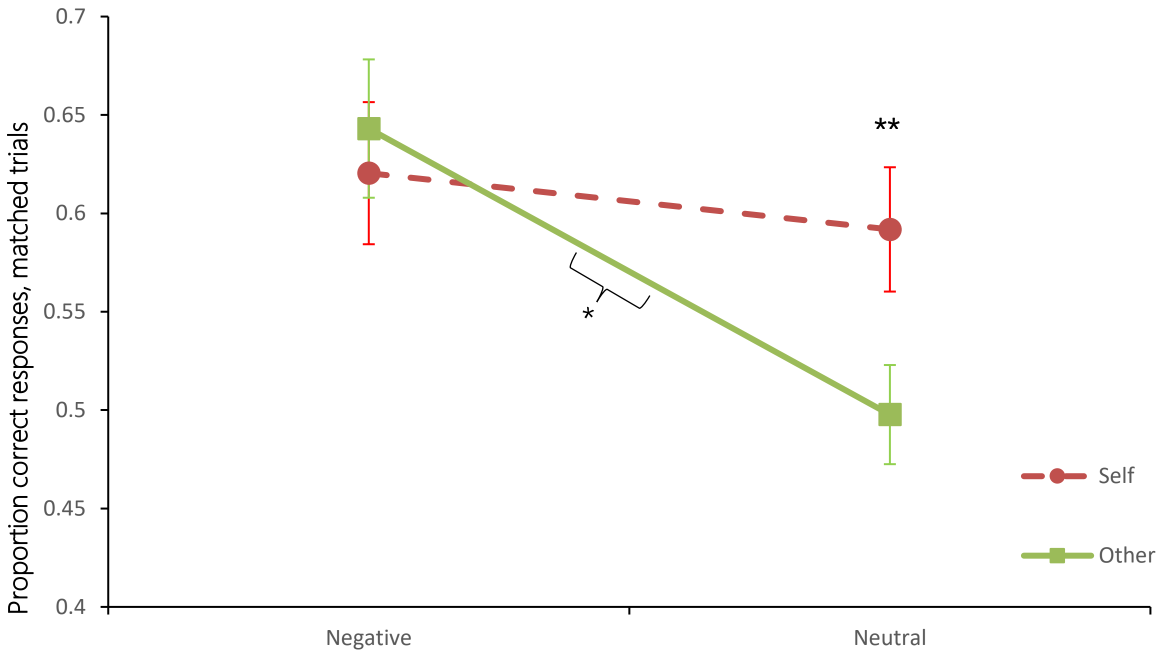

Figure 13. Proportion of correct responses old/new task, *Experiment 1c*. The interaction between emotion and perspective for the proportion of correct responses (Error bar = standard error,* = p<.05, ** = p<.01, *** = p<.001).

Table 6. Experiment 1c, old/new task. Proportion correct responses, Median RT, and d'. Standard error in parenthesis.

	Matched Trials	Non-Matched trials	D'
	Correct	Correct	
Self	.61 (.03)	.57 (.03)	0.53 (0.08)
Other	.57 (.02)	.53 (.03)	0.43 (0.07)
Negative	.63 (.02)	.59 (.03)	0.59 (0.07)
Neutral	.55 (.02)	.52 (.03)	0.38 (0.08)
Self/Negative	.62 (.04)	.61 (.04)	0.61 (0.07)
Self/Neutral	.59 (.03)	.53 (.04)	0.46 (0.10)
Other/Negative	.64 (.04)	.56 (.04)	0.57 (0.90)
Other/Neutral	.50 (.03)	.50 (.04)	0.30 (0.07)

Discussion

The matching task of *Experiment 1c* showed similar results as the previous two experiments. This means that no effect of emotion was found for the matching task for the matched trials. This is despite the fact that effort had been made to make the words more personally relevant by using negative trait-words. Therefore, the original explanation of this missing effect of emotion still stands: the colours of the words were processed faster than the meaning of the words and its subsequent emotional effect. Therefore, later memory processes were influenced by emotion, but emotion did not influence early perceptual processes. A main effect of perspective is found, and this replicates the findings of the previous experiments (*Experiment 1a-b*). *Experiment 1c* showed that participants were not only faster in detecting self-relevant information but also made more accurate judgements, and were more capable of distinguishing self-related signals from noise.

For the old/new task emotion had an effect on memory as d' revealed main effects of perspective and emotion. The d' measure therefore again indicated an overall effect of emotion and self but no interaction. However, when looking at the proportion of correct responses for only the matched trials, an interesting pattern unfolds. Unlike *Experiment 1a* and 1*b*, there was no main effect of perspective, indicating that emotional trait-words did influence the self differently than just emotional nouns, but there was an interesting interaction between emotion and perspective. The interaction was caused by an effect of self for the neutral words, but not for the negative words. An effect of emotion was only found for the words related to a distant other and not for words related to the self.

This shows that by using trait-words, the effect of negative emotions seem to influence the self-reference effect and similarly self-reference influences emotion, although the exact nature of this interaction between emotion and self remains unclear as negative self-related words do not outperform neutral self-related words or negative distant other-related words. If negative emotions were the main mnemonic influence, then negative trait-words should still result in more recognised words in the self condition for negative words. However, no differences between negative and neutral words were found for the self condition. The same holds in reverse: if the self-reference effect was the main reason behind the increase in memory recall, a self-reference effect should be observed for both negative and neutral conditions. These data, therefore, seem to suggest that emotion and self separately influence memory processes, but when both conditions coincide (i.e. emotional self-related information) no additive effect is found. It is difficult with the current data to interpret how self and emotional trait words influence each other. Therefore in the next two experiments, this process is examined further by replicating *Experiment 1c* with positive trait words in *Experiment 1d* and looking for any additive effect of self and emotion together in *Experiment 2*.

Experiment 1d: The self & positive trait words

In order to test whether the memory results of *Experiment 1c* were due to the influence of emotion per se or specifically to the influence of negative emotions, *Experiment 1*d used positive trait word stimuli. Research suggests that negative emotions might results in a distancing of the self (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Taylor, 1991), but *Experiment 1a* with negative nouns and *Experiment 1b* with positive nouns showed similar main effects of emotion and perspective on memory and no interaction.

Therefore, based on the results on *Experiment 1a* and 1b, it was predicted that positive valence would impact memory processes similarly to *Experiment 1c*. This is because the results of *Experiment 1a and Experiment 1b* did not show a different effect of positive or negative emotions on the self-reference effect. Like *Experiment 1c*, the use of emotional trait-words created a more personal emotional self-relevance. It is possible that the use of positive words will allow for an easier link to the self when compared to self-related negative words. Since both trait-words experiments are identical in the procedure, the results from *Experiment 1c* and 1d can be compared directly.

Methods

Participants

A total of 22 participants took part in this experiment. Two participants were removed from further analysis due to a below change level performance on the matching task. Of the remaining 20 participants, 19 were female, and one was male (mean age: 19.35 years; range 18–33 years).

Stimuli and procedure

For *Experiment 1d* the same stimuli and procedure were used as in *Experiment 1c*, except for the valence of the trait words. Whereas *Experiment 1c* used negative trait words, *Experiment 1d* used positive trait words. The positive trait words were derived from the same word database by Dumas, Johnson, and Lynch, (2002). The same word selection procedure was used as with *Experiment 1c*, but the selection of the positive words were all based on the likableness scale score > 5 and words familiarity score > 3.

Results

Matching task

For the matching task a signal detection analysis (d') revealed that participants were more capable in separating signal from noise in the self condition when compared to the distant other-condition, $F(1,19) = 15.183$, $p = .002$, $\eta^2_p = .397$, see Figure 14. Also see Table 7 for an overview of the means and standard errors. No such difference was found for emotion, $F(1,19) = .045$, $p = .834$. However, a significant interaction was found between perspective and emotion, $F(1,19) = 4.562$, $p = .046$, $\eta^2_p = .194$.

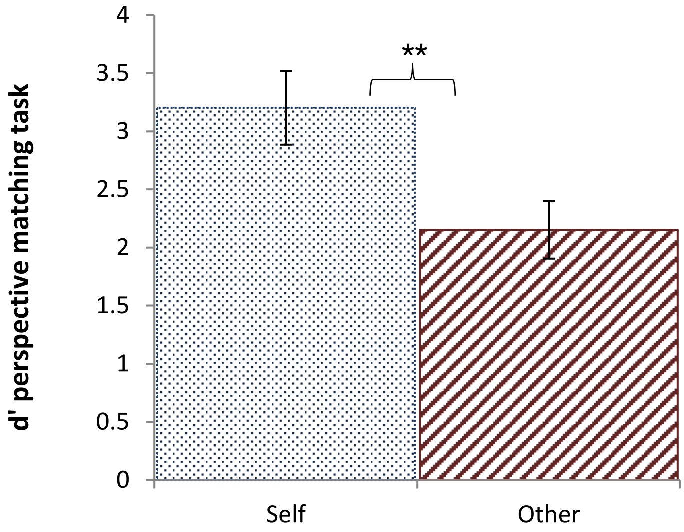

Figure 14. d' matching task, ***Experiment 1d.*** Mean d' of perspective for the matching task (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

The proportion of correct responses for the matched trials showed that participants responded more accurately to words related to the self than words related to a distant other, $F(1,19) = 13.535$, $p = .002$, $\eta^2_p = .416$. All other effect were non-significant: F(1,19) emotion <.001. p = 1.00; emotion × perspective = .014, p = .166; non-matched perspective = 2.430, p = .136; non-matched emotion = 1.120, p = .303; non-matched perspective × emotion = 1.046, p = .319.

The median reaction times for the matched trials were faster for the self-related words when compared to the words linked to a distant other, $F(1,19) = 33.173$, $p < .001$, $\eta^2_p = .636$, see Figure 15. No other significant effects were found: F(1,19) emotion = .921, p = .349; perspective × emotion = .018, p = .895; non-matched perspective = .714, p = .409); non-matched emotion = .061, p = .807; non-matched perspective × emotion = .180, p = .676.

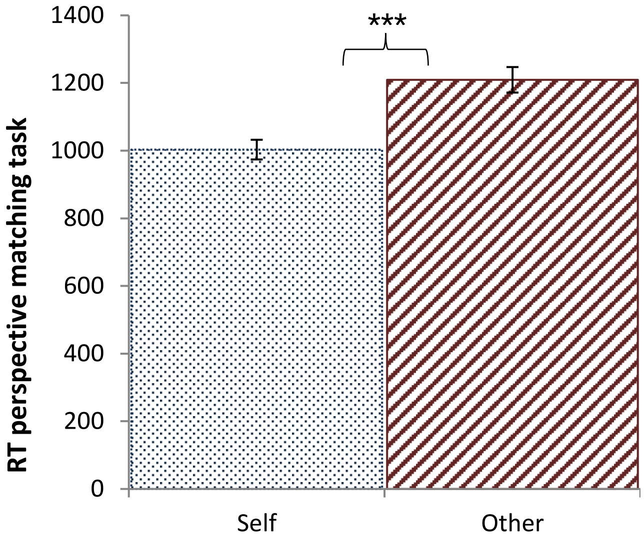

Figure 15. **Median RT matching task, *Experiment 1d.*** Median RT of perspective for the matching task, matched trials (Error bar = standard error,* = p<.05, ** = p<.01, *** = p<.001).

Table 7. Experiment 1d, Matching task. Proportion correct responses, median RT, and d'. Standard error in parenthesis.

	Matched Trials		Non-Matched trials		D'
	Correct	RT	Correct	RT	
Self	.91 (.03)	1012.36 (31.45)	.88 (.03)	1216.34 (34.16)	3.15 (0.32)
Other	.81 (.03)	1201.33 (33.63)	.84 (.03)	1191.83 (36.34)	2.28 (0.25)
Positive	.86 (.03)	1091.90 (26.58)	.84 (.03)	1206.49 (34.10)	2.68 (0.26)
Neutral	.86 (.03)	1118.79 (34.43)	.87 (.03)	1201.68 (34.06)	2.74 (0.26)
Self/Positive	.93 (.03)	998.58 (35.32)	.87 (.04)	1222.00 (35.54)	3.20 (0.32)
Self/Neutral	.90 (.03)	1026.15 (39.72)	.88 (.03)	1210.68 (35.90)	3.09 (0.32)
Other/Positive	.80 (.04)	1191.23 (32.36)	.81 (.04)	1190.98 (10.811)	2.15 (0.25)
Other/Neutral	.82 (.03)	1211.43 (41.77)	.86 (.03)	1192.68 (37.01)	2.40 (0.27)

Old/new task

The d' results from the old/new task revealed that that the participants were more sensitive in detecting signal from noise for the words related to the self than words related to a distant other, $F(1,19) = 6.034$, $p = .024$, $\eta^2_p = .241$, see Figure 16A. Similarly, participants were more sensitive in detecting a signal in the old/new task if the words were neutral (.573) compared to positive (.456), $F(1,19) = 4.674$, $p = .044$, $\eta^2_p = .197$, see Figure 16B. However, no interaction between the two main conditions of perspective and emotion was found, $F(1,19) = 1.800$, $p = .195$.

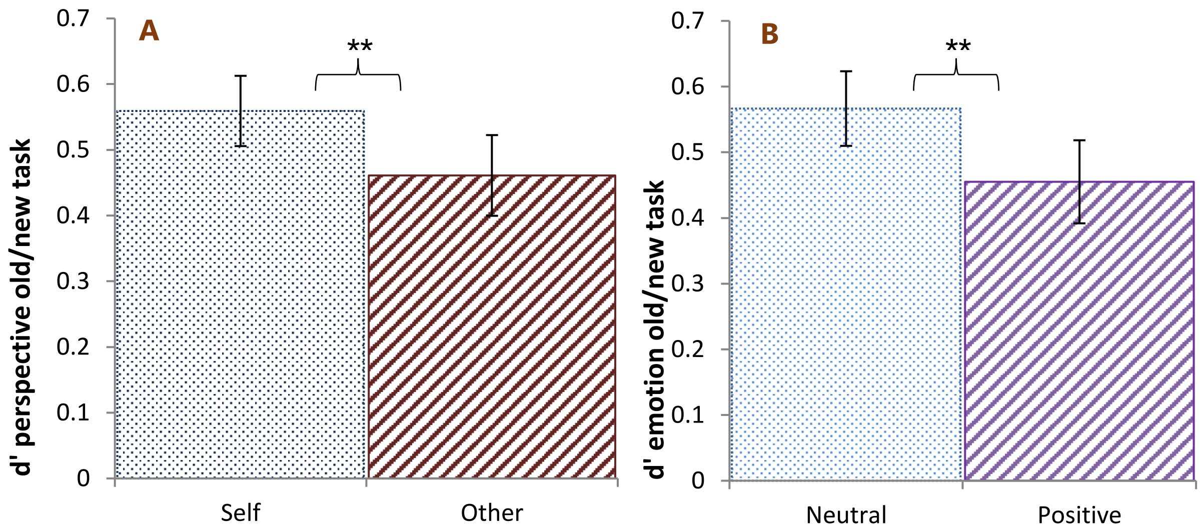

Figure 16. d' old/new task, *Experiment 1d.* Mean d' for perspective (**A**) and mean d' for emotion (**B**) for the old/new task (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

When looking at the matched trials old words only, the participants were more accurate for the words related to self than from the distant other-condition, $F(1,19) = 4.361$, $p = .050$, $\eta^2_p = .187$, and positive words were remembered correctly more often than neutral words, $F(1,19) = 23.514$, $p < .001$, $\eta^2_p = .553$. Furthermore, there was a significant interaction between perspective and emotion, $F(1,19) = 14.413$, $p = .001$, $\eta^2_p = .431$. Further analysis revealed that this interaction was driven by a significantly greater accuracy for positive words compared to neutral words linked to a distant other ($p < .001$). No significant effect of emotion was found for the self-relevant trials ($p = .285$). Furthermore, a significant self-reference effect was found for neutral words ($p = .002$).

There was no significant difference between self-related positive words and distant other-related positive words ($p = .126$). See Figure 17 for a graph of the interaction and Table 8 for the means and standard errors for the proportion of correct responses and d'.

For the non-matched old words, a significant effect was found for perspective, $F(1,19) = 5.159$, $p = .035$, $\eta^2_p = .214$, where words related to the self were more often correctly remembered than words related to a distant other. There was no main effect of emotion for the non-matched words ($F(1,19) = 1.739$, $p = .203$), and there was no interaction between emotion and perspective ($F(1,19) = .589$, $p = .452$).

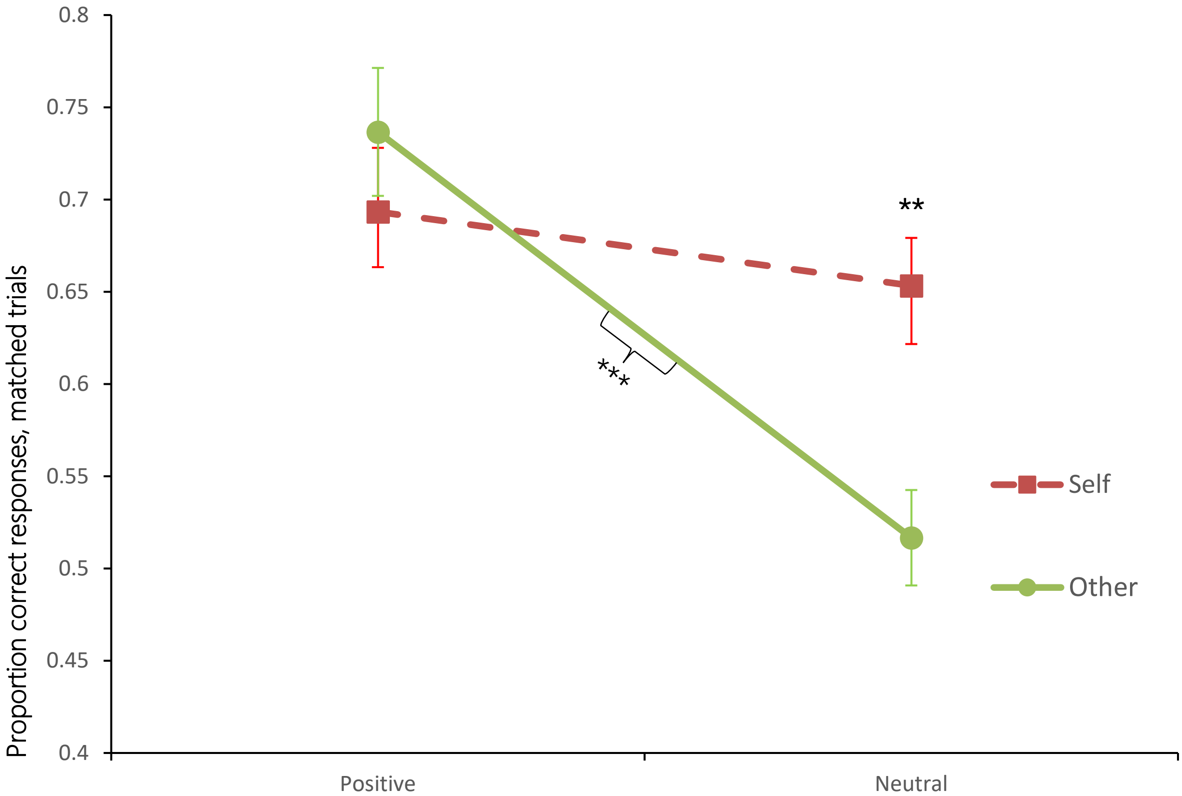

Figure 17. Proportion of correct responses old/new task, *Experiment 1d*. The interaction between emotion and perspective for the proportion of correct responses, matched trials (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

Table 8. Experiment 1d, old/new task. Proportion correct responses, Median RT, and d'. Standard error in parenthesis.

	Matched Trials	Non-Matched trials	D'
	Correct	Correct	
Self	.67 (.03)	.65 (.02)	0.57 (0.05)
Other	.63 (.03)	.60 (.03)	0.46 (0.06)
Positive	.72 (.03)	.65 (.03)	0.46 (0.06)
Neutral	.59 (.03)	.60 (.03)	0.57 (0.06)
Self/Positive	.69 (.04)	.66 (.04)	0.48 (0.06)
Self/Neutral	.65 (.03)	.63 (.02)	0.66 (0.07)
Other/Positive	.74 (.03)	.63 (.04)	0.43 (0.07)
Other/Neutral	.52 (.03)	.56 (.03)	0.49 (0.07)

Discussion

The results of *Experiment 1d* were very similar to the results of *Experiment 1c*. Again the matching task showed a strong effect of self as shown by better performance on the signal detection measure. This was also shown for the matched trials in terms of faster and more accurate responses. As previously explained, there was no effect of emotion for the matching task.

For the old/new task, the observed effects are again very similar to *Experiment 1c*. Interestingly the d' data revealed a weaker effect on memory for the positive trait-words compared to neutral. However, this was not further supported by the proportion correct responses which can be further subdivided into matched and non-matched conditions, possibly indicating that the non-matched trials influenced the d' data. When looking at the proportion correct responses data, positive trait-words and trait-words related to the self led to better memory separately, but positive emotion and the self together did not lead to greater recognition from memory than each condition by itself.

Taken together, Experiments 1a, 1b, 1c, and 1d all suggest that emotion and self are processed independently from each other, at least in terms of memory processing. Unlike the experiments of Gutchess et al. (2007) and Leshikar et al. (2015), positive or negative self-related information does not seem to lead to an increase or decrease of the self-relevance effect. No interaction was found in *Experiment 1a* or *Experiment 1b*, and the interaction between emotion and perspective in *Experiment 1c* or *Experiment 1d* did not support a direct influence of emotion on self-referential processing. If positive emotions did have an additive effect on the self, then a greater self-reference effect for the positive trials would have been expected when compared to neutral trials. Oppositely, if negative emotions disrupt self-related processes, a decreased self-reference effect should have been found for the negative trials when compared to the neutral trials.

As mentioned, there are important differences between the experiments of this thesis and the study of Leshikar et al. (2015) and Gutchess et al. (2007) that could account for these observed differences. First, the *Experiments 1a-d* studied negative and positive emotion separately and compared the emotion trials with neutral trials. Possibly the offset between positive and negative emotions helped highlight the differences between the two emotions. However, emotion still improved recall for the self and distant other condition equally when using nouns (*Experiment 1a* and 1*b*), and when using emotional trait words (*Experiment 1c* and 1*d*) emotion did not affect self-related words. If the self withdraws from negative emotions, no such improvement (or at least less improvement) should have been observed for the negative nouns in the self-condition. Lastly, in the encoding phase of the experiments by Leshikar et al. (2015) and Gutchess et al. (2007), participants have to actively judge if the adjective describes them or not. As it is much easier to think of yourself in a positive way than in a negative way (Mezulis et al., 2004; Taylor, 1991), positive emotions were possibly less distracting from the encoding task than negative emotions. In the current experiments, the influence of emotion was more subtle in the matching (encoding) task as no decision had to be made involving the meaning and/or valence of the word. Furthermore, the main strength of the current encoding or matching task was that participants did not judge if something described themselves, forgoing any influence of familiarity and social desirability.

Therefore, the tentative conclusion made for now is that the effect of emotion that has been reported in the literature on self-relevance (Gutchess et al., 2007; Leshikar et al., 2015) are possibly the result of richer or more in-depth encoding compared to items not related to the self. Furthermore, during these experiments, positive words are actively linked to the participant, whereas the opposite occurs with negative information. This, in turn, results in better recall for positive self-related words, and reduced recall for negative self-related words. This is due to the distancing of the self from negative information and preferring positive information about the self (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Kuiper & Derry, 1982; Mezulis et al., 2004; Ochsner, 2000; Sedikides & Green, 2004; Taylor, 1991). This did not happen in *Experiments 1a-1d*, because emotion was not directly linked to the self in a self-reflecting manner, but indirectly via the matching task for which the depth of encoding was equal across all conditions, but since self-related and emotional information is attended to faster and possibly more intensive, both aided encoding into memory. Thus, it seems that there is no interactive effect of self and emotion because the self-relevance judgement has already been made. Furthermore, emotion itself helps increase the salience of the word and as such, is goal relevant for the memory task (Mather & Sutherland, 2011).

The lack of influence of emotion on self-related items in memory can represent the possibility that information involving the self and emotion may be processed via independent channels. This is in line with the findings of previous research that found no correlation between emotion processing and self-relevance processing (Stolte et al., 2016). The argument here is not that emotion does not influence self-relevant processing. There is clear evidence that it does (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Taylor, 1991). Therefore, the above seems to illustrate that emotion and self-related information influence attention and memory similarly, but the underlying processes are different. Potentially the influence of emotion can make an item more or less self-relevant, but the methodology used in *Experiments 1a-d* does not link emotion and self together in a direct fashion. As a consequence, the stimuli used are self-relevant and emotional but not emotionally self-relevant.

Looking at the results of Experiment 1c and 1d, emotion, in general, seems to improve memory processes irrespective of valence. However, there is a limit to the improvement of memory processes in both experiments. Self-relevance, combined with emotion, does not increase the proportion of correctly recognised words or vice versa. It is currently unknown to what extent the self and emotion influence each other. The current paradigm might not be able to highlight the relation between self and emotion clearly enough. Therefore, Experiment 2, reported in the next chapter, was designed to see if there is any interactive benefit of emotional valence on self-referenced words or not. This was done by adapting the matching paradigm used so far and ensuring that the valence judgement of the trait-words occurs at the same time as the matching judgement.

Chapter 3:

Redundancy gain emotional self

Introduction Experiment 2

The main purpose of *Experiment 2* was to investigate the observed effects of self-relevant emotional information further. The old/new tasks of *Experiments 1* (especially *1c* and *1d)* showed that emotion and the self both influence memory. When memory items were paired with a self-associated stimulus, then those items tended to be better remembered than when items were paired with stimulus associated with someone other than the self. This shows the importance of self-relevance in driving memorability. When items were emotional in nature, then they also tended to be better remembered, against neutral-emotion control stimuli. However, *Experiment 1c* and *Experiment 1d* showed an interaction between emotion and self as well on the old/new task. The self-reference effect was only present for neutral stimuli, whereas improved recognition for emotional stimuli was only present for stimuli not related to the self. In other words, there appeared to be a ceiling where the combined effect of emotion and self is not greater than the effect of self and emotion separately. It is difficult to determine from this memory recognition data alone if self and emotion operate completely independently as the data seems to suggest, or if both emotion and self combined can impact information processing, as previous research seems to suggest (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Gutchess et al., 2007; Leshikar et al., 2015; Taylor, 1991).

In Chapter 2, the Experiments 1a-d all show a clear effect of self on attention. However, an effect of emotion was expected as well (Neisser, 1976; Öhman et al., 2001; Phelps et al., 2006; Ray, 1979; Reinecke et al., 2006; Vuilleumier, 2005; Williams, Ellis, et al., 1996). Self and emotion are two systems that are critical for our being in the world and guide our interpersonal relationships in our daily life. A close link between self and emotion shape our daily experiences. For example, it has been suggested that self is critical for emotional experience (Tracy & Robins, 2004), and emotion is critical for awareness of self (Northoff et al., 2006). Recent neuroscientific understanding of the role of self and emotion in guiding our behaviour has shown that self and emotion affects several cognitive processes. For example, self has been sown to increase perceptual and attention processes (Alexopoulos et al., 2012; Brédart et al., 2006; Cherry, 1953; Keyes & Brady, 2010; Shapiro et al., 1997; Tong & Nakayama, 1999), and memory process (M. A. Conway & Dewhurst, 1995; M. A. Conway & Pleydell-Pearce, 2000; M. A. Conway et al., 2016; Kelley et al., 2002; Klein & Kihlstrom, 1986; Rogers et al., 1977; Symons & Johnson, 1997; Turk et al., 2013). In a study investigating self, other, general, and superficial syllable level encoding of positive and negative trait words Craik et al. (1999) found non significantly increased memory performance for self-related words compared to all the three conditions. The PET activation data from their study showed increased activation of the medial and right frontal cortex related to self-condition. Similarly, Kelley et al. (2002) also found better memory performance for self-condition compared with other. In a study examining attribution of emotion to self and others, Ochsner et al. (2004) found selective activation of the medial prefrontal cortex (mPFC) and the left temporal cortex which was attributed to attention to and elaboration of internally generated information. In contrast to the self-related selective activation, the other related processing selectively activated the left lateral PFC including the Broca's area and the medial occipital cortex. In addition to this their findings also showed common brain structures such as the mPFC, superior temporal gyrus (STG) and posterior cingulate/precuneus involved in processing self and other related information. In another study Fossati et al. (2003) showed that bilateral dorsolateral prefrontal cortex (DLPFC) was active in self-related processing whereas the lateral prefrontal cortex was active in other related areas when participants were asked to judge if a trait word describe them or someone else. The right dorsomedial prefrontal was found to be mediating evaluation of emotional stimuli relevant to the self.

The findings suggest that the critical brain areas associated with self and emotional self might be different.

Similarly, emotion is the other system that has been consistently found to influence perceptual and attentional processing (Neisser, 1976; Öhman et al., 2001; Phelps et al., 2006; Ray, 1979; Reinecke et al., 2006; Vuilleumier, 2005; Williams, Ellis, et al., 1996) as well as memory (Alicke, 1985; LaBar & Cabeza, 2006; Levine & Pizarro, 2004; Mather, 2007; Sakaki et al., 2014). This remarkable similarity on their effects on modulating different cognitive processes may suggest that self and emotional systems are same or have very close relationship. Indeed emotional self is represented in the mDFC (Fossati et al., 2003) or in the ventral anterior cingulate, an area close to the mDFC region (Moran, Macrae, Heatherton, Wyland, & Kelley, 2006) which is suggested to integrate information from self and emotion. That makes emotional stimuli, negative or positive, self-related. However, neutral stimuli are not relevant to self and may not elicit the same responses as any emotional stimuli would do (Northoff et al., 2006). The emotional valance determines the strength of mineness and therefore, the response strength of the individual. For example, Greenwald and Farnham (2000) using the implicit association test to measure self-esteem found that participants were much faster to respond to self-positive affective (e.g., diamond, health, sunrise) and evaluative trait words (e.g., bright, noble, honest) than the self-negative affective (e.g., agony, filth, poison) and evaluative trait words (e.g., ugly, vile, guilty). However, it is important to understand that emotional valance alone is not sufficient to increase the response strength. Moran et al. (2006) demonstrated this by showing that participants were faster in responding to positively valanced highly self-relevant word.

However, some researchers argue that self and emotions are dissociable (Gutchess et al., 2007; Leshikar et al., 2015; Stolte et al., 2016). The contrasting nature of relationship between the self and emotion may suggest that in certain circumstances self is not needed to experience emotion (e.g., experience of fear when involved in an accident, joy of winning a lottery). However, in most of the situations self is critical in experiencing emotion what is called as self-conscious emotion (e.g., sense of pride, shame, guilt: Tracy and Robins, 2004).

Part of the difficulty in interpreting the effect of emotion so far is the apparent lack of emotional influence on attention as measured by the matching tasks of the previous chapter. In the previous experiments (*experiment 1a – 1d)*, the lack of an effect of emotion on attention was suggested to be the result of an early matching response based on the colour of the word. It is suspected that a response is made (or at least initiated) before the meaning of the word is extracted, and therefore before its emotional valence is processed. Because of this, the matching task may have been a poor choice for measuring any emotional influence in relation to the self. However, since an effect of emotion is observed in the subsequent old/new recognition task, the matching task used in the previous experiments (*1a -1d*) might have been unable to measure the effect of emotion on attention.

Therefore, the experiment described in this chapter (*Experiment 2)* adapted the matching task of the previous chapter (*Experiments 1b-1d)* to explore the possible effect of emotion on attention. Furthermore, this adaptation of the matching task will allow for the measurement of any potential gains when processing the combined effects of emotional self-related information. In other words, the current study sought to provide evidence for an interaction between self and emotion. The aim was to show that self-related and emotional information, when processed together, will lead to a more efficient processing of that information compared to emotional or self-related information by itself. This new paradigm used a redundancy gain approach to explore the effect of self, emotion and combination of self and emotion on perceptual processes.

One phenomenon which can be utilised in exploring the effect of emotional self-relevant information in more detail is that of redundancy gain. Redundancy gain is a phenomenon associated with response latencies towards stimuli which have multiple identifying target attributes. Generally, redundant stimuli are processed faster than single stimuli when the same response is required. In typical redundancy gain experiments participants either have to respond to audio stimuli, visual stimuli, or audio-visual stimuli. It is generally found that participants respond faster to a stimulus which contains redundant information across two dimensions, than to either audio or visual stimuli alone (Hershenson, 1962). Naturally, the phenomenon of redundancy is not limited to cross-modal experiments such as audio-visual experiments; instead, it seems to be a general principle of cognitive processing. For instance, the effect of redundancy has been observed with redundant signals within a single sensory system such as vision (Miller & Adam, 2006; Miller, Beutinger, & Ulrich, 2009). For example, in one of their experiments Miller, beutinger, and Ulrich (2009) used a simple reaction time task with target squares appearing to the left or right of fixation. The location of these squares would be cued with an arrow before being displayed, and this would be a valid cue in 80% of the trials. Participants were instructed to respond as quickly as possible if a square appeared. In the redundant condition, a square block would appear in both the top and bottom of the screen, either left or right of the fixation in the middle of the screen. In the non-redundant condition a single square would only appear one of the four corners of the screen. Their results showed a redundancy gain for when the squares were displayed in both the top and bottom of the screen, compared only one square in either the top or bottom side of the screen. In other words, participants were faster in responding when two visual stimuli conveyed the same information, compared to one stimulus.

There are two classes of model which differ in their interpretations of how having a redundant target reduces response latencies: the *race model* and the *coactivation model*. The difference between these model classes is an important one because they make fundamentally different assumptions about stimulus information processing. Race models assume that redundant stimuli are processed independently from one another (Miller, 1982). When there is a single stimulus the processing of that stimulus varies according to a statistical distribution. With two stimuli the distributions of each separate stimulus overlap, causing the slower stimulus to be compensated by the faster stimulus, which results in a faster response for redundant stimuli (Gondan & Minakata, 2016). For example, according to the race model when a participant is presented with two redundant stimuli (e.g. two different visual targets, both requiring the same response), then the average processing of one stimulus will be faster than the other. The fastest stimulus wins the race and initiates the response, the slower stimulus processing time overlaps with the faster processing time, resulting in a faster RT for redundant stimuli compared to single stimuli. In other words, a parallel race model proposes that each process is separate and each can lead to a response by themselves. However, with redundant targets, the faster process compensates for, the slower process.

Coactivation models propose that the two redundant stimuli are integrated into their processing rather than processed separately. Processes are still viewed to occur in parallel, but the processes of the redundant signals coalesce at some point and the summed processes, in having a higher strength signal, lead to a faster response being executed. Note that neither class of model makes any specific predictions about the state that this coalescence occurs. One way to determine if redundant stimuli are processed in an independent (race model) or dependent (coactive model) manner is to calculate capacity coefficients (Townsend & Nozawa, 1995). These coefficients are based on a capacity index where $C(t) = 1$ is the value indicating unlimited capacity which means that processing in a channel in unaffected by workload or the presence of a target in a different channel. If $C(t) < 1$, then this indicates limited capacity. This means that additional targets will decrease performance, possibly due to interference between stimuli processing. A value of $C(t) > 1$ indicates that there is *super-capacity*. Supercapacity indicates the presence of integration. It means that the two signals have been convolved together and improve decision-making processes.

Previous research on the self-priority effect has explored the notion of redundancy. It has been found that there is super-capacity for redundant self-related stimuli (Sui, Yankouskaya, & Humphreys, 2015). Their experiment was a variation of the matching task used by Sui et al. (2012), and four geometric shapes were equally assigned to either the participant or a friend, meaning that two different geometric shapes were linked to the self and two other distinct geometric shapes were assigned to a friend.

Participants were then shown a shape in the left or right visual field, two matching shapes, or two non-matching shapes. This created a total of six conditions: self, same shape displayed left and right; self, different shape presented left and right; self, one shape presented left or right; and then the same three conditions for 'friend'. By pressing a button the participant had to decide if the shape belonged to them or a friend. In this case, the redundancy was in two geometric shapes that result in the same response. Their results support a coactivation model for the self-trials. This showed that self-relevant shapes were processed with super capacity. Where self-trials benefited from redundancy, friend-trials did not.

The experiment described in this chapter (*Experiment 2)* will not look for redundancy gain between self-related stimuli. Instead, this chapter will explore if there is a redundancy gain effect for information that is both self-relevant and emotional. In order to make a direct comparison with the previous experiments of this thesis, a redundancy manipulation was added to the matching paradigm described in *Chapter* 2.

This means that participants had to give the same response for emotional words, label/colour matched words, and emotional label/colour matched words. The exact details are explained below in the methods section. It was expected that emotion and self-matching trials would lead to faster and more accurate responses. Furthermore, a redundancy gain analysis explored if redundant targets were processed completely independent or showed coactivation. An old/new task will again follow the matching task. The old/new task is exactly the same as *Experiment 1d* and can be used for easy comparison of the results. The same results are expected (i.e. an interaction between emotion and perspective).

Methods

Participants

In total, 27 participants took part in *Experiment 3*. Six participants were removed from further analysis, as two participants were removed due to a technical error during testing, and four participants were removed because they performed below chance level during the matching task. Of the remaining 21 participants, five were male and 16 were female. The mean age was 19 years (range 18-22 years).

Stimuli and procedure

The stimuli used in *Experiment 2* are selected from the same list using the same procedure as discussed in *Experiment 1d*. However, the nature of the task and the instructions were altered to reflect a redundancy gain task. The stimuli onset times were still exactly the same as in the previous four experiments. However, initially the words were displayed in white. After 150ms the trait-words turned into one of the two colours, linked to either the self or some distant other. Participants were instructed not to respond before the word changed into a colour. Added to the normal instructions of matching the trait-word colour with the label 'myself' and 'stranger' was a new rule in which had people respond to the emotion of the word as well.

For example, the matching task still required the participant to match the label 'myself' or 'stranger' with one of two colours which were linked to the self or a stranger in the instructions. Added to this was the instruction to press a button (same as the matched response) if the trait-word was positive. In other words, the participant had to press the left mouse-button if the label and colour matched, and the participant also had to press the left mouse-button if the trait-word was positive, disregarding any colour/label matches and the right mouse-button if the trait-word was neutral. This resulted in three instances where the same button response was required: Positive emotion but not-matched, neutral emotion but matched and positive emotion and matched. The only remaining condition was the neural not-matched trials and these required a different, right-mouse-button response. The button-presses required were counterbalanced across participants. There were no changes to the old/new task.

Analysis

The data were analysed in a similar fashion as the previous experiments. Added to the analysis is the race model of inequality. Omitted responses were assigned an RT value exceeding the allowed RT-time window. The race model of inequality was generated using R script from equation 8 by Gondan and Minakata (2016): $F^*_{PM}(t) + F^*_{C}(t) \leq F^*_{P}(t) + F^*_{M}(t)$, for all t. Assuming that fast guesses equally contaminate the RT for all distributions, the cumulative RT distribution (F*(t)) for the redundant trials ($_{PM}$) plus catch trials ($_{C}$) is always equal or smaller than the cumulative RT distribution for positive emotions trials ($_{P}$) plus matched trials ($_{M}$). This applies the 'kill-the-twin' method to correct for fast guesses (Eriksen, 1988).

If the race model fails, the capacity coefficient was used to examine the possibility of a coactivation model further. For OR Capacity coefficients ($C_{OR}(t)$) the survivor function of the response time (the probability of a to-be-made response) is the probability of a to-be-detected target on a channel, compared to the baseline assumption of unlimited parallel processing via multiple independent channels. $C_{OR}(t)$ is defined via integrated hazard functions, which is a measuring method of efficiency or capacity (Townsend & Ashby, 1978), and can be calculated by taking a –log of the survivor function for each t. $C_{OR}(t)$ is obtained by the ratio of the integrated hazard function of both sources ($_{PM}$) to the integrated hazard function from each single source ($_{P} + _{M}$): $C_{OR} = \frac{H_{PM}(t)}{H_P(t) + H_M(t)}$. When the performance of $_{P} + _{M}$ is equal to $_{PM}$ ($C_{OR}(t) = 1$) then this indicates unlimited workload capacity. If $_{P} + _{M}$ is smaller than $_{PM}$ ($C_{OR}(t) < 1$) then this indicates a limited workload capacity. Finally, if $_{P} + _{M}$ is greater than $_{PM}$ ($C_{OR}(t) > 1$), this means that performance reflects possible coactive processing i.e. super capacity. The coefficients were calculated using the methods described by Houpt, Blaha, McIntire, Havig, and Townsend (2014) using the R package SFT.

Results

Matching task

The data for the matching task has been analysed according to the three conditions requiring the same response. These are: just a matching response without emotion; just emotion without a matching response; and a matching and emotion response. These were split up in self and distant other condition and created a 3(redundancy [redundant, emotion, colour/label matched]) × 2(perspective [self, distant other]) repeated ANOVA design and a Bonferroni correction was applied with multiple comparisons. Again the sample size was based on the effect-sizes found in previous literature and the previous experiments. A power analysis showed that a sample size of 20 was needed for sufficient power. However, like the previous experiment this is again a novel task and therefore it remains difficult to accurately estimate an effect-size

For the proportion of correct responses, a main effect was found of redundancy, $F(3,60) = 23.652$, $p < .001$, $\eta^2_p = .542$. Participants were more accurate for the redundant trials where the stimuli were both matched and positive (.870), compared to neutral matched trials (.732, $p = .004$), positive non-matched trials (.541, $p < .001$), and neutral non-matched trials (.557, $p < .001$). Furthermore, neutral matched trials were also more accurately responded to than positive non-matched trials ($p = .024$), and neutral non-matched trials ($p = .043$). Lastly, there was no significant difference between the non-matched positive trials and the non-matched neutral trials ($p = 1.000$). There was no main effect of perspective, $F(1,20) = 1.464$, $p = .240$.

However, there was a significant two-way interaction between redundancy and perspective, Greenhouse-Geisser $F(1.37, 27.72) = 9.024$, $p = .003$, $\eta^2_p = .311$. This interaction showed that the redundant trials have a higher proportion of correct responses for the self-related trials compared to the distant other related trials ($p < .001$). This same pattern was found for the matched trials where again the self-relevant trials were responded to quicker than the distant other-related trials ($p = .025$). However, for the positive trials, the effect reverses as the non-matched positive trials were more accurately responded to for the trials related to a distant other, compared to self-relevant trials (p = .011). For the non-matched neutral trials, there was no significant difference between self and distant other (p = .100). Furthermore, for the self-relevant trials, the participants were more accurate for the redundant trials compared to either matched neutral trials, non-matched positive trials, or non-matched neutral trials (Respectively: p = .012, p < .001, p <.001). The neutral matched trials resulted in a higher proportion correct than the non-matched positive trials (p = .008) and the non-matched neutral trails (p = .031). No significant difference was found between the non-matched positive and non-matched neutral trials (p = .586). For the trials related to a distant other, only the difference between the redundant trials and the matched neutral trials was significant (p = .029) as the redundant trials have a higher proportion of correct responses compared to the matched neutral trials. All other differences were not significant: redundant/non-matched positive (p = 1.00); redundant/non-matched neutral (p = .099); matched neutral/non-matched positive (p = 1.00); matched neutral/non-matched neutral (p = 1.00); or non-matched neutral/non-matched positive (p = 1.00). See Table 9 and Figure 18 for an overview of the proportion of correct responses.

Table 9. Experiment 2, Matching task. Proportion correct responses, and median RT. Standard error in parenthesis.

	Self		Other	
	Correct	RT	Correct	RT
Matched/Positive	.941 (.020)	756.74 (45.05)	.799 (.036)	958.79 (38.40)
Matched/Neutral	.800 (.047)	912.31 (42.97)	.664 (.053)	1013.19 48.54)
Non-matched/Positive	.362 (.084)	1039.17 (55.01)	.719 (.060)	846.24 (52.55)
Non-matched/Neutral	.454 (.084)	1099.79 (44.70)	.660 (.049)	1123.29 (43.05)

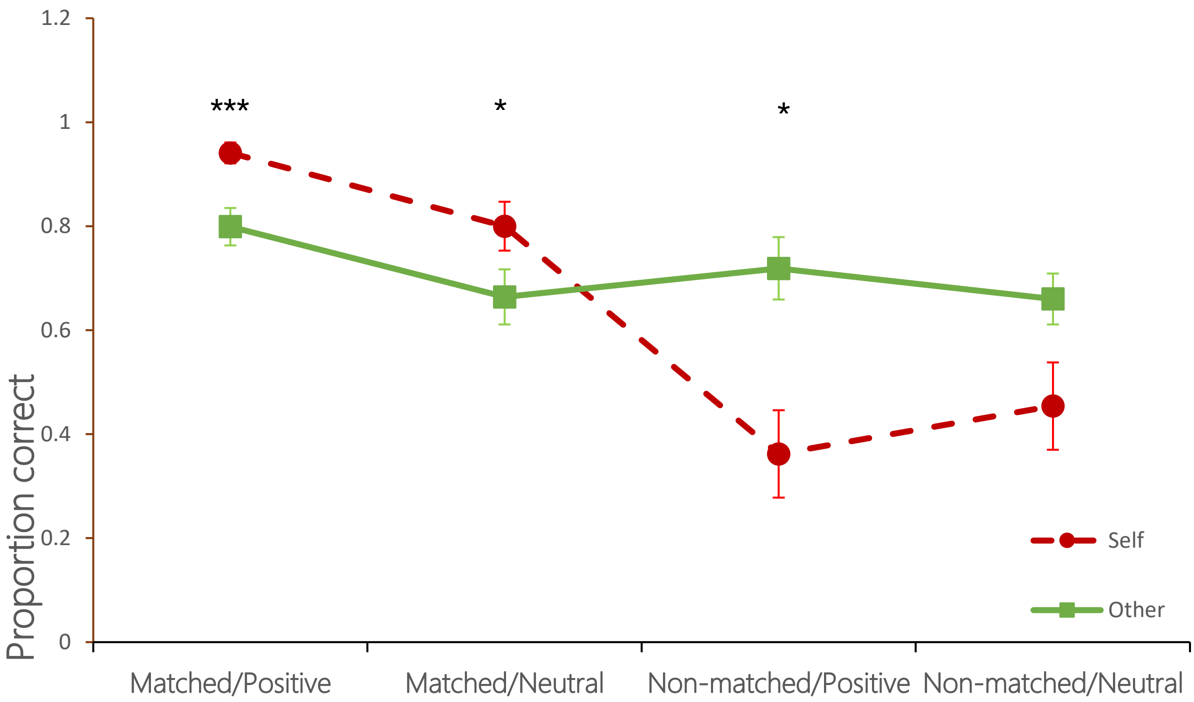

Figure 18. Proportion correct matching task, *Experiment 2.* Mean proportion correct responses per condition of the matching task (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

The RT for the correct responses data revealed a similar pattern. A main effect of redundancy was found, $F(3,60) = 16.217$, $p < .001$, $\eta^2_p = .448$. Participants generally were significantly faster in when responding to the redundant trials (857.76ms) compared to the neutral matched trials (962.75ms, $p = .005$), and when compared to the non-matched neutral trials (1111.53ms, $p < .001$). There was only a marginally significant difference between the redundant trials and the non-matched positive trials (942.70ms, $p = 0.53$). Furthermore, participants we faster for the matched neutral trials compared to the non-matched neutral trials ($p = 1.00$), but there was no significant difference between the matched neutral and the non-matched positive trials ($p = .004$). Lastly, there also was a significant difference between the non-matched positive trials and the non-matched neutral trials ($p = .017$), as participants responded faster to the non-matched positive trials.

No main effect of perspective was observed, $F(1,20) = 2.038$, $p = .169$. However, there was a significant interaction between redundancy and perspective, $F(3,60) = 8.843$, $p < .001$, $\eta^2_p = .307$, See Table 9 and Figure 19 for the means and standard errors. Similar to the proportion correct responses, there was a significant difference between self and distant other for the redundant, neutral matched, and non-matched positive trials (respectively: $p = .002$; $p = .046$, $p = 0.12$). The same pattern unfolded as participates were faster to respond on the redundant trials related to the self compared to a distant other, and likewise, the self-relevant matched neutral trials were responded to faster compared to matched neutral distant other related trials. Again this pattern reversed for the non-matched positive trials as participants were significantly slower for the self-related items compared to the distant other-related trials. No differences were found between the self and distant other for the neutral non-matched trials ($p = .551$).

Looking at the different levels of redundancy, for the self-related trials, there was a significant difference between the redundant trials and the other levels as participants responded fastest to the redundant trials: matched neutral ($p = .019$); non-matched positive ($p = .003$); and non-matched neutral ($p < .001$). No significant difference was found between matched neutral and non-matched positive ($p = .572$), but a significant difference was found between the faster responses on the matched neutral trials compared to the slower responses of the non-matched neutral trials ($p = .017$). There was no significant difference between the non-matched positive trials and the non-matched neutral trials ($p = 1.00$).

For the distant other related trials, a significant difference was found between the redundant and non-matched neutral trials ($p < .001$), as participants were faster for the redundant trials. There were no significant differences between the redundant trials and the matched neutral trials (1.00), or the non-matched positive trials ($p = .060$). A significant difference was observed for the matched neutral, and the non-matched positive trials ($p = 0.17$) as the participants were slower in responding to the matched neutral trials. No such difference existed between the matched neutral trials and the non-matched neutral trials (p = .177). Finally, participants were faster on the non-matched positive trials compared to the non-matched neutral trials (p = .001).

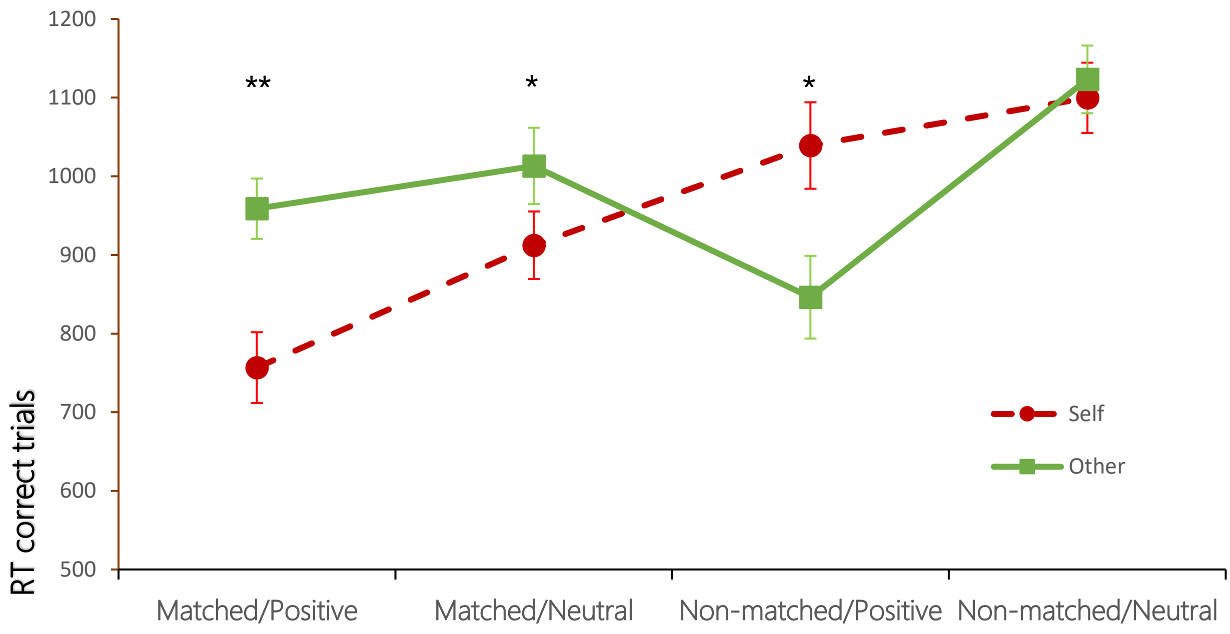

Figure 19. RT matching task, ***Experiment 2.*** Median RT for correct responses per condition of the matching task (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

Redundancy was tested using the race model of inequality, as described earlier. Using the race model inequality script of Ulrich, Miller, and Schröter (2007), the latencies distribution were calculated, as shown in Figure 20. The model compares the reaction times if the trials matched (X), were positive (Y), or matched and were positive at the same time, i.e. redundant (Z). If Z is to the left of the X + Y, then the race model of inequality is violated. As can be seen in Figure 20, the trials linked to the self seem to violate the model around 550ms to 650ms. For the trials linked to the distant other-condition, the model holds. Due to the nature of multiple testing, a permutation test was performed for the group data as described by Gondan and Minakata (2016). A rejection of the race model occurs if the maximum of the T values is greater than 95% (one-sided) of the simulated T^*_{max} values. Applying the inequality 8 method of Gondan and Minakata (2016) revealed the violation of the race model for the trials related to the self: t_{max} = 4.379, critical t_{max}* = 2.460, P = .001. For the trials with the distant other-condition, no violation of the race model of inequality was found: $t_{max} = 0.401$, critical $t_{max}^* = 2.530$, P = .783, indicating support for a parallel, first-terminating model.

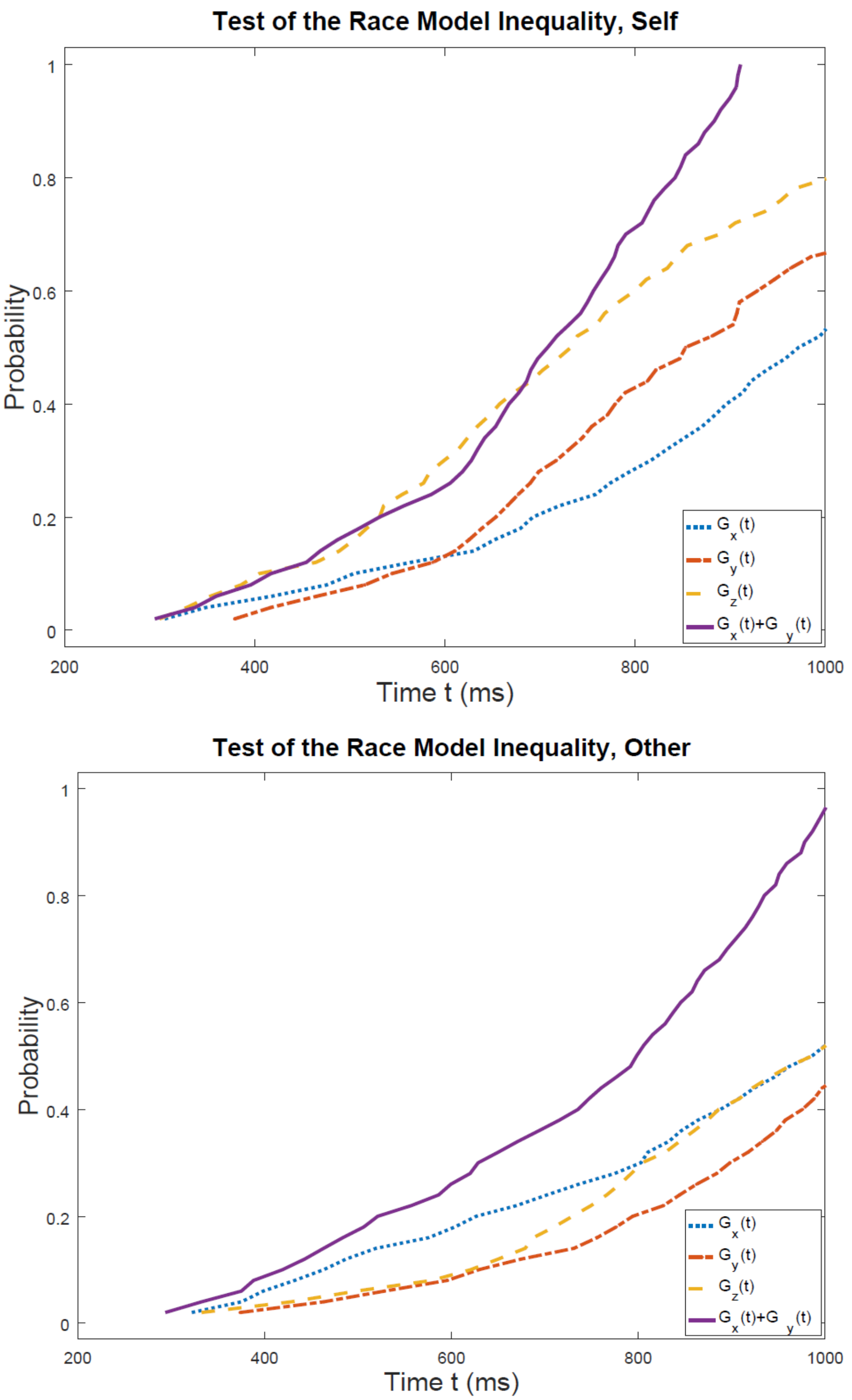

Figure 20. Race model of inequality for self and other trials, *Experiment 2*. The top figure shows the violation of the independent race model for the self-related trials. The bottom figure shows the model for the distant other-related trials.

However, the violation of the race model for the self-related trials does not by default imply a coactivation-model. For this reason, a follow-up coactivation model was applied to the data. Although the race models suggest that this was only needed for the self-related trials, a comparison is made again between self and distant other. In Figure 21, the capacity coefficient of each participant for the self-trials and the distant other-trials is depicted. These graphs illustrate coactivation for the self-trials but not for the distant other-trials, between 250ms and 400ms. The number of participants showing super-capacity was calculated. For the self-trials, 19 out of 21 participants showed super-capacity, which was significantly more than the distant other-trials where 10 out of 21 participants showed super-capacity: χ^2 = 7.11, p = .008.

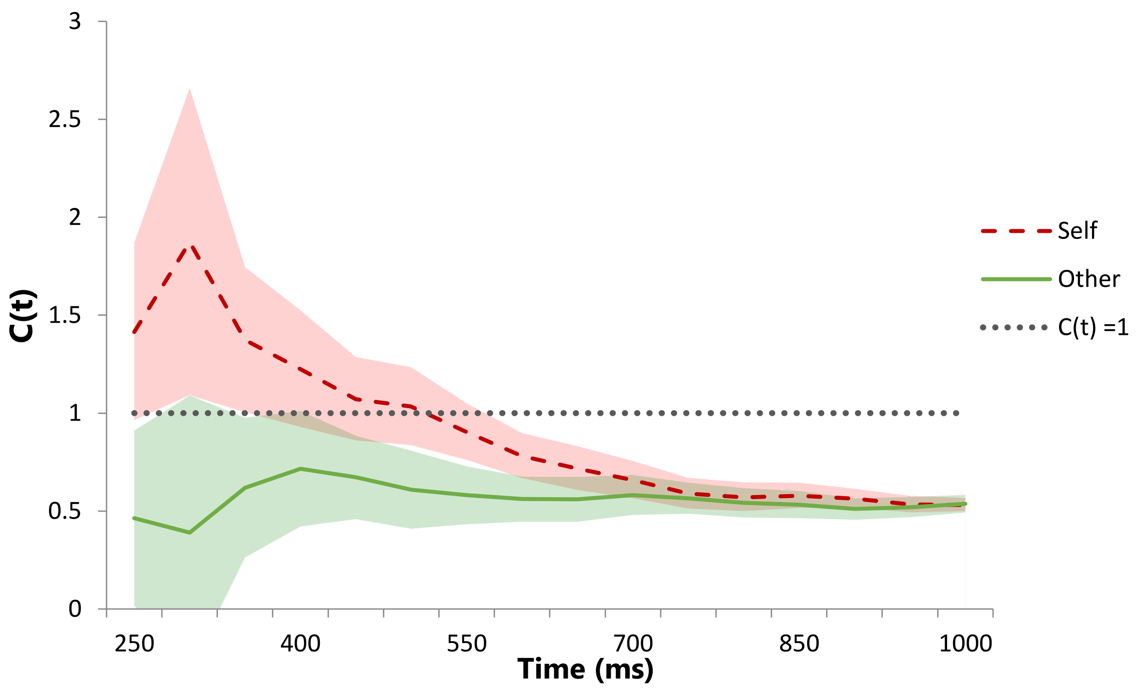

Figure 21. Capacity coefficients *Experiment 2*. A C(t) of 1 (the horizontal line) indicated the minimal values for unlimited capacity and any value above one reflects super capacity. The graph shows that the capacity coefficients for the self-trials and indicated a super-capacity (C(t)>1) for most participants, whereas the distant other-trials which showed limited capacity for redundant trials (C(t)>1) for most participants. The coloured band around the mean reflect the 95% confidence intervals.

Old/new Task

Table 10. Old New Task Redundancy gain experiment. Means for d′, and proportion correct responses. Standard error in parenthesis.

	Matched Trials	Non-Matched trials	d'
	Correct	Correct	
Self	.768 (.023)	.712 (.028)	1.24 (0.10)
Other	.700 (.029)	.710 (.028)	0.98 (0.06)
Positive	.735 (.025)	.723 (.025)	1.08 (0.07)
Neutral	.733 (.026)	.699 (.034)	1.13 (0.10)
Self/Positive	.741 (.029)	.742 (.025)	1.10 (0.10)
Self/Neutral	.794 (.031)	.683 (.038)	1.38 (0.14)
Other/Positive	.729 (.030)	.705 (.034)	1.06 (0.08)
Other/Neutral	.671 (.034)	.716 (.037)	0.89 (0.09)

See Table 10 for an overview of the means and standard errors for the old new task. The d′ results revealed a significant effect of perspective, $F(1,20) = 8.379$, $p = .009$, $\eta^2_p = .295$. Participants were better at separating signal from noise for trait words that are related to the self when compared to trait words related to a distant other. No significant effect of emotion was found, $F(1,20) = .334$, $p = .570$, but there was an interaction between emotion and perspective, $F(1,20) = 7.176$, $p = .014$, $\eta^2_p = .264$, see Figure 22. This interaction is mainly driven by a significant difference between self-related neutral trait-words and distant other-related neutral trait-words ($p = .003$). Furthermore, there is a marginally significant difference between positive and neutral trait words from the distant other-conditions ($p = .053$). There were no differences between positive and neutral trait words linked to the self, neither were there any significant differences between self and distant other-related positive trait words (respectively: $p = .088$; $p = .739$).

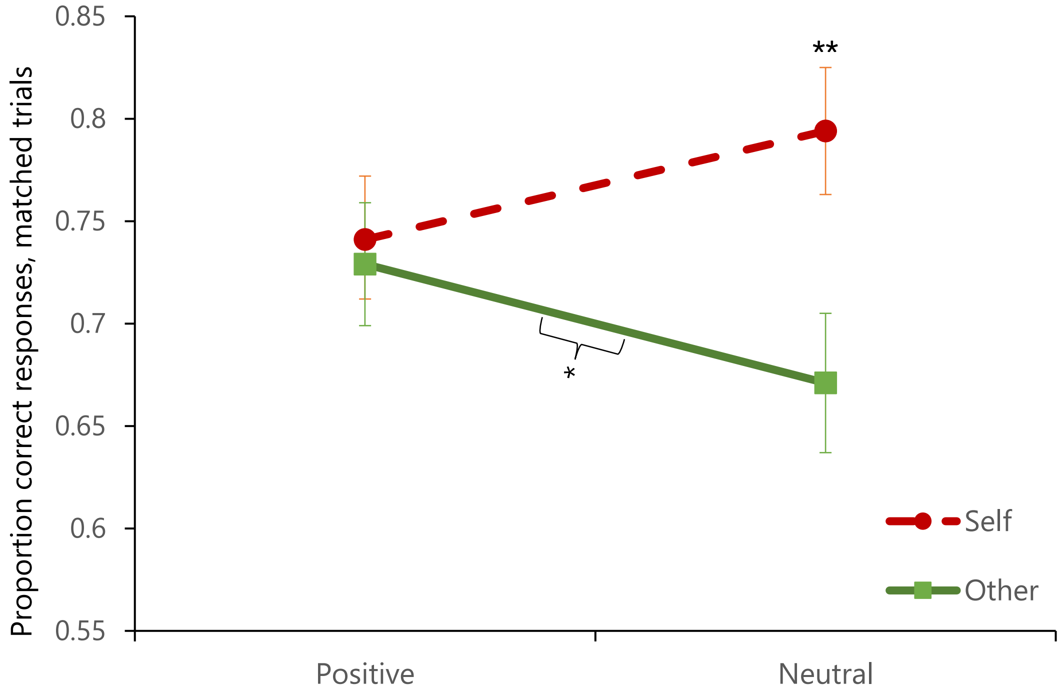

Figure 22. Proportion correct for the old/new task, *Experiment 2*, matched trials.
An interaction between perspective and emotion. (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

For the proportion of correct responses for the matching trials a main effect of perspective is revealed F(1,20) = 6.420, p = .020, η^2_p = .243. Participants were more accurate in recognising old words linked to the self, compared to words linked to a distant other. No main effect of emotion was found, F(1,20) = .010, p = .921, but there was an interaction effect between perspective and emotion, F(1,20) = 5.772, p = .026, η^2_p = .224. The interaction was formed by a significant difference between positive and neutral trait words related to a distant other (p = .048), where positive/distant other trait words were recognised more accurately than neutral/distant other traits words. Furthermore, neutral/self trials were more often correctly recognised than neutral /distant other trials (p = .005). There was no effect of emotion for the self related words (p = .199), and no effect of perspective for the positive words (p = .719). For the non-matching trials no significant differences were found for: perspective, $F(1,20) = .017$, $p = .898$; emotion, $F(1,20) = .802$, $p = .381$; perspective×emotion, $F(1,20) = 1.613$, $p = .219$.

Lastly, a correlation analysis was run between the proportion of correct responses for both the matching task and the old/new recognition task. If self-related and positive emotion both facilitate performance in an integrated manner, the increased accuracy in the matching task, should be associated with increased accuracy in the old/new task. The results only revealed a significant strong positive correlation between the positive self condition of the matching and old/new tasks, $r_s = .664$, $p = .001$. No other significant correlations were found.

Discussion

To examine the precise influence of emotion on self-relevant processing, this was designed to force the participant to make a judgement about emotion and self-related information. For this redundancy task, participants had to provide the same response when an item had emotional value, was linked to the self, or both. This required several adaptations of the matching task of (Sui et al., 2012) to ensure that the emotional value was processed at the same time as the self-related information. Furthermore, instead of geometric shapes, colours were used to link to the self or a distant other.

The matching task revealed that matched positive trials (i.e. redundant trials) were responded to faster and more accurately for the trials related to the self, compared to trials related to a distant other. For the matched trials alone, a similar difference was found as self-relevant trials were more accurately and faster responded to, compared distant other-related trials. Interestingly, this pattern reversed for the non-matched positive trials as positive stimuli were responded to slower and less accurately for the self-related trials when compared to the distant other-related trials. No differences were observed between the self-related and distant other-related stimuli for the non-matched neutral trials. As predicted, participants responded faster and more accurately on the redundant trials, especially for the trials related to the self compared to a distant other.

Interesting here is that although the expected superior performance was shown for the self-related and emotional stimuli, the interaction revealed the opposite pattern with self-relevant positive words for the non-matched trials. In other words, as soon as the participants were shown the colour related to themselves for positive words, but linked to the label 'stranger', the participants were slower and less accurate when compared to the trials related to a distant other. Although it is possible that the non-matching nature of the trials itself (as mention before) influenced the data, this should then still be the same for both the self-related and distant other-related stimuli. Furthermore, no significant difference was found for the neutral non-matched trials. This could potentially be explained by an initial attempt to link the positive self-related item to the self as indicated by the colour of the word and the conflicting non-matching information lead to a conflict in processing. Remember that for this redundancy experiment the same response is still required for the non-matched positive trials, meaning there is no increase in difficulty. Furthermore, the words chosen were either neutral or highly frequent very positive nouns. Especially since previous research has shown that it is easier to link positive information to the self (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Taylor, 1991). Furthermore, when an initial self-relevance connection is made, it is more discard this association (Wang et al., 2016). According to Wang, Humphreys, and Sui (2016), self-association could disrupt ongoing processes if the association has to be reassessed. In this experiment, the easier and faster link of positive self-relevant information to the self would need to be reassessed based on the conflicting information provided by the label. This does not happen for the neutral non-matched trials as the neutral trials do not benefit from the increased speed of creating a self-association generated with positive information. Naturally, for the trials related to a distant other, this conflict is easier to resolve as no association with the self is made.

With two potentially competing signals (self versus emotion), a RACE model (Miller, 1982) was applied when analysing the matching task data. This was done to see if there were any redundancy gains between emotion and perspective. Simply put, the experiment studied if one relevant signal (i.e. emotion OR self-relatedness) would result in an equally fast or slower response compared to the presentation of two relevant signals (emotion AND self-relatedness) for the same response. The redundancy data shows that the RACE model is violated which indicated that emotion and self-related information are not processed separately. A follow-up coactivation-model testing (Townsend & Nozawa, 1995) revealed that the majority of participants showed super-capacity for emotional self-relevant items. In other words, self-related information and (positive) emotional information together lead to more efficient processing. If both emotion and self-relevance are task-relevant, then the summation of the two leads to faster processing than self and emotion alone, especially between 250ms and 400ms. A result which on first glance lends support to the idea that positive self-related information can enhance attention because it is easier to link positive traits to yourself when compared to neutral or negative traits (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Taylor, 1991). These results show a similar advantage of the self in redundancy tasks as the experiment by Sui, Yankouskaya, and Humphreys (2015), where the authors found a clear effect of super-capacity for the self when displaying two self-related redundant visual stimuli.

In the old/new task, words were recognised from memory more accurately if they had a positive valence or if the words were related to the self. An interaction was found between emotion and perspective where a self-reference effect was found for neutral words only, and an effect of emotion was found only for the distant other-condition. Therefore it appears the super-capacity finding and the findings of the accuracy and reaction times of the matching task are at odds. Naturally, super-capacity and recognition memory are two different processes as the former revolves around decision time during the matching task and the latter on an old/new recognition judgement. However, super-capacity does enhance processing of emotional self-relevant words during the matching task, which could aid with encoding.

This possibility is further supported by the strong positive correlation found between the proportions of correct matching judgements of the positive self-related condition and the proportion of correctly recognised old words from the positive self-related condition. This indicated that there was a relationship between the matching task and the old/new recognition task as an increase of correct responses for positive and self-related words in the matching task was matched by an increase of correctly recognised self-related positive words. If self-relevant and emotional information are processed with super-capacity, as shown by the matching task, this should be reflected in superior encoding processes for positive words linked to the self over neutral words linked to the self.

Potential explanations include that the process measured by the redundancy data is not the same as the processes described old/new data. Another potential explanation suggests that although emotion and self-relevance improve memory, both do so to a maximum. This means that even when a word is both emotional and self-relevant, it cannot benefit more than each condition on its own.

To conclude, self-relevance and positive emotion together did integrate. The evidence suggested super-capacity of the two attributes. This shows more efficient attentional processing of positive self-relevant information compared to information which is only emotionally positive or only self-relevant. This supports the possibility that self-relevant and positive emotion, both independently and interdependently prioritise information. It also supports the idea that positive information can easily be linked to the self. However, despite these effects, the super-capacity for positive self-relevant words measured with the matching task did not translate to an effect on recognition. There was no greater recognition for positive self-relevant words when compared to positive words alone and self-relevant words alone as would be expected if this was affected. This may be because memory processes were unaffected or it could be because there was a possible ceiling effect in recognition of positive self-relevant words.

Therefore, *Experiment 3* and *Experiment 4* will have a more focussed investigation into the memory processes. As the previous chapters have shown, the self and emotion influence later memory processes. The matching task however is not a controlled encoding paradigm and thus any encoding into memory is, to some degree, incidental.

Participants were aware of a follow-up memory task, but the matching task itself would have been a distractor for any mnemonic the participant could have applied, as actively reading the words was not needed for the matching task, as it was assumed to be an automatic process (Logan, 1988; McKenna & Sharma, 1995). Therefore to ensure deeper encoding, the words used in the matching task will be repeated a few times, allowing for more opportunities to encode the words into memory. At the same time the assumed automaticity of emotional and self-referential processing is investigated. Both processes are described as fast and automatic (Alexopoulos et al., 2012; McKenna & Sharma, 1995; Moors & De Houwer, 2006). By repeating the stimuli, the beneficial effect of a fast and automatic process can be undermined.

Chapter 4:
Automaticity & Self

Introduction Experiment 3

The experiments so far have focused on investigating the facilitating effect of self-related information and emotion on attention and memory. The current chapter will focus on a specific aspect of self-relevant processing: that of the automaticity with which self-relevance facilitates attentional and memory processing.

The experiments of the previous two chapters (*Experiment 1a-1d, & Experiment 2)* have consistently shown a self-priority effect as measured via the matching task, which was followed by a self-reference effect as measured by the old/new task. *Experiment 3*, discussed in this chapter, will focus on a particular aspect of self-relevant information processing, specifically the apparent automaticity of the self. In the introduction of this thesis, self-relevant information processing was described as an automatic and effortless process (Alexopoulos et al., 2012; Moors & De Houwer, 2006). Therefore, an interesting question to ask is, what happens when this automaticity is less important in promoting recognition in memory?

So far, the results of the old/new task show a consistent advantage of self-related information. Participants recognise self-related words correctly more often than words related to a distant other. A similar effect was found for emotional words as more emotional words were correctly recognised compared to neutral words. These have been interpreted as reflecting an increase of binding into memory. With binding into memory is meant that events, features, or object are linked together in memory to form a coherent whole (Zimmer, Mecklinger, & Lindenberger, 2006). This binding into memory is arguably especially important for self-related information as it is suggested that self-related information enhances the binding of information in attention and memory (Sui, 2016; Sui & Humphreys, 2015b). The increased binding results in mnemonic advantages, creating richer memories when compared to information not related to the self (Symons & Johnson, 1997).

Of course, there are several ways by which memory strength can be improved. Repetition is a useful manipulation in memory research for improving a memory trace, as it has been known for some time that repetition does improve memory (Ebbinghaus, 2013; Hintzman & Block, 1971), albeit not very efficient and requires some intent to learn (Craik & Lockhart, 1972).

Although not efficient, repetition will be used in this *Experiment 3*. Repetition in this thesis means that a wordlist is presented again with the same colour/perspective associations. No attempt is made for deeper binding to already existing memories. As explained earlier, self-related information already enhances binding into memory, and a more elaborative rehearsal would likely benefit self-related information processing, which is not the goal of this chapter. Furthermore, the matching paradigm used in this thesis does not lend itself to more in-depth encoding as the matching task itself would distract from memorising the words. If a wordlist is repeated several times, the initial benefit of self-referenced processing is no longer the main influence of enhancing binding of information, which should result in increased memorability mostly for other-related words. The initial fast and automatic benefit of self-related information is still present but other-related words might be recognised more easily now as well. .

Using repetition, it is possible that repeating stimuli only helps enhance the overall memory strength regardless of condition. It is unlikely that self-related information can become more 'self' (i.e. repetition does not lead to more 'binding to self') and therefore the initial benefits of self-related information is not additive to learning through repetition. In other words, self-related information could result in faster and more stable binding, which is unaffected by repetitions, whereas other-related words are affected by repetition. This would result in an increase of recognition for other-related words.

Experiment 3 used similar stimuli to *Experiment 1a* (neutral and negative nouns). For the matching task is was predicted that the participants would become more proficient per repetition regardless of condition. The previous experiments (*Experiment 1a-1d)* have not shown an effect of emotion, and therefore no effect of emotion is expected for the same reasons as discussed in the previous chapters (the matching judgement is already initiated before the semantic meaning of the words is processed). A main effect of perspective is predicted as self-related trials should be processed more accurately and faster compared to trials not related to the self. Lastly, no interaction between repetition and perspective is predicted. Self-relatedness is determined by the colour of the word, which will not become more self-relevant over time. In other words, perspective will have a main influence as self-related words will be prioritised, and participants be better at the matching task in later blocks, compared to earlier blocks as overall proficiency increases.

For the old/new task it was predicted that the other-related information benefits more from repetition compared to self-related information. Since a self-reference effect would this be present, this result in other-related information to be recognised as accurately as self-related information In other words, repeating the same stimuli with the matching task most likely will not affect the old/new task beyond an overall increase of recognition memory of the participant. This is because the word meaning is irrelevant to the self-priority effect as measured with the matching task used in this thesis. However, although the meanings of the words had no intrinsic relation with self-priority, the word meanings were certainly attended to and processed to a semantic level. We can see this in the findings that the emotional valence of the word meanings had a clear effect on the old/new task in *Experiment 1a-1d* and *Experiment 2*.

Therefore, we have established that semantic meaning is processed in our task. We have also established that emotional valance is important in memorability. Given this, it is possible that word repetition and the resultant strengthening of these words in memory might vary in association with the valence of the words.

Methods

Participants

For this experiment, 22 participants recruited from Oxford Brookes University participated for course credit, but two participants were removed from the dataset because their performance on the matching task was below chance level. In total 20 participants were included in the data set (mean age 19.75, range: 18-33) of which one was male and 19 were female.

Stimuli & procedure

Both the matching task and the old/new recognition task are based on *Experiment 1a*. The word-lists were generated similarly as described in the methods section of *Experiment 1a*, but the procedure is based on the changes made in *Experiment 1b*. No changes were made to the old/new recognition task, but the matching task was changed on one point: the matching trials were now repeated three times, i.e. the matching task consisted of four blocks of 100 trials each. For each block the same trials were used but were presented in a pseudo-random order where each factor combination was never repeated consecutively more than three times. There were no other differences to the procedure *of Experiment 1b*.

Results

Matching task

In order to see if each repetition influences the self-priority effect a 2(perspective[self, distant other])×2(emotion[negative, neutral])×4(Time[time-window 1,2,3,4]) Repeated ANOVA was run to analyse the d', proportion correct, and RT data, and a Bonferroni correction was applied.

For the d′ data the three-way interaction was not significant, $F(3,57) = .393$, $p = .759$. Of the two way interactions, only the interaction between perspective and emotion was significant, $F(1,19) = 6.089$, $p = .023$, $\eta^2_p = .243$, see Figure 23. A self-priority effect was found for both negative and neutral trials ($p = .003$, and $p < .001$ respectively). However, no significant difference was found between negative and neutral trials for perspective (self $p = .114$, and distant other $p = .108$). The interaction was caused by a higher d′ for neutral-self words compared to negative-self words. Although this difference is not significant, the opposite pattern appeared for the words related to a distant other where negative words have a higher d′ than neutral words. This is reinforced by a main effect of perspective, $F(1,19) = 22.617$, $p < .001$, $\eta^2_p = .543$, where the self-related trials result in higher d′ than distant other-related trials. Furthermore, there was no main effect of emotion, $F(1,19) = .140$, $p = .712$. There was no significant main effect of time, Greenhouse- Geiser $F(3,57) = 2.883$, $p = .069$. The remaining two-way interactions were not significant: time×perspective, $F(3, 57) = .809$, $p = .494$; and time×emotion, $F(3, 57) = .186$, $p = .905$. See Table 11 for an overview of the means and standard errors.

Table 11. Experiment 3 d′, matching task. d′ for each per time-window. Standard error in parenthesis.

	d′			
Time	1	2	3	4
Self	3.37 (0.25)	3.44 (0.21)	3.58 (0.12)	3.64 (0.13)
Other	2.76 (0.27)	3.07 (0.27)	3.05 (0.20)	3.20 (0.16)
Negative	3.06 (0.26)	3.30 (0.24)	3.31 (0.17)	3.43 (0.13)
Neutral	3.06 (0.26)	3.21 (0.25)	3.32 (0.15)	3.41 (0.16)
Self/Negative	3.29 (0.29)	3.47 (0.22)	3.55 (0.13)	3.56 (0.17)
Self/Neutral	3.45 (0.24)	3.42 (0.22)	3.60 (0.16)	3.72 (0.12)
Other/Negative	2.84 (0.26)	3.14 (0.27)	3.06 (0.24)	3.30 (0.16)
Other/Neutral	2.68 (0.30)	3.00 (0.29)	3.04 (0.19)	3.11 (0.22)
Average	**3.06**	**3.26**	**3.31**	**3.42**

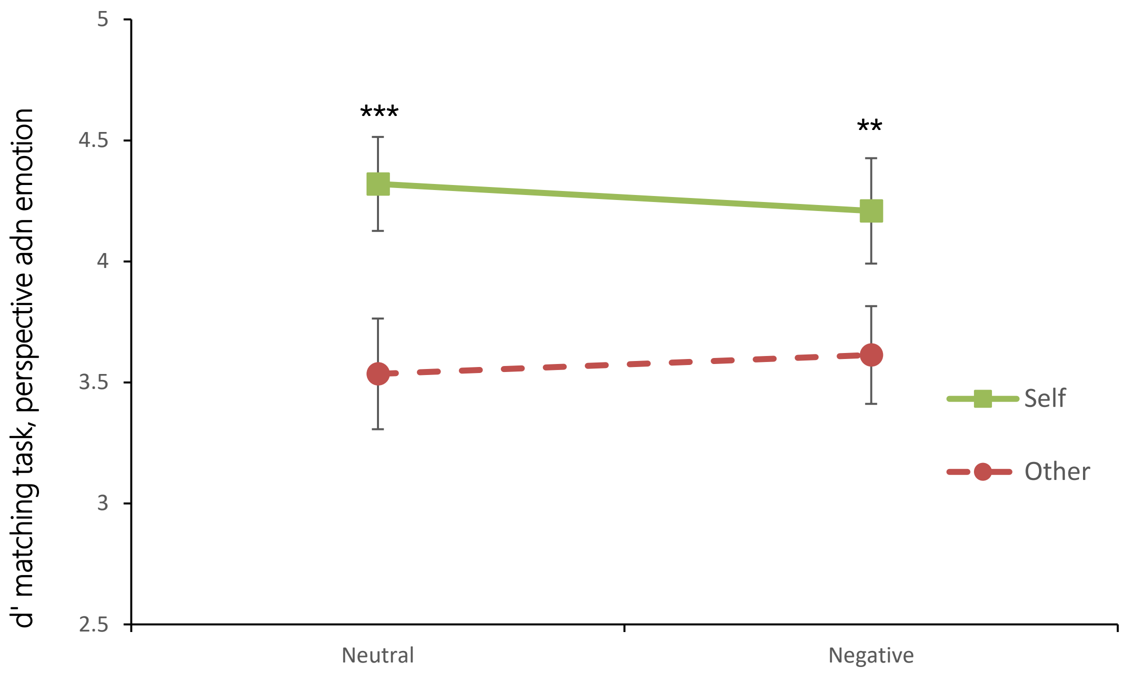

Figure 23. d' Matching task, *Experiment 3*. Mean d' for all conditions (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

The proportion of correct responses for the matching trials followed a similar pattern, see Table 12. Emotion and perspective did not interact with time: three-way, $F(3,57) = .998$, $p = .401$; two-way perspective, $F(1,19) = .361$, $p = .781$; two-way emotion, $F(1,19) = .060$, $p = .980$. There was a two-way interaction between emotion and perspective, $F(1,19) = 4.431$, $p = .049$, $\eta^2_p = .189$. The follow-up paired comparisons revealed a self-priority effect of perspective for the neutral trials ($p = .001$), and for the negative trials ($p =.005$). However, no differences between neutral and negative trials were found for proportion correct for self ($p = .325$), or distant other ($p = .215$). This showed a slightly more robust effect of self for the neutral trials compared to the negative trials. See Figure 24. Also a main effect was found for perspective, $F(1,19) = 14.543$, $p = .001$, $\eta^2_p = .434$, indicating that participants scored a higher proportion correct for the trials related to the self when compared to the trials related to a distant other. Lastly, there was a main effect of time for the proportion of correct responses, Greenhouse-

Geiser $F(3,57) = 4.072$, $p = .033$, $\eta^2_p = .176$. Nonetheless, a follow up comparisons did not reveal any significant differences between the time blocks.

For the non-matched trials only a main effect of time was found, $F(3,57) = 6.660$, $p = .001$, $\eta^2_p = .260$. However, a pairwise comparison revealed that only the difference between block one and block three ($p = .061$), and the difference between block one and block four ($p = .066$) approached significance. No differences were found between the remaining blocks. Furthermore, none of the interactions were significant: perpective×emotion×time, $F(3,57) = 1.176$, $p = .327$; perspective×time, $F(3,57) = .131$, $p = .941$; emotion×time, $F(3,57) = .838$, $p = .479$; perspective×emotion, $F(1,19) = .579$, $p = .456$. The remaining two main effects were also non-significant: emotion, $F(1,19) = .361$, $p = .555$; perspective, $F(1,19) = 3.020$, $p = .098$.

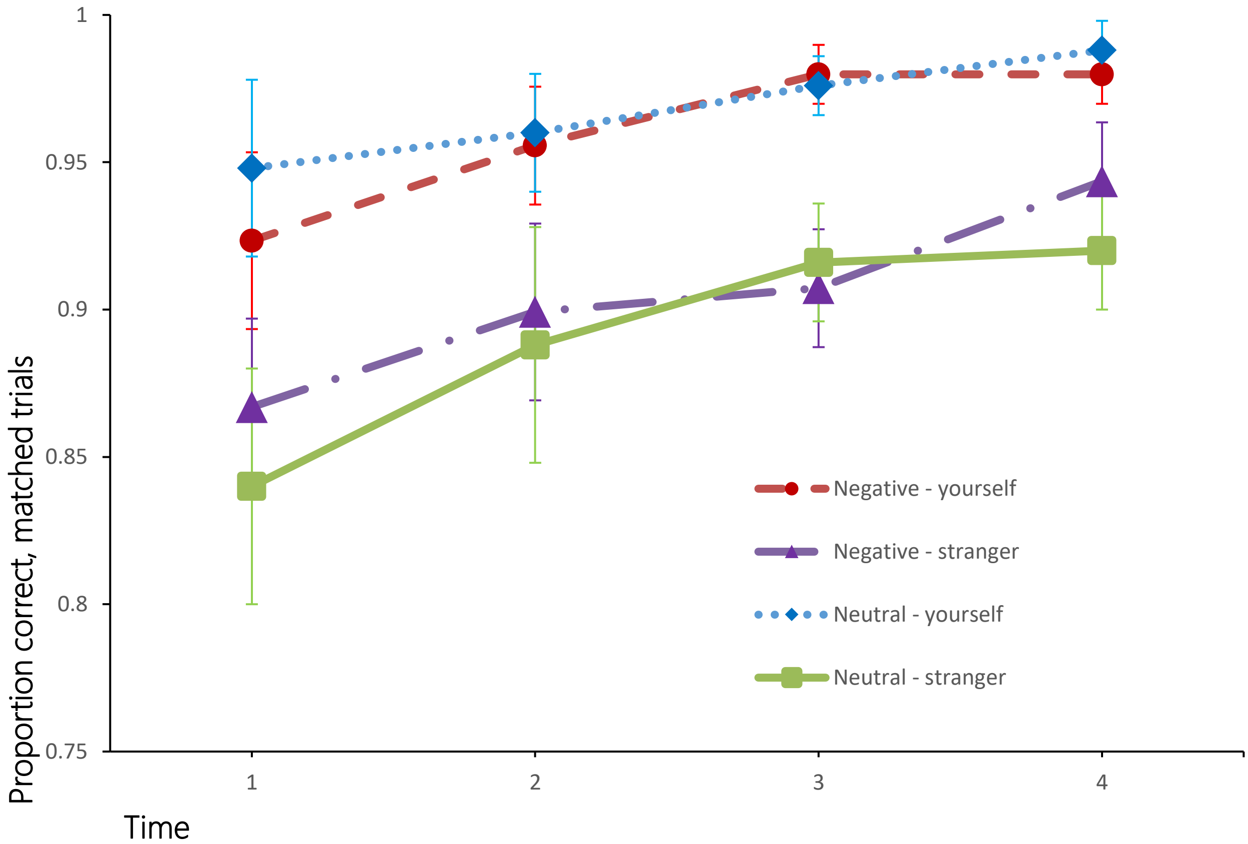

Figure 24. Proportion correct Matching task, *Experiment 3*. Proportion correct responses for all condition of the matched trials (Error bar = standard error)

Table 12. Experiment 3 proportion correct, Matching task. Mean proportion correct responses per time-window for the matched and non-matched trials. Standard error in parenthesis.

	Matched Trials				Non-Matched trials			
Time	1	2	3	4	1	2	3	4
Self	.94 (.03)	.96 (.01)	.98 (.01)	.98 (0.1)	.83 (.05)	.92 (.04)	.97 (.01)	.97 (.01)
Other	.85 (.04)	.89 (.03)	.91 (.02)	.93 (.01)	.81 (.06)	.91 (.03)	.94 (.02)	.96 (.01)
Negative	.90 (.03)	.93 (.02)	.94 (.01)	.96 (.01)	.82 (.06)	.92 (.03)	.95 (.02)	.97 (.01)
Neutral	.89 (.03)	.92 (.03)	.95 (.01)	.95 (.01)	.82 (.05)	.90 (.04)	.96 (.01)	.96 (.01)
Self/Negative	.92 (.03)	.96 (.02)	.98 (.01)	.98 (.01)	.83 (.06)	.93 (.04)	.97 (.01)	.97 (.01)
Self/Neutral	.93 (.03)	.96 (.02)	.98 (.01)	.99 (.01)	.82 (.05)	.91 (.04)	.96 (.01)	.98 (.01)
Other/Negative	.87 (.03)	.90 (.03)	.91 (.02)	.94 (.02)	.80 (.06)	.92 (.03)	.92 (.02)	.98 (.01)
Other/Neutral	.84 (.04)	.87 (.04)	.92 (.02)	.92 (.02)	.82 (.06)	.89 (.04)	.96 (.01)	.95 (.02)
Average	0.8925	0.92375	0.94625	0.95625	0.81875	0.9125	0.95375	0.9675

The median RT data revealed a clear effect of perspective for the matching trials, $F(1,19) = 14.821$, $p = .001$, $\eta^2_p = .438$. Participants responded faster on trials related to the self than to trials related to a distant other. The only other significant effect is the main effect of time, $F(1.74, 33.08) = 5.700$, $p = .010$, $\eta 2p = .231$. Although participants did not respond significantly faster in block two compared to block one, ($p = 1.000$), participants did respond faster for block three and four when compared to block one ($p = .038$), but no difference was found between block one and block four ($p = 0.147$). Furthermore, participants were faster in block three when compared to block two ($p = .041$), but again no difference was found between block two and block four ($p = .090$). Lastly, no difference in median RT was found between block three and block four, $p = 1.000$. For the main effect of emotion, there was no significant difference between the negative and neutral trials, $F(1,19) = 2.060$, $p = .167$. None of the interactions were significant: perspective×emotion×time, $F(3,57) = .379$, $p = .769$; time×emotion, $F(3,57) = .866$, $p = .464$; time×perspective, $F(2.20, 41.74) = .162$, $p =.869$; and perspective×emotion, $F(1,19) = 1.608$, $p = .220$.

Table 13. Experiment 3 RT, Matching task. Median RTs per time-window for the matched and non-matched trials. Standard error in parenthesis.

	Matched Trials				Non-Matched trials			
Time	1	2	3	4	1	2	3	4
Self	932.02 (46.42)	895.43 (28.40)	849.53 (22.77)	851.04 (26.14)	1089.15 (32.55)	1024.25 (26.93)	969.98 (26.35)	967.28 (27.99)
Other	1024.51 (34.83)	1004.48 (32.17)	960.78 (35.34)	952.42 (34.39)	1115.88 (31.79)	1045.35 (28.47)	1003.22 (30.87)	1001.04 (34.26)
Negative	980.94 (34.87)	936.13 (29.99)	905.37 (27.18)	887.03 (26.53)	1089.17 (34.59)	1023.31 (26.59)	995.30 (26.71)	987.87 (30.73)
Neutral	975.59 (41.81)	963.78 (25.50)	904.93 (28.28)	916.41 (26.63)	1115.85 (30.35)	1046.28 (30.00)	977.90 (28.00)	980.45 (31.07)
Self/Negative	943.25 (46.28)	892.59 (34.59)	853.83 (24.43)	833.97 (28.46)	1086.83 (36.22)	1024.49 (27.81)	976.98 (28.62)	968.66 (29.42)
Self/Neutral	920.80 (52.24)	898.27 (27.18)	845.22 (25.31)	868.10 (27.48)	1091.47 (31.92)	1024.01 (27.93)	962.99 (27.78)	965.89 (29.82)
Other/Negative	1018.63 (37.90)	979.67 (34.51)	956.91 (38.32)	940.09 (34.74)	1091.52 (38.91)	1022.14 (31.44)	1013.62 (30.56)	1007.07 (37.29)
Other/Neutral	1030.38 (37.46)	1029.29 (36.37)	964.65 (39.68)	964.75 (36.33)	1140.23 (33.80)	1068.56 (37.86)	992.82 (32.35)	995.01 (38.12)
Average	**978.26**	**949.95**	**905.153**	**901.726**	**1102.51**	**1034.80**	**986.601**	**984.159**

The median RT data for the non-matched trials again revealed a main effect of perspective, $F(1,19) = 4.963$, $p = .038$, $\eta^2_p = .207$. Trials related to the self condition were responded to faster than the trials related to the distant other-condition. The only other significant result was the main effect of time, $F(1.80, 34.12) = 10.042$, $p = .001$, $\eta^2_p = .346$. Participant responded slower to block one of the non-matched trial when compared to block two ($p = .005$), block three ($p = .005$), and block four ($p = .011$). There was no significant difference in median RT between the remaining block combinations. The last remaining main effect of emotion revealed no significant effect, $F(1,19) = .633$, $p = .436$. Lastly, the interactions for the non-matched trials were all non-significant: perspective×emotion×time, $F(3,57) = .803$, $p = .498$; time×emotion, $F(3,57) = 1.160$, $p = .333$; time×perspective, $F(3,57) = .110$, $p = .954$; and perspective×emotion, $F(1,19) = 1.065$, $p = .315$. View Table 13 for the median RTs and standard errors per time block.

Old/new task

The d' data revealed only a main effect of emotion, $F(1,19) = 54.626$, $p < .001$, $\eta^2_p = .742$, see Figure 25. Participants were more capable in discerning signal from noise for the negative trials (1.354) than the neutral trials (.794). No significant d' effect was found for perspective, $F(1,19) = 1.124$, $p = .302$, nor was the interaction between perspective and emotion significant, $F(1,19) = .028$, $p = .869$.

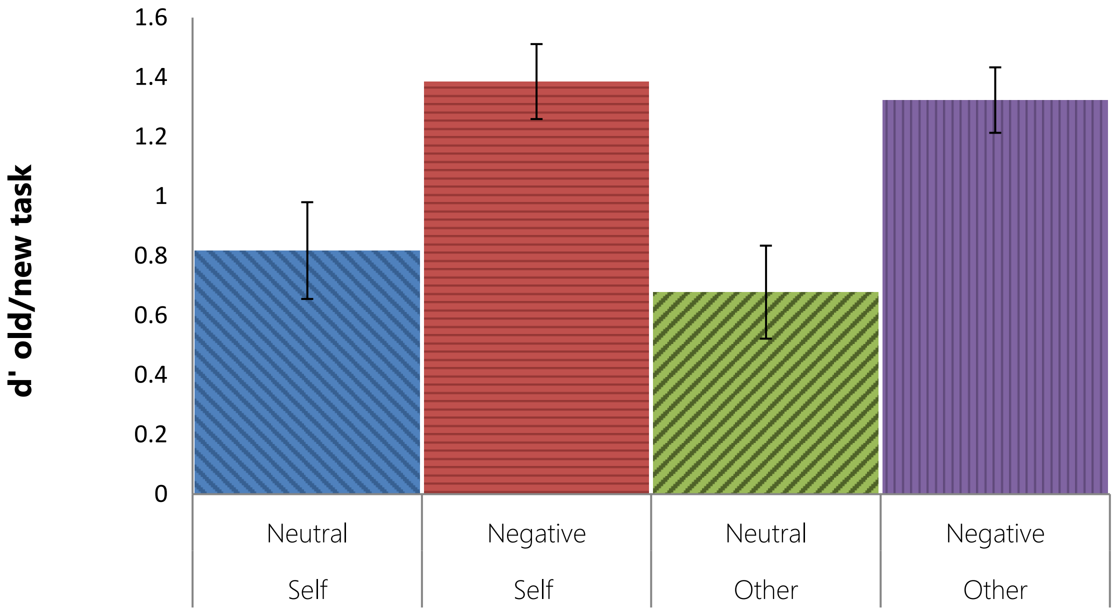

Figure 25. d' of the old/new task for all conditions, *Experiment 3*.
d' for all conditions (Error bar = standard error).

Just looking at the matched trials, the proportion of correct responses resulted in a significant effect between the negative trials and the neutral trials where participants scored a higher proportion correct for the negative trials, $F(19) = 39.623$, $p <.001$, $\eta^2_p = .676$. There was no significant interaction between emotion and perspective, $F(1,19) = .006$, $p = .940$, and there was no main effect of perspective, $F(1,19) = .143$, $p = .709$. Similarly, the non-matching trials only show a main effect of emotion, $F(1,19) = 38.951$, $p < .001$, $\eta^2_p = .672$. Again negative words were more often correctly recognised than neutral words. There was no main effect of perspective, $F(1,19) = 1.064$, $p = .315$. The interaction between perspective and emotion was also not significant, $F(1,19) < .001$, $p = 1.00$. See Table 14 for the averages and standard errors of the old/new task.

Table 14. Experiment 3 proportion correct, old/new task. Mean proportion correct responses and d' old/new task. Standard error in parenthesis.

	Matched Trials	Non-Matched trials	d'
	Correct	Correct	
Self	.71 (.03)	.66 (.03)	1.10 (0.13)
Other	.70 (.04)	.64 (.03)	1.05 (0.12)
Negative	.79 (.03)	.75 (.03)	1.35 (0.11)
Neutral	.63 (.04)	.55 (.04)	0.97 (0.14)
Self/Negative	.80 (.03)	.76 (.03)	1.39 (0.13)
Self/Neutral	.63 (.04)	.56 (.05)	0.82 (0.16)
Other/Negative	.79 (.03)	.74 (.30)	1.32 (0.11)
Other/Neutral	.62 (.04)	.53 (.04)	0.77 (0.14)

Discussion

Self-relevant information processing is generally viewed to be an automatic process (Alexopoulos et al., 2012; Moors & De Houwer, 2006). This *Experiment 3* explored the automatic nature of self-relevant information processing. This was achieved by repeating the stimuli three times. Using repetition as a manipulation, the influence of repetition on memory was measured and compared with the influence of emotional self-related information on memory. In other words, a comparison could be made between an automatic (self-relatedness) influence on memory and non-automatic influence of repetition on memory. If self-related information leads to an automatic enhancement of binding into memory, there should be no effect of repetition on self-related information. As repetition of self-related information does not become more 'self'. Naturally repetition itself was predicted to lead to an overall improvement on memory.

The results showed a robust effect of repetition for all time-windows with the matching task. An interaction was observed for emotion and perspective, but neither emotion nor perspective was influenced by time. It is possible that with each repetition the task became easier, freeing more mental resources, and since the words were repeated, these too could be processed faster. If repetition influenced the self-priority effect, an interaction should have been observed as the influence of time would have been greater for self-related stimuli compared to the influence of time on stimuli not related to the self. This interaction was not found, and it can be concluded that repetition itself did not influence the self-priority effect. Repetition on an item already deemed to be related to the self would not make it more self-relevant. In the matching task, self-relatedness is manipulated by linking the self to a specific colour, which is then either matched or not matched with a label. As suggested in the previous chapters, the meaning of the word is not relevant in the matching task, and only the colour/label combination is task-relevant for the matching judgement.

However, the interaction found between emotion and perspective suggested that emotion influenced the self-priority effect in the current task. This was not the case in previous experiments (*Experiment* 1a-1d), which used a similar matching paradigm, albeit without repetition. There is a likely explanation for this as the current experiment was likely to be much more sensitive. This was due to a quadrupling of the number of given trials in the current experiment compared to these earlier experiments. This larger number of trials was necessary in order to do the repetition manipulation. The increase in sensitivity which comes from the larger trial numbers may be the reason why the interaction, which was not previously exhibited, was found here. It suggests the interaction is a fairly weak one and not one which is consistently shown across participants.

Nonetheless, for the proportion of correct responses and d', the effect of self was greater for the neutral words than for the negative words in the matching task. This can only mean that the emotional value of the words was processed. Taken together, the increase in power and the faster processing of the words (learning the task via repetition) means a significant effect is found for emotion on self-relevant information. Like *Experiment 2*, emotion seems to impact the self, but unlike *Experiment 2*, emotion is not task-relevant, which could explain the smaller self-priority effect for negative words when compared to neutral words. As mentioned in the main introduction, it is possible that the negative emotion led to a distancing of the self for negative words (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Kuiper & Derry, 1982; Mezulis et al., 2004; Ochsner, 2000; Sedikides & Green, 2004; Taylor, 1991). However, the RT measure remained unaffected and only revealed a main effect of self and time, meaning that the decision time was not disrupted by emotion. This suggests that emotion distracted but not delayed the processing of self-related information. This finding is not in line with the concept that negative information results in distancing from the self (Williams, Mathews, et al., 1996). Furthermore, the old/new task revealed no adverse effect of emotion and negative words were more accurately remembered when compared to neutral words, regardless of perspective.

For the old/new recognition task, the four repetitions greatly affected the self-reference effect and resulted in no significant difference of perspective in any of the measurements. However, the effects of emotion were very similar to the previous experiment (*Experiment 1a-1d & Experiment 2)* and showed faster responses, greater signal detection, and overall more correct responses for negative emotional words. Although it has been suggested in previous research that people identify much more with positive emotions and much less with negative emotions (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Taylor, 1991), our current and previous results do not support this. If the negative valence of words is obscuring the self-reference effect, then this should not happen for neutral valence words. Since there is no interaction between emotion and perspective, emotion does not influence self-related information in this experiment. It is likely that the absent self-reference effect was caused by the added manipulation in this experiment, which is repetition. Furthermore, the participants were aware of a follow-up memory task, which made the words task-relevant and a priority. The emotional valence of the words helped to increase its saliency (Mather & Sutherland, 2011) for later recall despite being disruptive in the matching task and no general slow-down of ongoing activity was found (Algom et al., 2004).

If the added benefit of the self leads to a more efficient processing of words, then the repetition of words does not equally facilitate to self-related words and words that are linked to a distant other. The repeated processing of words would inevitably lead to greater recall of these words. Up to a certain point (learning curve) this effect is additive, each repetition further strengthening memory binding of the words. The binding of information to the self does not strengthen with repetition, as the main benefit is in the initial automatic and fast processing (Sui, 2016; Sui & Humphreys, 2015b). This gives self-related information an initial aid in binding into memory. However, this "boost" does not benefit from repetition as the binding of information to the self does not become more self-related after each repetition. The value of self remains the same. In short, with an increased number of repetitions, the initial benefit of the self-priority effect on memory is superseded by the additive benefit of repetition, the value of which is equal for all words.

Emotion is different compared to self-related information, as the former is linked to the meaning of the word directly, and the latter is linked to the colour of the word. The increased attentional resources for self-relevant information and the binding of information to self helps retrieve information from memory, but the emotional meaning of the words help the words stand out during the memory task. Each repetition might not strengthen the binding to the self, but it does strengthen the meaning, and thus the emotional valence of the word.

The old/new experiment was only presented at the end of all repetitions, and therefore, only the total effect of repetition could be measured. These results show that after three repetitions, the old/new experiment did not show any effect of self-reference. As the self-priority effect was still present in the matching task, when did the mnemonic boost of repetition catch up with the mnemonic effect of self-related information? The follow-up *Experiment 4* helped explore this question. However, the next experiment will focus purely on self-related information processing. *Experiment 3* did find an effect of emotion, which shows that repetition using the current paradigm does not influence the encoding of emotional words. However, the absence of a self-reference effect should be investigated further. Therefore, the next chapter will try and show exactly when a self-reference effect is present and when the self-reference effect disappears.

Chapter 5:

Free-Recall & Self

Introduction Experiment 4

In *Experiment 3*, the automatic mnemonic influence of self-relevance on information processing was explored using a repetition version of the matching paradigm used in this thesis. *Experiment 3* however, had a limitation due to its design. It only allowed us to measure the cumulative effect of the wordlist repetitions on memory. In other words, the time-course of the mnemonic effects of repetition is unknown. The main limiting issue is the choice of the old/new paradigm. This paradigm does not lend itself to any circumstance where repeated testing is required of the same item, not only because participants would be able to reach ceiling level fairly easily, but it would be difficult for the participant to keep the 'new' words from being seen as 'old' after the first trials.

Experiments 1-3 have all focussed on the memory processes on self-related information using the old/new paradigm. Testing memory via the old/new task is not an intensive recognition task. This is because the task only requires recognition rather than recall the task, it does not tax the processes associated with accessing memory (D'Argembeau et al., 2005; Norman & Schacter, 2014). It only requires participants to make a decision based on familiarity (Tulving, 1985). This means that some words are not clearly recalled per se, but recognised as being familiar. If a word reaches a certain threshold of familiarity, then this would be enough for the participant to judge the word as 'old'. The previous experiments have clearly shown that self-related information facilitates recognition memory, i.e. self-related old words are quicker and more accurately recognised as 'old' compared to words not related to the self. The aim of the current *Experiment 4* is to further elaborate these findings from memory recognition to recall, by combining the matching task used in *Experiment 3*, followed by a free-recall paradigm.

The main difference between an old/new recognition task and a free-recall task is that with the former a participant can use external retrieval cues to help retrieve the relevant memory, which makes memory retrieval easier to achieve. This is not possible with free-recall, and the participant will be dependent on only internal cues to recall relevant information (Norman & Schacter, 2014). Since self-related information increases the binding of information into memory, the increased difficulty of the free-recall task on recollection when compared to the old/new task should result in a strong self-reference effect. Nonetheless, the advantage of self-related information on recall would become less discernible as the effect of repetition will become more apparent over time.

Furthermore, the current experiment will build on the previous experiment on wordlist repetition. In *Experiment 3*, it was shown that repetition does not add to the self-reference effect, which resulted in equal retrieval of self-related and distant other-related words after three repetitions. In the current experiment, memory was tested after each learning phase (the matching task), and this was repeated three times. Also, since the main aim of this experiment was to test the self-reference effect using free-recall, no emotional stimuli were used. Including emotions, plus extra repetition would have made the experiment too long. In Chapter 7, *Experiment 6*, a non-repetition version of this experiment is described.

Based on the previous experiments, it was expected that self-related information would be learned faster than information related to a distant other, but after the last repetition, self-related information and distant other-related information would be recalled equally. For the matching task, it was expected that a self-priority is present in all time windows.

Methods

Participants

Twenty participants took part in this free-recall experiment. However, 3 participants were removed due to below chance level performance on the matching task. Three participants were male and 14 were female with a mean age of 20.88 years (range 18–35 years).

Material and procedure

The wordlist contained neutral nouns using the same list generation procedure as *Experiment 1 & 3*. However, all words used in this experiment were neutral. Similarly, the matching task was identical to *Experiment 1* and had no catch trials. However, two new elements were added: first, the overall procedure for the matching task was changed as the word-lists were divided into four word-lists containing 20 words each. These four word-lists were repeated four times in random order, which resulted in 16 blocks and created four time-windows which were used during the statistical analysis.

After each set of 20 words, a short distraction task was presented where participants had to count backwards aloud for 30 seconds. After the distraction task, participants had one minute to recall words from the preceding matching task. During the free-recall task, participants were presented with a fixation cross in the middle of the screen and were instructed to recall vocally as many words as they can in any order they wished. Each time a participant recalled a word, the fixation-cross disappeared and reappeared after each word was pronounced. The reappearance of the fixation-cross indicated to the participants that they could recall the next word. The responses were recorded and scored offline. After each block, the participant could take a self-paced break, and at the start of each block, the instructions were repeated.

Results

As with *Experiment 3*, the four different time-windows were used to study any effect of repetition during the matching task. However, due to the changes in methods, it was now also possible to see the effects of repetition during the memory or free recall task. Therefore, both the matching and free recall tasks were analysed by a repeated ANOVA 2(perspective[self, distant other])×4(time[time-window 1,2,3,4]) design, and a Bonferroni correction was applied for multiple comparisons. Sample size is 17 which means the tests were under-powered. Although throughout this thesis a sample size of 20 was seen as sufficient for reliably measure an effect of the self. However a general effect-size for a free-recall task is lower. Therefore, the current study is slightly under-powered. This means that the results might miss a potential significant effect. However, like the previous experiments, this paradigm is again novel and thus it is difficult to predict an exact effect-size for the power analysis.

Matching task

The d' data revealed a main effect of perspective as in *Experiments 1 - 3*, $F(1, 16) = 16.510$, $p = .001$, $\eta^2_p = .508$. Words linked to the self were more often correctly detected as matching to the label or not matching to the label than words not linked to the self. Furthermore, there was no main effect of time, $F(3, 48) = 3.023$, $p = .069$, but there was an interaction between time and perspective, $F(3, 48) = 2.909$, $p = .048$, $\eta^2_p = .154$, see Figure 26 and Table 15. This interaction was caused by a self-priority effect in signal detection for time-windows one ($p < .001$), three ($p = .003$), and a marginal effect in time-window two ($p = .055$). However, no self-priority effect was observed in time-window four ($p = .223$).

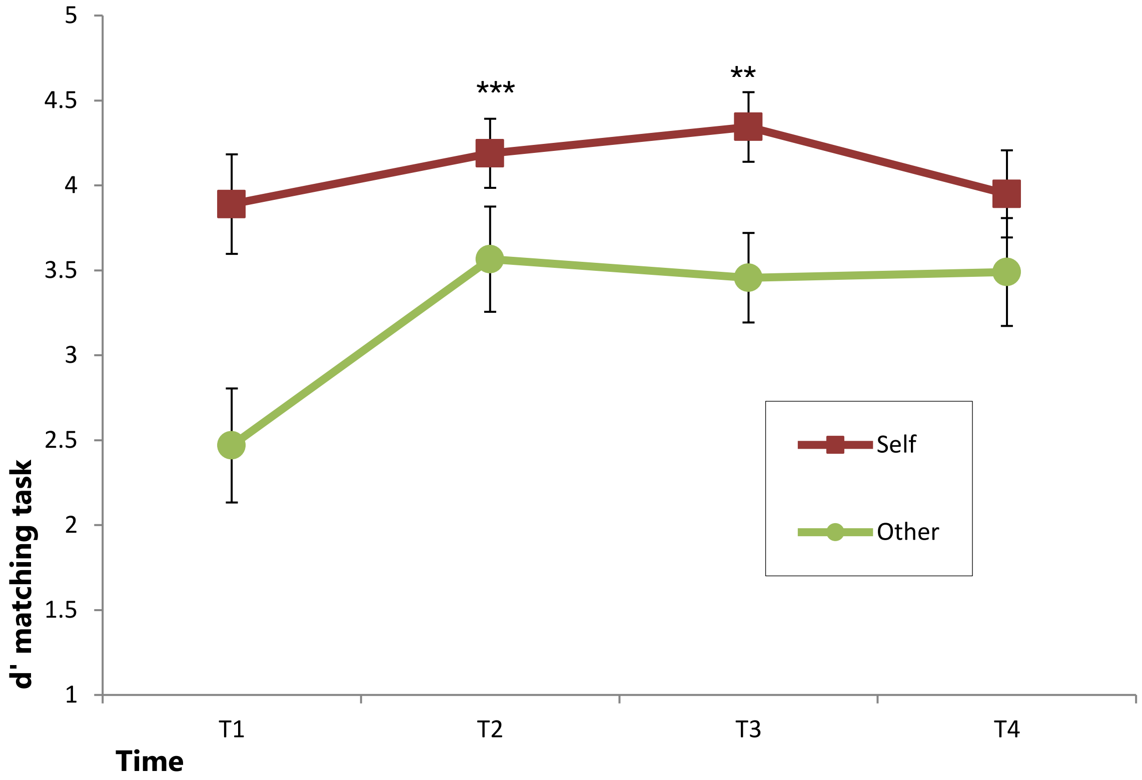

Figure 26. d' matching task, *Experiment 4*. Mean d' matching task per perspective (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

Table 15. Experiment 4 d', matching task. d' for each per time-window. Standard error in parenthesis.

	d'			
Time	1	2	3	4
Self	3.89 (0.29)	4.19 (0.20)	4.34 (.21)	3.95 (0.26)
Other	2.47 (0.34)	3.57 (0.31)	3.46 (0.26)	3.49 (0.32)
Average	3.18	3.88	3.90	3.72

Similarly, for the matched trials, the data of proportion correct responses found a main effect for perspective, $F(1,16) = 15.856$, $p = .001$, $\eta^2_p = .498$. More words related to the self were correctly judged as matching when compared to words linked to distant other. For the proportion of correct responses there is a main effect of time also, F(3,48)

= 4.234, p = .046, η^2_p = .209. Even though the pairwise comparisons show that the biggest difference occurs between time-window one and time-window two, this difference is not significant (p = .084). However, an interaction between time and perspective is observed also, F(3,48) = 3.934, p = .031, η^2_p = .197. This interaction was driven by significant differences between self-related words and words linked to a distant other for time-windows one, two and three (respectively: p < .001, p = .032, p = .005,), where words related to the self were more often correctly judged as matching with the label than words not related to the self. No significant difference between words related to the self and distant other were found for time-window four (p = .137). The non-matched trials showed no difference in proportion correct responses for perspective, F(1,16) = 3.080, p = .098; time, F(3,48) = 2.651, p = .108; nor an interaction between time and perspective, F(3,48) = 1.656, p = .189. See Table 16 for the averages and standard errors of the proportion of correct responses.

Table 16. Experiment 4 Proportion, matching task. Mean proportion correct responses. Standard error in parenthesis.

	Matched Trials				Non-Matched trials			
Time	1	2	3	4	1	2	3	4
Self	.95 (.03)	.99 (.01)	.98 (.01)	.97 (.01)	.92 (.02)	.94 (.02)	.96 (.02)	.93 (.02)
Other	.82 (.04)	.93 (.02)	.90 (.02)	.92 (.02)	.84 (.05)	.91 (.03)	.95 (.01)	.91 (.03)
Average	**0.885**	**0.96**	**0.94**	**0.945**	**0.88**	**0.925**	**0.955**	**0.92**

The median reaction time data for the matched trials only revealed a main effect of perspective, F(1,16) = 41.016, p < .001, η^2_p = .719. Participants responded faster to words related to the self when compared to words related to distant other. No other significant effects were found, Fs: time = 1.072, p = .370; self × time = .217, p = .884; non-matched time = .472, p = .703; non-matched perspective = .344, p = .566; non-matched perspective × time = 1.185, p = .326. See Table 17 for the median reaction times and standard errors.

Table 17. Experiment 4 RT, matching task. Median reaction time matching task. Standard error in parenthesis.

	Matched Trials				Non-Matched trials			
Time	1	2	3	4	1	2	3	4
Self	1214.44 (56.81)	1192.94 (45.29)	1223.06 (65.06)	1198.53 (55.22)	1369.38 (48.92)	1345.77 (47.16)	1397.88 (55.46)	1365.74 (60.14)
Other	1390.53 (51.98)	1345.65 (45.83)	1396.44 (62.50)	1340.27 (61.26)	1404.68 (46.87)	1360.18 (45.36)	1364.97 (53.85)	1405.91 (52.44)
Average	**1302.49**	**1269.30**	**1309.75**	**1269.4**	**1387.03**	**1352.98**	**1381.42**	**1385.83**

Free recall task

A direct comparison of the proportion of correct responses for the matching trials revealed a main effect of perspective, $F(1,16) = 19.636$, $p < .001$, $\eta^2_p = .551$. Participants recalled words related to the self more often than words related to a distant other. A main effect of time was observed also, $F(3,48) = 3.868$, $p = .015$, $\eta^2_p = .195$, which was mainly the results of a marginally significant greater recall for time-window four when compared to time-window one ($p = .050$).

As the Free-recall data was analysed using a 2(perspective[self, distant other])×4(time[time-window 1,2,3,4]) design, a potential learning curve could be examined. The results did reveal an interaction effect between perspective and time, $F(3,48) = 4.086$, $p = .012$, $\eta^2_p = .203$, see Figure 27 and Table 18. A follow-up paired comparison revealed that participants recalled more self-related words than distant other-related words for time-windows two ($p < .001$), and three, ($p < .001$). No such difference was observed for time-windows one ($p = .075$), and four ($p = .095$). Furthermore, when just looking only at the self-related words, there appears to be some effect of learning, $F(3,48) = 3.854$, $p = .015$, $\eta^2_p = .194$. Further analysis point towards a potential initial increase in recall between time-window one and time-window two ($p = .002$), time-window two and time-window three ($p = .001$), and time-window one and four (p = .010). No other significant differences were found (time-windows: two and three, p = .135; two and four, p = .702; & three and four, p = .686). For the other-related words a significant difference in time was found as well, $F(3,48) = 4.070$, $p = .012$, $\eta^2_p = .203$. When comparing differences between time-windows, significant differences were found for time-window one and time-window four (p = .032), time-window two and four (p = .041), and between time-windows three and four (p = .015). The remaining differences between time-windows were not significant (time-windows: one and two, p = .744; one and three, p =.565; & two and three, p = .277). For the non-matched trials no main effects or interaction were found: perspective, $F(1,16) = .120$, $p = .734$; time, $F(3,48) = 2.443$, $p = .075$; and perspective×time, $F(3,48) = .883$, $p = .457$.[8]

Table 18. Experiment 4 Proportion correct, free-recall task. mean proportion correct responses. Standard error in parenthesis.

	Matched Trials				Non-Matched trials			
Time	1	2	3	4	1	2	3	4
Self	.24 (.02)	.32 (.02)	.35 (.03)	.33 (.04)	.18 (.03)	.25 (.03)	.22 (.02)	.19 (.03)
Other	.17 (.03)	.18 (.02)	.16 (.02)	.26 (.04)	.17 (.03)	.22 (.03)	.23 (.03)	.24 (.04)
Average	**0.21**	**0.25**	**0.26**	**0.30**	**0.18**	**0.24**	**0.23**	**0.22**

[8] No recency or primacy effect were observed, most likely this is because of the distractor task disrupting any mnemonic actively utilised by the participant. Also, repetition itself would act like a mnemonic which is possibly more efficient than the organisational strategy underlying recency or primacy.

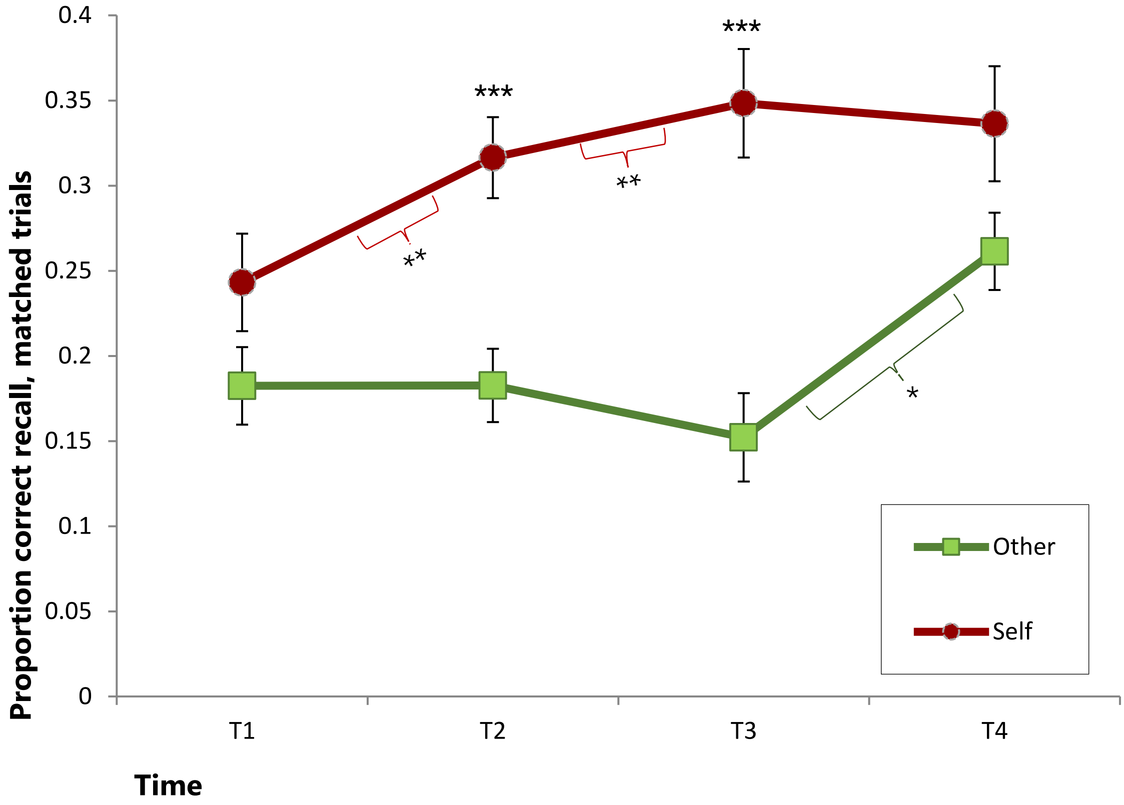

Figure 27. Proportion correctly freely recalled items, *Experiment 4*.

Mean proportion correctly recalled items on the free-recall task. Mean recall displayed for perspective on the matched trials per wordlist repeat. (Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

Discussion

In this *Experiment 4*, it was determined whether the findings reported in earlier chapters could be replicated using a recall, rather than recognition memory paradigm. A direct replication of the previous experiments, just with a recall, rather than recognition, was not possible. This was because of practical limitations, which required the removal of emotion as a condition. Including emotion would make the memory workload for the participants too high, and the duration of the experiment too long. Therefore, this experiment focussed purely on self-related words and not emotion. This 16 block design where each block contained a matching task and a free-recall task allowed the data to be split up into four time-windows.

Experiment 4 had a matching task, just like previous experiments. The results from this matching task were the same as reported for earlier experiments. Again there was a robust self-priority effect: compared to trials linked to a distant other, trials related to the self were more easily distinguished from noise, were more often correctly judged as matching with the label, and the participants were quicker in their matching decisions. This is all in line with the previous experiments (*1-3)*, but in this experiment an influence of repetition was also found. For both the d' data and the proportion of correct responses, the fourth time-window showed no significant difference between the self and distant other trials, whereas time-windows one, two, and three show the self-priority effect. This is at odds with the findings of the *Experiment 3*, which was a repetition experiment as well, but where no differences between time windows were observed.

However, as stated earlier, there were some necessary methodological differences between the two matching tasks of *Experiment 3* and the current *Experiment 4*. The matching task of *Experiment 3* displayed all trials without disruption, and there was only a small break between each repetition. In the current experiment, the word-list was divided into four blocks, which were repeated three times. After each block, a distraction task followed and a free-recall task. Therefore, there was some time between each of the blocks, and this was repeated three times, possibly providing time to learn the task to near ceiling level as both self and distant other words for the proportion of correct responses are above .92. Furthermore, in *Experiment 3*, all trials were displayed sequentially with a break every 100 trials, but no reminder of the instructions was provided. In the current experiment, a reminder of the instruction was provided before the start of each block. Furthermore, after each matching set, feedback was provided stating the percentage of correct responses. This was the same for every matching task, but with the increase of blocks and shortening of each matching block, there was an increased potential to learn the task. This, in turn, reduced the benefit of self-related words over repetitions.

Interestingly, for the proportion of correct responses, when a time-window was compared with a preceding time-window, only the distant other-trials showed a significant effect of learning (i.e. a higher score for a subsequent time-window). This indicated that trials related to the self were learned faster or easier than the trials related to a distant other. Participants performed at maximum for the self-related words much quicker (time-window one) than trials related to a distant other (time-window four). Simply put, it takes some time for the distant other-trials to catch up to the self-trials. A similar effect is observed for the d’ data, albeit less extreme. Here a learning effect is found for the distant other-trials between time-window one and time-window two only, which is not observed for trials related to the self.

The median reaction times did not show any effect of repetition but does reveal a self-priority effect. This indicated that the initial detection of self-relevant information drew the attention in a quick and automatic manner. The faster detection of self-relevant stimuli over stimuli not related to the self was not a taught response, and therefore repetition did not improve detection speed. The superior reaction time to self-relevant stimuli means that participants potentially detected the self-relevant information faster. In turn, this lead to more time for decision making, providing support for faster and more accurate detection of self-relevant information (Alexopoulos et al., 2012; Sui et al., 2012).

The free-recall task displayed similar findings as the old/new recognition tasks of the previous experiments. However, unlike the previous experiments, the current experiment allowed a look into four time-windows of repetition in memory.

Before discussing the findings, it should be pointed out that this particular memory experiment has a high memory workload and the nature of the encoding task (i.e. the matching task) in being an incidental learning task is far from optimal for learning items. The matching task itself does not require the memorisation of words, and therefore, the task distracts from encoding the words into memory. This makes the task fairly difficult, and on average, the participant recalls roughly five out of 20 items. This is in stark contrast with the old/new recognition task where the familiarity of the word itself was enough for a correct 'old' judgement. This means that in terms of difficulty, the old/new task was far easier for the participant.

This difficulty is reflected in the first time-window where no self-reference effect is found. Although it appears that the self-related words were recalled more often than words not related to the self, this difference is not significant. In other words, even the added benefit of self-referential processing was not enough to overcome the difficulty of the task in the first time window. However, in time-windows two and three, a clear effect of self-reference emerged. These two time-windows clearly showed increased recall for words related to the self when compared to words related to a distant other. These results are in line with the results of *Experiment 1-3* where an effect of self facilitated memory processes.

The results indicated a much steeper learning-curve for self-related words. In the first time-window no significant difference in recall between self- and other-related words was found. However, in the second time-window there was a clear self-priority effect. This is the result of a significant increase between time-window one and time-window two for self-related words. Such an increase in recall between time-window one and time-window two is absent for the other-related words. Only in the fourth time-window is a significant increase of correctly recalled items found for the other-related words when compared to the earlier time-windows for the other-related words. This is in contrast with the self-related words where no difference is found between time-windows four, three, and two. The only significant differences found for the self-related words were for time-window 1 compared to later time-windows. In other words, most of the learning occurred between time-window one and time-window three for the self-related words, whereas most of the learning occurred from time-window three to time-window four for the other-related words. In Experiment 5 of this thesis it will be shown that the learning curve of self-related items is not only steeper when compared to other-related words, but is more stable over time as well.

With Experiment 4 the self-reference effect in old/new recognition can be extended to free-recall, showing a strong benefit effect of self on memory even when there are no external retrieval cues (M. A. Conway & Dewhurst, 1995; Gutchess et al., 2007; Kelley et al., 2002; Klein & Kihlstrom, 1986; Leshikar et al., 2015; Symons & Johnson, 1997).

Interestingly, self-related information no longer facilitated recall by the fourth time-window. This finding is again similar to the findings of the previous experiment, where the words related to the self did not have a strong additive advantage with repetition. Together with the results of the current experiment and the result of *Experiment 3*, it can be concluded that repetition does not weaken the self-related items, but neither does it strengthen the memory of these items beyond the influence of repetition. The main benefit of self-relevant information lies with the fast and automatic processing of information, providing an initial boost to memory. Each repetition does not increase the self-value of an item, whereas each repetition does increase the memorability of the item regardless of self-relevance as the binding into memory becomes more stable after each repetition.

To conclude, repetition does not influence the RT on the matching task, nor does it impact the accuracy of processing self-relevant information. It does however greatly impact the accuracy of processing distant other-relevant information during the matching task, eventually bringing the accuracy to the same level of self-relevant processing. This indicates an attentional benefit of self-related information, but the self-priority effect does not increase with repetition. In recall, information related to the self is recalled more often, but repetition brings information not related to the self to the same level of recall.

With these behavioural experiments, some basic aspects of self-relevant information processing have been explored. The next two chapters will focus on elucidating the underlying neurological processes involved in emotional and self-related information processing. *Chapter 6* will continue the investigation of the automaticity of the self as explored in this chapter. It will use a different paradigm then the matching task as it will investigate the effect of suppressing self-related information. *Chapter 7* will tie all the previous experiments together and, like this chapter, use a free-recall experiment but now without repetition. This would also allow the further investigation and emotional self-related information during very difficult encoding and recall conditions.

Chapter 6:

Memory suppression & self

Introduction

The emphasis, up to this point in the thesis, has been on the processes involved in observable behavioural effects of emotion and self-related information on attentional and memory processes. The previous experiments repeatedly showed, a distinct effect of self-relevance on attention and memory, even though this self-relevance was arbitrarily assigned. This shows a potential top-down influence on bottom-up saliency of stimuli for information related to the self over information not related to the self. In other words, the arbitrary assignment of self to a specific colour results in a prioritisation of that colour over stimuli not related to the self.

This chapter and the next will present experiments which try to explore the neural correlates of the self-relevance and emotional processing that previous chapters have identified. *Experiment* 5 will further explore the automaticity of self-related information processing. *Experiment 6* will be similar to the free-recall *Experiment 4* but without repetition and will explore the neural correlates of emotion and self-related information processing with the matching paradigm. Both experiments will do this by using electroencephalogram (EEG) recordings while participants process material which varies in its self-relatedness. The overall aim is to explore the neural mechanisms involved in prioritising self-relevant and emotional information on attention and memory, using EEG.

In psychology, the neurophysiological underpinnings of behaviour are often studied using two mainstream techniques: functional magnetic resonance imaging (fMRI); and EEG. This chapter and the next will specifically focus on EEG research as this will be the method used in the subsequent two experiments. First EEG will be introduced together with the Event-Related Potentials (ERPs) method.

Electroencephalogram

The strength of EEG methods lies with the temporal resolution of this technique, as the activity of neurons can be measured, accurate to the millisecond level. EEG measures the postsynaptic potential generated by neurons in the brain. Although scalp EEG is not sensitive enough to measure the activity of a single neuron, a grouped activation of many neurons can be measured via electrodes placed on the scalp. Typical EEG experiments are primarily limited to the activity of the cortex of the brain as deeper brain regions may not be measured adequately.

Event-related potentials

Most EEG studies record event-related potentials (ERP), and an ERP is brain activity linked to a specific stimulus, event or action. A specific experimental condition is correlated with an ERP, and this is compared with a different (control) condition. Naturally, not only the ERP linking to the experiment is being measured and also picks up other, not-experiment related, EEG data. Furthermore, EEG is very sensitive to any muscle movement and surrounding electrical interference. For this reason, the brain activity needs to be measured by multiple trials. By averaging over many trials, the ERP is strengthened per trial (as it is constant) and any noise is averaged out (as it is random). In other words, increasing the number of trials increases the signal to noise ratio.

An ERP component is often described by measuring the typical latency and polarity of the signal. For example, a P600 ERP describes a positive going deflection, of which the peak amplitude is generally around 600 milliseconds after stimuli onset. However, the peak amplitude of an ERP component is not fixed and can be variable, and a P600 might peak as early as 500ms or as late as 800ms (Luck, 2014). The next few paragraphs will focus on introducing ERP components. The components described are often linked to attention and memory and are likely to be influenced by self-related and emotional information processing.

Attention

An early P200 with fronto-central distribution has been linked to initial word selection and is influenced by attention (Mangun & Hillyard, 1995; Peters, Suchan, Zhang, & Daum, 2005). Furthermore the P200 can be followed by a parietal occipital positive component (P250/P280) which reflects recognition or increased working memory load (Chapman, Gardner, Mapstone, Dupree, & Antonsdottir, 2015; Dunn, Dunn, Languis, & Andrews, 1998; Mangels, Picton, & Craik, 2001) and is potentially influenced by attention also (Talsma, Slagter, Nieuwenhuis, Hage, & Kok, 2005). Mangels et al. (2001) suggested that these anterior to posterior ERP components reflect an anterior to posterior attentional network proposed by Posner and Dehaene (1994). This attention network consists of medial frontal areas involved in directing attention and posterior parietal areas involved in engaging attention with the specific information to which the attention was directed, allowing for memory retrieval and recognition. As the matching experiments of this thesis have repeatedly shown, self-related information influences attention. Because of this, it is expected that the early P200 components will be more pronounced for items related to the self, as attention is directed to self-relevant information. Potentially this might influence the P280 as well, as retrieval and recognition should be easier for self-related information.

Another major EEG component is the P300. The P300 is a post-perceptual component, which means that the P300 is not influenced by the physical properties of a stimulus, but by a person's response to the stimulus. It can be evoked irrespective of the sensory modality of a stimulus. Importantly, like the N1, the P300 is observed in a task that requires stimuli discrimination and the allocation of attentional resources (Curran, 2004; Duncan-Johnson & Donchin, 1977; Gonsalvez & Polich, 2002). However, there is no clear consensus on the processes reflected by the P300. Generally, the P300 is thought to reflect the updating of working memory and stimulus categorisation (Luck, 2014). This means that the P300 amplitude increases based on task demand (how difficult is it to categorise the stimuli) and stimulus frequency. Typically the P300 component is observed to emerge approximately 250-500ms after stimulus onset, generally reaching its peak around 300ms.

The P300 consists of two distinct components, each with different topographic distributions. The P3a is believed to be more directly linked to stimulus evaluation via top-down attention allocation; its scalp topography suggests that it is generated by frontal lobe regions. The P3b, it is argued, reflects the subsequent consolidation and maintenance of the attended information into memory, its scalp topography suggests neural generators in the temporal-parietal regions (Polich, 2007). In his extensive review of the P300, Polich (2007) hypothesises that the way attention allocation and stimulus categorisation can occur is via the neural inhibition of ongoing processes, which is what is reflected by the P300. The direct inhibiting of distracting stimuli would allow easier processing of the focussed information and the updating of working memory.

The P300 is arguably of particular interest for this thesis in terms of its association with memory consolidation and maintenance processes for attended stimuli. The P300 can be explored as a potential neural marker of the process by which self-relevant information is enhanced in attention and memory, consistent with the behavioural effects we have found. As suggested by Sui & Humphreys (2015), the self functions as a hub that connects self-relevant information across domains. Therefore, if the self-related information influences attentional and memory processes, the P300 ERP component is likely to reflect this with a greater amplitude for self-related information processes. This is because even though self-related information is prioritised and processed more accurately (as shown by *Experiments 1-4)*. This is possibly achieved by inhibiting ongoing neural processes and an orienting towards the self-relevant stimulus. Interestingly the P300 has been linked to inhibition of ongoing electrophysiological processes (Polich, 2007). This could mean the inhibition of distracting information, but perhaps more interestingly, this could reflect the inhibitory "circuit-breaker" of TPJ mentioned in the main introduction. In other words, the P300 might reflect the inhibitory processes linked to switching attention towards more salient information like self-relevant information.

It is not completely novel to explore the P300 in terms of self-relevance processing. For example, the study by Zhou et al. (2010) revealed a larger P300 amplitude when pronouns were self-relevant compared to non-self conditions. In this study, the Chinese possessive pronouns 'wo de' (mine) and 'ta de' (his) were used in an oddball paradigm. 'Wo de' is seen as a self-related pronoun and 'ta de' and a non-self pronoun. Participants were shown a big circle (80% of trials), a small circle (10% of trials), the self-pronoun (5% of trials), or the non-self pronoun (5% of trials). The participants had to respond to the small circle and not to the other stimuli. By comparing the self and non-self pronouns directly, the ERP analysis revealed that the P300 amplitude was larger for the self pronouns than for the non-self pronouns. The authors conclude that the P300 is linked to the amount of attentional resources required. In other words, the larger amplitudes for self pronouns reflect the greater salience of the self pronouns. Furthermore, since high emotional stimuli evoke larger P300 amplitudes, the authors suggest that self-pronouns are more emotionally salient.

The N400 can have an onset as early as 250m after stimulus onset and can extend to 500ms. The N400 usually peaks around 400ms after stimulus onset. The N400 is a negative deflection in the EEG signal often more pronounced when the semantic meaning of a word does not match with the sentence it is used in (Luck, 2014). Typically an N400 is linked to language processing, and it is suggested to revolve around the effort of integrating the semantic meaning of a word in preceding context (Hagoort, 2007), or the effort in retrieving meaning associated with a word (Kutas, Van Petten, & Kluender, 2006).

A study using EEG investigated how emotion influences self-related information processing, focussed on the self-positivity bias (Watson, Dritschel, Obonsawin, & Jentzsch, 2007). The goal of this study was to disentangle the possible confound in many studies on self-relevant information processing: emotion. In their EEG study, Watson et al. (2007) asked participants to make self-referential judgments about emotional words by deciding if the word was 'like me' or 'not like me'. The ERP results showed a significant interaction between self-reference and emotion between 450ms and 600ms after stimulus onset at the midfrontal electrodes. Self-related negative words and non-self positive words showed a more negative-going deflection in the EEG signal when compared to self-related positive words and non-self negative words. The authors interpreted this as a N400 ERP and suggested that this interaction partially supports independent processing of self-related and emotional information. Since the results of Watson et al. (2007) showed a more negative N400 ERP for self-negative words compared to self-positive words, this might reflect a self-positivity bias as it is arguably easier to link positive words to the self compared to negative words.

Like the behavioural *Experiments 1-3* in this thesis, many ERP studies of human memory also use an old/new recognition paradigm. For these kinds of experiments and cued recall experiments, a frontal negativity is often found between 300-500ms, this ERP is called the FN400. The FN400 is generally linked to familiarity responses as measured in know versus familiar paradigms (Friedman & Johnson, 2000). Know versus familiar experiments are similar to old/new experiments but add another element. In the know versus familiar paradigm, a participant has to not just report an item as old or new but also indicate if the old item is either known or familiar. A familiar response would indicate a familiarity with the item but without any specific recollection of knowing when the item was learned or any other source memory material. The familiar response is, therefore, more subjective than the know response, which is the recall of the item including contextual details involving the recalled item. The FN400 is linked to the familiar response. Old items in an old/new experiment would show a reduced negativity modulated by the familiarity of the item.

Memory

As evident by the self-bias in free recall reported in the above study, and as shown in the behavioural data of this thesis, information related to the self is remembered more frequently than information unrelated to the self. Like attention, memory processes can be investigated using ERPs. If the self influences memory, then it is likely to do so either during encoding of the new information or via the retrieval of already stored information.

An ERP often linked to an old/new effect is the late positive component (LPC), which is observed over the parietal sites 400-800ms after stimulus onset. The LPC is greater in amplitude for the 'old' words than for the 'new' words. As such the LPC directly reflects recollection (Paller & Kutas, 1992; Rugg, 1995; Smith & Halgren, 1989). There is of course some difference between recognition tasks (i.e. old/new) and recall tasks (i.e. cued recall). This difference is mainly a negative going ERP from 100-200ms over the left inferior prefrontal sites for the cued recall tasks. This likely reflects the need to link the provided cue with the target word (Friedman & Johnson, 2000).

As with attention, remembering self-relevant information should be reflected in the ERPs related to memory processes. ERP literature on self-referential encoding and recall is however currently very limited, but two studies have used the idea of the self-reference effect in memory.

Dulas, Newsome, and Duarte (2011) studied which ERP components are involved in retrieving self-relevant information using an old/new plus source memory task, using younger and older adults. For this experiment, participants took part in an initial study phase, where they were presented with colour photographs of concrete objects. Each photo was depicted with a yes/no question. There were two conditions during the study phase and the yes/no questions related to these. One condition was a pleasantness condition for which the participants had to decide if the depicted photo was pleasant. Furthermore, the participants were instructed that they had to make the decision personal, e.g. "Yes, I do think apples are tasty". In the distant other condition participants had to make a commonness judgement, e.g. "Yes, computers are common". After the study phase, a variation of an old/new paradigm was presented. The participant had to decide if the presented photo was previously studied or not. Also, the participants had to make a source memory decision and tell if the photo was from the pleasantness or commonness condition. The authors only provided ERP data for the test phase.

The authors observed that the FN400 had an earlier onset time for young participants compared to old participants. Interestingly, where the onset of the FN400 is normally around 300ms, the authors report an old-new effect as early as 200ms after stimulus onset for the younger adults. The older adults still benefit from self-referencing, albeit with a slight delayed onset compared to younger adults (350ms) and the amplitude of the FN400 was reduced for the older adults. The authors suggested that this difference in FN400 ERP between younger and older adults show that both groups still benefit from self-referencing strategies, but the reduced amplitude for the older adults reflect the source memory impairments found in older adults.

A later LPC ERP component was observed for both groups and both conditions. However, the magnitude of the LPC did not differ between the self and non-self condition for young adults. Interestingly, older adults do show an increased LPC for the self condition. Dulas et al. (2011) hypothesise that the older adults were able to create more detailed episodic memories, which was reflected by the enhanced LPC amplitude. Via the self-referential encoding task, the self could have acted as a hub (Sui & Humphreys, 2015b) linking these details together and in doing so generate a more easily accessible memory trace. Even though the LPCs did not differ between conditions for the younger adults, the scalp distribution for both groups was more bilateral for the LPC linked to the self, whereas LPC was more left-lateral for the non-self condition, suggesting possible different generators. The authors explain that this is possibly due to the nature of the task, as the non-self condition was more likely to engage semantic processing than the self condition. Taken together these ERP results indicate that self-referenced processing can improve recall similarly for young and older adults.

Not all EEG research will show clearly identifiable ERP components. One EEG study on memory retrieval by Magno and Allan (2007), found a novel ERP component for self-related information. In this experiment, participants were divided into two groups: an autonoetic (*awareness of specific past experiences*); and a noetic (*self-knowledge* *abstracted from past experiences*) group. Participants in the autonoetic group were presented with a number of low-frequency words. Each word was preceded by the cue 'self' or 'friend'. If the cue was self, then the participant had to try and retrieve and describe a personal event related to that word. After which the participants indicated if it was a recollection or not. Similarly, when the cue 'friend' was displayed, the participants had to describe an event involving the word concerning their friend. For the noetic group, the setup was mostly the same, but now the participants had to recall a fact related to the word, which either concerned themselves or a friend.

The ERP results for both groups are interesting as the autonoetic group revealed a novel positive-going ERP component starting as early as 100ms after stimulus onset up to the end of the epoch at 1,944ms over the midline sites. The Noetic group also showed a positive ERP component over the midline site but had a later onset and shorter duration (800ms-1200ms) compared to the autonoetic group. Although the reason for this difference is currently unclear, one could postulate that autonoetic information is richer in self-related details and therefore is easier to link to the self and other self-related information. Even though the ERP components of this study are novel, it does show a clear difference between self and friend related processing. Furthermore, Magno and Allan (2007) suggest that the possible underlying generators, spanning the anterior and posterior medial cortex, are often linked to self-reference effects.

As seen from the examples above, there are many ERP components linked to attention and memory that are susceptible to self and non-self stimuli. Naturally, these EEG components are generated by underlying brain structures. The next two experiments will focus on the components discussed above, plus some more specifically related to the paradigms which will be discussed later.

Experiment 5: Think/No-Think paradigm

In *Experiment 3* and *Experiment 4*, the automatic and fast processing of self-related information was investigated. The basic findings of these experiments were that though a self-reference effect is robustly found in memory, further repetition of the self-association pairings did not assist in strengthening the self-reference effect, or at least not under the parameters that we tested. Self-related information is learned faster and remembered more often than information not related to the self. However, this appears to be the result of an automatic and fast process that offers initial benefits, with faster learning and a steeper learning curve when compared to information linked to a distant other. It seems repeated exposure to self-relevant information does not strengthen the binding into memory more than repetition does eventually. In other words, repeated self-related information memorisation is faster when compared to repeated distant other-relevant information memorisation, as discussed in *Experiment 3* and *Experiment 4*.

However, the repetition paradigms of *Experiment 3* and *Experiment 4* only approached the automatic self indirectly. This was done by creating a situation where automatic and fast prioritising of self-relevant information is no longer as beneficial compared to a situation where information can only be learned once. In this chapter, Experiment 5 will examine the automaticity of self-relevant information processing by comparing suppressed memories with non-suppressed memories. This manipulation is done using the *think/no-think paradigm* developed by Anderson and Green (2001).

The concept of suppressing memories, which is central to the think/no-think paradigm, revolves around the idea that the memorability of information can be reduced over time. In this paradigm, memory is suppressed, so it is claimed, by actively trying to suppress conscious recollection during recall. The main mechanism of this suppression, according to Anderson & Green (2001), lies with executive control. In other words, our ability to override an automatic/habitual response (M. C. Anderson & Green, 2001; M. C. Anderson & Levy, 2009), See Figure 28 (part A). In memory, this would imply the inhibition (or suppression) of existing memories from recall. Several studies have shown the importance of inhibition in memory (M. C. Anderson & Spellman, 1995; Logan & Cowan, 1984; Mayr & Keele, 2000), where one of the possible functions of inhibition is the inhibition of competing memories during retrieval. This inhibition reduces the memorability of the inhibited items. The think/no-think paradigm is based on this concept of reducing memorability of information through inhibition.

The classic think/no-think paradigm first performed by Anderson and Green (2001) involved a word pair association task. The experiment started with an encoding phase. In this participants had to learn unrelated word pairs, consisting of a cue-word and a target-word. After learning the word pairs, the presentation of the cue word required the participant to recall the target word. After this, the second part of the paradigm was given, which involve the think/no-think manipulation. In this phase, cue-words were presented, and participants had to either recall the target words (think) or actively suppress (no-think) the recollection of the target words. During this phase, the cue-words were presented sixteen times, after which a recall phase followed. Furthermore, not all words learned in the initial encoding phase were used in the think/no-think phase and were used as a baseline to measure the effect of the think/no-think phase. The results showed that with each repetition, an increase of memory suppression was observed when compared to baseline for the no-think trials (see Figure 28, part B). In comparison, words in the think trials were recalled more often compared to baseline. The authors conclude that these findings support a mechanism that removes unwanted memories out of awareness and this possibly reduces the memorability of the unwanted information over a long time period. Anderson and Green (2001) suggest that the suppression of memory incorporates part of the executive processes involved in cognition, which can be exploited using the think/no-think paradigm.

Figure 28 has been removed from this thesis due to copyright restrictions

Figure 28. An example of suppressing recall. **A)** An overview of stimulus linked to two responses. The solid line is the prepotent response and will be the default response unless the weaker response is strengthened or the prepotent response is blocked. **B)** The results of an experiment that showed significant suppression of recall compared to baseline. Figures are replicated without permission (M. C. Anderson & Levy, 2009).

In an EEG experiment, Bergström, Velmans, Fockert, and Richardson-klavehn (2007) used the think/no-think paradigm to study the underlying neurophysiological processes involved in suppressing memories. This experiment found a significant ERP effect during the think/no-think phase between 200ms – 300ms after stimulus onset with an interaction between the posterior and anterior sites. The think condition was reflected by a more positive deflection in the EEG at the frontal sites compared the no-think condition, whereas the parietal/occipital sites showed a more negative going signal for the think condition when compared to the no-think condition. These findings reflect a frontal selection positivity and a posterior selection negativity, respectively (Harter & Aine, 1984; Kenemans, Kok, & Smulders, 1993). These ERPs are both involved in attentional selection where the frontal selection positivity ERP is linked to selected information compared to the ignored information. The posterior selection negativity ERP is found with stimulus-specific selection, with a more negative activity for selected stimuli. According to Bergström et al. (2007), these two processes reflect early strategic processes involved in conscious recollection, which could mediate the suppression of unwanted memories. Furthermore, there was a difference between the think/no-think condition between 500ms and 800ms. This difference was a primarily left parietal positive going component starting around 452ms, and a right frontal negative component occurring later around 600ms. Both positive left parietal and negative right frontal components were greater for think learned words, when compared to no-think learned and think not learned words. Learned words in this paradigm means the words successfully learned during the encoding phase. The greater positive left parietal effect for the learned think condition is believed to reflect conscious recollection (Paller & Kutas, 1992; Rugg, 1995; Smith & Halgren, 1989) and is the same component often referred to as the parietal old/new effect (see introduction *Chapter 1*), but has been linked to cued recall as well (Rugg, Schloerscheidt, Doyle, Cox, & Patching, 1996). The authors concluded that the observed ERP differences between the think and no-think conditions show that voluntary inhibition of recollection is possible, and can be therefore used as an experimental manipulation to understand memory processes. However, their behavioural results did not reveal suppressed recall, and as such, the authors surmised that even if individuals inhibit recollection, this does not lead to actual forgetting per se.

The findings of Bergström et al. (2007) have been largely replicated in an EEG study conducted by Mecklinger, Parra, and Waldhauser (2009). Though their results were similar, there were also some crucial differences with the earlier experiment. The study by Bergström et al. (2007) revealed an interaction between learnedness of the words and condition in the form of a greater parietal positivity for think learned words and not-learned words. Because no difference was observed between learned no-think and not learned words, the authors suggested that words were equally unmemorable from words that were never learned to begin with. However, Mecklinger et al. (2009) found that there was a difference in parietal positivity amplitude between the think and no-think conditions for the not-learned words. The authors believe that more retrieval attempts were made in their experiment, as the parietal positivity was increased for the not-learned think condition compared to the no-think condition. Also, like in Bergström et al. (2007) a frontal selection positivity (reflected by a P200) was linked to greater attention to the colour used to indicate a think condition. Interestingly, Mecklinger et al. (2009) found a centro-parietal N200 as well, which was greater for the no-think when compared to the think condition. The N200 is often linked to inhibiting prepotent responses, and Mecklinger et al. (2009) therefore suggested that the N200 found in their study reflects the electrophysiological processes involved in successful memory suppression, an assumption which the authors tested in a follow-up stop-signal task.

This stop-signal task used the same words and subjects as the think/no-think paradigm, and in this task the participants had to make an animacy decision of the words (i.e. does the word describe something animate?) by pressing one of two buttons. In 20% of the trials, participants were unexpectedly told to withhold their response. In other words, these 20% reflect trials in which a prepotent response needed to be inhibited. The ERP results showed that correctly inhibiting one's response was linked to a centrally distributed N200 which was linked to the early mechanisms of inhibitory control, and a broadly distributed P300 potentially reflecting a post-inhibition evaluation process. Mecklinger et al. (2009) then compared the think/no-think experiment with the stop signal task and found that the N200 linked to inhibition of memories and the N200 linked to inhibition of prepotent motor responses were positively correlated, suggesting that the underlying neurophysiological processes of suppressing memory and inhibiting motor responses are similar in nature.

As mentioned several times in this thesis (see *Experiment 3 and Experiment 4)*, the processing of self-related information seems to be fast and automatic. Therefore, it is possible that inhibition would have a different effect on information related to the self when compared to information related to a distant other. If self-related information processing benefits from an automatic process, then inhibiting memories linked to the self would possibly be more effortful. Therefore, the think/no-think paradigm might be especially suited for testing the automaticity of the self, by linking the self or a distant other to specific word-pairs. Displaying a cue word of a self-related word pair should more easily allow for the recall of the connected target word when compared to the other related word-pairs. The other-related words will, in turn, be more easily suppressed in the no-think condition when compared to the word pairs related to the self. Suppressed recall is compared with the recall from the baseline trails which were part of the encoding phase but was not part of the trials trying to suppress (no-think) or promote (think) recall.

As the think/no-think paradigm involves cued recall this experiment will also examine the well-known electrophysiological correlates involved in encoding and recall of information, and how this is different for self-related information compared to information not related to the self. Based on the the EEG papers on the think/no-think paradigm discussed earlier, the P200, P300, FN400 and the LPC components are of special interest.

The P300 has been linked to attention and memory processes as well, but also to self-relevant information processing (Caharel et al., 2002; Fischler, Jin, Boaz, Perry, & Childers, 1987; Gray, Ambady, Lowenthal, & Deldin, 2004; Herbert, Herbert, Ethofer, & Pauli, 2011; Holeckova, Fischer, Giard, Delpuech, & Morlet, 2006; Scott, Luciana, Wewerka, & Nelson, 2005; Sui, Zhu, & Han, 2006; Zhou et al., 2010), which has been discussed in the introduction of *Chapter 1*. As mentioned in the introduction the two components of the P300 (the P3a and P3b (Polich, 2007)) have been linked to both attentional and memory processes and are therefore possibly representative of attention to memory transfer. The P3a seems to be involved in early target discrimination, whereas the P3b ERP reflects the maintenance and processing of the attended information. This, combined with the findings of a P300 in self-related information research, makes the P300 a potentially interesting ERP component in all phases of the current think/no-think study.

Another potentially interesting component is the FN400 or the midfrontal N400 old new effect, so called because of the greater negative deflection in the EEG signal for 'old' words when compared to 'new' words between 300ms and 500ms (Friedman & Johnson, 2000). The FN400 is topographically different from the N400, which is usually has a more central parietal distribution, whereas the FN400 typically has a more anterior central distribution. However, the exact relation between the FN400 and the N400 remains unclear. Although the current think/no-think experiment does not contain a typical old/new phase, during the learning and recall phase the cue words would prime or generate familiarity with the target words which should generate an FN400 ERP component.

Another ERP component linked to recollection is the LPC, a component which was first mentioned in this thesis in the main introduction of *Chapter 1*. Previous research has found that a positive ERP between 400ms and 800ms was linked to recollection (Allan & Rugg, 1997; Allan, Wilding, & Rugg, 1998; Curran, 1999, 2004; Curran & Doyle, 2011; Tsivilis, Allan, Roberts, Williams, & Downes, 2015), and not familiarity. As a consequence of improved memory for self-related items, the LPC was expected to be more positive for the self-related items when compared to the items related to a distant other. *Experiments* 4 and 5 showed that repetition allows for the recall of distant other-related items to "catch-up" with items related to the self and therefore it is expected that the LPC will only be more positive for the self condition after the first repetition, but for the second repetition, no difference between self and distant other is expected. This is because the repetition itself would lead to increased memorability. For the second repetition, memory would have improved for the other-related words as well, and as such the LPC for self-related words and other-related words would be relatively similar. Based on the literature described in this thesis on self-relevance and the think/no-think paradigm, this study will investigate several ERP components, which are summarised in **Table 19**.

In short, the goals of this chapter are threefold. The first is to further elucidate the influence of self-related information during learning and later retrieval. The second is to investigate if memories related to the self can be suppressed as easily compared to memories related to a distant other. Finally, the third goal is to reveal any specific electrophysiological processes involved or influenced by self-related information processing.

Table 19. Overview key ERP components and the processes the ERPs are correlated with.

ERP	Location	Key words	Predictions	Literature
P200	Central anterior	• Attention, • Conscious recollection	More pronounced for items related to the self (compared to other), as attention is directed to self-relevant information.	Bergström et al., 2007; Mangun & Hillyard, 1995; Mecklinger et al., 2009; Peters et al., 2005
N200	Central	• Inhibitory control	More pronounced for items related to the self (compared to other), as inhibitory control would be more taxed for self-related items.	Bergström et al., 2007
P280	Central posterior	• Recognition, • Increased memory workload, • Attention	More pronounced for items related to the self (compared to other), as retrieval and recognition is easier for self-related items.	Chapman et al., 2015; Dunn et al., 1998; Mangels et al., 2001; Talsma et al., 2005
P300	Central posterior	• Attention, • Self-relevant information, • Attention to memory transfer, • Attention switching	More pronounced for items related to the self (compared to other), as self-related information is more salient, influencing attentional and attention-to-memory processes.	Caharel et al., 2002; Fischler et al., 1987; Gray et al., 2004; Herbert, Pauli, & Herbert, 2010; Holeckova et al., 2006; Polich, 2007; Scott et al., 2005; Sui et al., 2006; Zhou et al., 2010
(F)N400	Midfrontal	• Recognition, • Familiarity	More pronounced for items related to the self (compared to other), as self-related items are processed more efficiently, leading to improved recognition/ familiarity.	Friedman & Johnson, 2000
LPC	Left parietal occipital	• Recollection	More pronounced for items related to the self (compared to other), as self-related words are predicted to be recalled more easily, but only for the first repeat.	Allan & Rugg, 1997; Allan et al., 1998; Curran, 1999, 2004; Curran & Doyle, 2011; Tsivilis et al., 2015

Methods

Participants

There were 21 participants in this study. However, the initial learning phase (explained in detail later) showed that not all participants were able to learn the target words. Five participants were rejected from the study for not being able to learn more than 40% of the target words. Thus, 16 participants were used in the behavioural analysis (eleven females, five males; age range: 21 – 60 years). However, a further four participants were removed from further analysis due to EEG artefacts. The data of the remaining 12 participants were used for EEG analysis. Of these participants, nine were female, and three were male. The average age of the participants was 29 years, ranging from 21 to 60 years old. The participants could apply for this study by responding to an advertisement on a website for people living around Oxford UK (dailyinfo.co.uk). Each experiment lasted around two hours, and the participants received 12 Pounds for taking part.

Stimuli

For *Experiment 4*, neutral word-pairs were selected from the database of Warriner, Kuperman, & Brysbaert (2013). Of these 54 word-pairs, four were used as fillers and were used to explain the experiment to the participants, ten words were used as baseline word-pairs, and the remaining 40 word-pairs were used throughout the experiment. Each word pair was presented on the middle of the screen and consisted of a cue word (on the left and a target word on the right, separated by a dash ('-'). The pairing of cue and target words were randomised across participants so that a word would have been both target and cue in the experiments and paired to different words. The pairing of words was semi-random as very obvious word pairing where the cue words primes the target word (e.g. kitchen - table or sleep - tired) were avoided.

Procedure

The experiment consisted of three main phases: a learning phase; a critical phase; and a final recall phase. The participants were seated in an electrically shielded darkened room in front of a 17″ 60hz monitor, seated 60cm away from the screen. Responses were measured using a microphone, and the researcher checked the responses online for correctness and was seated in an adjacent control room.

Learning phase

The learning phase consisted of all 54 word-pairs (including four practice word pairs and the ten baseline words pairs) and consists of two sub-phases. In the first part (the study phase) the word-pairs were displayed in the middle of the screen in white on a grey background either the label "myself", or the label "other" was displayed. The participants were instructed to memorize the word-pairs. The participants were also instructed that half of the words belonged to them, and the other half were linked to a distant stranger, someone they did not know. The participants were free to apply any mnemonic strategy that would help them to remember the word-pairs. The word pairs were shown on screen for 2500ms, followed by a blank grey screen lasting between 1000ms up to 1250ms. After all 54 word pairs were shown a test phase followed. In the test phase, only the label and cue word was displayed similar to the encoding phase, but the space with the target word was left blank. The participants were asked to recall the target word. The cue was displayed for 2500ms during which the participant had to try and remember the target word but not yet say it aloud. After a blank screen, the cue word reappeared but this time with a question mark in place of the target word, indicating to the participants to say the target word aloud if they recalled the target word. The cue and the question mark remained on the screen until a response was made or for 4500ms, after which the correct target-word was displayed for 1000ms. Each trial was again concluded with a blank screen. This setup was necessary to prevent muscle activity from disrupting the EEG data.

In total, three or four blocks of the learning phase were displayed and each time the word order was semi-randomised to prevent any condition from being repeated more than three consecutive times in a row. The number of repeats depended on the learning capabilities of the participant. All participants received at least three blocks of the learning phase, but if the participant scored lower than 40% after third block, a fourth block followed. If the participant was unable to recall more than 40% of the target words after four blocks, the participant was excluded from the rest of the experiment. See **Figure 29**, which is displaying both sub-phases of the learning phase.

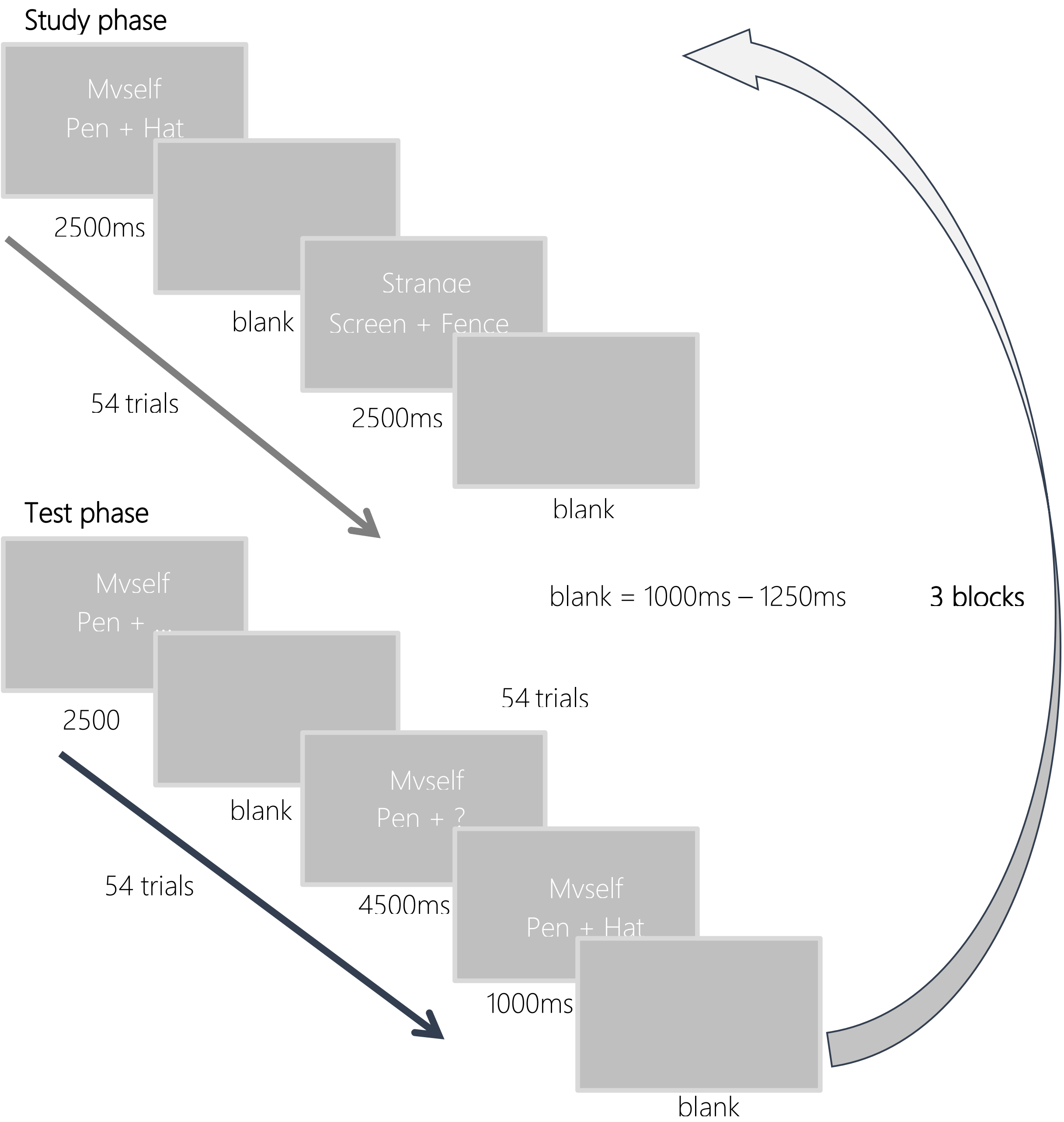

Figure 29. Procedure think/no-think paradigm, learning phase, *Experiment 5*.

Critical phase

During the critical phase, the 40 main word-pairs are used, and the filler word-pairs were used to explain the task to the participant. The ten baseline word-pairs were not used in this phase of the experiment but were used to measure the influence of the critical phase in the final recall phase.

Half of the word-pairs in the critical phase were linked to the think condition, and the remaining half were linked to the no-think condition. Each trial started by displaying a fixation-cross for 200ms, which was followed by one of the cue words in the centre of the screen. However, unlike the other phases, the cue word was displayed in one of two colours, either yellow (RGB 255, 255, 0), or jade (RGB 0, 168, 107). Participants were instructed that each colour was linked to a specific condition, either the think condition or the no-think condition, and this was counterbalanced across participants. The cue word remained on screen for 3500ms during which the participant had to try to recall the target word when in the think condition, and in the no-think condition, the participant had to actively try to suppress the recall of the target word. The participants were told they could use any method to suppress the recall of the target word but were told that reading the cue word backwards was a good way to prevent the recall of the target word (M. C. Anderson & Green, 2001). Each trial was concluded with a blank screen. One block contained all 40 cue words, and a total of twelve blocks were used in the critical phase. The cue words were semi-randomly presented in each block, making sure that each condition was never repeated more than three times sequentially. After each block, the participant was offered a self-paced break. See **Figure 30** for a schematic overview of the critical phase.

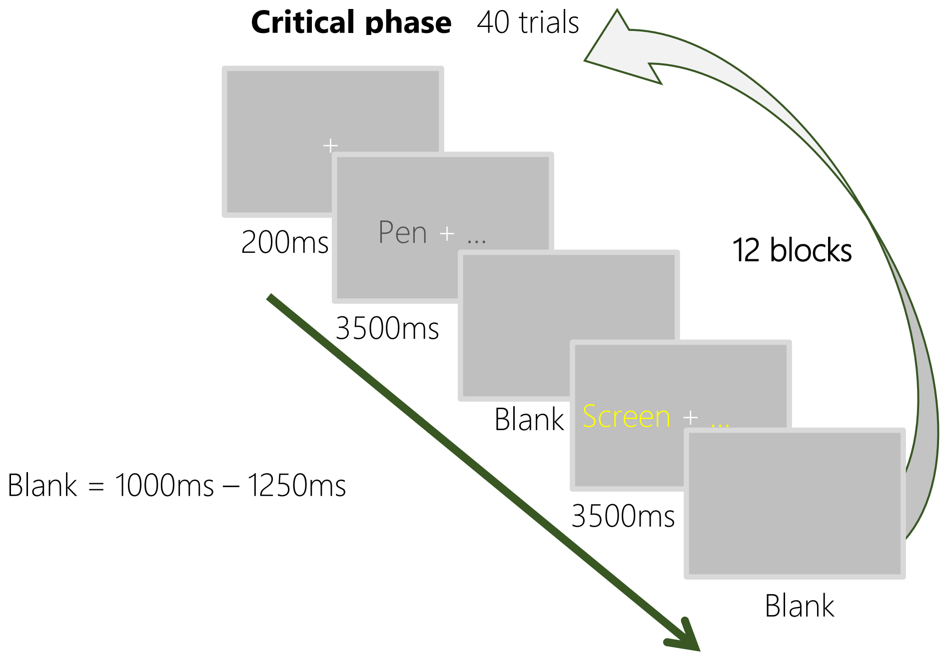

Figure 30. Procedure think/no-think paradigm, critical phase, *Experiment 5*.

Final recall phase

During the final recall phase, the participants had to try to recall all the target words and try to recall if the words were linked to themselves or to a distant other. The trials consisted of all the critical phase word-pairs and the baseline word-pairs, 50 word-pairs in total.

The final recall phase was very similar to the test phase during the learning trials although this time the label ("Myself" or "Stranger") was not displayed. Like the test phase, the cue word was displayed left to the fixation cross and a blank space to the right of the fixation cross for 2500ms, followed by an blank screen, and a response opportunity (maximal 4500ms or until response), which was again followed by an blank screen, and the trial finished by providing another response opportunity (maximal 4500ms or until response) where the participants were asked to recall if the word was linked to themselves or a stranger by saying 'self' or 'other' aloud. All recordings were recorded and scored live, although no feedback was provided during the final recall phase. See **Figure 31** for an overview of the procedure.

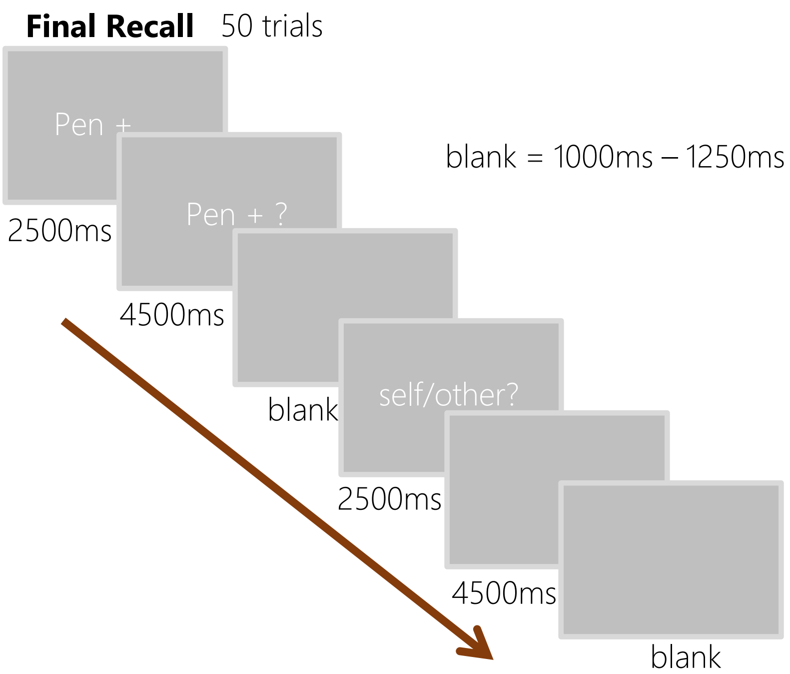

Figure 31. Procedure think/no-think paradigm, final recall phase, *Experiment 5*.

EEG recording

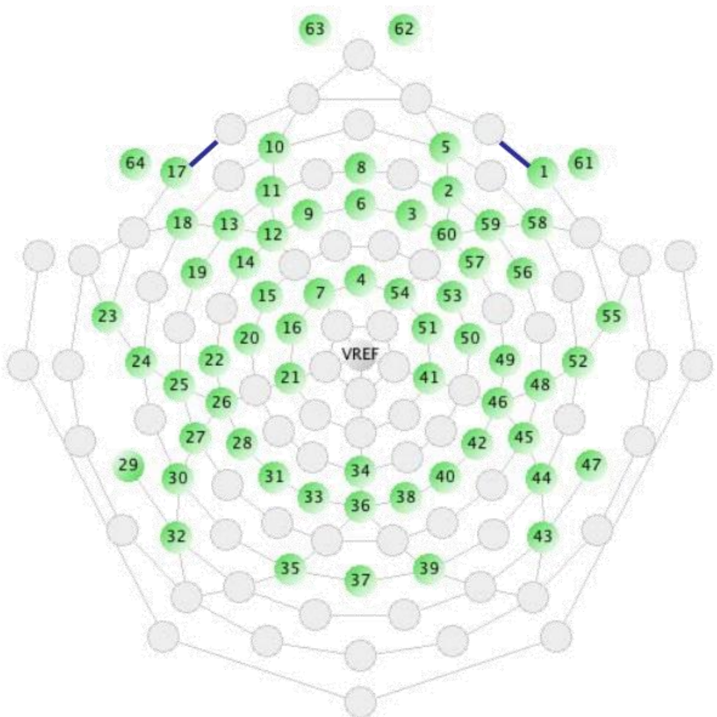

Figure 32. EEG 64-channel cap electrode layout, *Experiment 5*.

The EEG data were continuously recorded from a 64-channel electrode cap from Electrical Geodesic Inc. The data was recorded with a band-pass filter from DC to 100Hz and was digitised at a sampling rate of 500Hz. Impedance level for each electrode was aimed to be below 50kΩ. Online recording was referenced to the vertex electrode. See **Figure 32** for an electrode layout.

Offline processing was conducted using Brainvision Analyser 2 (BVA2, Brain Products GMBH) and the electrodes were re-referenced to the average of the left and right mastoid. The data was filtered (IIR Filter) with a band-pass of 0.1Hz to 25Hz, plus 50Hz Notch filter. An independent component analysis (ICA) was performed to identify any artifacts. ICA is a statistical procedure where linear independent sources can be identifies in the EEG signal. This makes ICA ideal to remove artifacts from the EEG data as most artefacts will be independent from each other. ICA was used to identify and correct horizontal and vertical eye movements.

All trials were time-locked to cue word onset and epochs were created (-100ms to 2500ms), the 100ms before stimulus onset was used as the baseline; Trials that included severe muscle artifacts or other large disruptions in the EEG signal were removed from further analysis. Four participants had to be removed because too many trials had to be rejected due to unwanted artifacts.

Although EEG was continuously recorded for the entire experiment, the final recall phase contains too few segments per condition and is therefore not included in the EEG analysis. Similarly, only block two and three were analysed in of the learning phase, as the first block resulted in too few recalled items to analyse using EEG. All data was split by conditions: perspective (self versus distant other) Time (repeat one and repeat two); and NoThink (think versus no-think). The data were further split into trials that were successfully learned or not successfully learned. This resulted in an average number of 38.13 segments in the study phase, 38.33 segments in the test phase, and 113.98 segments in the critical phase, for the correctly recalled items, over all blocks.

Data analysis

The data was potentially noisy and therefore the EEG data was analysed by applying the jackknife technique (Luck, 2014). Visual inspection of the EEG data revealed that waveforms were noisy, especially for a few participants. Applying the jackknife method allowed the application of conventional statistics to grand averages, which decreases the probability of a Type II error, whilst not increasing the probability of a Type I error (Luck, 2014). The jackknife technique works by creating leave-one-out grand averages of all participants. This resulted in twelve grand averages of the current dataset for each condition. Standard repeated ANOVAs were applied to these grand averages. Naturally, this inflated the F-values and these were corrected by dividing the F value by $(N-1)^2$. All EEG analyses were run on a dataset created with the jackknife technique.

ERP waveforms in the learning phase were quantified based on prior research using several time windows and different scalp sites aimed to identify specific ERP component in both the learning and recall phase: anterior P200, 220ms – 270ms (electrodes Cz, E4, E6, E7, E54); posterior P280, 250ms – 300ms (electrodes E33, E34, E36, E37, E38); posterior P300, 300 – 500 (electrodes E33, E34, E36, E37, E38); midfrontal N400, 300ms – 500ms (electrodes Cz, E4, E6, E7, E54); and the left posterior positivity, 600ms – 800ms (electrodes E28, E31, E33, E34. E36). Furthermore, in the recall phase, it was observed that the left posterior activity occurred later and over broader temporal parietal scalp region, therefore a broader time-window was chosen: 1000ms – 2000ms (electrodes E19, E22, E23, E24, E25). Similarly the FN400 in the critical phase seemed to occur later as well, and therefore a later time-window was also used (600ms -1200ms). All data were analysed using ANOVA within-subject repeated measures and a Bonferroni correction was applied for multiple comparisons. However due to technical and methodological issues (explained in more detail later) the sample-size of this experiment in underpowered. Therefore the tests shown in the results section might not have been able to detect all significant differences and any subtle differences may not be replicable.

Results

Behavioural findings

Learning phase

The behavioural data from the learning phase was analysed using a repeated ANOVA design: 2(perspective[self, other])×3(time[time-window 1,2,3]). During the test phase the proportion of correctly recalled words revealed a significant effect of learning over time via the main effect of time, $F(2,30) = 143.505$, $p < .001$, $\eta^2_p = .905$. This main effect of time reflects an increase in correct response accuracy over time after the first learning block to the second block ($p < .001$), and correctly recalled target words from the second learning block to the third learning block ($p < .001$). However, this increase in time is affected by perspective differently as highlighted by the significant interaction between perspective and time, $F(2,30) = 10.420$, $p < .001$, $\eta^2_p = .410$. Further analysis revealed that there was no difference between self-related and distant other-related words in the first learning cycle (p = .669). Participants did score higher after the first repeat for the self-related words when compared to the distant other-related words (p = .028). Furthermore, in their last repeat, participants recalled more target words related to a distant other than words related to the self (p = .033), see **Figure 33**, and **Table 20**. No main effect of perspective was found, F(1,15) = 1.005, p = .332.

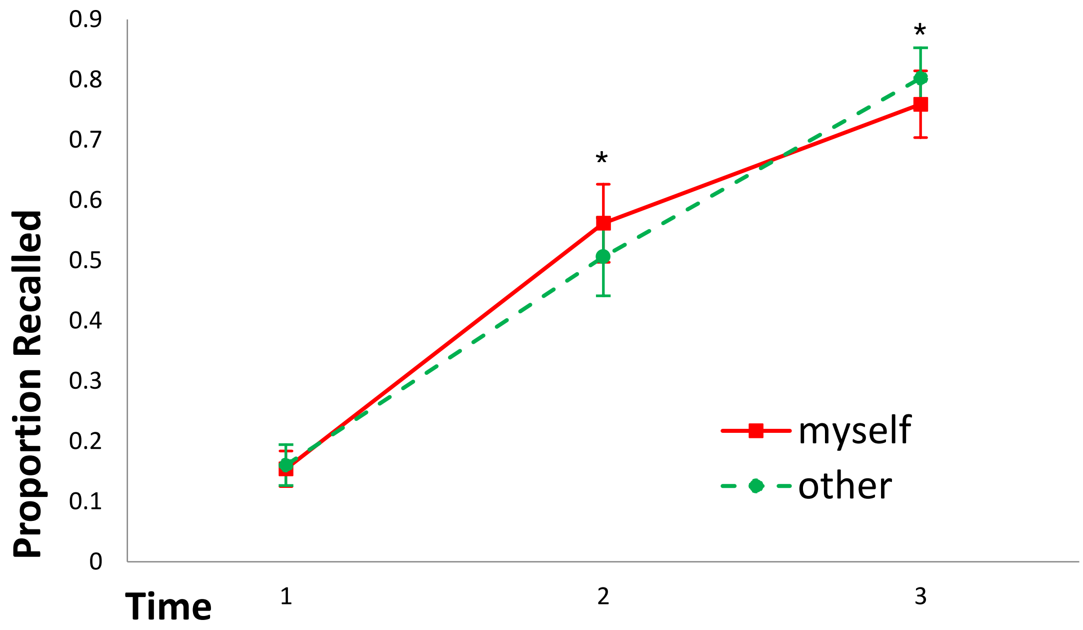

Figure 33. Test phase: proportion recalled per time-window, *Experiment 5*.
(Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

Table 20. Test phase: means proportion correct recall. The mean proportion of correct recall per time-window and perspective for the test phase. Standard error in parenthesis

	Time 1	Time 2	Time 3
Self	.149 (.026)	.563 (.052)	.748 (.050)
Other	.141 (.028)	.484 (.056)	.787 (.051)

Final Recall phase

There is no behavioural data of the critical phase as the participant did not have to respond, but for the final recall phase the baseline (words not shown during the critical phase) can be compared to the words from the critical phase. The data was analysed using a repeated ANOVA design: 3 (condition [baseline, Think, NoThink]) ×2(Perspective [Self, Other]) repeated design. This allows for a comparison between the words from the baseline and the Think/NoThink words, which should either a promotion of recall of the critical Think words when compared to baseline, and a suppression of recall of the critical NoThink words when compared to baseline.

No main effect of condition $F(2,30) = 1.772$, $p = .187$, nor a main effect of perspective, $F(1,15) = 2.357$, $p = .146$, was found. However, an interaction effect between condition and perspective was observed, $F(2,30) = 4.009$, $p = .029$, $\eta^2_p = .211$. Upon exploring this interaction a significant effect of perspective was found only for the baseline words ($p = .013$). Participants remembered more self-related target words when compared to target words related to a distant other for the baseline words. No effect of perspective was found for either the think ($p = .509$) or no-think condition ($p = 1.00$).

When comparing the think and no-think condition against the baseline condition, only the difference between baseline/distant other and think/distant other was significance ($p = .010$). Participants successfully recalled more target words from the think/distant other condition compared to the baseline/distant other condition. The difference between the no-think/distant other and baseline/distant other was not significant ($p = .219$). For the words related to the self, there was no significant difference when comparing to baseline think/self ($p = 1.00$), or no-think/self ($p = 1.00$). See Figure 34 and Table 21 for an overview of the proportion correct recall.

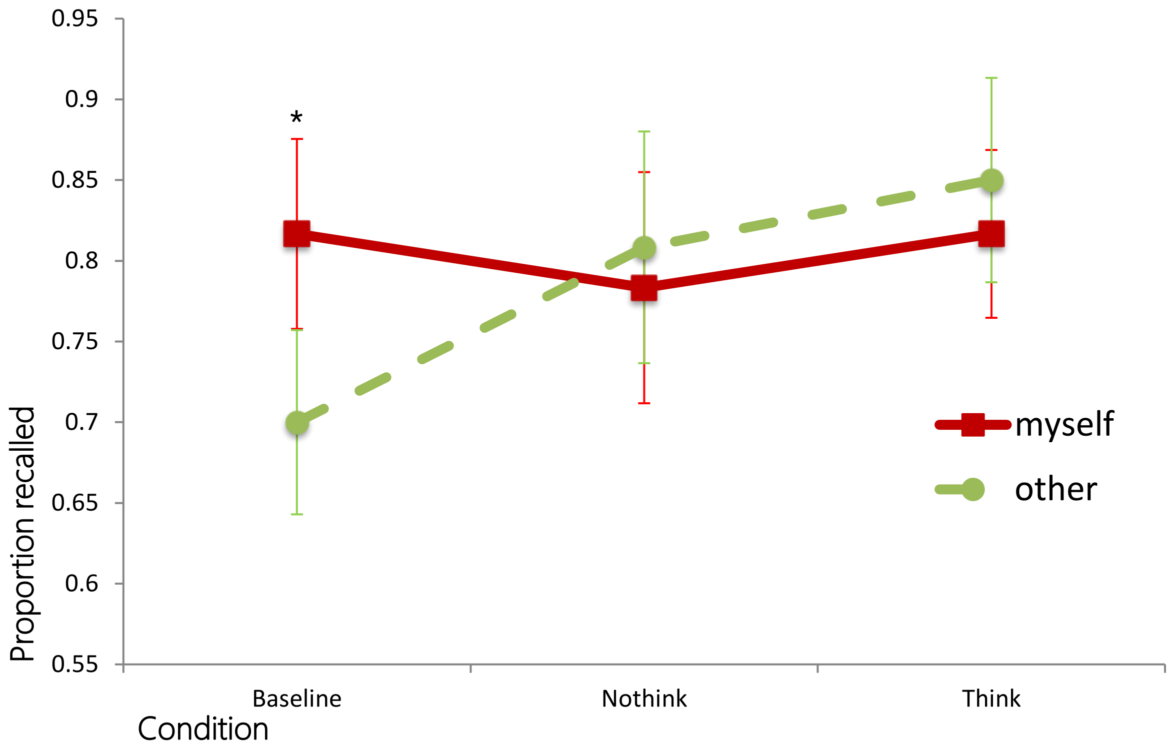

Figure 34. Effect of Think / No-think compared to baseline, *Experiment 5*.
(Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001)

Table 21. Final recall phase: means proportion correct recall. The mean proportion of correct recall per time-window and perspective for the final recall pahse. Standard error in parenthesis

	Baseline	Think	NoThink
Self	.788 (.067)	.781 (.063)	.788 (.050)
Other	.663 (.072)	.800 (.065)	.788 (.054)

Neurophysiological results

Learning phase

Study phase

All ERP components in the learning phase were analysed using a repeated ANOVA design: 2(perspective[self, other])×2(time[time-window 1,2]).

P200, central anterior (220ms – 270ms). A significant main effect of time was found, $F(1,11) = 9.325$, $p = .011$, $\eta^2_p = .459$. There was a larger P200 amplitude for repetition 1 when compared to repetition 2. Only a marginally significant effect was found between self and distant other, $F(1,11) = 4.608$, $p = .055$, $\eta^2_p = .295$. However this time-window did reveal an interaction between time and perspective, $F(1,11) = 9.133$, $p = .012$, $\eta^2_p = .459$. This interaction was driven by a P200 activity for the self-related word-pairs for during the first repeat compared to word-pairs related to a distant other during the first repeat ($p = .008$). No significant difference was found for perspective during the second repeat ($p = .101$). This means that the positive ERP component for the self word-pairs found during the first repeat was reduced in the second repeat ($p = .002$). See Figure 35 for the waveforms and scalp distribution per condition. There was no difference for the word-pairs related to a distant other between repeat one and repeat two ($p = .306$). Also, all EEG data for the encoding phase is summarised in **Table 22** Error! Reference source not found..

P280 central posterior (250ms – 300ms). Only a marginally significant main effect of time was observed for the P280 time-window, $F(1,11) = 4.737$, $p = .0521$, $\eta^2_p = .301$. A marginally greater positive P280 activity was found for repeat one when compared to repeat two. No main effect was found for perspective, $F(1,11) = 0.355$, $p = .563$, and no interaction between self and time, $F(1,11) = 1.879$, $p = .198$.

P300 central posterior (300ms – 500ms). For this time-window no main effect of time was found, $F(1,11) = 1.066$, $p = .324$, and no interaction effect was observed between time and self, $F(1,11) = 1.001$, $p = .339$. However, a main effect of perspective was found,

$F(1,11) = 5.165$, $p = .0441$, $\eta^2_p = .320$, where a larger P300 component was found for the self condition when compared to the distant other condition (see Figure 36).

N400 midfrontal (300ms – 500ms). Similarly to the P300 time-window, the FN400 midfrontal ERP component revealed an effect of perspective, $F(1,11) = 5.783$, $p = .0349$, $\eta^2_p = .345$. The words-pairs related to the self revealed a much weaker FN400 when compared to the distant other-related word-pairs. No main effect of time was found, nor an interaction effect between time and perspective (respectively, $F(1,11) = 0.967$, $p = .347$; $F(1,11) = 1.038$, $p = .330$).

LPC Left parietal occipital (600ms – 800ms). For this late time window a more positive going ERP component was observed for self when compared to distant other, $F(1,11) = 6.117$, $p = .031$, $\eta^2_p = .357$. The difference between repeat one and repeat two was also significant, $F(1,11) = 4.977$, $p = .047$, $\eta^2_p = .312$. No interaction was found between perspective and time, $F(1,11) = 0.131$, $p = .724$ (see Figure 37).

Table 22. Study phase: means EEG amplitudes. The mean EEG amplitudes during the study phase per time-window and perspective, for each suspected ERP component. Standard error in parenthesis and all values provided are in μV

	Self		Other	
ERP	Repeat 1	Repeat 2	Repeat1	Repeat 2
P200	2.82 (.047)	0.81 (.054)	1.01 (.059)	1.20 (.044)
P280	2.57 (.060)	1.54 (.053)	1.92 (.063)	1.83 (.050)
P300	1.83 (.059)	1.69 (.062)	0.85 (.050)	1.62 (.066)
N400	0.33 (.062)	-0.57 (.048)	-1.31 (.069)	-1.20 (.079)
LPC	1.94 (.067)	2.80 (.075)	1.04 (.075)	2.08 (.067)

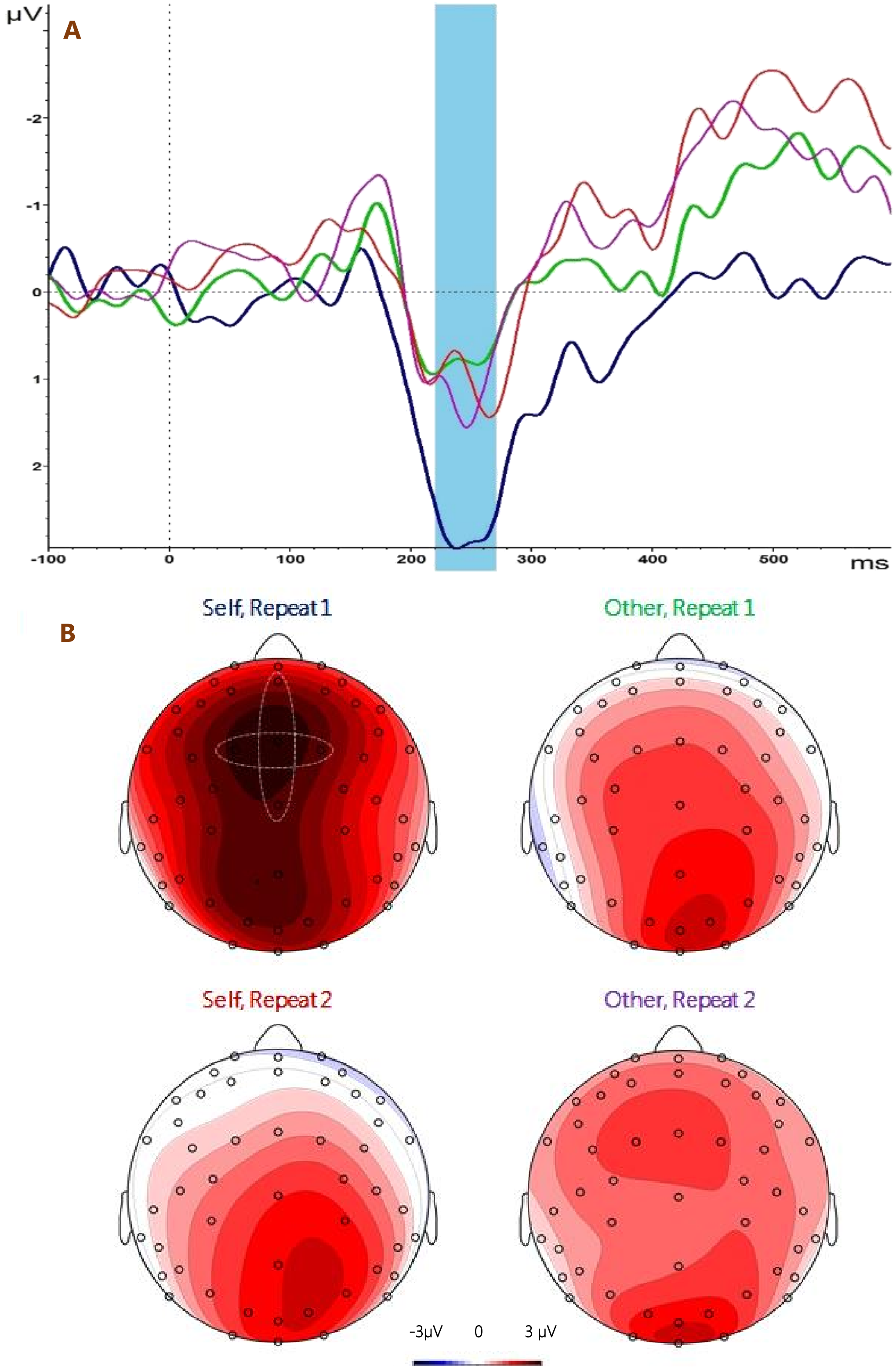

Figure 35. Study phase, P200 (220ms – 270ms), *Experiment 5*

Upper panel **(A)** shows the EEG pooled waveforms from -100ms to 600ms, from electrodes Cz, E4, E6, E7, and E54. Highlighted area is the time-window 220ms – 270ms, marking a potential P200 effect. Lower panel **(B)** shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top-left topographical map.

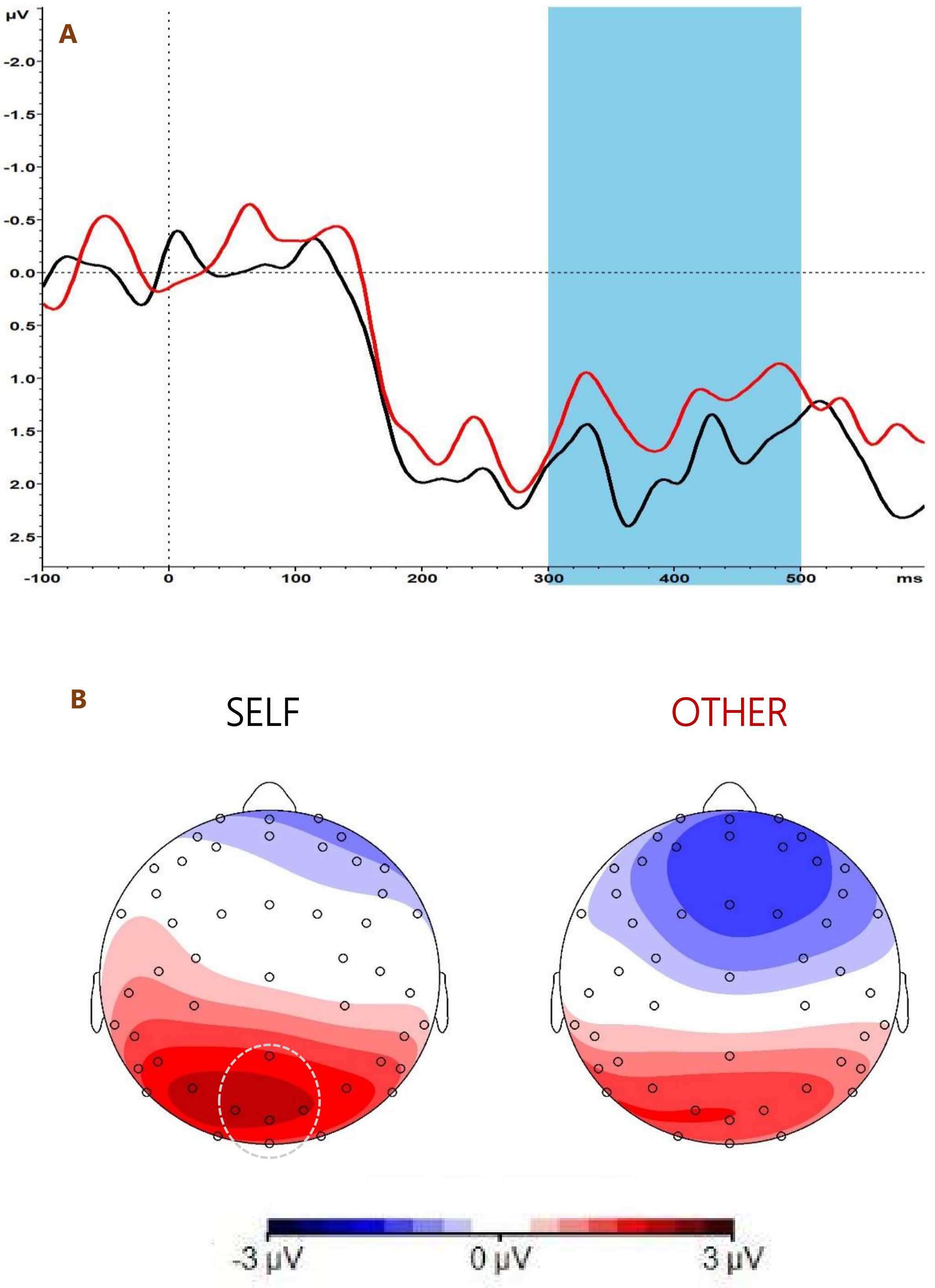

Figure 36. Study phase, P300 (300ms – 500ms), *Experiment 5*

Upper panel **(A)** shows the EEG pooled waveforms from -100ms to 600ms, from electrodes E33, E34, E36, E37, E38. Highlighted area is the time-window 300ms – 500ms, marking a potential P300 effect. Lower panel **(B)** shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top-left topographical map.

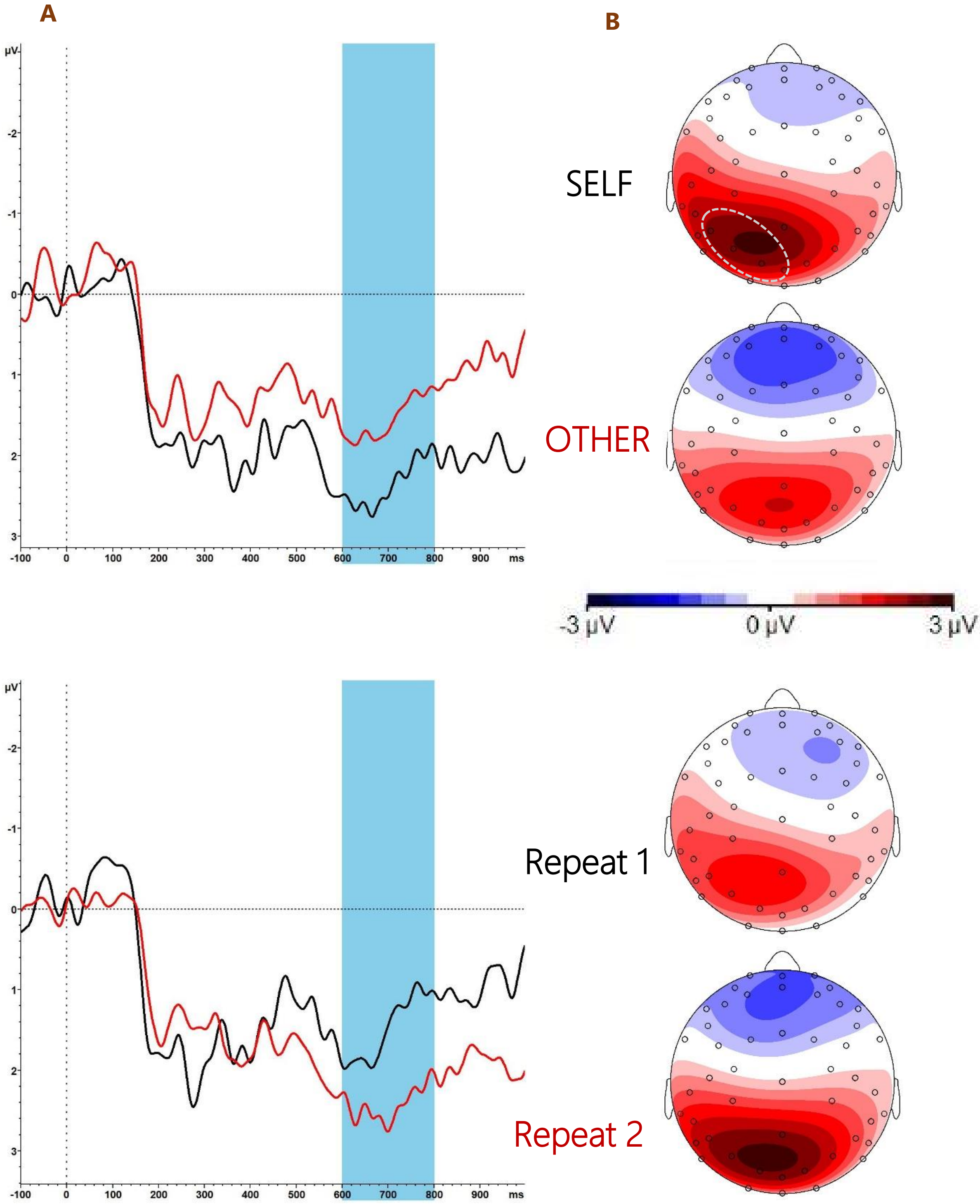

Figure 37. Study phase, LPC (600ms – 800ms), *Experiment 5*

Upper panel **(A)** shows the EEG pooled waveforms from -100ms to 600ms, from electrodes E28, E31, E33, E34. E36. Highlighted area is the time-window 600ms – 800ms, marking a potential LPC effect. Lower panel **(B)** shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top topographical map.

Test phase

P200, central anterior (220ms – 270ms). No significant differences were observed in this time-window between perspective $F(1,11) = 0.004$, $p = .952$ and time, $F(1,11) = 0.134$, $p = .721$. No significant interaction between perspective and time was observed $F(1,11) = 0.018$, $p = .896$.

P280 central anterior (250ms – 300ms). Visual inspection of the waveforms revealed no posterior P280 during the recall phase. Instead there was a central anterior positive going ERP in this time-window, which was analysed instead. However, again no interaction was found between perspective and time $F(1,11) = 0.238$, $p = .635$, and no main effects: perspective, $F(1,11) = 0.224$, $p = .645$; time, $F(1,11) = 0.635$, $p = .442$.

P300 central posterior (300ms – 500ms). Similar to the previous two time-windows, no differences were found in the P300 time-window. No effect was found of perspective ($F(1,11) = 0.006$, $p = .939$, no effect was observed of time ($F(1,11) = 2.624$, $p = .134$, and there was no interaction between perspective and time ($F(1,11) = 0.325$, $p = .580$.

Sustained midfrontal negativity (600ms – 1200ms). No FN400 was present during the recall phase. However, a sustained midfrontal negativity from 600ms to 1200ms was present. This negativity was significantly different for time, $F(1,11) = 51.531$, $p < .001$, $\eta^2_p = .824$. This difference was caused by a larger negative activity the recall of word-pairs during the second repeat when compared to the word-pairs of the first repeat (see Figure 38). No significant effect was found for perspective, $F(1,11) < .001$, $p = .999$, and no interaction between perspective and time, $F(1,11) = 0.558$, $p = .818$.

Late Left parietal occipital (1000ms – 2000ms). Again a left parietal component was observed and like the mid frontal negativity, the left posterior positivity was sustained for longer. The broad time-window of 1000ms to 2000ms was chosen to reflect this sustained left parietal temporal positivity. Again a significant effect of time was observed, $F(1,11) = 10.115$, $p = .009$, $\eta^2_p = .479$. ERP linked to the words-pairs of the first repeat showed greater positive activity when compared to the word-pairs of the second repeat. Although no main effect of perspective was found, $F(1,11) = 1.883$, $p = .197$, there was a significant interaction between perspective and time, $F(1,11) = 5.756$, $p = .035$, $\eta^2_p = .344$. This interaction was driven by a significant difference between a more positive ERP for self, compared to distant other for the first repeat ($p = .017$). This difference between self and distant other is no longer significant during the second repeat of the word-pairs ($p = .432$). This was mainly because the greater positivity for self during the first repeat was significantly reduced during the second repeat ($p = .003$), see Figure 39. The difference between the first and second repeat for word-pairs linked to a distant other was not significant ($p = .102$). See **Table 23** for an overview of the significant component found in the test phase.

Table 23. Test phase: means EEG amplitudes. The mean EEG amplitudes during the Test phase per time-window and perspective, for each suspected ERP component. Standard error in parenthesis and all values provided are in μV.

	Self		Other	
ERP	Repeat 1	Repeat 2	Repeat1	Repeat 2
P200	1.49 (.051)	1.28 (.077)	1.48 (.052)	1.34 (.056)
P280	1.80 (.058)	1.90 (.055)	1.29 (.078)	1.66 (.053)
P300	1.75 (.053)	1.54 (.087)	2.01 (.076)	2.28 (.068)
Sustained midfrontal negativity	-0.14 (.052)	-1.94 (.088)	-0.25 (.060)	-1.83 (.055)
Late LPC	2.73 (.043)	0.96 (.041)	1.55 (.061)	1.04 (.060)

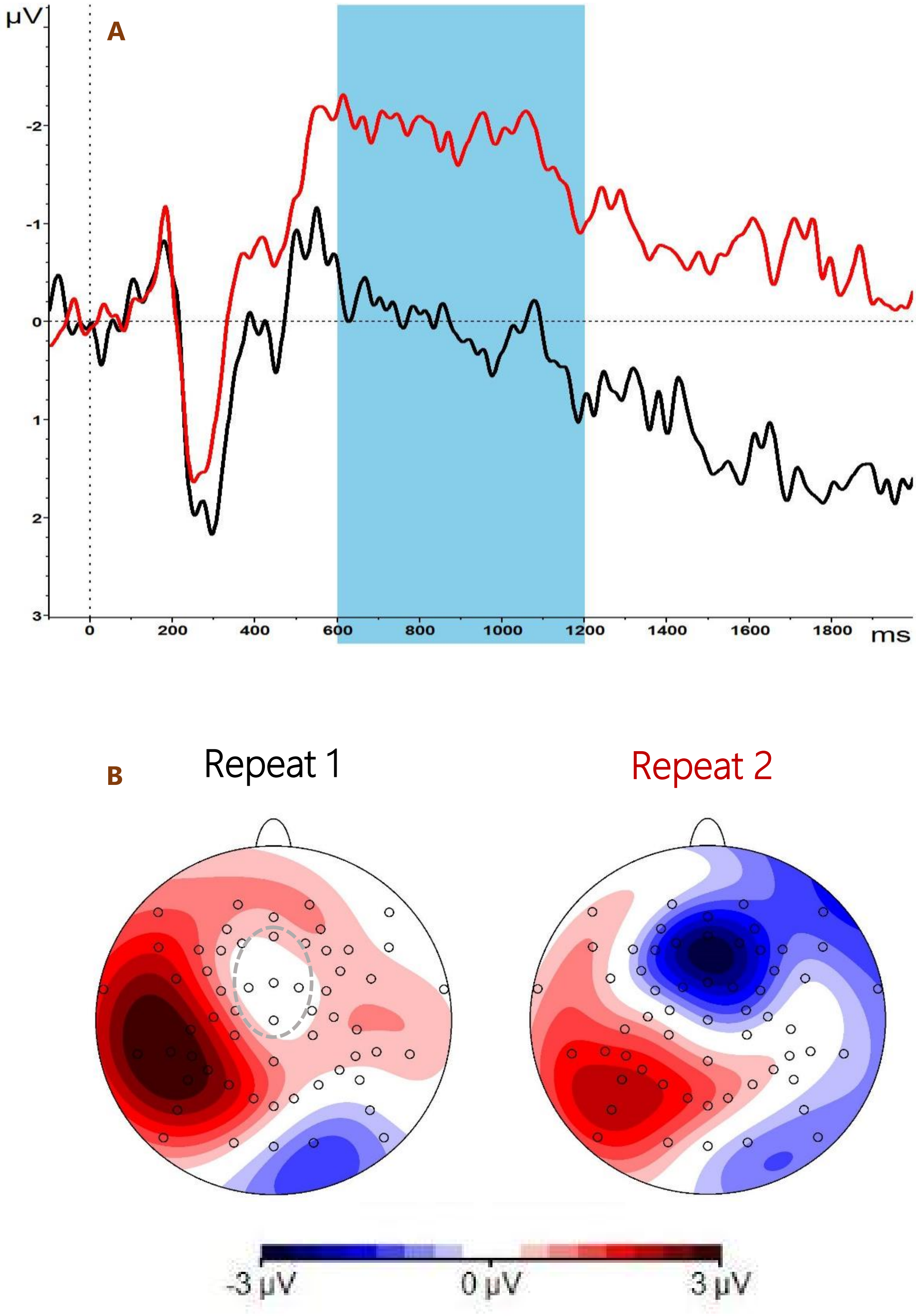

Figure 38. Study phase, Sustained midfrontal negativity (600ms – 1200ms), *Experiment 5*
Upper panel **(A)** shows the EEG pooled waveforms from -100ms to 2000ms, from electrodes Cz, E4, E6, E7, E54. Highlighted area is the time-window 600ms – 1200ms, marking a potential Sustained midfrontal negativity effect. Lower panel **(B)** shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top topographical map.

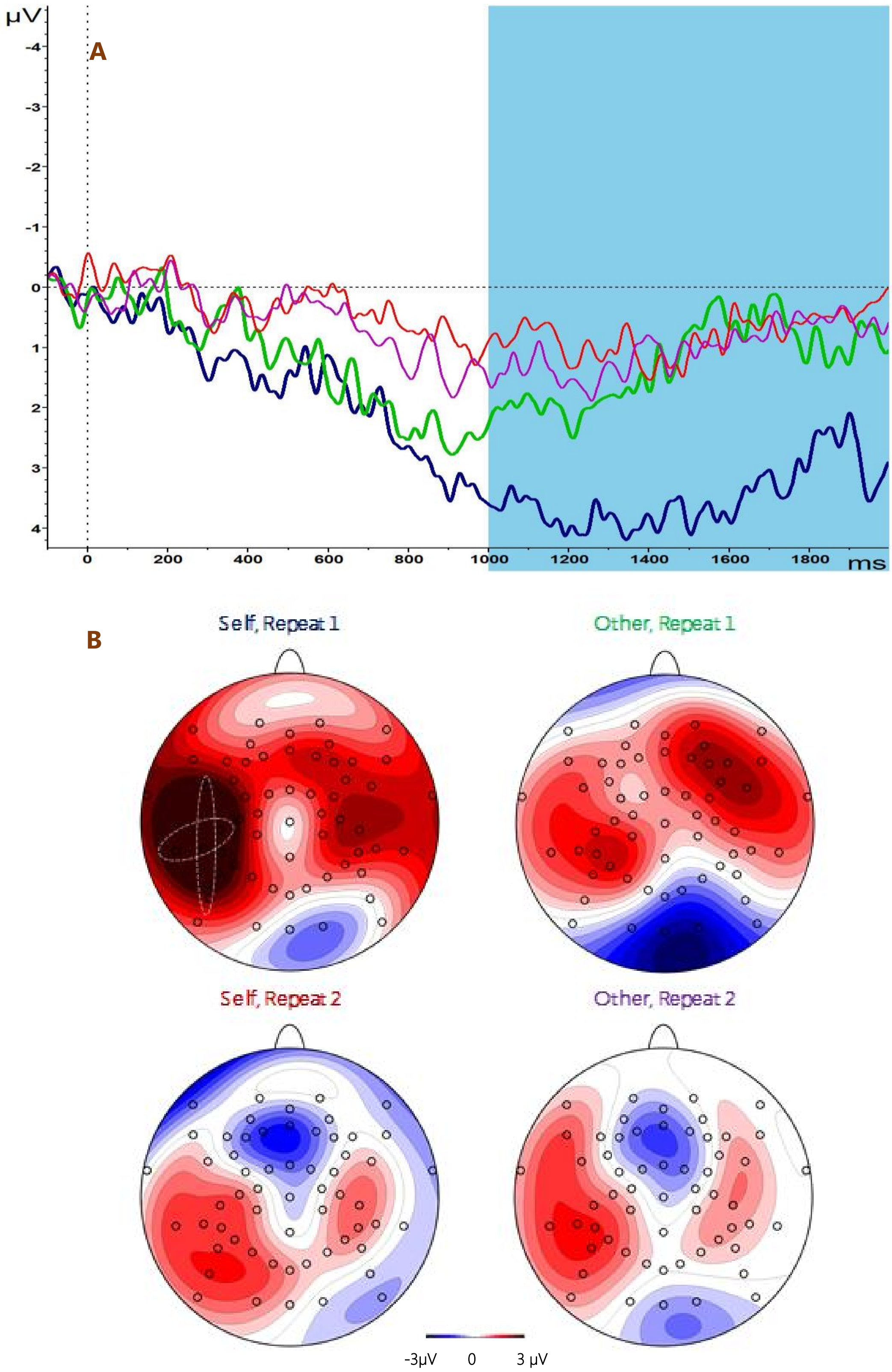

Figure 39. Test phase, late LPC (1000ms – 2000ms), *Experiment 5.* Upper panel **(A)** shows the EEG pooled waveforms from -100ms to 2000ms, from electrodes E19, E22, E24, E25, and E30. Highlighted area is the time-window 100ms – 2000ms, marking a potential late LPC effect. Lower panel **(B)** shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top-left topographical map.

Critical phase

The time-windows and region of interest for the critical phase followed regions and time-windows reported by Mecklinger et al. (2009) and Bergström et al. (2007), and aligned with the time-windows used thus far in this experiment. Furthermore, like the analysis used by Mecklinger and Bergström a comparison with not-learned and learned items is made. Although previous research by Bergström et al. (2007), suggested a N200 linked successful memory suppression, visual inspection revealed no negative deflection of the EEG signal around 200ms after stimulus onset.

P200, central anterior (220ms – 270ms). No significant differences were observed in learnedness, $F(1,11) = 0.009$, $p = .925$; NoThink, $F(1,11) = 0.354$, $p = .854$; or perspective, $F(1,11) = 0.071$, $p = .795$. Furthermore, no interactions were observed either: learnedness×NoThink×perspective, $F(1,11) = 3.517$, $p = .088$; learnedness×NoThink, $F(1,11) = 2.518$, $p = .141$; learnedness×perspective, $F(1,11) = 0.516$, $p = .488$; or perspective×NoThink, $F(1,11) = 2.555$, $p = .138$.

P300 central posterior (350ms – 450ms). Again no significant differences were found for any of the conditions (learnedness, $F(1,11) = 0.463$, $p = .510$; NoThink, $F(1,11) = 0.010$, $p = .924$; perspective, $F(1,11) = 3.5189$, $p = .087$) or their interactions (learnedness×NoThink× perspective, $F(1,11) = 0.641$, $p = .440$; learnedness×NoThink, $F(1,11) = 2.136$, $p = .172$; learnedness×perspective, $F(1,11) = 0.002$, $p = .964$; perspective×NoThink, $F(1,11) = 0.975$. $p = .345$).

Parietal positivity (450ms – 600ms). This time-window revealed a significant three-way interaction of learnedness×NoThink×perspective, $F(1,11) = 5.157$, $p = .044$, $\eta^2_p = .319$, indicating that the difference between learnedness and NoThink was not the same for perspective. A closer look revealed that in the no-think condition a greater positive activity was present for not-learned self-related words when attempting to recall the target words compared to not-learned distant other-related words when trying to suppress recall ($p = .012$). Furthermore, there was also a significant difference between the not-learned nothink words and the not-learned think words ($p = .021$) for the other-related words. This difference did not occur for not-learned items related to the self (p = .174). For the not-learned think words, there was no significant effect of perspective (p = .126), see Figure 40 and Figure 41. No such differences are observed for the learned trials: for the think trial no effect of perspective (p = .301); for the nothink trials no effect of perspective (p = .405); for the self trials no difference between think and nothink (p = .434); and for the distant other trials no difference between think and nothink (p = .324).

Anterior negativity (600ms – 800ms). A significant effect of the NoThink condition was found in the 600ms-800ms time window, $F(1,11) = 5.145$, $p = .0445$, $\eta^2_p = .319$. The ERP showed a greater negative deflection for the think trials (-1.386μV), when compared to the no-think trials (-0.756μV), see Figure 42. No other main effects were found for either perspective, $F(1,11) = 0.635$, $p = .443$; or learnedness, $F(1,11) = 0.023$, $p = .883$. Like the previous time-windows, no interactions were observed either (learnedness×NoThink×perspective, $F(1,11) = 0.061$, $p = .810$; learnedness×NoThink, $F(1,11) = 1.428$, $p = .257$; learnedness×perspective, $F(1,11) = 1.467$, $p = .251$; perspective×NoThink, $F(1,11) = 0.441$, $p = .521$). See **Table 24** for an overview of the significant ERP components found during the critical phase. In **Table 25**, all ERP results of this chapter are summarised.

Table 24. Critical phase: means EEG amplitudes. The mean EEG amplitudes during the critical phase per time-window and perspective, for each suspected ERP component. Standard error in parenthesis and all values provided are in μV

	Learned				Not Learned			
	Think		NoThink		Think		Nothink	
ERP	Self	Other	Self	Other	Self	Other	Self	Other
P200	1.38 (.03)	1.22 (.04)	1.96 (.05)	1.63 (.05)	1.43 (.05)	2.13 (.09)	1.67 (.06)	1.13 (.09)
P300	1.77 (.06)	1.63 (.05)	2.23 (.07)	1.84 (.06)	2.33 (.10)	2.43 (.10)	2.38 (.08)	1.78 (.09)
Parietal Positivity	2.02 (.07)	1.76 (.06)	2.07 (.07)	1.99 (.05)	2.20 (.10)	2.82 (.10)	2.77 (.09)	1.98 (.08)
Anterior Negativity	-1.20 (.04)	-1.26 (.05)	-1.05 (.06)	-0.88 (.03)	-1.22 (.08)	-1.87 (.08)	-0.45 (.06)	-0.65 (.06)

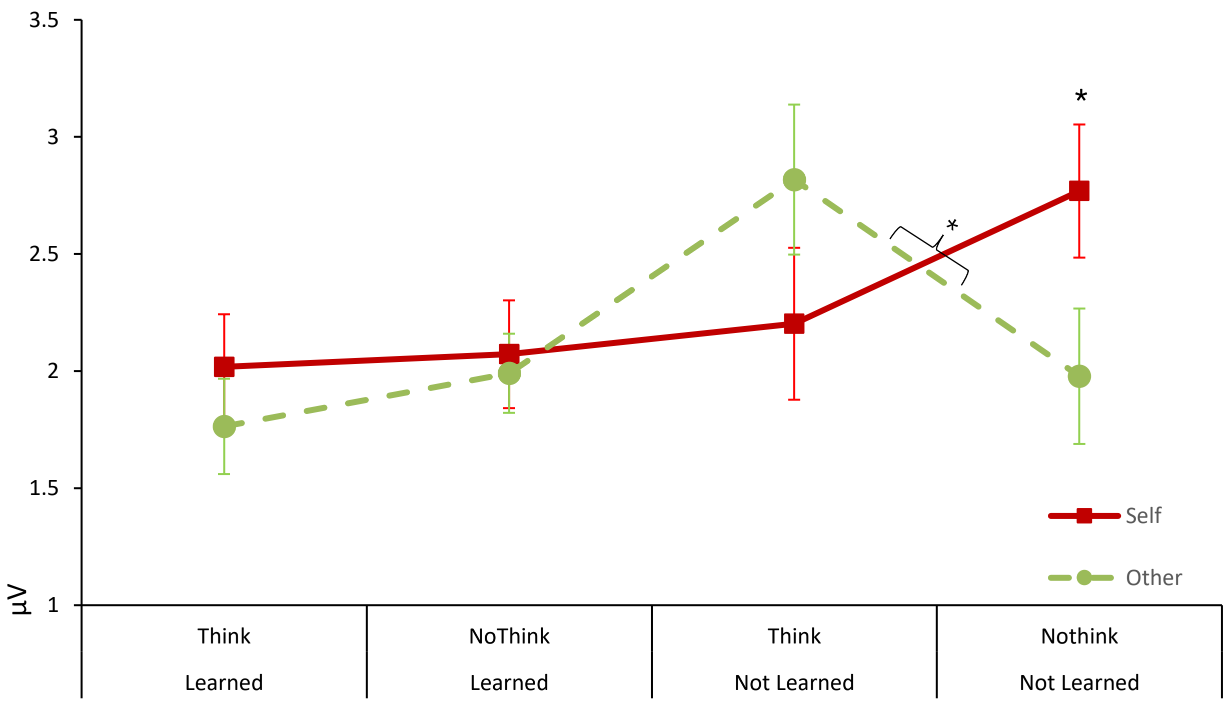

Figure 40. Critical phase, Three-way interaction Parietal Positivity (450ms – 600ms), *Experiment 5* (Error bar = Standard error, * = p<.05, ** = p<.01, *** = p<.001).

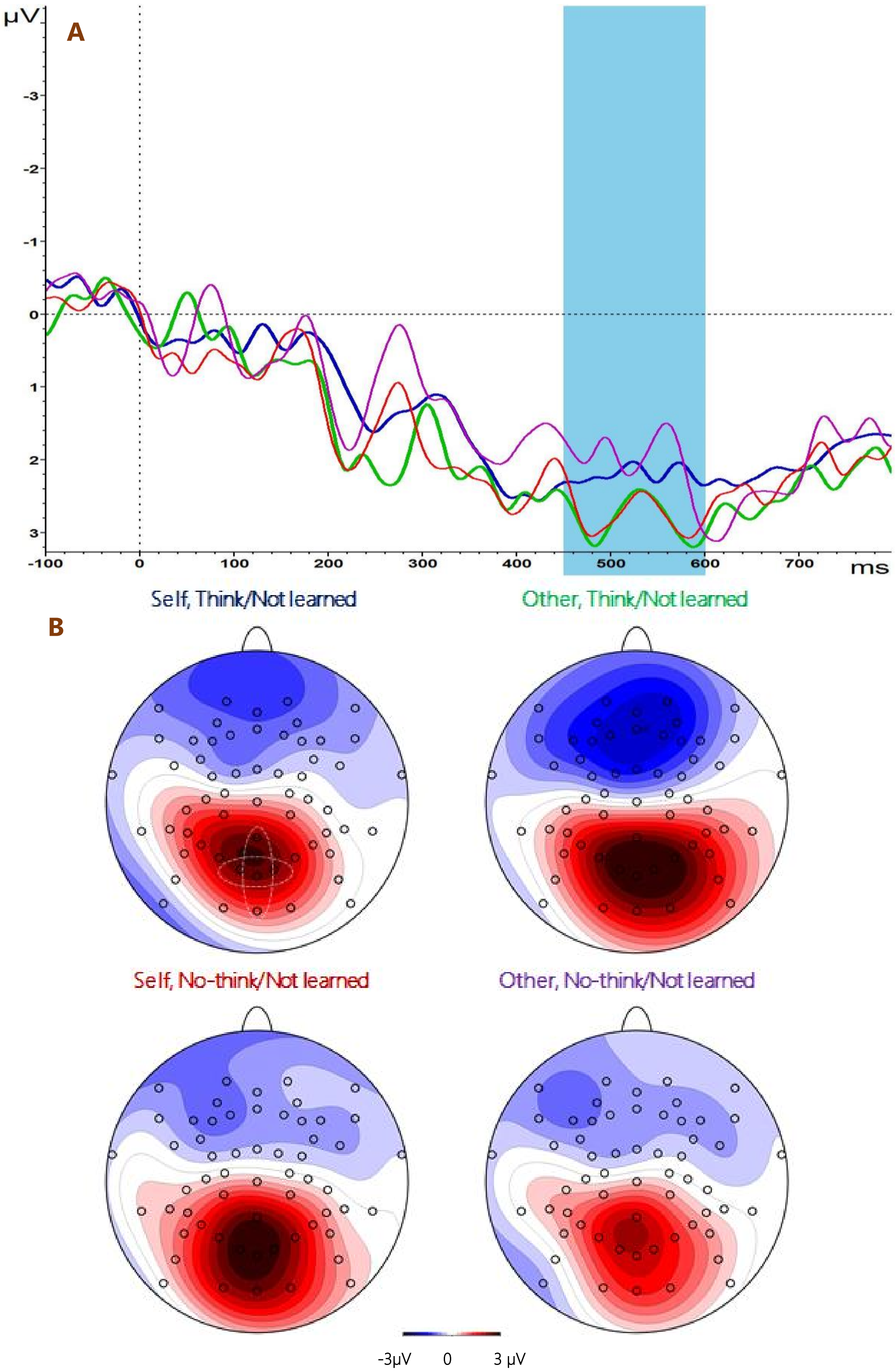

Figure 41. Critical phase, Parietal (450ms – 600ms), *Experiment 5*. Upper panel (A) shows the EEG pooled waveforms from -100ms to 800ms, from electrodes E33, E34, E36, E37, and E38. Highlighted area is the time-window 450ms – 600ms, marking a potential parietal positivity effect. Lower panel (B) shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top-left topographical map.

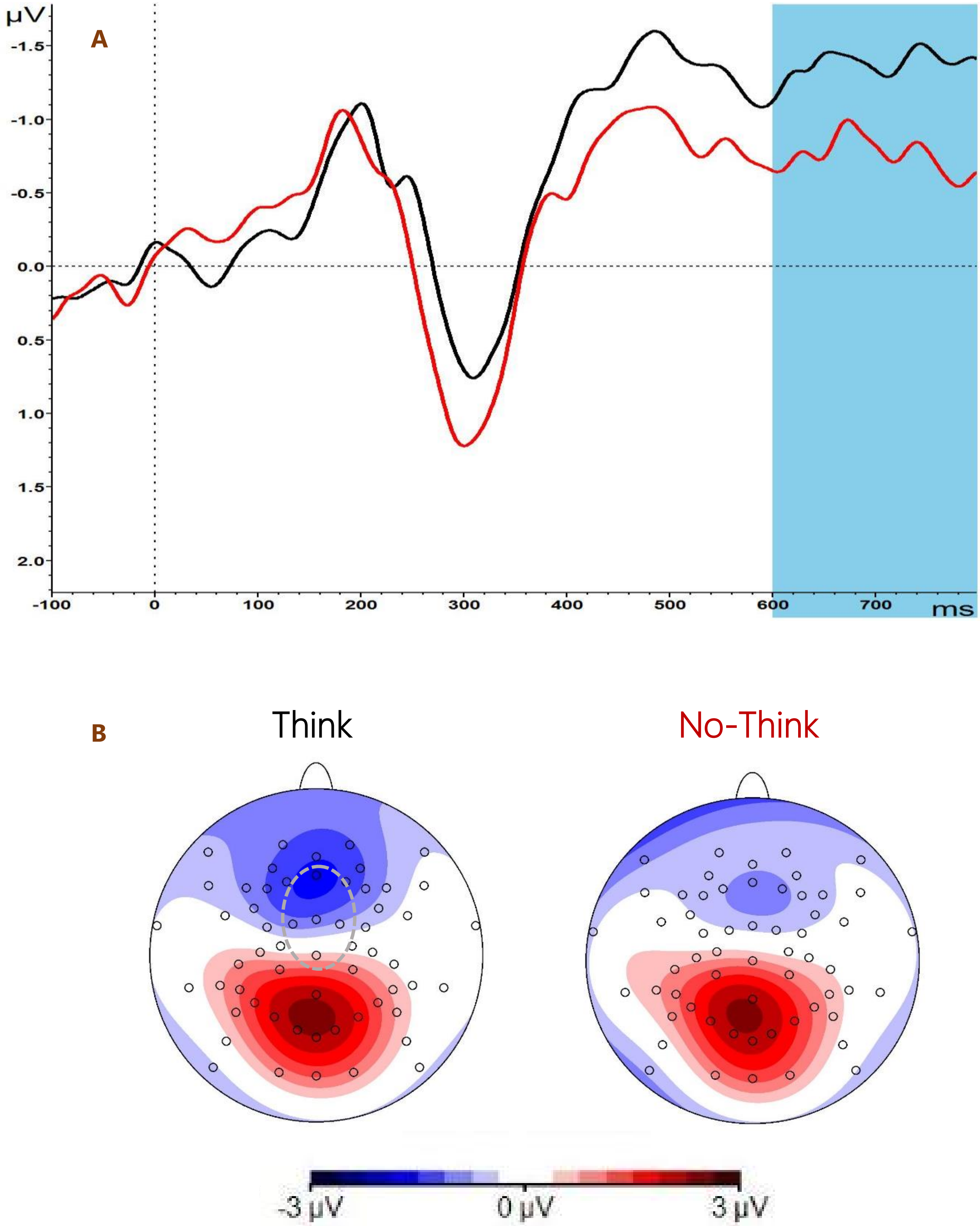

Figure 42. Critical phase, Anterior Negativity (600ms – 800ms), *Experiment 5*. Upper panel (A) shows the EEG pooled waveforms from -100ms to 800ms, from electrodes E33, E34, E36, E37, and E38. Highlighted area is the time-window 600ms – 700ms, marking a potential Anterior Negativity effect. Lower panel (B) shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top-left topographical map.

Table 25. Summary of the ERP components findings and predictions.

ERP	Location	Key words	Predictions	Results
P200	Central anterior	• Attention, • Conscious recollection	More pronounced for items related to the self (compared to other), as attention is directed to self-relevant information.	**Study phase:** Time×Perspective, greater P200 for self for repeat 1, no difference between self and other for repeat 2. **Test phase:** No differences. **Critical phase:** No differences.
N200	Central	• Inhibitory control	More pronounced for items related to the self (compared to other), as inhibitory control would be more taxed for self-related items.	Not observed
P280	Central posterior	• Recognition, • Increased memory workload, • Attention	More pronounced for items related to the self (compared to other), as retrieval and recognition is easier for self-related items.	**Study phase:** Marginally significant effect of time, where a greater effect of repeat 2 was found compared to repeat 1. **Test phase:** No differences. **Critical phase:** No differences.
P300	Central posterior	• Attention, • Self-relevant information, • Attention to memory transfer, • Attention switching	More pronounced for items related to the self (compared to other), as self-related information is more salient, influencing attentional and attention-to-memory processes.	**Study phase:** Main effect of perspective, with a more pronounced P300 for self-related words. **Test phase:** No differences. **Critical phase:** No differences.
(F)N400	Midfrontal	• Recognition, • Familiarity	More pronounced for items related to the self (compared to other), as self-related items are processed more efficiently, leading to improved recognition/ familiarity.	**Study phase:** Main effect of perspective, a more pronounced N400 was found for other-related words. **Test phase:** No N400, but a sustained midfrontal negativity was present: Main effect of time, with a greater negativity for repeat 2 compared to repeat 1. **Critical phase:** Not observed.
LPC (600-800)	Left parietal occipital	• Recollection	More pronounced for items related to the self (compared to other), as self-related words are predicted to be recalled more easily.	**Study phase:** Main effect time with greater positivity for repeat 2 than repeat 1; main effect of perspective with greater positivity for self than other. **Test phase:** a late LPC was found with a Time×Perspective difference, there was a clear self-reference effect for repeat 1 which was absent during repeat 2. **Critical phase:** Not observed.
Parietal positivity (450-600)	Parietal	• Recollection	More pronounced for items related to the self (compared to other), as self-related words are predicted to be recalled more easily.	**Study phase:** Not observed. **Test phase:** Not observed. **Critical phase:** learnedness×NoThink×perspective, see main text for a clear explanation.
Anterior negativity (600-800)	Central Anterior	• post-retrieval processing/ maintenance	N/A	**Study phase:** Not observed. **Test phase:** Not observed. **Critical phase:** Main effect of the NoThink condition, with a greater negative deflection for the think trials compared to the no-think trials.

Correlations

It also remain possible that some of the ERP components found during the learning phase are correlated with each other as some component are likely related. Therefore, a correlation analysis was performed as well of which the results can be found in **Table 26** for the study phase and in **Table 27** for the test phase.

Table 26. Study Phase ERP component correlations

	P280	P300	FN400	LPC
P200	.08	-.03	.24	-.20
P280		.74**	.19	.67*
P300			.504	.871**

* Correlation is significant at the .05 level (two-tailed)

** Correlation is significant at the .01 level (two-tailed)

Table 27. Test Phase ERP component correlations

	P280	P300	Sustained Negativity	Late LPC
P200	.89**	-.06	.45	.25
P280		.21	.28	.28
P300			-.15	.62*

* Correlation is significant at the .05 level (two-tailed)

** Correlation is significant at the .01 level (two-tailed)

For the test phase, the P280 strongly correlates positively with the P300, and the LPC. During the test phase, the P200 positively correlated strongly with the P280. Lastly, the P300 showed a strong positive correlation with the Late LPC during both the test and the study phase.

An attempt has also been made to correlate the ERP components found during the learning phase with the behavioural results observed during the test phase. These results are summarised in **Table 28**.

Table 28. Test Phase ERP component correlations with proportion correctly recalled during the testing phase.

Study						Test				
	P200	P280	P300	FN400	LPC	P200	P280	P300	Sustained Negativity	Late LPC
Self_repeat1	-.29	.33	.66*	.46	.73**	-.13	.07	.54	.09	.28
Other_repeat1	-.12	.10	.59*	.49	.66*	.05	.22	.35	.11	.04
Self_repeat2	-.43	.39	.72**	.40	.84**	-.08	.16	.67*	-.01	.32
Other_repeat2	-.32	.47	.74**	.42	.82**	-.03	.26	.65*	-.08	.30

* Correlation is significant at the .05 level (two-tailed)

** Correlation is significant at the .01 level (two-tailed)

As can be seen, the proportion of correctly recalled items positively and strongly correlated both the P300 and the LPC of the study phase. Only the items during the second repeat showed a strong positive correlation with the P300 of the test phase.

Lastly, the ERP components found during the critical phase could potentially be related. Therefore a correlation analysis was performed on these ERP components as well, see **Table 29**. The P200 showed a strong positive correlation with the P300, and Parietal Positivity, but a strong negative correlation with the Anterior Negativity. The P300 was very strongly and positively correlated with the Parietal Positivity.

Table 29. Critical Phase ERP components correlations

	P300	Parietal Positivity	Anterior Negativity
P200	.85**	.86**	-.67*
P300		.95**	-.37
Parietal Positivity			-.50

* Correlation is significant at the .05 level (two-tailed)

** Correlation is significant at the .01 level (two-tailed)

Discussion

Behavioural data

Test phase

The behavioural results show that initially self-related words are learned faster and are recalled more often than words related to a distant other. However, with repetition of the cue-target words during the learning phase, this facilitatory effect of self on memory disappears. After the second learning cycle, no more difference in recall is observed between self and a distant other. These results are similar to those of *Experiment 3* and *Experiment 4*, both of which contained a repetition element also. Therefore the conclusion remains the same: the benefit of self-related words during recall does not add to the effects of simple repetition. Self-related words are recalled more accurately initially but are 'caught-up' by distant other-related words after two repetitions. However, despite 'catching-up', after the delay of the critical phase, the baseline words showed a clear facilitatory effect of self-related words on memory. In other words, during the learning phase, the distant other-related trials might have 'caught-up' with the self-related trials, but the distant other-related words are encoded into memory less strongly compared to self-related words, as the next section will show. Overall, it is interesting that the correlation analysis showed that the proportion correct for all condition were positively correlated with the P300 and the LPC, both of which have been connected to encoding and recall (Gonsalvez & Polich, 2002; Paller & Kutas, 1992). Although all items correlated strongly and positively with these components words related to a distant other during the first repeat showed the weakest correlation, but during the second repeat the correlation between self- and other-related items were similar.

Final recall phase

The main purpose of *Experiment 5* was to investigate if the automaticity of self-related processes could be influenced by suppressing the recall of self-related words, as done in the think/no-think paradigm. Previous research found that memory could be suppressed by forcefully redirecting one's thoughts away when primed for a memory. In other words, by not thinking of the memory over several repetitions, the to-be-recalled information would be suppressed. However, no direct evidence for suppression was found, as recall of words related to a distant other or words related to the self were not decreased compared to baseline for the no-think trials, compared to the think trials. Although the distant other-related words of the think condition were recalled significantly more often when compared to the baseline words, this is most likely the result of forgetting of the baseline distant other-related words, whereas the distant other-think words were repeated in the critical phase and thus remembered more often. In fact, even the no-think distant other related words approach significance in favour of remembering more words compared to baseline distant other-related words. This forgetting of the distant other related words did not happen for the self-related baseline words as no difference was observed between baseline self-related words and self-think and self-no-think words. Together these results show the robustness of self-related words in long-term memory and failed to reveal any form of suppression in the no-think trials in all conditions.

It should be noted that, since the initial publications of suppression of memories by executive control (M. C. Anderson & Green, 2001; M. C. Anderson & Levy, 2009), several studies have reported that they have been unable to replicate the results of suppression using the think/no-think paradigm (Bulevich, Roediger, Balota, & Butler, 2006; Hertel & Calcaterra, 2005; Hertel & Gerstle, 2003). However, despite also not replicating the behavioural results of Anderson and Green (2001) the EEG studies of Bergström, Velmans, Fockert, and Richardson-klavehn, (2007) and Mecklinger, Parra, and Waldhauser (2009) did find ERP correlates linked to intentional forgetting (P200, N200, P300, and LPC). It was exactly these ERP components the current experiments aimed to replicate for the words related to a distant other, but not for self-relevant words as these were speculated to be automatically processed too fast to be able to be suppressed intentionally.

EEG data

Learning phase

The free recall *Experiment 4*, where during the matching task, the self-priority effect disappeared after three repetitions, only showed that the matching judgment was no longer faster and more accurate for the self-related trials compared the distant other-related trials. As the matching task is not a specific encoding task, no conclusions could be drawn beyond the improved attention for self-related items. The current study phase does allow an examination of encoding via the EEG data. However, due to the nature of the study phase and the methodological limitations involved, not just encoding, but recall occurred at the same time. This is because of the repetition element within this experiment. Since the first block did not contain enough correctly recalled items, only the second and third block were used in the EEG analysis. This means that repetition, and therefore potential recognition or recall, is already present with the first repetition. In other words, the presenting of the cue and target words during the study phase would result in recognition (from the first block) while also attempting to study (or encode) the cue and target word pair.

The ERP findings in the study phase showed a central anterior P200 ERP, which was more pronounced for the self-related words when compared to words related to a distant other but more interestingly this effect interacted with time. This interaction revealed that although there is a more positive ERP activity for self-related words at first, the greater positivity disappears with further repetition. As predicted, this finding can reflect additional attentional processes directed towards self-related information (Mangun & Hillyard, 1995; Peters et al., 2005) for the first repetition. The second repetition no longer shows this enhanced P200 for self-related items. The experiments involving repetition in this thesis (*Experiment 3 and Experiment 4*) have shown that the benefit of self-related information is 'caught-up' after two repetitions, these result possibly indicate that self-related information no longer benefits from increased early attentional processing with repetition. As seen in earlier studies the P200 observed in this experiment is followed by a later P280 (Chapman et al., 2015; Dunn et al., 1998; Mangels et al., 2001), which possibly indicates an attention to memory process.

This anterior to posterior ERP could reflect the involvement of attentional networks proposed by Posner and Dehaene (1994). In this experiment, the self-related information initially captures attention, which leads to an increased P200. This attended information is then engaged further to help memory retrieval or recognition. This stage of information processing might be similar regardless of perspective, and therefore, no difference in ERP's was found between self and distant other-related information in the P280 time window. Like the previous two components, the P300 found in this study has also been investigated to examine attentional and memory processes (Polich, 2007).

The P300 found during the study phase was more positive for self-related information when compared to distant other-related information. This greater positivity for self-related information could reflect the greater saliency of self-relevant information. The P300 has been linked to target discrimination, and like the P280, it is involved in the maintenance of attended to information (Polich, 2007). Interesting here is that self-related information increased the amplitude of the P300 component associated with inhibitory processes for self-relevant information which the TPJ mentioned in the self-relevance network is proposed to do (Corbetta & Shulman, 2002), and research has linked the P300 to the parietal cortex and the TPJ specifically as a potential generator of the P300 (Linden, 2005). The TPJ, in turn, is part of the DMN which is highly implicated in self-relevant information processing (Northoff & Bermpohl, 2004; Qin & Northoff, 2011; Spreng & Grady, 2009; Whitfield-Gabrieli et al., 2009). It is also interesting is that the P300 is related to the LPC as shown by a strong positive correlation. This helps highlight that the P300 could be involved in encoding information into memory as previous research as suggested (Polich, 2007).

After the P300, a negative going signal was observed around 400ms after word-pair onset, this midfrontal FN400 was more sensitive (greater negativity) to distant other-related information compared to information related to the self. With the link of familiarity or memory recognition to the FN400 (Friedman & Johnson, 2000), it is possible that the greater negativity found for distant other-related information is due to the increased difficulty in encoding distant other-related information compared to self-related information. However, if this is true, then an interaction with time would be expected as distant other-related words are recalled more often during the last repeat than self-related words. However, no such interaction was observed. It is possible that due to the increased binding of self-relevant information the recollection of self-related words is still less effortful, although this does not lead to an increase in recall per se. This could indicate that despite the 'catch-up' of distant other-related information, the self-related information is still processed more easily, however, more research is required. In short, there may be two distinct neural processes involved with self- and distant other-related information processing: a sustained effortful process related to distant other-related information as reflected by an enhanced N400 for word-pairs linked to a distant other; and an enhanced P200 and P300 for self-related information.

The last time-window investigated during the encoding phase was the LPC which has been connected to recollection (Allan & Rugg, 1997; Allan et al., 1998; Curran, 1999, 2004; Curran & Doyle, 2011; Tsivilis et al., 2015). As predicted, a larger LPC was found for both time and perspective. However, the expected interaction with time was not found. This is probably because this phase was an encoding task with both cue- and target-words presented on screen, allowing for easier encoding, and recollection from the first block. Together these results show a clear engagement of attention and memory-related electrophysiological processes as reflected by the P200, P300, FN400, and the LPC during the test phase, with self- and distant other-related information clearly differentiated.

Test phase

It is important to realise that with the first repetition of the test phase, the participant would have seen the cue- and target-words four times already. This could explain why, by the time the first repeat for the recall phase appears, no differences are observed for perspective. The late sustained mid frontal negativity showed a more negative activity for the second repeat compared to the first repeat. As mentioned In introduction of this chapter, the FN400 is a measure of familiarity and recognition. As such, the familiarity of the word-pairs after the second repeat should be more recognizable and familiar than words from an earlier repetition, resulting in a more enhanced FN400.

The last component to be analysed in the test phase was the late LPC. For this ERP, a similar pattern was revealed as the early P200 ERP during the study phase. Namely, a greater left parietal positivity was observed for self-related information compared to information related to a distant other, but only for the first repetition. The greater positivity for self-related information disappears with the second repetition. As mentioned before, the LPC is linked to recollection, and typically a more positive LPC is linked to successfully recalled items. In this sense, a more positive LPC for self-related information could reflect easier recollection of self-related information. However, this does not explain why, during the second repetition, the LPC for the self is indistinguishable from distant other-related information. Unless the 'catching-up' of distant other-related information to self-related information as suggested earlier in this chapter, is reflected by the LPC (i.e. recollection of both conditions is equally easy). Conjointly, this effect mirrors the behavioural finding, as self-relevant information is no longer recalled more often with the second repetition. As with the P200 during the learning phase, the late LPC during the test phase is no longer sensitive to self-relevant information after the first repeat. Possibly reflecting that self-relevant information is no longer more salient compared to distant other-relevant information.

Critical phase

In the critical phase, an attempt was made to suppress memories. The aim of the current experiment was to see how self-related versus distant other-related information processing would impact these NoThink ERPs. The current study was modelled after earlier research, which reported a link between frontal selection positivity (P200) and attention to think, within the think/no-think paradigm. This earlier research also found a central parietal N200 which was believed to be associated with inhibition for the no-think trials, a P300 evaluation process, and a greater LPC for learned words regardless of

NoThink condition (Bergström et al., 2007; Mecklinger et al., 2009). This is likely because The LPC component found in the current study is not the same as in previous research as no difference was found between the think and no-think learned words. In the current study, a difference was only observed between a more positive LPC for distant other-related think words compared to no-think words, but only for the not-learned trials. Similarly, for the not-learned words in the no-think condition, words related to the self were linked to a more positive going LPC compared to the not-learned no-think words related to a distant other. However, it is not surprising that no effect of perspective was found for the learned words as the learning phase already showed that after two repetitions the effect of self is abolished. This means that by the time the critical phase starts (which is essentially more repetition), self and distant other-related information are recalled equally.

It was unexpected that, unlike the previous studies (Bergström et al., 2007; Mecklinger et al., 2009), no ERP differences between think and no-think trials were found for the learned words. In other words, the study failed to replicate the basic 'signature' of the think/no-think paradigm. Why is this? One possibility is that it is due to the high percentage of correctly learned (76%) words in our paradigm, versus 55% (Bergström et al., 2007) and 68% (Mecklinger et al., 2009). This meant it was possibly more difficult to suppress the recollection of the target words upon presentation of the cue word. However, since there was no way of ensuring that participants followed the given instructions during the critical phase, it is also possible that participants did not perform the no-think task correctly.

Nonetheless, the difference with the parietal positivity between perspectives for the no-think not-learned words remains interesting. A parietal positivity was found for the not learned self-related words, for both the think and no think condition. If the amplitude of the parietal positivity is interpreted as reflecting retrieval attempt difficulty, then no difference was found for the self-related not learned words between the think and no-think trials. This means that for the self-related words, both the think and no-think trials resulted in an attempt to retrieve the target word. These retrieval attempts were much reduced (I.e. a reduced parietal positivity) for the distant other-related no think not learned words when compared to the distant other-related think not learned words. This suggests that a retrieval attempt was made for the think trials, but the retrieval attempt of the no-think trials was less strong. Tentatively, it is, therefore, possible that the retrieval attempts for the self-related words were equally persistent, which in turn could support the notion that self-related information processing is an uncontrollable automatic process. For the learned trials, this effect does not occur because repetition strongly encoded the words-pairs equally for both perspectives, which made suppression equally difficult for both conditions.

Finally, an ERP effect was found in the shape of an anterior negativity. This negative deflection of the EEG signal was observed for the think trials and not for the no-think trials. The anterior negativity probably reflects the different cognitive requirements for the think and no-think trials. For the no-think trials, the participant was encouraged to read the cue word backwards to aid in suppressing the recall of the target word, whereas the think condition required the participant to remember the target words and keeps the target word in mind until the next phase. The greater negativity found could be similar to the sustained negativity observed in the recall phase, meaning that the anterior negativity found in the critical phase potentially reflects post-retrieval processing/maintenance of the recalled target word.

The correlations analysis showed that the ERP components found (P200, P300, parietal positivity, & anterior negativity) seem to be related as they were all strongly correlated. The exceptions seems to be that the anterior negativity is not correlated with the P300 or the parietal positivity. However, this could reflect the possibility that the P300 and the parietal positivity are more involved in memory processes.

The main limitation of *Experiment 5* is the inefficacy of the think/no-think paradigm, at least under the conditions tested in this study. One major limitation of this experiment is the lack of suppression compared to baseline for the no-think trials. Both

ERP and behavioural data revealed no effect of suppression. The main aim of this paradigm was to show that recall of target words could be actively suppressed. The aim of *Experiment 5* was to explore if this suppression would happen for self-related trials. It was expected that since self-related information processing is automatic, suppression would be more difficult if not impossible. Therefore, not finding any form of suppression of target words severely limits the interpretation of the results. It should be noted that several behavioural studies other studies have also been unable to replicate the putative memory suppression effect in the think/no-think paradigm (Bulevich et al., 2006; Hertel & Calcaterra, 2005; Hertel & Gerstle, 2003). However, this study not only failed to replicate the behavioural aspect but also no modulation of the ERPs associated with the memory suppression manipulation was found. Thus this study also failed to replicate the findings of two separate ERP studies of the think/no-think effect (Bergström et al., 2007; Mecklinger et al., 2009).

The failure to replicate the think/no-think manipulation could be argued to be a consequence of low statistical power. Arguably this study was underpowered in having relatively few participants (*N*=12). There are a number of reasons for the arguably low N. Firstly, several participants did not complete the study because they could not reach the 40% recall rate of the word-list after four repetitions. Unlike many psychological studies, most participants were recruited from around Oxfordshire and were not university students. Although this is better for generalisation purposes, these participants were no longer used to memorising information to the same degree university student can be expected to be. Furthermore, although intelligence was not measured, the general population's intelligence is likely to be lower compared to university students.

The EEG system itself was arguably unsuited for this experiment. The system used involves an older technology which is poor at proving clear data across the duration of long (i.e. more than 30 minutes) experiments. The impedance levels tend to rise fairly quickly after this (due to the EEG relying on water-based conductance to control impedances (rather than a gel-based system). This undoubtedly resulted in more noise in the signal the longer the experiment lasted. This meant that many trials had to be removed due to poor signal. The removal of EEG trials resulted in not enough EEG trials for several participants to have an acceptable signal to noise ratio (less than 20 segments). Everything combined, the participants' attrition rate was roughly 50%. Therefore, it was decided that is was not feasible or practical to continue this experiment with more participants. A major redesign of this paradigm is required to make this a valid approach. As discussed later, the suppression paradigm is also not replicated very robustly by other researchers and a lack of behavioural evidence for suppression makes the interpretation of the EEG signals more difficult. It has been argued that EEG components can show suppression attempts even if it does not result in actual suppression in the behavioural data (Bergström, Velmans, De Fockert, & Richardson-klavehn, 2007).

Conclusion

Despite the limitation, the results did allow for insight into the automaticity of the self as possible retrieval attempts seemed to be present in the think condition with distant other-related words, compared to the no-think condition. Moreover, this difference was not observed for the self-related words. This possibly suggests a similar level of retrieval attempts of the self-related words for the think and no-think not learned trials. Less intense retrieval attempts were present for the no-think not learned distant other-related trials when compared to the think not learned distant other-related trials. However, further research is required to further substantiate this.

Furthermore, the memory encoding and subsequent recall have been able to elucidate the robustness of self-referenced information as it seems to not suffer from the same level of forgetting when compared to information related to a distant other. Moreover, this research has replicated the findings of *Experiment 3 and Experiment 4* and showed a steeper learning curve for self-related words of which the ceiling is reached faster than distant other-related words. More importantly, the ERP findings help support the previous and current conclusion during encoding of an early benefit for self-relevant information (P200), greater attentional/memory saliency for self-relevant information in general (P300, FN400), but distant other-related information does "catch-up" (LPC).

With this *Experiment 5*, an attempt was made to examine the automaticity of the self-related processes via memory suppression and repetition. However, this research question does require a deviation from the methods used in most of this thesis. Therefore, the last EEG experiment will study the underlying electrophysiological mechanism of the matching task combined with a free-recall experiment. Compared to *Experiment 5*, *Experiment 6* will be a more focussed experiment. Where the think/no-think paradigm was interesting to examine if suppression of self-related words was possible, the EEG system was not suited for this type of (long) experiment, as discussed earlier. *Experiment 6* therefore focusses on the matching task used in the previous chapters 2, 4 and 5. The matching task is much shorter and more controlled compared to the think/no-think paradigm. This should allow for a more focussed investigation of the relevant ERP component found in this chapter. Also, *Experiment 5* did not use emotional words, and therefore, in *Experiment 6*, emotional words are once more used in the matching task, as this would allow for an EEG analysis on emotional self-relevant information. In short, the next chapter will allow for a more direct investigation of the underlying neurophysiological mechanisms of the matching task, and the replication of the earlier matching task experiments (*Experiments 1a-d*, *3*, *& 4)*. Furthermore, by using repeating blocks with free-recall the next chapter will draw together the findings of the previous chapters on repetition (*Experiment 3 and 4)* and the self-reference effect. Lastly, since the redundancy gain (*Experiment 2)* showed super capacity, an increase of recall difficulty might help show the benefit of emotional self-related information. Using free-recall, the potential influence of self-related information will be maximised. This would allow for the possibility to see if emotional self-related information will be recalled more compared to just emotional or self-related information alone.

Chapter 7:

Self, emotion & free recall

Introduction Experiment 6

This *Experiment 6* aimed to explore the neurophysiological processes involved in the matching task paradigm, used in this thesis. Furthermore, this experiment would use free-recall as the follow-up memory task, similar to *Experiment 4*.

The preceding experiments (*Experiments 1c-1d and 2)* suggested an influence of emotion on self-related information, especially the redundancy gain study. *Experiment 2* showed that super-capacity (i.e. the presence of integration) does exist for self-relevant positive words. Nonetheless, despite the observed super-capacity, positive self-related words were not recalled more often than just positive/stranger or self-related/neutral words alone.

For this reason, the influence of self-related positive words is examined in this *Experiment 6*. The paradigm used for the current experiment was similar to *Experiment 4*. However, unlike *Experiment 4,* all words are presented only once without repetition. The main goal for this free-recall version is to increase the memory workload for the participant. The reason for this is that an increased memory load may allow for the self-reference effect to emerge, more clearly. Furthermore, in the previous chapters, it was found that self-related words and emotional words interact. Nonetheless, emotional self-related words were not recalled more often than self-related words or emotional words. However, the redundancy gain experiment did show super-capacity, and therefore, emotional self-relevant words should lead to better recall. It is possible that with a more difficult memory task, the observed super capacity would results in better memory performance for emotional self-related word compared to emotional words or self-related words by themselves. With old/new experiments and cued recall experiments, the cue helps prime recollection or recognition of the to-be-remembered items. Therefore, the memory workload is lower for these cued experiments when compared to an unstructured and un-cued free-recall task. By increasing the memory load and increasing the difficulty of the recall task, it is predicted that super-capacity of positive self-related words will be translated into more recalled items than self-related or emotional words alone. Moreover, since this is an EEG experiment, the underlying electrophysiological correlates will also be examined in order to shed additional light on these cognitive processes.

The matching paradigms used in this thesis (or the original perceptual matching paradigm (Sui et al., 2012)) have not been used combined with EEG methods before. Therefore this novel approach examined if early attentional processes are influenced by self-relevant information. All matching experiments in this thesis provide support for a clear self-priority effect directing attention towards self-relevant information compared to information not related to the self.

The earliest ERP components linked to attention are the P1 and N1 (Luck et al., 1994; Mangun, Buonocore, Massimo, & Amishi, 1998). The P1 is a positive deflection in the EEG signal roughly 100ms after stimulus onset, whereas the N1 is a negative going signal with a roughly similar onset time. Both are potentially generated in the lateral extrastriate cortex (Eimer, 1998; Mangun, Hillyard, & Luck, 1993), and reflect early stages of visual-perceptual processes. In other words, a P1 and N1 are present in the EEG signal when visual information is processed. The amplitude of the P1 and N1 vary according to visual properties (e.g. colour intensity or motion), but attention too influences the amplitude of these ERP components. The P1 component is suppressed at non-target locations and reflects the attentional "cost" of having to switch to the target location. Furthermore, the processes reflected by the P1 are possibly only needed when a target and distractors are highly similar (Luck et al., 1994). The N1 component is also amplified when attending the target location, especially when selecting between different stimuli. The N1 therefore, possibly reflects a discriminatory process (Vogel & Luck, 2000).

Most studies focus on the self-priority effect using the participants' own names (Fischler et al., 1987; Holeckova et al., 2006) and faces (Caharel et al., 2002; Scott et al., 2005; Sui et al., 2006) as stimuli. As discussed in *Chapter 1*, these stimuli are highly learned and very familiar to the participant, and therefore the effect measured in these studies might not reflect the self only, but to some degree familiarity as well. Consequently, it is not clear what conclusion can be drawn regarding the effect of self on these early components based on the evidence available. Indeed, to this author's knowledge, two studies reported an effect of self-relevant information on an early ERP component related to attention (Keys & Brady, 2010; Liu et al. 2016). Both of these studies, however have used paradigms which conflate self-relevance with familiarity. Keyes and Brady (2010), found an enhanced posterior N170 amplitude, and at the fronto-central site an enhanced vertex positive potential amplitude when participants were presented with their own face, compared to a face of a stranger or friend. Also using faces as stimuli, Liu, He, Rotsthein, and Sui (2016), found an increased N1 ERP component for self-related faces. This N1 correlated with a later observed P300 component related to the self.

As mentioned in the introduction of the previous chapter, the P200 is influenced by attention, and therefore the main expectation in this *Experiment 6* is a modulation of the P200 by self-relevant information compared to information not related to the self. At this stage (as the behavioural data suggests in *Experiments 1-2*), emotional information is not yet processed as the words have yet to be interpreted. As suggested by Herbert, Herbert, and Pauli (2011) emotional words can be reflected by a more negative (compared to neutral) ERP between 200ms-300ms and 300ms-400ms, with pleasant self-related words showing a larger positive ERP around 450ms-600ms (LPP) compared to neutral words. This suggested an early self and emotional identification before an integration between self-relevant emotional information occurs. An important difference between the experiments of Herbert et al. (2011) and the current experiment is that the meaning of the word is processed more slowly than self-relevance as only colour recognition is required to make a matching judgement. The task of Herbert et al. (2011) had participants actively reading the words, whereas in the matching task of the current experiment it is not necessary to read the word in order to make a successful matching judgement. Therefore, emotion is not task-relevant, but as the emotional valence of the words is not part of the matching judgement, it is not disruptive for the matching task. However, the words themselves are high-priority as participants know that there is a free recall task following the matching task, and emotion may increase the perceptual saliency and memorability of the words (Mather & Sutherland, 2011).

An ERP component often linked to attention and emotional information processing is the early posterior negativity (EPN). Compared to neutral items, emotionally arousing stimuli are reflected by a more negative going EPN. The onset of the EPN can be as early as 150ms with a peak amplitude between 250ms and 300ms (Schupp, Flaisch, Stockburger, & Junghöfer, 2006). It is believed that the EPN does not just exclusively reflect emotional processing, but possibly also selective attention to specific stimuli features (like emotion, or colour). In cases of emotional stimuli, this would be the detection and selection of emotional stimuli compared to neutral stimuli. However, the EPN is a probably not just linked to arousal but to selective attention. For example, in a study on attention and emotion, the role of the EPN was studied in a non-emotional attention task (Schupp, Junghöfer, Weike, & Hamm, 2003). In this task, participants had to count the number of checkerboard images presented in the centre of the screen that contained either a white or black rectangle. These task-relevant images were presented sequentially with emotional pictures (pleasant, neutral or unpleasant) in random order. Their results showed an increased EPN for emotional pictures, which showed that since the attention task could be performed without processing the emotional pictures, emotion would still be selectively processed during the early stages of stimuli processing.

Another component of interest for emotional information processing is the P300. This component has been described in the previous chapter as a component of interest for self-related information and is most commonly linked to oddball experiments where the P300 is associated with perceived unexpectedness. In general, the P300 is thought to reflect the allocation of attention. Unexpected items could potentially be behaviourally relevant. Therefore one's attention is directed towards unexpected stimuli by inhibiting ongoing attentional processes. Similarly, self-relevant information is behaviourally relevant, and this results in the allocation of attentional resources to self-relevant information over information not relevant to the self. Naturally, the same is true for emotional information (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Mezulis et al., 2004; Sedikides & Green, 2004; Taylor, 1991; Vuilleumier, 2005; Wadlinger & Isaacowitz, 2006). As it is known that emotional information (similar to self-relevant information) automatically captures attention, the P300 very likely plays a role in this reallocation of attention to potentially behaviourally relevant emotional information.

Another ERP component linked to emotion is a late positive potential with a centro-parietal distribution around 400ms-600ms (Hajcak, MacNamara, & Olvet, 2010; Schupp et al., 2006). This is often referred in the emotion literature as the late positive potential (LPP), and it shares temporal and spatial similarities with the late positive component (LPC) discussed later as a component reflecting working memory processes. This late positive potential in emotion research is more enhanced when viewing emotionally arousing stimuli (Schupp et al., 2004). As discussed in *Chapters 1-4*, emotion and self-related information both seem to influence attention and memory, and this interplay between emotion and self has been studied in EEG research as well.

Herbert, Herbert, Ethofer, and Pauli (2011) also investigated the influence of emotion on self-relevant information processing using EEG. In their study, they compared the effect of self on emotional pronoun-nouns. In this study, participants were presented with pleasant, unpleasant and neutral nouns which were displayed together with the pronoun 'my' or 'his', or the definite article 'the'. These pronoun-nouns were presented in three separate blocks, and after each block a free-recall test followed. During each block, participants were asked to read the pronoun/article-nouns silently, and during the free recall session participants were asked to remember the pronoun/article-noun pairs of the preceding phase and rate each on perceived valence and arousal. ERPs were measured during the reading phase and revealed that the amplitude for the emotional words between 200-300ms and 300-400ms was greater and more negative when compared to neutral words. A similar distinction was observed for the pronoun-nouns when compared to the article-nouns in the same time-windows. According to the authors, this suggests that during early visual processing, the general aspect of the information is identified (i.e. emotion and self-related) before integrating and specifying said information. Furthermore, this occurs separately for emotional and self-related information. The distinction in ERPs between self and distant other became apparent at 250-350m, and 350-550ms at frontal sites and these differences were greater for the unpleasant self-related pronoun-nouns. Pleasant self-related pronoun-nous revealed larger positive amplitudes 450-600ms (LPC) after stimulus onset over more centro-parietal sites. Not only does it seem that self-related pleasant and unpleasant nouns are processed at different times, but source localisation also suggested different generators for the ERP components. The unpleasant self-related nouns had neural sources in the medial prefrontal gyrus and the anterior cingulate cortex, whereas the pleasant self-related nouns ERP component was generated in the medial prefrontal cortex, precuneus and the posterior cingulate cortex. Although ERPs were not recorded for the free recall phase, Herbert et al. (2011) show that positive self-related nouns are recalled more often than distant other nouns. The authors propose that the superior recall for positive self-related words and the neurophysiological differences support a self-positivity bias for incoming information. Although the LPP is often linked to high arousal emotional information processing, LPP is has been linked to information processing associated with working memory (Schupp et al., 2006). The LPP is similar to the LPC, and the term LPC will be used in this chapter.

Taken together, there is some overlap between the ERPs linked to emotion, and the ERPs linked to self-relevant information processing. Both are expected to influence our attention and memory processes. For example, the LPC is often linked to emotion, but it is more likely linked to working memory processes, which is modulated by emotional valence and arousal. Therefore, the ERP components do not measure emotion or self-relevance per se, but their influence on attentional or memory processes reflected by the ERP components. Like emotion, self-related information influences the LPC. However, the LPC is linked to recollection, and as such, the influence of self on recollection can be measured. In this *Experiment 6*, the EPN and LPC will be examined, and the early attentional processes mentioned in *Experiment 5* (like the P300 mentioned earlier) will be examined also. The EEG analysis of the current study will only be reported for the matching task, as the costs of increasing the difficulty in recall resulted in too few segments for EEG analysis of the free-recall task due to large individual variation in memory recall.

Therefore, the purpose of the current study is to examine the effect of self-relevant positive information during a free recall task with a high memory workload. It is predicted that due to the increased difficulty, an interaction between perspective and emotion will be found. This interaction will be driven by a greater difference between self-related words and distant other-related words for the positive trials when compared to the difference between self and distant other for neutral trials. In other words, it is predicted that the self-reference effect will be greater for positive words compared to neutral words. The behavioural findings of the matching task will be like all previous experiments using the matching task in this thesis. However, the novel addition of EEG will aim to investigate the early (emotional) self-related information effects on attention. Specifically, the N100, P200, P300, EPN and LPP/LPC will be investigated.

Methods

Participants

A total of 21 participants (12 female, 9 male; mean age 25.76, range 18 - 39) took part in this study. However, for the EEG analysis, one participant had to be removed because too few segments remained after artifact rejection (overall less than 15 segments per condition). This left 20 participants (12 female, 8 male; mean age 25.55 years, range 18 – 39 years) for the EEG analysis.

Stimuli & procedure

The stimuli were selected in the same way as described in *Experiment 1d*. In total, one training block of 10 trials and 15 experimental blocks, each containing 28 trials were created. Like *Experiment 1d*, the wordlists contained neutral and positive words, and half of each was linked to the self or a distant other by linking a specific colour to each condition. The procedure was exactly the same as in *Experiment 4*. Each matching block was followed by a distractor task, which in turn was followed by a free recall task. After each block, the participant was able to take a self-paced break. The total length of the experiment was around 45 minutes, excluding EEG setup.

EEG recording and analysis

The EEG was recorded using the same EEG system, EEG procedure, and EEG data analysis as the previous EEG *Experiment 6*. All trials were time-locked to stimulus onset and epochs were created of -200ms to 1000ms. Separate epochs were created for matching and non-matching trials each containing self-relevant/positive words, self-relevant/neutral words, distant other-relevant/positive words, and distant other-relevant/neutral words. The epochs were further split up in correct trials and incorrect trials. Based on the literature, the following time-windows and electrodes were used: N100, 140ms-200ms (electrodes Cz, E4, E6, E7, E54); posterior P200, 170ms – 220ms (electrodes E33, E34, E36, E37, E38); Anterior P200, 220ms – 270ms (electrodes E2, E3, E6, E8, E9, E11); EPN, 270ms – 320ms (E33, E34, E36, E37, E38); and the LPC, 450ms – 1000ms (electrodes E31, E33, E34, E36, E38, E40). All data is analysed using Repeated ANOVA design: 2 (perspective[self, other]) x 2 (emotion[positive, neutral]). A Bonferroni correction is applied for multiple comparisons. G*Power showed that with the general robust effect-sizes linked to the matching task and the Free recall experiment of *Experiment 4* a sample-size of 20 should provide sufficient power.

Results

Behavioural findings

Matching task

Two main effects are revealed in the d' analysis: perspective, $F(1,20) = 37.273$, $p < .001$, $\eta^2_p = .651$; and emotion, $F(1,20) = 6.101$, $p = .023$, $\eta^2_p = .234$. Participants correctly identified match and non-matched trials for the words linked to the self, compared to distant other. Participants were also better with positive words than with neutral words in identifying a correctly or incorrectly matched label and colour, see Figure 43. No interaction between perspective and emotion was observed, $F(1,20) = .109$, $p = .745$.

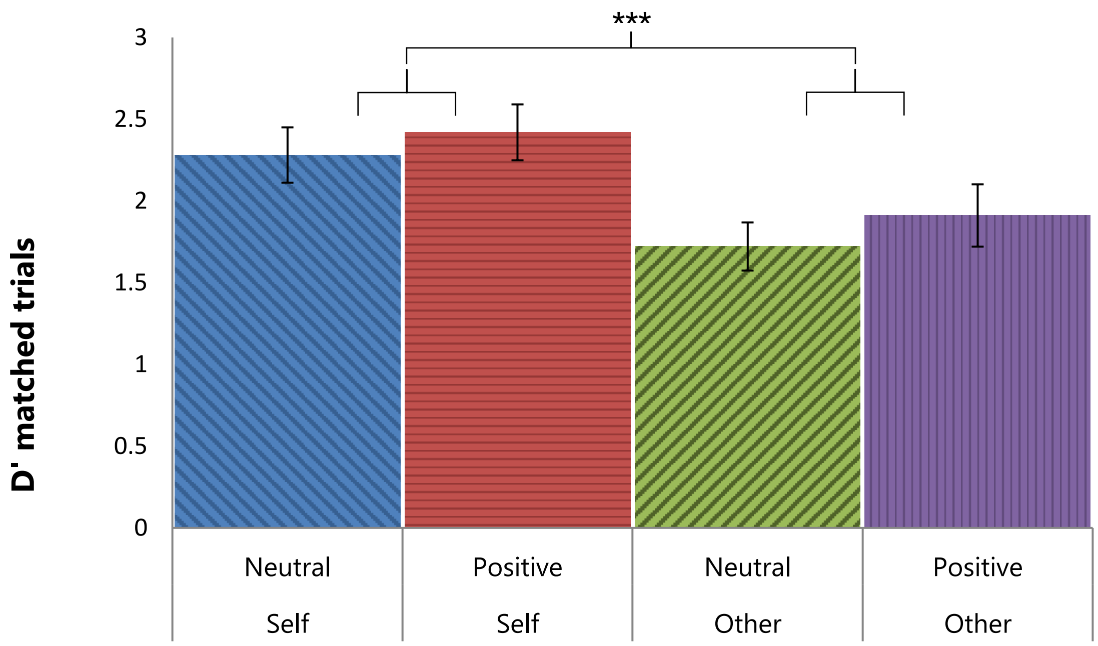

Figure 43. D' matching task for all conditions, *Experiment 6*.
(Error bar = standard error,* = p<.05, ** = p<.01, *** = p<.001).

For the proportion of correct responses for the matched trials only a main effect was found for perspective, $F(1,20) = 31.835$, $p < .001$, $\eta^2_p = .614$. Again participants correctly matched label and colour for the self-related words when compared to distant other-related words. There was no main effect for emotion, $F(1,20) = 2.405$, $p = .137$, and no interaction between emotion and perspective, $F(1,20) = 0.062$, $p = .807$. For the non-matched trials no significant differences were found: perspective, $F(1,20) = 1.828$, $p = .191$; emotion $F(1,20) = 1.008$, $p = .327$; perspective×emotion, $F(1,20) = .516$, $p = .481$.

The last measurement analysed for the matching task was the median reaction times. For the matched trials participants were significantly faster in making a matching judgement for the self-related words when compared to the words not related to the self, $F(1,20) = 45.664$, $p < .001$, $\eta^2_p = .695$, see Figure 44. There was no significant difference between positive words or neutral words, $F(1,20) = .516$, $\eta^2_p = .025$, and there was no interaction between perspective and emotion, $F(1,20) = .003$, $p = .960$. See Table 30 for an overview of the means and standard errors for the matching task.

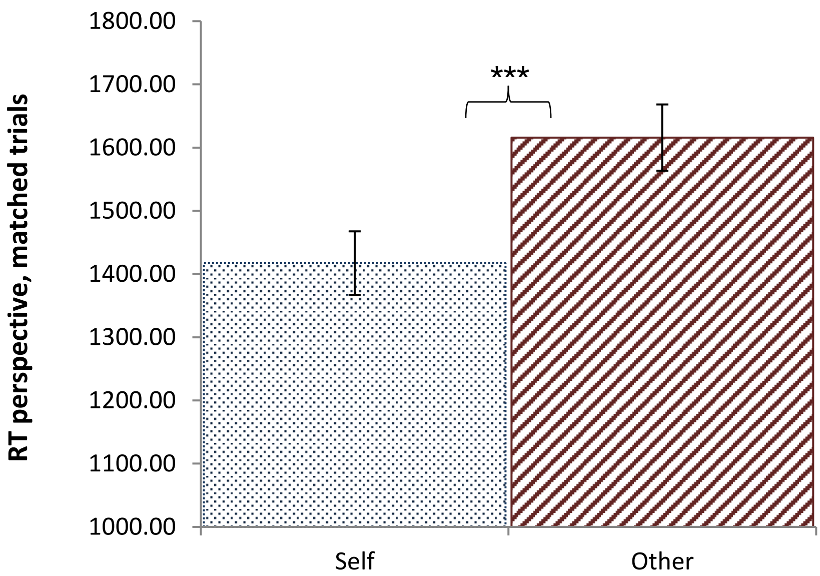

Figure 44. Median RT matched trials for perspective, *Experiment 6*.
(Error bar = standard error, * = p<.05, ** = p<.01, *** = p<.001).

Table 30. Experiment 6, Matching task. Proportion correct and median RT for the matched and non-matched trials, and mean d'. Standard error in parenthesis.

	Matched Trials		Non-Matched trials		D'
	Correct	RT	Correct	RT	
Self	.884 (.015)	1417.13 (50.46)	.833 (.022)	1565.20 (51.93)	2.35 (0.17)
Other	.785 (.026)	1615.82 (52.51)	.811 (.019)	1611.24 (54.95)	1.82 (0.16)
Positive	.843 (.021)	1523.49 (52.13)	.827 (.020)	1582.32 (50.04)	2.17 (0.17)
Neutral	.827 (.019)	1509.46 (48.41)	.817 (.019)	1594.04 (53.99)	2.00 (0.15)
Self/Positive	.893 (.015)	1424.55 (52.01)	.834 (.023)	1549.29 (50.03)	2.42 (0.17)
Self/Neutral	.875 (.016)	1409.71 (51.95)	.833 (.022)	1580.95 (57.56)	2.28 (0.17)
Other/Positive	.792 (.031)	1622.43 (57.58)	.820 (.023)	1615.36 (54.44)	1.91 (0.19)
Other/Neutral	.778 (.025)	1609.21 (50.27)	.802 (.020)	1607.12 (57.81)	1.72 (0.15)

Free Recall

For the matched trials, participants freely recalled more words that were linked to the self than linked to a distant other, $F(1,20) = 25.618$ $p < .001$, $\eta^2_p = .562$. Participants also recalled more positive words than neutral words, $F(1,20) = 28.057$, $p < .001$, $\eta^2_p = .584$, Furthermore, a significant interaction was observed also, $F(1,20) = 4.421$, $p = .048$, $\eta^2_p = .181$. A follow-up analysis revealed that self-related positive words were more often recalled than self-related neutral words ($p < .001$). A similar effect was found for words related to a distant other where more positive words were recalled than neutral words ($p = .032$). However, for only positive words, an effect of perspective was found as self-related words were significantly more often recalled than positive words linked to a distant other ($p <.001$). However, for the neutral words, no effect of perspective was found, ($p = .067$). See Table 31 for an overview of the proportion correctly recalled items for the free recall task.

Table 31. Experiment 6, Free-recall task. Mean number of correctly recalled words over all blocks. Standard error in parenthesis.

	Matched Trials	Non-Matched trials
Self	9.07 (0.86)	6.81 (0.62)
Other	6.36 (0.74)	6.91 (0.75)
Positive	9.17 (0.93)	7.93 (0.71)
Neutral	6.26 (0.65)	5.79 (0.66)
Self/Positive	11.10 (0.98)	7.71 (0.71)
Self/Neutral	7.05 (0.90)	5.91 (0.78)
Other/Positive	7.24 (1.01)	8.14 (0.90)
Other/Neutral	5.48 (0.61)	5.67 (0.80)

For the non-matched trials only a significant main effect of emotion was observed, $F(1,20) = 14.493$, $p = .001$, $\eta^2_p = .420$. Positive words were more often recalled (7.929) than neutral words (5.786). No main effect of perspective was found, $F(1,20) = .025$, $p = .877$, and no interaction between perspective and emotion, $F(1,20) = .356$, $p = .558$.

EEG results

Only the EEG results of the matching task are provided. The number of words recalled was not sufficient in all conditions to create enough segments to reliably distinguish ERP signals and therefore, recall-related EEG analyses were not carried out. Furthermore, since it is difficult to interpret the non-matched trials, only the matched trials are analysed, see Table 32 for the means and standard errors of the ERP components discussed below.

N100, *central anterior (140ms – 200ms)*. Only a significant main effect was found for perspective, $F(1,19) = 7.401$, $p = .014$, $\eta^2_p = .280$. The ERP waveforms were more negative in this time-window for words related to the self (-2.452μV) compared to the

ERPs linked to a distant other (-1.934μV), see Figure 45. Neither a main effect of emotion was found, $F(1,19) = .613$, $p = .443$, nor an interaction between self and emotion, $F(1,19) = .073$, $p = .790$.

Parietal positivity (450ms – 1000ms). Again only a significant result was achieved for perspective, $F(1,19) = 17.683$, $p < .001$, $\eta^2_p = .482$. Words related to the self were had a more positive going ERP after 450ms (3.569μV) than words linked to a distant other (2.788μV), see Figure 46. No main effect of emotion was found, $F(1,19) = .131$, $p = .721$, and no interaction effect between emotion and perspective was found either, $F(1,19) = 1.092$, $p = .309$.

No significant finding were observed for the following observed ERPs: P100, *lateral occipital (170ms – 220ms)* perspective, $F(1,19) = .030$, $p = .865$; emotion, $F(1,19) = .292$, $p = .595$; perspective×emotion, $F(1,19) = .258$, $p = .617$; P200, *central anterior (220ms – 270ms)* perspective, $F(1,19) = .086$, $p = .773$; emotion. $F(1,19) = 2.057$, $p = .168$; perspective×emotion, $F(1,19) = .251$, $p = .622$; P300, central anterior (*270ms – 320ms)* perspective, $F(1,19) = .271$, $p = .609$; emotion. $F(1,19) = .751$, $p = .397$; perspective×emotion, $F(1,19) = .229$, $p = .638$.

Table 32. Means of the EEG signal Matching task. Mean EEG signal for each ERP component. Standard error is given in parenthesis and all values provided are in μV.

ERP	Positive		Negative	
	Self	Other	Self	Other
N100	-2.50 (.654)	-2.05 (.657)	-2.41 (.603)	-1.81 (.498)
P100	2.31 (.666)	2.09 (.508)	2.29 (.506)	2.42 (.696)
P200	1.76 (.535)	1.70 (.508)	1.89 (.497)	2.15 (.497)
P300	3.07 (.641)	2.79 (.521)	3.16 (.641)	3.20 (.663)
Parietal positivity	3.51 (.581)	2.99 (.575)	3.63 (.558)	2.59 (.416)

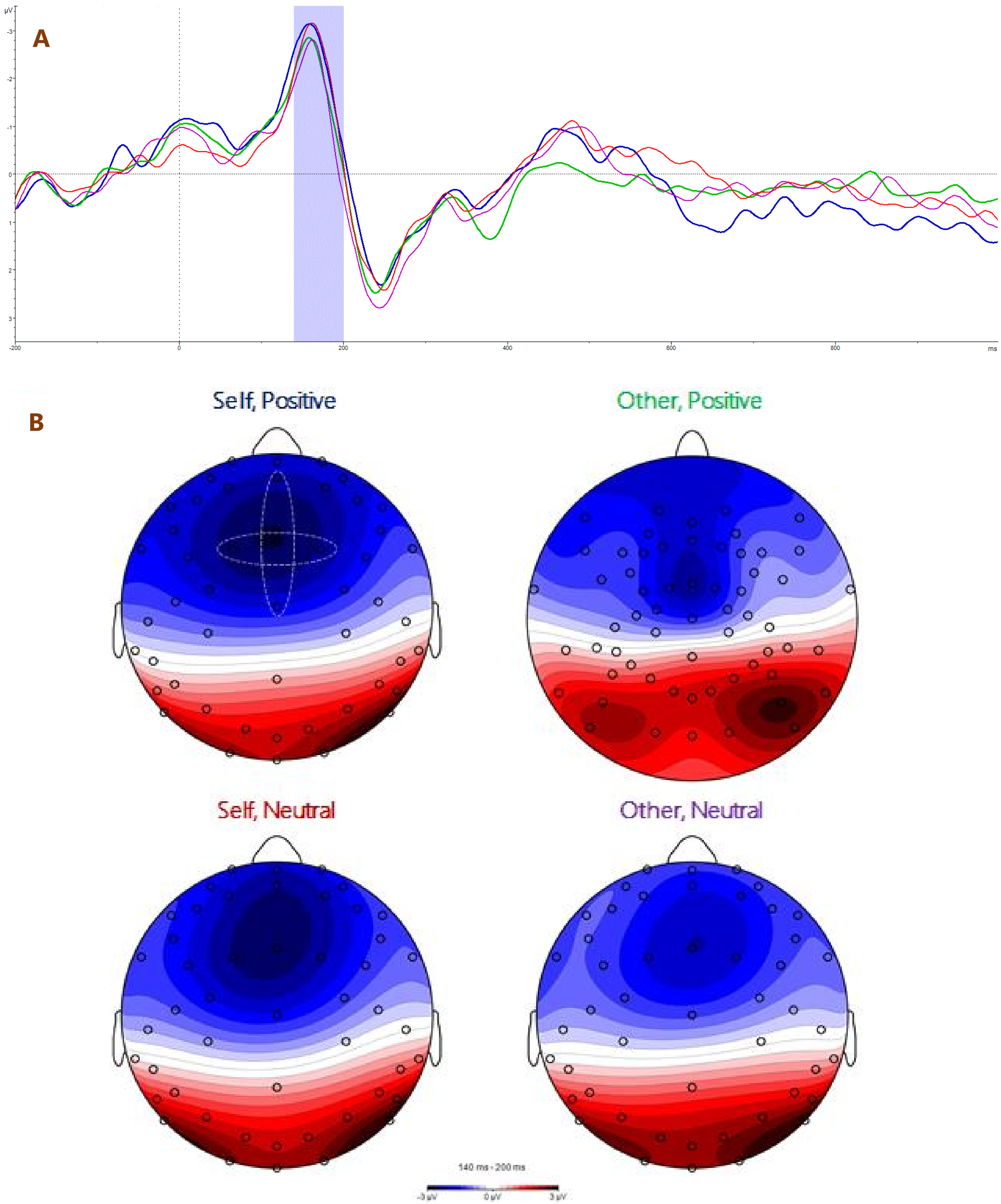

Figure 45. Matching task, N100 (140ms – 200ms), *Experiment 6.* Upper panel **(A)** shows the EEG pooled waveforms from -200ms to 1000ms, from electrodes Cz, E4, E6, E7, and E54. Highlighted area is the time-window 140ms – 200ms, marking a potential N100 component. Lower panel **(B)** shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top-left topographical map.

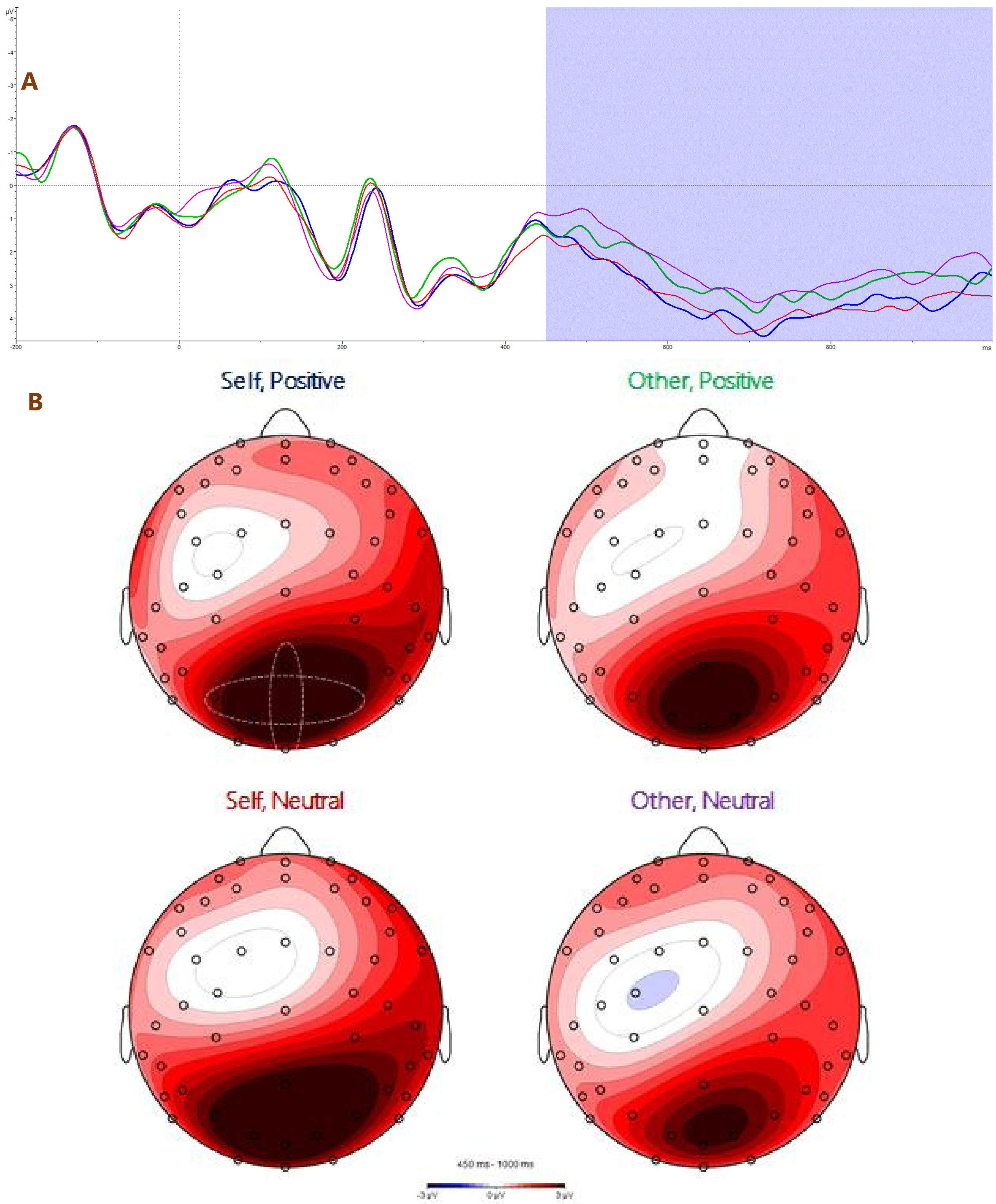

Figure 46. Matching task, parietal positivity (450ms – 1000ms), *Experiment 6*

Upper panel **(A)** shows the EEG pooled waveforms from -200ms to 1000ms, from electrodes Cz, E4, E6, E7, and E54. Highlighted area is the time-window 450ms – 1000ms, marking a potential parietal positivity component. Lower panel **(B)** shows the topographical maps with brain activity highlighted in the upper panel. The electrodes used in the statistical analysis are highlighted in the top-left topographical map.

Discussion

Behavioural findings

The main goal of this research was to investigate the effects of positive emotion on self-relevant information processing under high memory load during free recall. Furthermore, EEG was used to examine the underlying electrophysiological processes involved in the prioritisation of (emotional) self-related information.

The behavioural findings of *Experiment 6* revealed a self-priority effect during the matching task. Participants were more precise in distinguishing signal from noise (d'). Moreover, participants' responses were not only more often correct on self-related trials but were also faster when compared to words not related to the self. Unlike the results from *Experiments 1a-d*, emotion was found to significantly increase d'. Based on the previous experiments (*Experiments 1a-1d*, *Experiment 3)* containing emotional words, it was suggested that in the matching task, the (emotional) meaning was not needed to make a matching response. This was because emotion did not seem to influence the matching judgement. Since the matching judgement is based solely on the colour and the label, a matching response could be made as soon as the colour was identified. As a consequence, emotion did not impact the matching task. It is important to point out that neither the reaction time data nor the proportion of correct responses showed an effect of emotion on the matching task. This suggests that the effect of emotion is not as robust as the findings on perspective across all measurements. However, it remains possible that this version of the matching task had more power to find an effect, as there were more trials in this experiment. Also, the matching task was spread over 15 blocks and the instructions were repeated at the beginning of each block, which possibly helped with learning the task. A final possible explanation is that participants would know after the first block that the task demand of the free recall task was high, on average a participant recalled only 4.5 words from the matching task per block. This required participants to pay more attention to the words, which possibly delayed the overall response slightly. The average RTs of *Experiments 1a-d and Experiment 3* (self = 976ms; distant other =

1155ms) compared to the average of the current *Experiment 6* (self = 1417ms; distant other = 1615ms) does seem to support this.

The increased task demand of this experiment might have an unexpected circumstance to show an effect of positive emotion on attention. However, like *Experiment 3*, which also found an effect of emotion on the matching task, the d' measure includes the non-matched trials. As discussed before, it is difficult to interpret the non-matching trials as the label and colour mismatch makes it difficult to know if the trial was self-relevant. This is because the label itself can possibly be enough to elicit a self-priority response. In other words, if the colour of the word is linked to a distant other but the label is linked to the self, which of these two determine if the trial is self-relevant or distant other-relevant?

If the d' measure is used as clear measurement of self-relevance, then *Experiment 6* directly supports the claim that emotion affects attention (Baumeister & Cairns, 1992; Blaine & Crocker, 1993; Mezulis et al., 2004; Sedikides & Green, 2004; Taylor, 1991; Vuilleumier, 2005; Wadlinger & Isaacowitz, 2006). Furthermore, the apparent beneficial effect of emotion in our task can be explained within the ABC-theory (Mather & Sutherland, 2011). This theory states that emotional arousal enhances the processing of high priority events driven by bottom-up perceptual salience and top-down goal relevance. As the words were of high-priority (needed to be remembered in the free recall task), emotion helped increase the perceptual salience of the words, which is reminiscent of how self-related items are prioritised. Together, perspective and emotion help orientate attention towards goal-relevant information and in doing so, allow for improved consolidation into memory as is shown by the results of the free recall task. Nonetheless, emotion is not consistent across the different measurement as participants were not faster in responding during positive trials.

One of the benefits of using a free recall task is that there are no cues that help prime recall. The act of recalling is made a purely mental task. This makes the task of recalling information more difficult, but at the same time, this allowed this experiment, together with a high memory load, to push participants' memories to the limit. It was predicted that this increase in difficulty would help elucidate the role of emotion on self-relevant information processing.

The results of the free recall experiment did reveal a main effect of perspective and a main effect of emotion showing that self-related words and positive words were recalled more often. More interesting is the interaction between perspective and emotion, which is not like the interaction observed in the previous experiments that combined the matching task with an old/new recollection task. Where the previous experiments (*Experiment 1c-1d and Experiment 3)* showed an interaction between emotion and perspective, this interaction was mainly caused by a self-reference effect for neutral words and an effect of emotion for distant other-related words. Therefore, the difference between self and distant other was smaller for the positive words, compared to the neutral words. This led to the conclusion that self and emotion influence memory separately but together not more than each condition alone. In other words, there appears to be a ceiling effect, in the sense that recall is not improved for the combination of self and emotional items beyond the separate effect of emotion or self-relevance on memory. However, it was not clear that if the influence of emotion and self-related information simply reached a task-related maximum, which was the same for the combination of emotional self-relevant information. This seemed to be reinforced by the findings of *Experiment 2* where the redundancy gain version of the matching task did show super-capacity (i.e. positive emotion and self-related information together led to more efficient processing of information). The interaction of the current *Experiment 6* showed that self-related positive items were recalled more often than positive distant other-related words or neutral self-related words. This showed that recall does benefit from a combination of self-related and positive words when the memory task is more difficult.

These finding of a greater self-reference effect for positive words, compared to neutral words are more consistent with the results of Gutchess, Kensinger, Yoon, and

Schacter (2007), and Leshikar, Dulas, and Duarte (2015). These two studies did reveal an effect of positive emotion on self-related information processing but used an encoding task that had participants actively judge if emotional traits described them or not. In the discussion section of Chapter 2, it was discussed that this way of encoding possibly results in less distraction for positive words compared to negative words as it is easier to link positive information to the self (Mezulis et al., 2004). This would, in turn, lead to more enriched encoding for self-related positive words. Since emotion was not directly linked to the self in *Experiments 1a-1d* such enriched encoding could not occur. Even though in this *Experiment 6* emotion is still not linked directly to the self in the matching task, the RT does appear to be slower in this version of the matching task when compared to earlier versions. As said before, this is possibly because of the increased number of blocks and because the participants know how difficult the free-recall task is, which forces them to focus on the words more. This makes the reading of the words more active compared to the more passive reading of the words in the previous matching task versions. This increase in attention for the words would lead to more enriched encoding , more so for self-relevant positive words as it is easier to link positive information to the self (Mezulis et al., 2004), than neutral self-related words, positive distant other-related words, and distant other-related neutral words. This combined with the greater difficulty makes self-related positive words more memorable than other conditions. This is further highlighted by the lack of self-reference effect for neutral words and the medium effect size of emotion for distant other-related items. This shows that self-related neutral words or positive distant other-related words are not as often recalled as positive self-related words during free recall.

EEG results

The EEG analysis revealed only two significant main effects of the matching task: a more pronounced central anterior negative deflection in the EEG signal between 140ms and 200ms for the self-related words compared to words related to a distant other, which is interpreted as a N100; and a more positive ERP for self-related words compared to distant other-related words between 450ms to 1000ms occipital parietal sites, interpreted as a LPC. No effects of emotion were found in the ERPs during the matching task.

The N100 is linked to early visual processing and is believed to reflect discrimination processes (Vogel & Luck, 2000). In the current experiment, a greater central anterior N100 was linked only to self-related information, and it is therefore likely that the automatic capture of self-related information and the increased attentional processes for self-related information is reflected by the increased N100. A second difference in the ERPs was found after 450ms where an LPC was found with greater positivity for self-related words compared to words related to a distant other. These findings are in line with the previous chapter's *Experiment 5*. The LPC reflects the maintenance of the attended information allowing for encoding into memory (Dien, Spencer, & Donchin, 2004; Gevins, Smith, McEvoy, & Yu, 1997). Taken together, the two ERP processes might reflect the initial automatic capture of attention by self-related information (N100) and the maintenance of the attended information (LPC) into memory.

No effect of emotion was found in the EEG analysis. However, this might be due to the nature of the matching task for which the emotional value of the word is not relevant to the task. Nonetheless, after the initial matching judgement, the emotional valence should impact the ERPs, especially with the behavioural findings of the matching task, which show an effect of emotion on self-related words. The ERPs are time-locked to the onset of the word plus label, and at that time the colour of the word is of key importance, not the emotional meaning of the word. The later processing of the emotional valence of the words could then be masked by ongoing ERPs. For example, it is possible that the EPN is not measurable because it is overlapping with the P300 elicited by the matching task. Therefore, the matching task might not be suited (in its current form) to study the ERPs of emotional self-related information processing as the ERPs linked to the matching judgement overlap with the ERPs linked to emotion.

Conclusion

Although the behavioural findings showed an effect of positive self-related information processing, there are methodological limitations to this matching task to examine the role of emotion on self-related information processing clearly. Nonetheless, the main goal of having a memory experiment with high memory workload was successful. Participant found it very difficult to recall the words freely. Because a free-recall task recall depends purely on the strength of the memories, the full benefits of self-related positive words were shown. More self-related positive words were recalled than words from any other condition. This was possible because of the increased binding into memory for positive self-related information.

The behavioural finding of the matching task was partially supported by the EEG findings. The matching task revealed two ERPs which are thought to reflect early attentional discrimination processes and a later component believed to be involved in the maintenance of attended information into memory, with greater amplitudes for self-related items. Taken together, this suggests that, compared to distant other-related information, self-related information is prioritised at early attentional stages, and the attended information is maintained and encoded into memory more efficiently than distant other-related information. The next chapter will focus on a general discussion of the whole thesis, where experimental findings will be tied together, and the broader implications and future research suggestions will be discussed.

Chapter 8:
General Discussion

This chapter will start by revisiting the specific aims of this research project. This is then followed by a summary of the findings of the nine experiments and their interpretations. The limitations of these experiments is then discussed. Continuing from this, several suggestions for future research will be proposed, and the broader implications of the research will be discussed. This chapter will then conclude by making some statements regarding the status of self and emotion in attention and memory based on the findings of this thesis.

Review of aims

The aims of this thesis were to examine the influence and interdependence of emotion and self-related information on attention and memory. The motivation for this research was that many previous studies studying the self-reference effect in the domain of memory tended to conflate self-reference with familiarity. For example, names and faces of the participants are often used when studying the effects of self on information processing. However, these kind of stimuli are not just self-relevant, they tend to be highly familiar also in relation to the non-self relevant stimuli used as controls (e.g. the faces or names of strangers). Furthermore, the influence of emotion on self-relevant information processing was unclear. Therefore, a concrete goal of this thesis was to study the effect of emotion and self-relevance with the aim of exploring any putative independent and interactive effects on attention and memory. A study by Sui, He, and Humphreys (2012 demonstrated that there is a reliable effect of self-related information on perceptual processing. They found that arbitrarily linking self to a geometric shape would lead to a prioritisation of that shape compared to shapes not linked to the self. Furthermore, by arbitrarily linking the self to a stimulus, this perceptual matching paradigm controlled for possible confounds of familiarity that stimuli with inherent self-relevance (e.g. one's own name or face) would possess.

It is well known that attention tends to influence memory encoding and therefore memorability itself (Baddeley et al., 1984; Craik et al., 1996). It, therefore, seemed reasonable to look at how the attentional effects of self-relevance have implications on later memorability. For this reason, the matching task of Sui, He, and Humphreys (2012) was adapted in a novel way for use in conjunction with a memory task (using recognition memory, cued recall, and free-recall). This was done by arbitrarily linking the self to a colour, and using (emotional) words as stimuli instead of geometric shapes (*Experiment 1-4, & Experiment 6)*. Moreover, since self-related information processing is deemed to be a fast and automatic process (Alexopoulos et al., 2012; Moors & De Houwer, 2006), this aspect of self-related information was also examined. In this thesis, this was examined by adding repetition of the word-list used in the matching paradigm, keeping same perspective associations (*Experiment 3, & Experiment 4)*. Another approach used in this thesis was by attempting to suppress memories (*Experiment 5)*. The goal of this approach was to explore the automaticity of self-relevant information processing. This was achieved by observing if self-related memories are as easily suppressed as memories related to a distant other.

The final aim of this thesis was to elucidate the underlying neurophysiological processes involved in self-related and emotional information processing in attention and memory, using EEG methods (*Experiment 5, & Experiment 6)*. These research aims were the basis of nine experiments across six chapters, which are summarised below.

Summary Experiments

In total, nine experiments were conducted to examine the influence of self-relevant information on attention and memory, together with emotion. Most of these experiments tried to link the established self-priority effect (e.g. Alexopoulos et al., 2012; Cherry, 1953; Sui et al., 2012) with that of the self-reference effect (e.g. Brown & Kulik, 1977; Conway, 2005; Symons & Johnson, 1997). This was achieved via a novel adaptation of the perceptual matching paradigm by Sui, He, and Humphreys (2012).

In most of the experiments in this thesis, a robust effect of perspective was found in attention (i.e. a self-priority effect). The often found self-priority effect showed that the matching task used in this thesis, reliably measured a facilitation effect of self-relevant information on attention. However, no effect of emotion was found on most of the matching tasks. Only by making emotion part of the response (redundancy gain *Experiment 2)* or by increased power (*Experiment 3*, *& Experiment 6)*, was an effect of emotion found on the matching task. It is likely this was because emotion was not part of the response required on the matching task (matching judgement) as participants only had to compare the label and the colour of the word. This meant that the matching response was possibly already initiated before the semantic meaning of the word (and therefore the emotional value) was processed.

In most experiments, the matching task was followed by an old/new task. Where most matching tasks did not show an effect of emotion, all old/new tasks do show an effect of emotion. *Experiment 1a* and *Experiment 1b* both revealed a main effect of emotion and a main effect of perspective. This meant that words which were experimentally manipulated to be associated with the self in the matching task were later correctly recognised more often than words that had not been linked to the self. The processing of positive and negative words during the matching phase increased the likelihood of later retrieval compared to neutral words. Indirectly, this provided further evidence that emotion had been processed during the matching task. Since no interaction between perspective and emotion was observed, it appears that self and emotional stimuli influence recognition memory separately.

To further investigate the influence of emotion, *Experiment 1c* and *Experiment 1d* used negative and positive trait-words. Emotional trait-words were used because traits should be more applicable to either the self or a distant other. The matching task again revealed a significant self-priority effect, and no effect of emotion.

However, the memory data for the trait experiments (*Experiment 1c* and *1d*) were different from the noun experiments (*Experiment 1a* and *Experiment 1b*). The effect of perspective only occurred for the emotionally neutral trait words. For the emotional trait words (positive or negative) the effect of self was no longer found. This was expressed in an interaction between perspective and emotion in the old/new task. In other words, for the self-related words there was no effect of emotion on memory, which was present for the words related to a distant other. Furthermore, when looking only at the emotional trait-words there was no effect of perspective, which was present for the neutral trait words.

These results seem to indicate that perspective and emotion both influenced memory, but the effect of perspective and emotion are not cumulative. However, this does not mean that the presence of emotion and self are non-additive as it is possible that there was a ceiling effect of some kind. The best performance was around 70%, and therefore there still was room for improvement. Nonetheless, emotion and self-relatedness improve recognition, but both combined did not result in even greater memorability per se. Possibly this was because the words though emotionally valenced, were not specifically emotionally self-relevant.

Experiment 2 studied the effects of redundant information to try to elucidate the interaction between emotion and self-related information further. This required several novel adaptations to the matching task to allow the measuring of redundancy gain between self-relevant and emotional information. In this experiment, participants were asked to give the same button press for emotional words and self-relevant words. The results showed that when a word is both emotional and self-relevant, participants respond faster compared to a self-related word or an emotional word. In other words, there was super-capacity (i.e. integrated processing between self-related and emotional information) between self-relevant and emotional information, during the matching task.

Interestingly, this super-capacity was not translated into better memory for emotional self-relevant words, indicating that emotion and self do interact, but the effects are not cumulative for recognition. This means that emotional words and self-relevant words were correctly recognised equally often as words that were both emotional and self-relevant. Possibly this is due to the nature of the matching task as the words were only self-relevant by association and not directly linked to the word. Conversely, the emotional meanings of the words were not linked to the self-relevance of the words' colour. Indeed, this has been suggested as the very reason for not finding an effect of emotion in the matching tasks of *Experiments 1a-1d*, where the matching response was made as soon as the colour was detected.

Experiment 3 and *Experiment 4* employed an extension of the matching paradigm. This was done by having repeated blocks of-of the same wordlist. Repetition of stimuli is known to improve memorability (Craik & Lockhart, 1972; Ebbinghaus, 2013; Hintzman & Block, 1971). Therefore, the extent of self-association effects on memory can be determined by repeated association. Furthermore, this manipulation allowed us to track the time course of repeated perspective association and the effect of repetition of the word stimuli on memory.

Experiment 3, was very similar to *Experiment 1b* with the exception of added repetition of the wordlist. The perspective associated with the words was kept the same for each repetition (i.e. the colour of the words did not change, nor did the instructions that linked self or distant other to a specific colour). The procedure of the matching task was otherwise exactly the same as *Experiment 1b*. Like all matching paradigms, *Experiment 1b* also found an effect of perspective. Self-related words were again prioritised compared to words not related to the self. Interestingly, where none of the previous matching experiments found an effect of emotion, *Experiment 3* did find an effect of emotion. This possibly suggests that self-related negative words were prioritised less than neutral self-related words. However, this finding is only found for the d' measure and not for proportion correct responses and not for the reaction time data. Since the d' measure included the non-matched trials, the interpretation of the perspective and emotion interaction is difficult. This is because the self-relatedness of the trials in the non-matched condition is not clear (e.g. when the label is linked to the self, and the colour of the word is linked to a stranger).

No effect of repetition was found on the matching task, meaning that the effect of self was the same for all time-windows during the matching task. This lends some further support to the assertion that the semantic meaning of the word (and therefore the emotional meaning) is not fully processed when the matching judgement is initiated. In other words, only the colour of the word impacts the matching judgment during the matching task.

However, after the repetitions, an old/new memory task was administered. Nonetheless, despite showing a strong self-priority effect during the matching task, a self-reference effect for the old/new task was absent. Only a main effect of emotion was found in this experiment. This suggests that self-relevant information processing has an initial benefit in memory, but eventually, simple repetition will allow non-self-related words to be equally memorable as self-relevant information. It is likely that the initial effects of self steepen the learning curve for self-related words but plateaus out, at a similar level as other mnemonic strategies, such as repetition. Especially since repetition itself has no effect on increasing the self-relatedness of a word. Emotional words are still remembered more often after repetition compared to neutral. This is likely because emotional meaning of the word does get processed (after initiation of the matching response) and repetition does strengthen the memorability of words (Craik & Lockhart, 1972; Ebbinghaus, 2013; Hintzman & Block, 1971).

For *Experiment 4*, the old/new task was replaced by a free-recall task. This allowed for a memory test to follow after each matching task block of 20 words. According to the data of *Experiment 4*, the self-reference effect is still initially present in time-window two and three but disappears in the fourth time-window. Although a ceiling effect is not present, a peak in learning curve seems to be occurring much faster for self-related words. This is reflected by a significant increase in the number of words recalled after the first time-window and after the second time-window for the self-relevant words. However, after this initial fast increase, the number of words recalled remains roughly around the same level for subsequent time-windows. For the words related to a distant other, the reverse occurs as initially there is no difference between the first two time-windows, but there is for the last and penultimate time-window.

Taken together, the data suggests that the peak in a learning curve is reached faster for words related to the self when compared to words not related to the self. Self-related words might help improve overall efficiency, but not beyond the normal learning curve present for each task. Therefore repetition does not seem to promote a self-reference effect as shown by previous research as well (Symons & Johnson, 1997). It is possible that binding of information via the self is fast and robust, but further repetition does not lead to stronger binding into memory.

The automaticity of the self was further investigated with *Experiment 5*. *Experiment 5* used a different experimental approach to the self-reference effect in memory, called the think/no-think paradigm. Using the think/no-think paradigm, it was shown that actively suppressing the recall of an item decreased the probability of later recall (M. C. Anderson & Green, 2001; M. C. Anderson & Levy, 2009).The main purpose of this experiment was to examine if the supposed automatic process of self-related information processing could be actively suppressed compared to distant other-related information. Participants were shown a list of cue-target words-pairs in the study phase, which they had to memorise. After the study phase, the test phase followed where participants were shown the cue word only had to remember the (unrelated) target word. The wordlist was presented three times. Unlike the previous experiments (*Experiment 1 – 4)*, this allowed insight into the learning speed of self-related words during the encoding phase. After learning the words, a critical phase followed where participants were asked to either suppress the target word after being presented the cue word or remember the target when presented with the cue word. The word list was repeated 15 times. After the critical phase, the participants were again presented with the cue words and were asked to remember the associated target words. This performance could then be compared with words not included in the critical phase (i.e. the baseline).

Even though this experiment did not reveal an effect of suppression with the think/no-think paradigm, it did show that self-related information was learned faster and with less forgetting over time than distant other-related information. The effect of repetition of self-related words seems to be caused by a steeper learning curve of self-relevant information, but eventually, the same level of recall was reached by distant other-related information, but with a more shallow learning curve. Therefore, it appears that self-related information is learned faster, but up to a maximum. Repetition did not result in better memory for self-related words compared to words linked to a distant other. In other words, items related to a distant other, "catch-up" to words related to the self as each repetition also results in stronger binding into memory. However, the baseline measure of the think/no-think paradigm showed that this binding into memory seems to be more robust and less prone to forgetting for the self-related words compared to the words related to a distant other.

The finding of words related to a distant other being learned slower but eventually to the same level as self-related words were supported by the EEG data. In the study phase, the data showed an initial greater P200 component for self-related words after the first repeat, compared to distant other-related words. This effect was not present for the second repeat. ERP differences for all repeats showed a P300 for self-related items which indicated the top-down reallocation of attention towards self-relevant information. This possibly reflects an inhibitory process involving the TPJ by inhibiting ongoing attentional processes and reorienting towards self-relevant information. Furthermore, during encoding an increased midfrontal negativity (FN400) for distant other-related items, compared to self-related items, showed that self-related information is processed with greater ease or efficiency than distant other-related information. Also, a more pronounced LPC for self-related items compared to distant other-related items was found in the study phase. This possibly reflected greater memorability for self-related items. However, an expected interaction with time (distant other-related items "catching-up") was not found. Interestingly, during recall in the testing phase, this interaction was observed. Results revealed a more positive going LPC for self-related items, compared to distant other-related items, but only after the first repeat. During the second repeat, no difference between self- and distant other-related items were found, possibly reflecting the "catching-up" of distant other-related items with self-related items after the first repetition. The "catching-up" possibly reflects increasingly more robust memory traces after each repetition.

During the critical phase of *Experiment 5*, there were two clear markers associated with the manipulations. First, there was a greater anterior negativity for the think condition, when compared to the no-think condition. This component possibly reflects the different cognitive demands from the think versus no-think conditions. Secondly, a more positive LPC was found during the think/no-think phase for not learned distant other/think compared to not learned distant other/no-think trials. This possibly reflects the greater retrieval attempt for the not-learned distant other related words during the thinking trails, compared to the not learned distant other/no-think trials. This difference between think and no-think for the not learned words was not present for the self-related trials. This possibly suggested that for the non-learned self-related words, retrieval attempts were equal for think and no-think trials. Altogether, *Experiment 5* showed faster learning of the wordlist for self-related words when compared to distant other-related words, which is supported by the underlying electrophysiological signals. The final study of this thesis, *Experiment 6*, investigated the EEG responses associated with the matching task and followed the more traditional experimental set-up used of this thesis.

Experiment 6 put together many of the elements found in the studies in this thesis. This experiment consisted of a matching task which was divided into 15 blocks of 28 words. Each block was followed by a free-recall task. *Experiment 6* builds on the finding of emotion and self-related information reported in *Experiments 1a-1d*, and *Experiment*

2. In particular, the redundancy gain experiment of *Experiment 2* showed that positive self-related information should be processed more efficiently together than self-related information and emotion apart. A major finding of *Experiment 6* was the identification of an early ERP component linked to the matching judgement of the matching task. This early central anterior component (N100) was more pronounced for self-related information compared to distant other-related information. This showed that early attentional processes are prioritised towards and more sensitive to self-related information compared to distant other-related information. This was reinforced by a later ERP component (LPC) which was more positive for self-related information than for distant other-related information and this possibly reflected the processing of the attended information into memory.

The behavioural findings of *Experiment 6*, again showed a clear self-priority effect for the matching task. Furthermore, like *Experiment* 3, there was an effect of emotion for the matching task. Possibly, there was an increase in power when compared to the other matching experiments of this thesis. Similarly to the repetition *Experiment 3*, this effect was only found for the d' measure. Again, this limits the interpretation of the finding as the d' includes the non-matched trials. For the old/new task, an interaction between perspective and emotion was found. Positive self-related words were remembered more often than neutral self-related words or positive distant other-related words. Taken together, *Experiment 6* expands on the findings of *Experiment 1a-1d*, *Experiment 2 and Experiment 3* in showing an interaction between emotion and self-relatedness on memory. Possibly this is because of the increased difficulty of the free-recall task compared to the memory recognition task. With a free-recall task, there are no cues to facilitate recall, and this potentially highlights any influence of emotion and self on recall.

Bringing it all together

The most consistent finding of this thesis is that every chapter that used the matching paradigm found a clear effect of the self. This shows that the adapted perceptual matching paradigm of Sui, He and Humphreys (2012) is very robust in producing a self-priority effect. Using the different approaches summarized in the previous section, it has become clear that self-related information is prioritised over information not related to the self. In other words, self-related items appear to be more salient. This increased saliency results in a more prioritised attentional processing. Not only does this allow to process the prioritised information more efficiently, it also allows for better encoding. Furthermore, the ERP data supports the view that self-related information is prioritised as a self-priority effect was linked to several ERP components (most notably the N100). However, as efficient as the matching task is in highlighting the beneficial effect of self-related information, the effect of emotion on attentional processes were not as clear in most experiments. Nonetheless, when taking special care to insure that the participants' responses included the effect of emotion (the redundancy gain *Experiment 2*), a clear interaction between positive emotion and self-related information was found.

As discussed in the introduction (*Chapter 1*), previous literature found that emotional and self-related information interact. More precisely, positive emotions are thought be more easily linked to self-related information and negative emotions are more difficult to link to self-related information (Baumeister & Cairns, 1992; Fredrickson, 1998; Grol et al., 2014; Mezulis et al., 2004; Wadlinger & Isaacowitz, 2006). The general viewpoint of this thesis therefore was that emotion strongly influences how self-related information is processed but emotion alone does not explain the beneficial effects found for self-related stimuli as several studies had found (Gutchess et al., 2007; Leshikar et al., 2015; Stolte et al., 2016). The concept that emotion and self-related information processing are two interacting but ultimately separate systems was further strengthened with the findings of *Experiment 2*, via the redundancy gain paradigm. *Experiment 2* showed super-capacity for emotional self-related words during the matching task. In other words, during attentional processing, there was integration between self-related and emotional information. This integration lead to faster processing of emotional self-related information compared to stimuli only related to the self or emotional stimuli. Taking all the matching paradigms together, it can be concluded that there is a clear effect of self on prioritising self-related information during attentional processes and that although self and emotional information is processed by separate systems, they do interact. Based on the experiment chapters with the matching task, it can be concluded that this interaction between emotion and self-related information leads to an increase in efficiency in attentional processing. However, this might only be because the emotion was task relevant (Mather & Sutherland, 2011). Therefore, it remains interesting to see how emotion would impact self-related information processing when not task-relevant. Nonetheless, the main finding of the matching task is that if further replicates and strengthens the finding of previous literature (e.g. Alexopoulos et al., 2012; Cherry, 1953; Sui et al., 2012) on a self-priority on attentional processing. That being said, finding a self-priority effect was not the only goal of this thesis as one of the main goals was to link an initial self-priority effect of attention to a subsequent self-reference effect in memory.

This goal of attaining a self-reference effect in memory following a self-priority effect in perceptual attention was achieved in every experiment of this thesis. A self-reference effect was observed most old/new recognition task, the cue-recall used in the think/no-think experiment and in the free-recall tasks. This beneficial effect of self-related information on memory was in line with the predictions made in the introduction of this thesis (M. A. Conway & Dewhurst, 1995; Kelley et al., 2002; Klein & Kihlstrom, 1986; Rogers et al., 1977; Symons & Johnson, 1997). In a divided attention study, Turk et al. (2013) found that this advantage of self-related items on memory disappeared when attention was divided. Suggesting that attention is required for any benefit of self on memory. However, in *Experiment 4 and* 5 a self-reference effect was not always followed by a self-reference effect even when attention was fully on the encoding (i.e. matching) task. This suggests that despite an initial benefit of the self, repetition by itself does not influence self-related information per se. However, other-related information is affected by repetition and therefore "catches-up" with self-related information. The EEG chapters (*Experiment 5 and 6)* have further supported these findings by showing increased EEG activity for the ERP components linked to memory for self-related items, when compared to other-related items (e.g. LPC). Nonetheless, *Experiment 5* also showed that words related to the self are more stable in memory and recalled more accurately over a longer period of time compared to words not linked to the self.

Furthermore, all experiments that contained a manipulation of emotion (*Experiment 1a-1d, 2, 3, &6)* showed a positive effect of emotion (both for negative and positive emotions) on memory. A possible explanation of this effect was that for a memory experiment the emotional meaning of the word would increase saliency of the word and was therefore task-relevant (Mather & Sutherland, 2011; Sakaki et al., 2014). The effect of emotion on memory remained when, in *Experiment 3*, repetition caused the self-reference effect to disappear. This again suggests a difference in processing of emotional stimuli and self-related stimuli. Where repetition of self-related information does not further increase the salience of the stimuli beyond a fast, automatic initial gain, emotional stimuli seems to increase in saliency when compared to emotional neutral words regardless of repetition.

Despite a clear finding of emotion, a clear interaction between self-related information and emotional information remained absent until the last experiment (*Experiment 6*). Despite showing a significant interaction in several memory tasks, all earlier experiment showed a cumulative effect of self and emotion. This cumulative effect showed a main effect of emotion and self-related words, but emotional self-related words more not significantly different than either emotional words or self-related words alone. It appeared that emotional self-related words could not help improve memory more than each of its part could. In other words, a maximum of improvement was already reached via emotion alone or self-related information alone. However, with *Experiment 6*, this maximum was much more difficult to reach because of the increase in task difficulty. This allowed for a clear indication of an interaction between self and emotional information. This further expands the findings of the redundancy gain paradigm (*Experiment 2)* which found super-capacity for emotional self-related words but no clear superior effect on memory by emotional self-related words.

In short, this thesis has shown that the self-priority effect clearly leads to a self-reference effect and while emotion interacts with self-related processes, emotion and self-related information processes are clearly distinct processes. These findings clearly support the concept of an 'integrative' self (Sui & Humphreys, 2015b). As discussed in the introduction, Sui and Humphreys (2015b) see the self as a way in which different bits of information are linked together across cognitive domains. This thesis has repeatedly shown that self-related information, when prioritised when first encountered also leads to improved memory for those items. This too might be reflected in the EEG research as a P300 was found when actively encoding words in *Experiment 5*. This is interesting because the P300 has been linked with attention to memory processes (Polich, 2007), and the P300 in this experiment was more pronounced for self-related items when compared to other-related items.

Several models have been suggested by previous literature to explain the underlying neurophysiological mechanisms involved in the apparent beneficial effect of self on attention and memory. The next section will link the (ERP) findings of this thesis with those models discussed in *Chapter 1*.

Link to models of the self

In *Chapter 1*, several models of self-relevant information processing were discussed, namely the integrative self (Sui & Humphreys, 2015b), the SAN model (Humphreys & Sui, 2016), and the SMS (M. A. Conway, 2005). It should be noted that the methods used in this thesis are limited in terms of what they can actually tell us about the structure of the underlying brain networks. In this sense, they do not, in any way, constitute a direct test of this, or other models. However, despite this, some inferences can be made from the results we have.

The findings of this thesis are broadly in line with the predictions of the SAN. To reiterate, the SAN consists of three components that form a neural network: an attention network, self-representations; and a bottom-up communication process (Humphreys & Sui, 2016). In some respects, the behavioural data were fairly consistent in this thesis. In particular, all experiments have shown a distinct self-priority effect. This clearly demonstrated an advantage of self-related information in directing one's attention. Furthermore, in the matching task, this advantage of self-related information was achieved by linking an arbitrary colour to the self with simple instructions. This link of an arbitrary colour to the self arguably shows an interaction between top-down and bottom-up processes as the colour of the word is possibly primed by self-relevance. The EEG data of *Experiment 5 and 7* also help inform the SAN model. EEG for the matching task showed clearly that early N100 components were linked to the self, which shows that early discrimination attentional processes were influenced by self-relevant information. Furthermore, a P200 has been linked to self-relevant information processing together with a P300. Both components are believed to reflect mechanisms associated with directing and maintaining attention to presented information. Lastly, similar to what the data from this thesis suggest, the SAN proposes that the self is a distinct function in the brain and the self-relatedness of information is processed at a low level in the brain, i.e. the self is not some higher and separate cognitive function, but is possibly a basic aspect of brain function which is incorporated within multiple other cognitive processes.

The basis of the SMS is the interconnectedness between memory and the self (M. A. Conway & Pleydell-Pearce, 2000). The SMS is proposed to aid coherence between the self and current/future goals by maintaining and creating highly goal-relevant memories. Arguably this process involves promoting self-relevant information, thus increasing the saliency of self-relevant memories. As the SMS is thought to monitor self-related information in order to maintain a coherent self, some form of top-down selection of self-related information must take place. Via the working self of the SMS, self-related information can be linked to attended information, either internally with memory retrieval and maintenance or externally with the processing of sensory information. This thesis has demonstrated that self-related information is processed faster and more accurately. More relevant to the SMS is the finding that memories related to the self are remembered more easily and are less subject to forgetting. This finding can be explained with richer self-related information that is more salient than information not related to the self. These findings were further supported by the EEG results of *Experiment 5* with an enhanced (late) LPC for self-related information, compared to distant other-related information. This enhanced LPC possibly reflects richer memories of self-relevant information. Also, an enhanced P300 for self-relevant information compared to distant other-relevant information showed a reallocation of attention towards self-relevant information.

Bridging the influence of self on attention and memory together is the model of a neural network of the self-as-object (Sui & Gu, 2018), which adds to the concept of an integrative self (Sui & Humphreys, 2015b). The idea of the integrative self suggests that information related to the self binds together across cognitive domains, which increases the saliency of self-relevant information. This binding of self-relevant information also possibly increases the stability of the information over time. This is demonstrated in *Experiment 5*, where less forgetting for self-relevant information is observed compared to distant other-related information. Furthermore, this thesis has consistently shown that self-related information prioritised by attention is later also remembered more often. Like the SAN, the self-as-object neural framework consists of three interconnected components: a core self system involved in internal self versus distant other judgements; a cognitive control system related to external information processing; and a salience node which focusses on emotion and reward. The data from this thesis has shown some support for these three interconnected components. For example, in the matching tasks, an internal link is made between a colour and the self. This influences the perception and attention toward external stimuli which could be primed to be perceived as self-relevant which causes the now self-relevant stimuli to be prioritised over distant other-related stimuli via increased saliency.

Limitations

Some limitations have already been highlighted in each chapter relevant to the respective experiments. However, there are two broader limitations inherent to the research described in this thesis.

There are some limitations linked to EEG research in general. First is the question of causality, which currently remains unanswered as EEG research is correlational in nature. Second is the difference between self and emotional information processing. This thesis has shown that these are possibly two different processes affecting attention and memory in a similar way. However, the current EEG analysis has been unsuccessful in showing this difference. Possibly this lack of differences might be because of the similarities in the processes influenced by self and emotion. For example, the P300 which reflects the reallocation of attention to goal-relevant stimuli via inhibition would be similar for both emotion and self-relatedness. Nonetheless, how these two processes influence the P300 should be different, which should, in turn, be reflected in the neurophysiological networks involved. The EEG analysis used in this thesis is unable to detect such networks, but different analyses do exist, which could help solve this problem. Both the limitations of causality and underlying networks can be addressed in future studies or reanalyses, and two examples are given in the future studies section.

Arguably foremost, there is a general limitation of ecological validity in the paradigms, using in this thesis. Naturally, the main reason for selecting the paradigms was to control for possible confounding factors such as familiarity. The arbitrary linking of the self to a colour helped to control for confounds such as familiarity and assisted in further isolating and examining self-related processes. Nonetheless, this does come with a trade-off of losing ecological validity. Naturally, more ecological valid paradigms can be used, but this would inevitably introduce noise when trying to measure self-relevant information processing. For example, previous research have used faces and names to generate a self-priority effect (Alexopoulos et al., 2012; Cherry, 1953; Shapiro et al., 1997; Tong & Nakayama, 1999), or studied the self-reference effect by asking participants to link traits to themselves and compare this to semantic processing (M. A. Conway & Dewhurst, 1995; Kelley et al., 2002; Klein & Kihlstrom, 1986). However, as discussed in *Chapter 1*, this possibly creates confounds such as familiarity, or other forms of enriched encoding beyond the influence of the self. Another way to increase ecological validity is by giving or removing items that participants think are theirs in variations where *ownership* is manipulated (S. J. Cunningham et al., 2008; Turk et al., 2011).

Nonetheless, this paradigm can be used to investigate attentional and memory processes. Throughout this thesis, a clear self-priority and self-reference effect have been demonstrated. Furthermore, with the robust findings of this paradigm and relative ease of administering this to a wide population range means that emotion and self-relevant information processing can easily be studied under many different scenarios. An example of this is provided in the next section on future research suggestions, where among others, a clinical study is proposed.

Future Studies

In this section, some ideas for future research will be suggested. Some of these suggestions are different kinds of analyses which would require only minimal adaptations of the paradigms used in this thesis. However, other suggestion builds on the research of this thesis but would require more substantial adaptations of the paradigms.

Phase synchronisation

Phase synchronization is based on the idea that neurons are part of a network, and these neurons influence each other via inhibitory and excitatory signals. These inhibitory and Excitatory communications between neurons generate rhythmic activation or inhibition patterns (Buzsáki, 2006), which are called neural oscillations. Also, frequencies in several regions can correlate with each other; this is called phase synchronization (Fell & Axmacher, 2011).

The aspects of neural oscillations are especially interesting for research on the self and how self-relevant information is prioritised of information not related to the self. If the self is a hub connecting different levels of processing in the brain, this should be reflected by increased communication between neural networks and previous research has shown specific phase synchronisation linked to self-relevant information processing

(Mu & Han, 2010). The results of Mu and Han (2010) show that higher frequencies were involved in self-referential judgement and that lower frequencies were involved in discriminating between positive and negative emotions when referenced to the self. This suggests that the relevance and emotional components of self-reference processes are mediated by separate neural networks. These concepts could be applied to the current research to further investigate the neural networks involved during the matching task and subsequent recall.

Transcranial magnetic stimulation

As mentioned earlier, one of the limitations of the EEG methods, in general, is the correlational nature of EEG. Via transcranial magnetic stimulation (TMS), where a magnetic pulse directly disrupts ongoing brain activity, causality can be tested directly. Via TMS a localised magnetic pulse can be introduced to a specific area in the brain via a magnetic coil placed against the scalp of a participant. This magnetic pulse creates an electric current in neural networks, which activates the neurons in the targeted area. The general idea behind TMS is fairly straightforward. If a specific area in the brain is responsible for a specific measurable behavioural finding, then activating the neurons in that area would disrupt the observed behavioural findings. These disruptions in behaviour are the direct consequence of the induced electric current that effects excitatory and inhibitory neuronal connections of which the effect spread transynaptically. In short, via TMS you can introduce noise into neural information processing. Often the measurable behavioural effect is a reduced reaction time for a specific task.

In a TMS experiment by Lou et al. (2004), the medial parietal region was stimulated to disrupt ongoing neural activity whilst participants were performing a self-reference task. The task was, again, a trait-word judgement task. In this particular experiment, participants either judged how well a trait-word applied to themselves, their best friend, or the Danish Queen. During a subsequent retrieval phase, participants had to indicate if the trait was judged in the initial task to fit them or their best friend. During an earlier PET scanning session, using a similar task, the authors identified brain regions involved in self-referencing and found that the medial parietal/posterior cingulate region was interacting with the right inferior parietal cortex and mPFC, suggesting it is possibly involved in self-referenced information retrieval. For the TMS experiment, a magnetic pulse was administered during the retrieval phase at one of three regions: Occipital pole, medial parietal region, and anterior to the vertex. During the retrieval phase, each trait-word was presented one at the time and the TMS pulse was administered with different latencies of: 0, 80, 160, 240, and 480ms. The results demonstrated that TMS impaired the self-reference effect at the medial parietal cortex with a latency of 160ms. This lead the authors to conclude that the lateral parietal cortex plays an important role in the self-reference effect as it connects the inferior parietal cortex with the mPFC, which, as mentioned earlier, is involved in self-referencing in memory. Furthermore, as part of the DMN the inferior parietal cortex is closely connected to other brain regions involved in processing self-relevant information (e.g. ACC and PCC).

As mentioned earlier in *Chapter 1*, many studies link the mPFC to the processing of self-relevant information. However, in a TMS study very similar to the one described in the previous paragraph, the self-reference effect was not disrupted via stimulation of the mPFC (Lou, Luber, & Lisanby, 2010). Where in the previous study (Lou et al., 2004) the Parietal midline regions (precuneus) were targeted for TMS, this time the left and right parietal cortex (AG) and mPFC were targeted, again with different latencies. TMS to the mPFC had no effect on the self-reference effect, but TMS to both left and right parietal cortex did. However, TMS to the parietal cortex did not influence the self-reference affect in the same way for the left and right sites. TMS to the right parietal cortex revealed similar results as the previous experiment at a latency of 160ms, although the effect of TMS did last longer than when the precuneus was stimulated. The left parietal cortex showed an effect of TMS at all latencies (80-480ms), even to the point of reversing the self-reverence effect for the 160ms interval. Lou et al. (2010) suggest that the lack of effect from the mPFC might be because the mPFC is specialised in processing different, albeit sill self-related, information. The authors refer to the work of Kwan et al. (2007)

where a self-positivity effect was reduced after TMS to the mPFC. This implies that the mPFC is more involved in the affective components of self-relevant information, whereas the parietal cortex is more involved in self-referential processing. Together these results suggest a role for the DMN in processing self-relevant information, as discussed in *Chapter 1*. In principle, TMS can be applied to the current experimental set-up without major changes to the methodology.

Clinical study with self-related information processing

The findings of this thesis could be applied to a more clinical investigation of self-related information processing, and beyond further elucidating the processes involved, it could potential directly influence and aid people with memory difficulties, especially knowing that the DMN is involved in self-referential processing.

As mentioned during *Chapter 1*, the DMN is a network of brain areas which have been proposed to be implicated in self-referential processing (Qin & Northoff, 2011; Spreng & Grady, 2009). The network includes the medial prefrontal cortex (mPFC), the medial, lateral and inferior parietal cortex and the precuneus posterior cingulate cortex. The DMN shows consistent task related de-activation and is more active at rest. Cognitively demanding tasks generally result in greater deactivation of the DMN (Singh & Fawcett, 2008). However, the opposite is true when the task involves self-referential processing (Mitchell, 2006). Patients with Parkinson's disease (PD) have been found to have reduced connectivity in the DMN (Yao et al., 2014). This suggests the brain network associated with self-related processing might be compromised in these patients. In PD a decrease of DMN functionality is linked with cognitive impairments (Lewis, Dove, Robbins, Barker, & Owen, 2003; van Eimeren, Monchi, Ballanger, Strafella, & Eimeren, 2009; Whitfield-Gabrieli et al., 2009).

Within the PD population over a third of the patients additionally suffer from dementia (J. L. Cummings, 1988). Despite severe memory impairments, self-awareness and self-reference seem to be relatively intact in patients who suffer from dementia

(Gross et al., 2004). The study by Gross et al. (2004) study showed that patients suffering from dementia could learn to recognize self-relevant pictures when compared to other pictures not relevant to the self.

It is notable that in some Alzheimer's patients, the self-reference effect seems to help improve recall (Kalenzaga & Clarys, 2013; Rosa, Deason, Budson, & Gutchess, 2014). In the study by Kalenzaga and Clarys (2013), Alzheimer's patients displayed a self-reference effect but only for negative words. Alzheimer's patients did not rate themselves negatively, but, other people seem to perceive them more negatively. Kalenzaga and Clarys (2013) suggested that the negative perception of Alzheimer patients could generate a more negative self, which could explain the negative emotion self-reference effect. Normal controls, in general exhibit a positive emotion self-reference effect (Mezulis et al., 2004). Therefore, it is possible that despite the memory impairments, the beneficial treatment of self-related information is still largely intact. An intact self-referential processing network can, in turn, help facilitate memory. However, some research on Alzheimer's patients shows a reduced self-reference effect (Genon et al., 2014; Wong et al., 2017).

Nonetheless, it is possible that self-referential treatment of information could facilitate memory in patients with PD. Future research could aim to evaluate self-related effects in general and how self-based processing of information can enhance memory of patients with PD. Using EEG whilst having participants perform self-based matching and memory tasks could help show if patients with PD show normal self-referential processing and compare the EEG finding with normal controls. One component of interest in this EEG is the P300 component, which has been linked to self-referential processing (Knyazev, 2013). For example, higher P300 amplitudes are recorded when participants view their own names (Fischler et al., 1987; Holeckova et al., 2006) or faces (Ninomiya, Onitsuka, Chen, Sato, & Tashiro, 1998; Sui et al., 2006) when compared to the names and faces of others. Furthermore, we will analyse changes in DMN activities in the theta, alpha, and beta frequency bands of EEG, which are typically associated with the DMN and self-referential processing (Knyazev, 2013). Although the basics of the matching task and memory task combination discussed in this thesis can be used, since dealing with a clinical population several methodological changes would have to be made (e.g. the experiment must be shorter as patients with PD get tired much faster, healthy controls must be added, and cognitive assessments would have to be performed).

Conclusion

The experiments in this thesis have shown clear evidence for an effect of self on attention and subsequent memory. This, on its own, is not novel. Earlier work starting with the perceptual matching task of Sui et al. (2012) has shown a clear effect of self on attention on a similar task. Nonetheless, the matching task used in this thesis was a novel adaptation of the original matching task, which could now be used as an encoding task as well. This familiarity-controlled encoding of self-relevant information and its later recall is novel and allowed for a clear insight into the prioritising effect of self-relevant information on attention and consequently more accurate later recall. The effect of emotion during the matching task is less clear, although there does seem to be an indication of prioritisation of emotional information (*Experiment 6)*.

Nonetheless, combining the findings of *Experiments 1a-1d*, *Experiment 2*, *Experiment 3*, *and Experiment 6*, emotion appeared to influence the memorability of an item, and since word salience was beneficial to the participants' current goal (i.e. to remember words for the memory tasks) emotion increased the likelihood that a word was recalled during a later memory test. Furthermore, since *Experiment 2* revealed a super-capacity for words that were both positive and self-related, it is likely that emotion and the self influence attention and memory via different underlying processes, which was further exemplified by *Experiment 3*, and *Experiment 6*. *Experiment 3* showed that repetition abolished the self-reference effect in memory without influencing the facilitatory effect of emotion on memory. Furthermore, *Experiment 6* revealed that potentially with increased memory load, self-positive words are recalled more often than self-related or emotional information.

The EEG results of *Experiment 5* and *Experiment 6* supported these behavioural findings. A N100 was directly linked to early discrimination attentional processes where a larger N100 was linked to self-relevant information. An enhanced P200 and P300 showed that self-related information is overall more efficiently processed than distant other-related information. Also an FN400 revealed that distant other-related information was potentially more laboursome to process than self-related items, as shown by an increased FN400 for distant other-related words. Lastly (late) LPCs showed that self-related items were linked to increased recollection as the LPC was more positive for self-related words than distant other-related words.

In short, this thesis suggests that emotion and self both help prioritise information by directing our attention towards more salient information via top-down/bottom-up control mechanisms. This prioritised information is then recalled more easily and remains in memory for longer than information not related to the self or neutral valence information. Self-relatedness and emotion influence attention and memory arguably in a similar way but are distinctly separate processes that, when occurring together in a single item, can increase the efficiency of that item's processing. Both emotional and self-relevant information increase the saliency of information, which leads to an increase in attentional resources being used. This allows for prioritised information processing of potential goal-relevant information. In turn, increased attention leads to increased or more efficient encoding into memory. This alone improves later recall, but with the greater integrative binding of self-related information, self-relevant information is easier to retrieve from memory.

The finding that self-relevant information improves attention towards and memory for stimuli is an important one. The robustness of the effects across experiments suggests that these effects may well translate into more cognitively natural, 'real life' situations. It suggests that in order to improve memory for stimuli, it is useful to link it to the self in some way. By making the stimulus self-relevant, it is more likely to focus attention and memory processes, leading to richer encoding of the stimulus and better recognition and recall. This finding is important both as a potential everyday mnemonic technique and as a possible intervention for clinical groups for whom memory problems are a significant feature.

In the previous section (future research), a study was proposed that will test self-related information processing in PD patients with dementia. Patients with dementia can be helped to improve their memory using a self-reference memorisation technique. For example, by linking important information to themselves (via for instance a photo of themselves, or something else which is highly self-relevant), the memorability of that information could be improved (Gross et al., 2004). In this way, one can take advantage of the automatic self- processes which facilitate memory, as identified in this thesis.

Knowledge of how emotion and self are prioritised by attention can be applied to non-clinical populations as well. By personalising information (using positive self-related stimuli), that information becomes salient. In the current matching paradigm, a simple set of instructions is enough to link the self to a specific colour and increase the saliency of that colour compared to a colour not linked to the self. Although non-experimental settings are much more complex, linking the self to important scenarios or messages would prioritise that information. This could help ensure that vital information is attended to, and processed with priority. For example, using personalised signs (containing self-relevant information) could possibly make people more aware of the signs. Self-reference effects could also be utilised by the advertising industry. A major goal of advertising is to have a memorable brand. Much advertising in the modern world occurs on the internet. This allows considerable flexibility and bespoke targeting of the advert to the end user. Companies can easily draw on the database of personal information available to produce on-line advertisements which contain self-relevant positive information. By doing so, our results suggest this would make the advert more likely to prioritise attention and thus make the brand or brand symbol, more likely to be later recognised and recalled.

To conclude, the processing of emotional and self-relevant information is distinct, but both are fast and automatic processes which help increase the saliency of information relevant to one's goals. Even though emotional and self-related information processing starts out as two separate processes, they can interact to potentially further increase the efficiency of information processing.

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Appendix

Wordlists

Experiment 1a:

Negative nouns

1. abuse
2. ache
3. admissible
4. alzheimers
5. angry
6. annihilate
7. anxious
8. arrest
9. assault
10. attack
11. avalanche
12. battlefield
13. bombing
14. bury
15. cannibal
16. chase
17. comatose
18. crabby
19. crazed
20. craziness
21. crisis
22. crocodile
23. cuss
24. destructive
25. dictatorship
26. disgusting
27. distressed
28. doom
29. earthquake
30. execution
31. fatal
32. fight
33. fireball
34. fistfight
35. freak
36. fucker
37. ghetto
38. gunfire
39. hangover
40. harass
41. hellhole
42. horrid
43. horrific
44. hostility
45. jagged
46. jeopardize
47. jerk
48. killer
49. laceration
50. lawsuit
51. madness
52. mafia
53. maggot
54. maniacal
55. miserable
56. mistrust
57. motherfucker
58. mugger
59. obscenity
60. obsessive
61. overkill
62. poisoning
63. pornography
64. prosecutor
65. prostitution
66. provoke
67. psychotic
68. puke
69. quake
70. rabid
71. racism
72. revenge
73. robber
74. satanic
75. schizophrenia
76. scoundrel
77. seducer
78. shithead
79. sneaky
80. snoop
81. sociopath
82. stew
83. stickup
84. stinging
85. suffocate
86. suicide
87. swarm
88. tarantula
89. thief
90. threaten
91. torment
92. tornado
93. treacherous
94. tsunami
95. turbulence
96. unjust
97. violent
98. warhead
99. warning
100. zombie

Neutral Nouns

1. adjacent
2. aisle
3. angora
4. appliance
5. asparagus
6. assessment
7. asterisk
8. autobiography
9. ballpoint
10. baseline
11. basket
12. bathroom
13. bedside
14. binoculars
15. butler
16. cabernet
17. cargo
18. cattle
19. cauliflower
20. center
21. channel
22. chess
23. comb
24. comparison
25. compass
26. conference
27. constant
28. crayon
29. demeanor
30. department
31. describe
32. desk
33. disinfectant
34. docile
35. doghouse
36. domestic
37. dresser
38. dune
39. editorial
40. epidemic
41. footing
42. format
43. foundation
44. freezer
45. gospel
46. governess
47. guidebook
48. hairdryer
49. inlet
50. insignia
51. intercom
52. level
53. likelihood
54. listing
55. livestock
56. manhunt
57. mantle
58. mild
59. milkman
60. naval
61. noon
62. optional
63. outline
64. overall
65. parallel
66. pause
67. pigeon
68. practice
69. predictable
70. preface
71. proper
72. provincial
73. pruning
74. punctuation
75. rectangular
76. researcher
77. rowboat
78. sample
79. scripture
80. sediment
81. shallows
82. sheet
83. shirt
84. shoe
85. slavery
86. solid
87. soundproof
88. spatula
89. spoonful
90. stairwell
91. stationary
92. tapestry
93. tinker
94. tomato
95. township
96. tutor
97. unpack
98. wall
99. workings
100. yawn

Experiment 1b

Positive nouns (plus 40 catch-words)

1. active
2. adore
3. adventure
4. affection
5. album
6. amazing
7. ambitious
8. astonished
9. award
10. beautiful
11. bonus
12. bravery
13. brewing
14. brilliant
15. caffeine
16. cash
17. celebrate
18. cheerful
19. cheetah
20. christmas
21. cinema
22. climax
23. comedy
24. create
25. curious
26. dazzling
27. delightful
28. desire
29. diamond
30. dinosaur
31. discover
32. dragon
33. eager
34. ecstasy
35. embrace
36. energetic
37. euphoria
38. excited
39. exotic
40. expansion
41. expertise
42. fantastic
43. female
44. festive
45. fireworks
46. fortune
47. freedom
48. frisky
49. generous
50. girl
51. glory
52. gold
53. goldfish
54. gourmet
55. graduation
56. grin
57. happy
58. hilarious
59. honeymoon
60. horny
61. incredible
62. innovation
63. inspire
64. intimate
65. invent
66. jackpot
67. jazz
68. joke
69. jolly
70. kids
71. kiss
72. kitten
73. koala
74. laugh
75. legendary
76. leopard
77. lottery
78. lover
79. lust
80. magic
81. martini
82. mermaid
83. meteorite
84. mindful
85. money
86. musical
87. nintendo
88. nude
89. outgoing
90. panther
91. party
92. passion
93. payday
94. penthouse
95. perk
96. playful
97. pleasure
98. pregnant
99. princess
100. prosper
101. puppy
102. qualify
103. quest
104. reasoning
105. romance
106. rose
107. safari
108. sale
109. saucy
110. score
111. sensual
112. sexy
113. sparkly
114. speed
115. spicy
116. stimulate
117. stunning
118. success
119. succulent
120. surprise
121. swim
122. tequila
123. thrill
124. thrive
125. tickle
126. tiger
127. treasure
128. tree
129. unicorn
130. vaccine
131. value
132. vibrant
133. victory
134. voyage
135. weekend
136. winning
137. witty
138. wolf
139. workout
140. youthful

Neutral nouns (plus 40 catch-words)

1. abbey
2. aisle
3. albatross
4. armchair
5. await
6. backdrop
7. basic
8. basket
9. bathroom
10. binoculars
11. bulletin
12. bunch
13. calendar
14. camel
15. canvas
16. card
17. cargo
18. cattle
19. ceiling
20. ceramics
21. chair
22. channel
23. click
24. compass
25. conference
26. continue
27. cooker
28. counter
29. crab
30. cross
31. curtains
32. department
33. desk
34. dishwasher
35. document
36. dozen
37. editorial
38. entire
39. equipment
40. external
41. ferret
42. flooring
43. format
44. fortnight
45. foundation
46. freezer
47. frog
48. furniture
49. geography
50. goat
51. grass
52. ground
53. habitat
54. hairdryer
55. hairspray
56. holder
57. horse
58. housing
59. indicator
60. item
61. lamp
62. lawnmower
63. lens
64. level
65. list
66. magpie
67. match
68. mention
69. middle
70. mill
71. mini
72. mole
73. moth
74. mouse
75. mule
76. mushroom
77. name
78. napkin
79. naval
80. newspaper
81. norm
82. north
83. occasional
84. outline
85. parallel
86. parchment
87. patch
88. pause
89. pavement
90. pendulum
91. philosophy
92. phrase
93. pigeon
94. plausible
95. pole
96. pottery
97. powder
98. practice
99. print
100. proper
101. quote
102. rail
103. relevant
104. resolve
105. respond
106. round
107. sample
108. scenario
109. seat
110. sequence
111. sheep
112. shelf
113. shirt
114. solid
115. specific
116. spot
117. spruce
118. station
119. stir
120. straw
121. strings
122. study
123. suit
124. surface
125. symbol
126. table
127. telegraph
128. terrain
129. theme
130. title
131. token
132. tomato
133. toothpaste
134. translate
135. trolley
136. turtle
137. typewriter
138. vault
139. wallpaper
140. workings

Experiment 1c

Negative trait-words

1. terrible
2. liar
3. thoughtless
4. pathetic
5. unfriendly
6. attacking
7. vicious
8. immature
9. disobedient
10. downcast
11. insincere
12. gruesome
13. impolite
14. crude
15. violent
16. uptight
17. annoyed
18. dismal
19. abusive
20. dislikable
21. whiny
22. rude
23. uncongenial
24. uninspiring
25. ungracious
26. fussy
27. disruptive
28. vengeful
29. prejudiced
30. mad
31. nasty
32. unsociable
33. hateful
34. insulting
35. neglectful
36. cursed
37. unforgiving
38. phony
39. suicidal
40. disrespectful
41. cranky
42. lifeless
43. arrogant
44. crabby
45. cold
46. awful
47. repulsive
48. distrustful
49. bragging
50. disgraced
51. unruly
52. untrustworthy
53. selfish
54. dishonest
55. jealous
56. heartless
57. antisocial
58. incompetent
59. hostile
60. offensive
61. pushy
62. unethical
63. unobliging
64. negligent
65. conceited
66. wretched
67. egotistical
68. low
69. uninteresting
70. dull
71. bad
72. bitter
73. unattentive
74. bossy
75. mean
76. irresponsible
77. unreasonable
78. discriminating
79. unreliable
80. threatening
81. doomed
82. deceitful
83. quarrelsome
84. disgusting
85. cruel
86. miserable
87. grouchy
88. uncivil
89. humorless
90. failure
91. disturbed
92. manipulative
93. irrational
94. snobbish
95. discourteous
96. dreary
97. irritable
98. unsympathetic
99. useless
100. shallow
101. vulgar
102. ungrateful
103. unkind
104. scolding
105. sadistic
106. scornful
107. empty
108. unhappy
109. pitiful
110. greedy
111. unpleasant
112. angry
113. boring
114. worthless
115. malicious
116. unproductive
117. nagging
118. morbid
119. unfair
120. furious

Neutral trait-words

1. amiable
2. amorous
3. assertive
4. average
5. bashful
6. blunt
7. boisterous
8. bold
9. brimming
10. brisk
11. bubbly
12. buoyant
13. candid
14. cautious
15. changeable
16. clownish
17. clumsy
18. coercive
19. competitive
20. congenial
21. conservative
22. conventional
23. convincing
24. crafty
25. daredevil
26. daring
27. daydreamer
28. decisive
29. definite
30. dependent
31. diligent
32. discreet
33. dramatic
34. driven
35. eccentric
36. emotional
37. enterprising
38. extravagant
39. exultant
40. fearless
41. flamboyant
42. forward
43. frank
44. frisky
45. genial
46. headstrong
47. idealistic
48. impressionable
49. impulsive
50. individualistic
51. informal
52. ingenious
53. inoffensive
54. inquiring
55. inquisitive
56. intense
57. jovial
58. light
59. literary
60. maternal
61. mathematical
62. meditative
63. mellow
64. methodical
65. meticulous
66. moderate
67. modern
68. nonconforming
69. obedient
70. objective
71. obliging
72. orderly
73. ordinary
74. outspoken
75. peppy
76. perfect
77. perfectionist
78. persistent
79. persuasive
80. philosophical
81. poised
82. popular
83. powerful
84. precise
85. prideful
86. privileged
87. proficient
88. prosocial
89. purposeful
90. quiet
91. racing
92. radical
93. realist
94. refined
95. reflective
96. religious
97. renewed
98. reserved
99. robust
100. scientific
101. seductive
102. serious
103. shy
104. striving
105. suave
106. subtle
107. superstitious
108. systematic
109. tactful
110. theatrical
111. thrifty
112. thriving
113. tolerant
114. tough
115. triumphant
116. upright
117. venturesome
118. vigilant
119. vigorous
120. vivacious

Experiment 1d, 2

Positive trait-words

1. able
2. achieving
3. active
4. admired
5. adventurous
6. affectionate
7. alert
8. ambitious
9. amusing
10. appreciative
11. assisting
12. attentive
13. brave
14. bright
15. brilliant
16. caring
17. casual
18. charming
19. cheerful
20. clean
21. clever
22. comforting
23. comical
24. competent
25. composed
26. concerned
27. confident
28. considerate
29. courageous
30. courteous
31. creative
32. delighted
33. dependable
34. determined
35. devoted
36. easygoing
37. efficient
38. encouraged
39. energetic
40. entertaining
41. enthusiastic
42. exceptional
43. excited
44. experienced
45. extraordinary
46. fair
47. forgiving
48. friendly
49. generous
50. gentle
51. genuine
52. glad
53. glorious
54. good
55. gracious
56. grateful
57. great
58. happy
59. helpful
60. hilarious
61. honest
62. honorable
63. hopeful
64. humorous
65. independent
66. intelligent
67. interesting
68. joyful
69. kind
70. likable
71. lively
72. loving
73. loyal
74. marvelous
75. moral
76. neighborly
77. nice
78. optimistic
79. organized
80. original
81. outgoing
82. outstanding
83. passionate
84. perceptive
85. pleasant
86. polite
87. positive
88. practical
89. productive
90. realistic
91. reasonable
92. relaxed
93. reliable
94. remarkable
95. respectful
96. responsible
97. romantic
98. secure
99. sensitive
100. sexy
101. sharing
102. sharp
103. sincere
104. skilled
105. smart
106. social
107. spirited
108. successful
109. sunny
110. supportive
111. talented
112. terrific
113. thoughtful
114. trustworthy
115. truthful
116. understanding
117. warm
118. whole
119. wise
120. wonderful

Neutral trait-words

1. amiable
2. assertive
3. authoritative
4. average
5. bashful
6. boisterous
7. brisk
8. buoyant
9. candid
10. cautious
11. changeable
12. clownish
13. clumsy
14. coercive
15. competitive
16. congenial
17. conservative
18. contented
19. conventional
20. convincing
21. cordial
22. cunning
23. curious
24. daredevil
25. daring
26. daydreamer
27. decisive
28. definite
29. deliberate
30. dependent
31. diligent
32. discreet
33. dramatic
34. driven
35. eccentric
36. elated
37. enterprising
38. extravagant
39. exultant
40. fearless
41. flamboyant
42. forward
43. frank
44. frisky
45. genial
46. headstrong
47. idealistic
48. important
49. impressionable
50. impulsive
51. individualistic
52. industrious
53. inexperienced
54. informal
55. ingenious
56. innocent
57. inquiring
58. intense
59. inventive
60. jovial
61. literary
62. loud
63. maternal
64. mathematical
65. mediocre
66. meditative
67. mellow
68. methodical
69. moderate
70. modern
71. modest
72. nonchalant
73. obedient
74. objective
75. obliging
76. opportunist
77. orderly
78. ordinary
79. outspoken
80. passive
81. peppy
82. persistent
83. persuasive
84. philosophical
85. poised
86. precise
87. prideful
88. privileged
89. proficient
90. prosocial
91. prudent
92. purposeful
93. quiet
94. radical
95. realist
96. refined
97. reflective
98. religious
99. renewed
100. reserved
101. righteous
102. robust
103. sarcastic
104. satirical
105. scientific
106. serious
107. skeptical
108. striving
109. subtle
110. systematic
111. tactful
112. theatrical
113. thriving
114. tidy
115. tolerant
116. tough
117. unpredictable
118. upright
119. venturesome
120. wordy

Experiment 3

Negative nouns

1. abuse
2. aggressive
3. alarm
4. angry
5. annoying
6. anxious
7. argue
8. arrest
9. ashamed
10. assault
11. attack
12. battle
13. bitch
14. bloody
15. bomb
16. bug
17. bullet
18. bury
19. chaos
20. chase
21. collapse
22. combat
23. crime
24. crisis
25. criticism
26. danger
27. death
28. debt
29. deny
30. destruction
31. dick
32. disaster
33. disgusting
34. drugs
35. earthquake
36. emergency
37. evil
38. expensive
39. explosion
40. fear
41. fight
42. freak
43. freezing
44. frightened
45. gang
46. gun
47. harm
48. harsh
49. hate
50. hell
51. horrible
52. hungry
53. illegal
54. injury
55. invasion
56. jealous
57. killer
58. late
59. mad
60. monster
61. murder
62. nervous
63. nightmare
64. noise
65. operation
66. pain
67. panic
68. punch
69. raid
70. rape
71. rat
72. revenge
73. ridiculous
74. risky
75. rob
76. scandal
77. scared
78. scheme
79. scream
80. shit
81. shock
82. shot
83. spider
84. strike
85. struggle
86. sue
87. suicide
88. surgery
89. suspicion
90. terrified
91. terrorism
92. threat
93. tragedy
94. trouble
95. violent
96. war
97. warning
98. weapon
99. wicked
100. worry

Neutral nouns

1. abbey
2. area
3. assessment
4. basis
5. basket
6. bathroom
7. box
8. branch
9. brand
10. calendar
11. card
12. carpet
13. category
14. cattle
15. ceiling
16. channel
17. civil
18. click
19. client
20. clip
21. common
22. compass
23. conference
24. constant
25. continue
26. counter
27. cow
28. cup
29. den
30. department
31. describe
32. desk
33. discuss
34. document
35. domestic
36. dozen
37. entire
38. envelope
39. ford
40. foundation
41. geography
42. goat
43. granny
44. ground
45. hat
46. hay
47. hole
48. housing
49. hull
50. ingredient
51. item
52. ivory
53. lamp
54. level
55. lounge
56. maintenance
57. mention
58. middle
59. mill
60. newspaper
61. north
62. ordinary
63. overall
64. pardon
65. patch
66. pigeon
67. plain
68. pottery
69. practice
70. press
71. profile
72. proper
73. quote
74. rail
75. reckon
76. relevant
77. resolve
78. round
79. scenario
80. sequence
81. sheep
82. shirt
83. shoe
84. short
85. shoulder
86. soil
87. specific
88. spot
89. statue
90. straw
91. symbol
92. telegraph
93. title
94. tomato
95. trousers
96. wall
97. way
98. weekly
99. will
100. wool

Experiment 4

Neutral nouns only

1. abbey
2. adjacent
3. aisle
4. area
5. armchair
6. basic
7. basket
8. bathroom
9. branch
10. bulletin
11. bunch
12. calendar
13. canvas
14. card
15. cargo
16. ceiling
17. ceramics
18. chair
19. channel
20. civil
21. client
22. compass
23. compost
24. count
25. curtains
26. desk
27. document
28. dozen
29. ford
30. format
31. founding
32. freezer
33. hall
34. housing
35. item
36. lamp
37. lens
38. level
39. list
40. mention
41. middle
42. naval
43. north
44. optional
45. outline
46. parallel
47. pardon
48. patch
49. pause
50. pavement
51. potted
52. powder
53. practice
54. press
55. print
56. proper
57. quote
58. rail
59. reckon
60. reserved
61. round
62. sample
63. scenario
64. sequence
65. shirt
66. shoe
67. shoulder
68. solid
69. specific
70. spot
71. stew
72. strings
73. study
74. symbol
75. tapestry
76. title
77. trousers
78. vault
79. warranty
80. winter

Experiment 5

Word-pairs (nouns, cue-target)

1. acre-outline
2. apron-lofty
3. basin-fixture
4. basket-patron
5. branch-ground
6. butler-seal
7. card-housing
8. cargo-goat
9. celery-format
10. chair-shoe
11. channel-grain
12. chess-sample
13. chord-granny
14. click-naval
15. compass-statue
16. fence-brand
17. foam-proper
18. freezer-pause
19. item-hall
20. lens-footing
21. mild-hole
22. misty-chalk
23. mitt-ivory
24. north-gospel
25. notch-midst
26. overall-willow
27. palate-bunch
28. pardon-counter
29. patch-basic
30. pigeon -ford
31. plain-entire
32. potted-middle
33. pottery-spot
34. powder-counsel
35. print-hull
36. putt-lamp
37. quail-comb
38. rail-wool
39. round-civil
40. seating-winter
41. shade-glance
42. sheet-lounge
43. soil-desk
44. stew-area
45. steward-aisle
46. study-cushion
47. symbol-level
48. third-abbey
49. tile-shirt
50. tomato-ceiling
51. tutor-press
52. wall-straw
53. weekly-dozen
54. will-carrier

Experiment 6

Positive nouns

1. accelerate
2. action
3. adore
4. adrenaline
5. adventure
6. affection
7. alive
8. amazing
9. ambitious
10. animation
11. anticipate
12. arcade
13. astonished
14. awake
15. award
16. awesome
17. barbecue
18. bargain
19. beautiful
20. birth
21. blonde
22. bonus
23. bravery
24. brewing
25. brilliant
26. caffeine
27. cash
28. celebrate
29. cheerful
30. christmas
31. cinema
32. climax
33. comedy
34. conception
35. confetti
36. create
37. curious
38. dance
39. daring
40. dazzling
41. delightful
42. desire
43. diamond
44. discover
45. dollar
46. eager
47. ecstasy
48. embrace
49. enchanting
50. endurance
51. energetic
52. enjoyment
53. euphoria
54. excited
55. exercise
56. exotic
57. expansion
58. expertise
59. fancy
60. fantastic
61. festive
62. fireworks
63. flirt
64. fortune
65. freedom
66. frisky
67. gallant
68. generous
69. genius
70. glory
71. gold
72. gourmet
73. graduation
74. grin
75. happy
76. hilarious
77. hire
78. honeymoon
79. horny
80. incredible
81. innovation
82. inspire
83. intimate
84. invent
85. jackpot
86. jazz
87. joke
88. joyful
89. kiss
90. laugh
91. legendary
92. lick
93. lottery
94. lust
95. magic
96. marry
97. martini
98. meteorite
99. mindful

100.miracle
101.mission
102.money
103.musical
104.naked
105.naughty
106.nintendo
107.nude
108.orgasm
109.outgoing
110.outing
111.overcome
112.overjoyed
113.party
114.passion
115.payday
116.penny
117.penthouse
118.perk
119.playful
120.pleasure
121.positive
122.powerful
123.praise
124.pregnant
125.pretty
126.pride
127.prize
128.profitable
129.prosper
130.proud
131.qualify
132.quest
133.reasoning
134.rejoice
135.reward
136.rich
137.riches
138.romance
139.running
140.safari
141.sale
142.satisfy
143.saucy
144.score
145.sensual
146.sexy
147.snuggle
148.sparkly
149.speed
150.spicy
151.spring
152.star
153.stimulate
154.stunning
155.success
156.succulent
157.summer
158.superpower
159.surf
160.surprise
161.sushi
162.swim
163.talent
164.tempting
165.tequila
166.thrill
167.thrive
168.tickle
169.trampoline
170.treasure
171.triumph
172.vaccine
173.value
174.vibrant
175.victory
176.voyage
177.weekend
178.winner
179.witty
180.youthful

Neutral nouns

1. abbey
2. accordion
3. acre
4. advice
5. aisle
6. apron
7. area
8. armchair
9. await
10. backdrop
11. basic
12. basin
13. basket
14. bathroom
15. bedside
16. beige
17. binoculars
18. biography
19. botany
20. broth
21. bulletin
22. bunch
23. butler
24. calendar
25. canvas
26. card
27. cargo
28. ceiling
29. center
30. ceramics
31. chair
32. channel
33. civil
34. click
35. clip
36. comb
37. compass
38. conference
39. continue
40. cooker
41. counsel
42. counter
43. crayon
44. cross
45. curtains
46. department
47. desk
48. dishwasher
49. document
50. dozen
51. dryer
52. dune
53. duster
54. editorial
55. entire
56. equipment
57. external
58. eyebrow
59. flipper
60. flooring
61. foam
62. fold
63. footing
64. format
65. fortnight
66. foundation
67. freezer
68. funnel
69. furniture
70. geography
71. gradual
72. grotto
73. ground
74. habitat
75. hairdryer
76. hairspray
77. hall
78. holder
79. hole
80. housing
81. indicator
82. ingredient
83. item
84. ivory
85. ladle
86. lamp
87. lawnmower
88. lens
89. level
90. list
91. listing
92. lofty
93. mantle
94. match
95. mention
96. middle
97. midst
98. mill
99. mini
100. misty
101. mitt
102. name
103. napkin
104. naval
105. newspaper
106. noon
107. norm
108. north

109.notch
110.occasional
111.outline
112.overall
113.padded
114.parallel
115.parchment
116.pardon
117.patch
118.pause
119.pavement
120.pebble
121.pendulum
122.philosophy
123.phrase
124.pickled
125.plausible
126.plume
127.pole
128.pottery
129.powder
130.practice
131.prairie
132.print
133.proper
134.quote
135.rail
136.relevant
137.resolve
138.respond
139.rinse
140.round
141.sample
142.scenario
143.seat
144.sentence
145.sequence
146.sheet
147.shelf
148.shirt
149.shoe
150.solid
151.specific
152.spot
153.station
154.stew
155.stir
156.straw
157.strings
158.study
159.suede
160.suit
161.surface
162.symbol
163.table
164.telegraph
165.terrain
166.theme
167.threshold
168.title
169.token
170.toothpaste
171.translate
172.trolley
173.trousers
174.typewriter
175.usage
176.vault
177.wallpaper
178.washer
179.workings
180.yawn