To Step or To Spring:

The Influence of State Anxiety on Perceptual Judgments and Executed Action

Sophie Harris and Kate Wilmut

Faculty of Health and Life Sciences, Oxford Brookes University

Corresponding author:

Dr. Kate Wilmut, k.wilmut@brookes.ac.uk, @KWilmut

The data that support the findings of this study are openly available in RADAR at https://doi.org/10.24384/7v74-5h17;The role of anxiety on perceptual and action tasks: to spring or to step.

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Abstract

Emotional state and in particular anxiety has been shown to constrain perceptual judgement of action capabilities. However, whether anxiety also constrains actual behaviour is unknown. The current study therefore aimed to determine whether state anxiety constrained firstly perceptual judgements of action capabilities and secondly actual behaviour. To do this we asked participants to make perceptual judgements and perform action behaviours in relation to crossing ground-based apertures representing puddles. State anxiety was measured in 30 participants using the State-Trait Anxiety Inventory (STAI). The critical ratio of aperture-size relative to leg length at which participants' behaviour choice would switch between a step and a spring was calculated. In a perceptual judgment task participants judged the ratio at which they *would* choose to switch. In a subsequent executed action task, the ratio at which they *actually* switched was measured. Perceptual critical ratio could be predicted via state anxiety and age, while action critical ratio was not predicted by either. Therefore, this study has demonstrated that state anxiety and age both constrain perceptual judgement of action capabilities, as shown in previous studies. However, this does not seem to result in a change in emergent behaviour. This highlights the importance of measuring emergent behaviour rather than inferring it from perceptual judgements even when they are couched in terms of action.

Keywords: Action capabilities, State Anxiety, Constraints, Action and Perception, Affordances

Introduction

We move around a complex and demanding environment every day with little conscious thought, however, this skill actually requires numerous complex processes in order to avoid collision or injury. One of these complex processes involves the ability to judge our action capabilities in a given environment. The constraints-based-approach (Newell, 1986) states that any emerging movement is constrained by the individual, the task, and the environment. Previous research has shown that action capabilities are constrained at an individual level by body size (Franchak & Adolph, 2014; Warren, 1984), age (Hackney & Cinelli, 2011) and movement variability (Wilmut & Barnett, 2011). At the task level, (Higuchi, Cinelli, Greig, & Patla, 2006), have shown that asking participants to judge passability when sat in a wheelchair changes one's perception of action capabilities. The current study focuses on other possible constraints to action and whether emotion, specifically anxiety, might constrain the way in which we move.

The motivation for this consideration has come from findings within the perception literature which essentially demonstrate the effect emotion has on our perceptual processes. For example a heightened sense of anxiety has been shown to influence gaze behaviour (Nieuwenhuys, Pijpers, Oudejans, & Bakker, 2008) and that the presence of a fearful face, inducing anxiety, modulates attention (Phelps, Ling, & Carrasco, 2006). This has been extended to the ability to judge aspects of the environment, for example asking participants to judge the steepness of a slope or their standing height above the ground. Stefanucci, Proffitt, Clore and Parekh (2008) found that when fear was induced by placing participants on a skateboard at the top of a hill as opposed to on a stable wooden box of the same height, the hill was judged to be steeper by those on the skateboard. Along similar lines (Riener, Stefanucci, Proffitt, & Clore, 2011) demonstrated that participants listening to ‘sad’ music viewed hills as steeper to potentially climb relative to those listening to ‘happier’ music. Stefanucci and Proffitt (2009) found that the height of the balcony on which participants were stood was judged as significantly higher when emotional arousal was higher. Although these studies highlight the role of emotion in perceptual judgement they do not directly relate to how emotion might constrain an emerging movement or the judgement of an emerging movement.

Focusing on that specific question, Graydon, Linkenauger, Teachman and Proffitt (2012) induced anxiety and considered the judgement of three motor skills: horizontal reaching distance; maximum grasp size and hand passability through gaps. They found that the participants in whom they had induced anxiety consistently underestimated their action capabilities across all tasks in comparison with participants in which no anxiety had been induced. Similarly when anxiety was induced by asking participants to traverse a high or low climbing wall higher state anxiety reduced both perceived and actual maximum reaching height (Pijpers, Oudejans, Bakker, & Beek, 2006). These studies suggest that anxiety plays a role in perception and may constrain how we perceive action capabilities. A study by Jiang and Mark (1994) suggest a similar relationship between fear of falling and perceived ground-based gap ‘crossability’. Although this study did not directly manipulate anxiety, they did increase the depth of a ‘to be crossed gap’, thus potentially increasing anxiety about stepping across. As gap depth increased, there was a consistently increasing tendency for participants to underestimate the maximum gap width they judged they could step across. Therefore, it would seem that gap depth did constrain the judgement of action capabilities and this may be explained in terms of gap depth acting as a proxy for anxiety, which would fall in line with the previous findings.

An important point to make at this stage is that although the studies above tell us a lot about perceptual judgement, they tell us little about the role of emotion in constraining actual movement and whether a change in perception results in a change in *behaviour*. A previous study focusing on stair climbing in older and younger adults found that body size, flexibility and strength all influenced both the perception *and* the action of older adults (Konczak, Meeuwsen, & Cress, 1992). This study suggests that factors which constrain action do also influence perception and so we might think that factors which constrain perception also constrain action. The current study, therefore, aimed to investigate the influence of state anxiety on individuals' perception of what they would do in a given situation and on what they actually did. We considered these factors within the context of crossing over a 'puddle': when presented with a small puddle a comfortable step is sufficient to allow passage, however, as the puddle size increases an individual will need to modify their behaviour and perform a springing action. This study essentially measured the puddle size at which behaviour switched from a step to a spring indicating the point at which individuals felt this change in behaviour was necessary. We measured this both in regard to perceptual judgements (what a participant thought they would do) and in regard to movement behaviour (what they actually did). It was predicted that perceptual judgements would be constrained by state anxiety with higher state anxiety being associated with more cautious ground-based aperture-crossing behaviour, as demonstrated in similar tasks (Graydon et al., 2012; Riener et al., 2011; Stefanucci & Proffitt, 2009; Stefanucci et al., 2008). We also expected, given the inter-related nature of perception and action and the findings of Konczak et al. (1992), to see those differences mirrored in actual behaviour. A propensity to step more than to spring could be related to a number of factors, to step is a more familiar movement, requires less leg power and less momentum once the lead foot has hit the ground and so to continue to step might be considered a more cautious behaviour. However, to step a very long way can result in the loss of balance and difficulty with moving the trailing foot, with research demonstrating that increasing step length reduces trunk stability (Espy, Yang, Bhatt, & Pai, 2010; Young & Dingwell, 2012). Therefore, given the relatively young age of our participants a loss of balance is more likely from an over-extended step that from a pre-emptive spring.

Methods

Participants

Thirty participants aged between 18 and 55 years, with an average age of 34.13 years (15 female), were recruited to take part[1]. Standing leg length was measured from the ground to the anterior superior iliac spine for each participant this resulted in a mean leg length of 105cm (SD 7.68), range of 88 – 120 cm. All participants were free from severe or diagnosed anxiety disorders. This project was approved by the Oxford Brookes University Research Ethics Committee and all participants gave informed consent prior to participation.

Materials and Procedure

State anxiety levels were measured using the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) which measures state anxiety and asks about anxiety and stress in the given moment. The STAI has scores which can range from 20-80 with a higher score indicating a higher level of state anxiety. A cut point of

[1] An a priori power analysis indicated that this number was sufficient given the number of predictors to be used in the regression analysis and based on a large effect size (Faul, Erdfelder, Lang, & Buchner, 2007). The expectation of a large effect size came from the calculated Cohen's F values of similar previous studies.

scores above 39 – 40 has been suggested to detect clinically significant symptoms for the state anxiety (Addolorato et al., 1999; Knight, Waal-Manning, & Spears, 1983). Participants completed this paper and pen task first.

This was followed by the perceptual task and then the action execution task. Both of the experimental tasks used the same set up. Four red foam sports mats (1m by 1m) were interlinked to provide a 4m x 1m walk-way. On top of the middle two of these three smaller blue rubber mats (38cm x 45cm x 3mm) were placed to represent a 'puddle'. These were placed so that the short side ran down the length of the sports mat. These 'puddle' mats could be moved together or apart in order to make the 'puddle' larger or smaller and a dressmakers measuring tape attached to the shorter side of each mat allowed the experimenter to accurately set the 'puddle' to any size between 38cm (the three mats stacked on top of each other) and 152cm (the three mats placed side by side). Actual 'puddle' sizes were then calculated with respect to leg length for ratios: 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1 and 1.2.

The 'perceptual' task required participants to stand directly in front of the puddle (so that their toes were close to touching it) and state whether they would 'step' or 'spring' across. A step was defined as one foot always remaining in contact with the ground, while a spring was when both feet left the floor at the same time. This difference was demonstrated by the researcher for clarity. At the start of each trial the 'puddle' was set at either at the smallest ratio, 0.5, or the largest ratio, 1.2. Participants responded as to whether they would step or spring and then the puddle size was either increased (if starting at 0.5) or decreased (if starting at 1.2) incrementally for each ratio size. The trial was terminated when the participant reported a change in behaviour, i.e. from stating 'step' to 'spring' or vice versa and that ratio size was noted. Each participant completed 6 trials, 3 increasing in size and 3 decreasing in size. Participants were asked to turn around each time puddle size was adjusted to avoid any potential influence on their perceptual judgment.

The 'action' task comprised 32 trials which required participants to walk up to and then cross the 'puddle', either using a step or a spring action. Once the 'puddle' had been crossed participants then continued walking to the end of the walk-way and back around to the start point (located 1.5m in front of the puddle). Participants completed four trials for each ratio size, and these were presented in a pseudo-randomized order. Participants were given no specific instructions regarding how they should navigate the puddle but they were told to act as though they might if it were a real puddle trying not to think about their response too much. This task was video recorded so that the researcher could later code steps versus springs for the purposes of data analysis. The video recordings were considered frame-by-frame. Where one foot always remained in contact with the ground, it was coded as a step. Where both feet left the ground during crossing, it was coded as a spring. This was done for every trial, resulting in four instances for each ratio size.

No time constraints were imposed on participants at any point, but in all cases participants completed the tasks in a timely fashion.

Data processing

All trials were included in the analysis and for the action task all of the puddles were stepped over or sprung over and in all instances the movement in the action task was a single movement with no pause between the start of the puddle and the action to cross it. For the experimental tasks an overall mean critical ratio for each participant was calculated. This was done in the same way for the two tasks. Firstly, the proportion of 'step' responses for each participant was calculated for each ratio (for the perceptual task this was taken across the six trials and for the action task across the four trials). Then the ratio at which step responses were seen on 50% of the trials was calculated and this represents the 'critical' ratio. This method was used because it could be applied to both tasks and because it demonstrates a point at which a participant is unsure of the appropriate response[2]. A smaller critical ratio indicates springing for a smaller puddle size (relative to leg length) compared to when we see a larger critical ratio.

Statistical analysis

The computer software jamovi (version 1.0) was used to conduct statistical analyses on the data. To determine whether state anxiety influenced mean critical ratio (the point at which behaviour changed) we performed regression analysis to see whether STAI score could determine mean critical ratio. Due to the large age range of participants chronological age, this was entered into the regression model first in order to account for variance in perception / action due to age, followed by STAI. Adjusted R^2 is reported as a measure of effect size. Prior to the regression analysis data was checked to determine whether assumptions were met. Pearson correlations were also calculated to see whether a relationship existed between action critical ratios and perceptual critical ratios and to determine whether the difference between action and perception critical ratios was related to STAI score. For all statistical testing, the alpha level was set at 0.05.

Results

[2] This is not the same as the method used in other studies and so might produce critical ratios which are greater or lesser than seen previously, however, as the critical ratios are calculated in the same way across the tasks it makes comparison more valid.

The critical ratio values for the whole cohort across both the perceptual and action tasks are given in Table 1 alongside the STAI scores. The STAI scores obtained from the participants in the current study show a wide variation which ranges from the lowest value possible to a value which could be considered as clinical levels of anxiety.

Anxiety and perceptual judgments

A linear regression was performed on the perceptual judgment data using STAI score and chronological age as predictor variables and perceptual critical ratio as the outcome variable. Preliminary analyses were undertaken to ensure the assumptions of normality, independence of observations, linearity and multicollinearity were not violated. Normality of residuals was confirmed using a Q-Q plot and residuals plots were checked to ensure equality of variance and linearity both of which were not a problem in these data. Multicollinearity was tested using the Variance Inflation Factor (VIF) which gave a value of 1.01. A test for Cook's Distance also indicated that there were no observations exerting undue influence on the regression model.

The regression model found that perceptual critical ratio could be predicted by STAI score and chronological age when just chronological age was entered (F (1, 28) = 4.62, p = .040, Adjusted R^2 = .11) and then when STAI was also entered (F (2, 27) = 4.93, p = .015, Adjusted R^2 = .21). Coefficients, confidence intervals and associated t and p values can be found in Table 2.

Anxiety and action judgements

A second linear regression was performed on the action judgment data again using STAI score and chronological age as predictor variables and action critical ratio as the outcome variable. Once again appropriate assumptions were checked and data did not deviate from normality with the Variance Inflation Factor (VIF), again giving a value of 1.01. A test for Cook's Distance also indicated that there were no observations exerting undue influence on the regression model. The regression model found that action critical ratio could not be predicted by STAI score or chronological age, F (1, 28) = 4.62, p = .040, Adjusted R^2 = .11 < 1, p > .05. The non-significant findings here are supported by examining the confidence intervals of the coefficients. In each case these values straddle zero and are very small values demonstrating the high likelihood that these variables do not account for any variance in the action critical ratio. Coefficients, confidence intervals and associated t and p values can be found in Table 3.

<u>The relationship between perception and action</u>

The critical ratio in the perceptual judgment task was significantly and moderately positively correlated with the critical ratio in the action task (Pearson's r = .412, p = .024). Individuals with high perceptual critical ratios also demonstrated high action critical ratios.

Discussion

The current study aimed to determine whether state anxiety influences perceptual *and* action judgements. Our findings demonstrated that perceptual judgements are indeed constrained by state anxiety with more anxious individuals decide to spring for smaller puddles compared to less anxious individuals. This finding of anxiety constraining perceptual judgement of action capabilities mirrors findings from previous papers. For example, Graydon et al. (2012) and Pijpers et al. (2006) found that induced anxiety constrained judgements of horizontal reaching and maximum grasp capabilities and for vertical reaching height. The combination of the similarity of these findings, despite many methodological differences, does provide strong evidence that anxiety can constrain our perception of action capabilities. This study also found that age constrained the perceptual judgement, with individuals with increasing age opting to step for puddles for which younger individuals choose to spring (increasing critical ratio). Previous studies have also demonstrated age as a constraint on perceptual judgement, whereby older adults show more conservative perceptual judgements in an aperture crossing task (Hackney & Cinelli, 2013) and in a stair climbing task (Konczak et al., 1992).

The novel aspect of this study was to also measure how actual behaviour was influenced by anxiety. However, our results failed to demonstrate a similar relationship between state anxiety and actual behaviour. This disparity between perception and action is more directly supported by a relationship between the difference between action and perceptual critical ratios and state anxiety, with individuals with higher state anxiety showing a higher disparity between what they said they would do and what they actually did. In essence the combination of our findings suggests that state anxiety levels affect perception but not action in relation to crossing behaviour of this kind. In addition, it would seem that in this study age does not influence action judgements. This in itself does not counter previous studies as age differences in action judgements are found in studies comparing very young adults groups (circa 20 years) with much older adults groups (circa 70-80 years) and the current study used a young to mid age group in which we did not expect to find any age differences. What is interesting is that we see age influences perception *and not* action. Could it be, that in this young to mid-adult age individuals take their ‘age’ into account when judging their abilities (perceiving) but not when actually acting out a behaviour. There is a general paucity of data looking at differences in this young to mid-adult range and so it is hard to draw firm conclusions, but this second disparity between perception and action highlights the differences in the constraints acting on these processes. It may be that there are other influential constraints which may override state anxiety's influence and age's influence on perception during the execution of action. For example, motor control might be more important in action and if motor control does not differ across state-anxiety or age we would not see that reflected in the data in our current study.

This goes against the findings of Konczak et al. (1992) who demonstrated that factors which influence the action of stair climbing (body size, flexibility and strength) also influenced the perception of older adults' ability to climb a stair. Furthermore, it contrasts findings which have shown that similar factors influence perception and action in young adults' aperture passage (Warren & Whang, 1987) and older adults' aperture passage (Hackney & Cinelli, 2013). Interestingly, if we look at the critical ratios in the current study, we see no difference in the group perceptual ratio and the group action ratio, which is what the latter two studies named above essentially demonstrated. However, our study also demonstrated that these critical ratios were influenced by different factors, with the perceptual critical ratio being increased as age increased and decreased as state anxiety increased, neither of these factors influenced the action critical ratio. One important factor to consider is that age and state-anxiety only explained 21% of the variance in the perceptual critical ratio and so 79% remains unexplained and the factors which explain that other percentage of variance might influence both perception and action.

Interestingly, another study which considered factors which constrain perception and action found, similarly to the current study, that there is not always a direct relationship between perception and action. Wilmut, Du and Barnett (2017) considered passability through gaps or apertures, measuring both the aperture size at which participants actually switch from walking through frontally to walking through whilst rotating the shoulder and the aperture size at which participants report this change would occur. This task was conducted in individuals with and without motor difficulties. Surprisingly, results showed that the children with movement difficulties underestimated the space they would need when making a 'passability' judgment while overestimating the space they needed when executing the action of passing through. This indicates that perception of ability is different from actual behaviour, at least in this population. Furthermore, this study demonstrated that movement viability influenced behaviour in the movement task but not in the perceptual task suggesting that these factors are not always constrained in the same way (Wilmut, 2019). Therefore, the current study suggests that a similar critical ratio in a perception and action task in a typical population is not necessarily driven by the same factors and the constraints to those critical ratios may very well be different. The complex relationship between perception and action demonstrated the factors which do or do not constrain emerging perceptions / movements.

Critics have suggested that action capabilities and other nonvisual factors may influence judgments resulting from post-perceptual processes rather than perception itself (e.g., Loomis & Philbeck, 2008). Witt (2011) recognises these difficulties in measuring perceptual judgements and they are of particular difficulty when trying to use perceptual judgements to draw conclusions about action. Interestingly this may provide an explanation for why, in the current study, we see that anxiety has an influence on perception *but not* action. Higher anxiety may cause individuals to verbalise a more cautious approach but that this may change post-perceptually once movement has started and so may not be seen in executed action. Equally data from the (Wilmut et al., 2017) study may also be due to these post-perceptual processes, with movement variability only being integrated into the decision to turn or not turn once movement has started (i.e. after the point at which we asked for a perceptual judgement). In the current study we have demonstrated a relationship between the perceptual critical ratio and action critical ratio and so, although perception and action seem to be constrained in different ways these responses are related, suggesting some level of shared mechanism.

It may be that experience or familiarisation with the task at hand would narrow the gap between perceptual critical ratio and action critical ratio. In a follow up study to Jiang and Mark (1994) who found that perceptual judgement varied in line with gap depth (which may act as a proxy measure for anxiety), Mark, Jiang, King and Paasche (1999) demonstrated that exploratory movements facilitated accurate gap judgments which no longer covaried with gap depth. In other words, exploration of the environment ameliorated the constraining effect of the anxiety proxy and such experience in the current study may have done the same. In fact, one could argue in both the current study and in Wilmut et al.'s (2017) that the 'action task' allowed exploration of the environment (albeit briefly via the approach phase) and so this exploration may have ameliorated the constraint of anxiety (in the current study) on action and highlighted the importance of movement variability (in Wilmut et al., 2017) on action. Asking for a perceptual judgement of action capability after an approach phase could be an avenue for future exploration of this explanation. This change would also ensure a more comparable perception and action measurement as in the current study we may not have asked for the perceptual judgement at the spatial point at which this decision would naturally have been made. This is an inherent difficulty in measuring perceptual judgements as a single snapshot of the world is not used during movement execution.

The current study has two clear limitations. State anxiety, by its very nature, fluctuates continuously depending on individual-, task-based, and environmental factors. In the current study, the perceptual task always preceded the action task and so by the time participants were completing the action task their state anxiety level may have changed due to an increased familiarity with the lab environment and task set-up. An easy way to counter this would be to counterbalance the ordering of the tasks across participants, however, there is some evidence to suggest that perceptual judgements can change following action experience (Du, Barnett, & Wilmut, 2016). Alternatively STAI scores could have been taken once prior to the perceptual task and then again prior to the action task. However, this short test-retest window could bias responses and focus participant too closely on those questions. In terms of the data from the current study, all of the participants were known to the experimenter or were familiar with the lab setting and psychological testing, therefore, we do not feel that this fully explains the results found in this study. A second limitation regards the slightly differing task procedures. In the perceptual task participants were asked to stand directly in front of the 'puddles', while the action task involved an approach phase. Previous studies have considered perceptual judgement after an approach phase (a dynamic perceptual judgement) and this can differ from a static judgement, therefore, this misalignment between the two could be caused by this difference (Warren & Whang, 1987). Whether perceptual judgement would differ when participants are provided with dynamic visual information and whether this would be influence by state-anxiety would be an interesting question for a future study.

In conclusion, the results of this study indicate that, within a typical adult population, higher state anxiety levels lead to more cautious perceived crossing behaviour but not to more cautious executed crossing behaviour. These findings apply in this case to the type of everyday crossing behaviour prompted by the specific affordance relation activated when an individual is faced with a ground-based aperture such as a puddle. These findings suggest that state anxiety acts as an individual- and capability-based constraint on perception, but not on action in crossing over a ground-based aperture such as a puddle. This study further emphasises the importance of considering perception alongside action so that conclusions are not drawn from perceptual processes only which may be subject to differing constraints from actual action.

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Table 1. Critical Ratio Values for Perceptual and Action Tasks and STAI Scores

	Mean	Minimum	Maximum	SD
Perceptual Critical	0.92	0.60	1.50	0.17
Ratio Action Critical	0.94	0.73	1.15	0.10
Ratio STAI	29.5	20	57	8.84

Table 2. Model Coefficients for the Perceptual Judgement Task.

Model	Predictor	β	Confidence intervals		T	p
			Upper	Lower		
1	Age	.00755	.0147	.00035	2.15	.040*
2	Age	.00700	.0138	.00020	2.11	.044*
	STAI Score	-.0068	-00033	-.0133	-2.16	.040*

*Indicates a significant effect, p<.05

Table 3. Model Coefficients for the Action Judgement Task.

Model	Predictor	β	Confidence intervals		T	p
			Upper	Lower		
1	Age	.000308	.00496	-.00435	.136	.893
2	Age	.000132	.00481	-.00454	.058	.954
	STAI Score	-0.00220	.00225	-.0066513	-1.014	0.320

*Indicates a significant effect, p<.05