Longitudinal continuity in understanding and production of giving-related behavior from infancy to childhood

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Abstract

Infants have an early understanding of giving (the transfer of an item by one agent to another), but little is known about individual differences in these abilities or their developmental outcomes. Here, nine-month-olds (*N*=59) showing clearer neural processing (ERP) of a give-me gesture also evidenced a stronger reaction (pupil dilation) to an inappropriate response to a give-me gesture, and at two years were more likely to give in response to a give-me gesture. None of the differences in understanding and production of giving-related behaviors were associated with other socio-cognitive variables investigated: language, gaze-following, and non-giving helping. The early developmental continuity in understanding and production of giving behavior is consistent with the great importance of giving for humans throughout the life-span.

Keywords: infancy; childhood; giving; gestures; social perception; ERP; P400; pupillometry

Giving is of great importance across ages and cultures, being intrinsic to voluntary ownership transfer (Godbout & Caillé, 1998; Mauss, 1954) and playing an important role for early social development (Hay & Cook, 2007; Rochat 2009). Although giving is a fundamental part of higher-level acts such as gifting and sharing, and previous developmental studies have focused on such concepts, the focus here is on young children's understanding and production of giving itself. We define giving as the deliberate transfer of object possession by one agent to another (Tatone, Geraci, & Csibra, 2015), and the broader class of giving-related behavior to include giving and gestural requests for giving.

By 3-months infants show some social evaluation of object transfer events (Hamlin & Wynn, 2011) and by the end of their first year infants have clear representations of giving and taking and interpret the actions as inherently social (Dahl, 2015; Dahl, Schuck, & Campos, 2013; Hay & Murray, 1982; Tatone et al., 2015). By 12 to 18 months many infants give items (Brownell, Svetlova, & Nichols, 2009; Caselli, 1990; Dunfield & Kuhlmeier, 2010; Hay, 1979; Hay, Caplan, Castle, & Stimson, 1991; Hay & Murray, 1982; Hobbes & Spelke, 2015; Warneken & Tomasello, 2006). By 2 to 3 years children spontaneously share goods (Chernyak & Kushnir, 2013; Sommerville, Schmidt, Yun, & Burns, 2013; Warneken & Tomasello, 2013). Despite the variation in contexts and motives across these different studies, they have in common the understanding or production of giving. However, to our knowledge, no study has examined the consistency of infants' understanding of giving across different contexts or methodologies, nor has any study examined the relation between the understanding and production of giving, or examined these issues longitudinally.

Because of the early importance of the understanding and production of giving, we propose two hypotheses to be tested here. First, infants' understanding of giving-related behavior across different tasks is supported by relatively well-developed and therefore task-general cognitive mechanisms for processing giving-related behavior. This hypothesis predicts that measures of understanding will correlate across tasks in infancy as these mechanisms will be capable of processing different but related stimulus types. The second hypothesis is that because these mechanisms are relatively well-developed already in infancy, performance on these passive processing tasks will predict production of giving behavior later in childhood.

Children begin understanding giving-related behavior at an age when they are mainly pre-verbal but make frequent use of gestures (Caselli, 1990; Crais, Douglas, & Campbell, 2004). By the second year of life infants have an understanding of other's gestures (Elsner, Bakker, Rohlfing, & Gredebäck, 2014; Thorgrimsson, Fawcett, & Liszkowski, 2014) and communicate using both pointing (Bates, Camaioni, & Volterra, 1975; Tomasello, 2010) and giving-related gestures (Caselli, 1990; Crais, Douglas, & Campbell, 2004). The gesture often associated with giving is the give-me gesture, in which the upraised palm is outstretched. The gesture serves multiple communicative functions, such as referring to a specific object, expressing a request, and communicating an action goal (Mundy, Sigman, Ungerer, & Sherman, 1986; Shwe & Markman, 1997). By 12-months of age infants have clear expectations concerning object transfer actions in a social exchange between two agents incorporating the give-me gesture (Elsner et al., 2014; Thorgrimsson et al. 2014). Communicative gestures may therefore be functionally important in the development of giving understanding and behavior.

The first aim of this study, in line with our hypothesis of well-developed task-general giving-related cognitive mechanisms, is to identify consistent individual differences in giving-related perception and evaluation across two separate tasks at 9 months using methods incorporating the give-me gesture. The first task is a previously reported ERP paradigm (Bakker, Kaduk, Elsner, Juvrud, & Gredebäck, 2015) that examined the *neural correlates of give-me gesture perception* as indexed by the P400 ERP. The second task examines *evaluation of give-me gesture interactions* between third-parties as indexed by pupil dilation in an action evaluation task (see Gredebäck & Melinder, 2010; 2011, for a similar design).

Bakker et al.'s (2015) results from the first task revealed that 9-month-olds are already sensitive to the give-me gesture: the P400 ERP was more pronounced for the give-me gesture than for a control hand-shape. This difference was significant despite the fact that the infants did not demonstrate any behavioral responses to the give-me gesture. Additional studies have also found that the P400 component has expressed sensitivity to typical and referential cues, such as congruent pointing (Gedebäck, Melinder, & Daum, 2010), and congruent eye-gaze (Senju, Johnson, & Csibra, 2006), compared to incongruent control stimuli.

In the second task, assessing evaluation of give-me gesture interactions, evaluation is indexed by pupil dilation in response to an object transfer interaction. During the interaction, the giving partner either appropriately complies with a give-me gesture or violates the give-me request by placing the object on the recipient's head. Infants have previously shown greater pupil dilation when viewing similar social exchange situations in which norms are violated (Gredebäck & Melinder, 2010). We predict greater pupil-dilation when viewing inappropriate responses to give-me gestures.

To investigate whether individual differences in giving understanding during infancy predict the production of giving behavior in social interactions at two years of age, we utilize a novel giving task (similar to previous helping tasks, e.g. Warneken & Tomasello, 2006). The experimenter invites help from the child using a give-me gesture, but the context means that non-giving helping as well as giving would both be appropriate responses. We predict that individual differences in giving understanding at 9 months predict giving responses (but not non-giving helping) to the give-me gesture at two years. We note that as such, our selection of ages allows us to test whether understanding of giving before individuals themselves give predicts giving once they are older – as previously reported (Bakker et al. 2015), none of the current sample of infants engaged in giving behavior at 9-months-old.

Because performance in these three giving-related tasks could arguably represent more generalized gesture processing ability or even general socio-cognitive ability, it is important to also establish that they are related independently of associations with other socio-cognitive variables. Control socio-cognitive variables include non-giving helping in the giving task, gaze-following at 9 months, and language development across the study period. Gaze-following has been suggested to be a highly socially relevant cue used by infants to infer intentionality in social contexts (Johnson, Slaughter, & Carey, 1998). Language is a useful index of broad socio-cognitive development (Nelson, 1998) and has also been found to be correlated with gaze-following (Brooks & Meltzoff, 2005), so we predict this correlation will also be obtained here (see Figure 1 for a summary of all predicted relations between variables).

Method

Study sample

A total of 59 infants (30 females) were first tested at 9 months of age (mean 8.7, *SD* = .55). At two years 42 participants (23 female; mean age 25.1 months, *SD* = 1.9) returned to the lab to take part in the behavioral task. Participants were a self-selected sample who responded to an invitation letter sent to all families with children of appropriate age living in Uppsala, a medium-size Swedish city; therefore, participants were mostly ethnically Swedish and had mixed socioeconomic backgrounds biased towards the upper and middle classes. Individual task exclusions are given in supplementary materials, including a discussion of the relatively high attrition for some tasks. Parents provided informed consent and received a 10€ equivalent gift voucher for each visit. The study was conducted in accordance with standards specified in the 1964 Declaration of Helsinki and approved by the local ethics committee.

Stimuli and Materials

Data from the 9 month ERP task have been previously published (see Bakker et al., 2015) – the dependent variable here is the P400 amplitude. For descriptions of the ERP and standard gaze-following measures at 9 months, and the standard language inventory measures at 9, 18, and 24 months, see supplementary materials.

Evaluation of give-me gesture interactions at 9 months. Each video trial consisted of a 40 s interaction with a baseline period, a familiarization phase with the purpose of creating a context for giving, and the test phase in which there were object transfers in response to give-me gestures (Figure 2a). The baseline period began immediately at the start of the trial before any interaction began (1 s). It ended, and the familiarization phase began, when the first actor (the 'giver') moved a block from one end of the table to a bowl at the other end of the table. This action was repeated three times (13 s total) before the test phase began with the second actor (the 'receiver') performing a give-me gesture, while simultaneously performing a head-nod (to roughly equate the amount of motion between the head and hand). The giver then picked up one block from the bowl and passed it to either the receiver's outstretched hand (appropriate response condition) or the top of the head (inappropriate response condition) of the receiver, with the receiver then moving the block from her hand or head back to the starting position at the end of the table. During the test phase this sequence of a give-me gesture followed by appropriate or inappropriate giving was repeated three times (26 s total).

A total of four appropriate and four inappropriate trials were presented. The dependent variable for each trial was the difference between the mean pupil size during the baseline period and the mean pupil size during the test phase. Preliminary analyses found no effects of presentation order of trials (see supplementary results); therefore, data were aggregated across the four trials within each condition. For correlation analysis we calculate a difference score for each individual as the extent to which the pupil dilated more in the inappropriate than appropriate condition.

Behavioral giving at 2 years. The task consisted of a warm-up phase of a game of knocking down four bowling pins with a ball, and a test phase. The experimenter sat across from the child on the floor with a box placed in the corner of the room. To begin the testing phase, the experimenter crouched next to a box, placed one pin into it, and extended her hand towards the participant with a still give-me gesture. She sat silently waiting without any insistence toward the child with an extended hand until the child placed the remaining four toys (three pins and a ball, four trials) one at a time either in her hand (coded as giving) or in the box (coded as non-giving helping). In the case of giving, the experimenter herself then placed the item in the box and returned to making a give-me gesture. If the child did not respond after 30 seconds (coded as no action), the experimenter fetched the next of the remaining toys, placed it in the box, and resumed crouching with a give-me gesture. Other behavior (i.e. throwing or kicking the toy) was coded but not analyzed, as the behavior was ambiguous. Parents wore opaque glasses during the test. In this task, the experimenter is intended to be ambiguously inviting two responses which both help with tidying but are incompatible: copying the placement in the box, or complying with the give-me gesture.

For each participant, we calculated the proportion of trials containing the behavior, and the latency from the start of the first trial to the first occurrence of the behavior in any trial for (a) giving and (b) non-giving helping. To avoid excluding participants from correlation analyses of latency, we set latencies to perform actions that were never performed to a high value of 100 s, invalidating the assumptions of parametric tests. Proportion data also violated parametric assumptions due to skewness (>1) as a result of many zero values. For both latency and proportion data, correlations are therefore calculated using Spearman's non-parametric method.

Procedure

At the 9 month visit an experimenter explained the study and obtained informed consent. Infants first participated in the EEG task, lasting approximately 10 minutes. Twenty minutes elapsed before the next tasks (during which the behavioral give-me task was administered, as reported in Bakker et al., 2015, but not analyzed here as no infants gave). During the two eye-tracking tasks (give-me and gaze following), infants sat on their parent's lap facing the stimulus monitor. The experimenter requested parents to not interact with their infant to avoid influencing their infant's interest in the stimuli. Following a standard 5-point infant calibration procedure, the study began with sound and animation to attract the infants' attention to the monitor. For evaluation of give-me gesture interaction trials, infants viewed four presentations from each condition for a total of eight trials, with presentation order counterbalanced. After each evaluation of give-me gesture interaction trial, infants viewed a presentation of the gaze-following task, for which there were also eight trials (so give-me gesture interaction trials and gaze-following trials were interleaved). Orders of trials for both tasks were counterbalanced.

The two eye-tracking tasks lasted approximately eight minutes in total. Stimuli were presented using E-Prime Professional 2.0 (Tobii Extension). Gaze was measured using a Tobii T120 near infrared eye tracker (33.7 x 27 cm, 1280 x 1024 resolution); precision 0.15°, accuracy 0.4°, and sampling rate 60 Hz. Infants sat approximately 60 cm from the monitor (0.022 x 0.023 visual degrees per pixel).

Results

Task specific results

For information on the ERP task (previously published, see Bakker et al., 2015) and results from the gaze-following task see supplementary materials. In the evaluation of give-me gesture interactions task, there was a significant difference in pupil dilation between the appropriate and inappropriate conditions, paired samples $t(52) = 3.855$, $p < .001$, $d = .56$, with greater pupil dilation in the inappropriate gesture response conditions ($M = .544$, $SD = .267$) than the appropriate gesture response ($M = .396$, $SD = .267$; Figure S1).

In the giving behavior task, 37 children (88%) displayed giving or non-giving helping, 24 children displayed non-giving helping (57%), 15 children displayed giving (36%), and 5 children produced none of these behaviors (12%). The four dependent variables of interest included the proportion of trials with giving ($M = .29$, $SD = .41$), proportion of trials with non-giving helping ($M = .45$, $SD = .41$), latency in seconds to the first giving ($M = 16.22$, $SD = 14.94$), and latency in seconds to the first non-giving helping ($M = 19.63$, $SD = 17.07$; these latency descriptive statistics exclude children who did not perform the actions).

Correlations of giving related measures at 9-months and 2-years-old

Nine months. We conducted parametric and non-parametric correlation analyses to test the predicted relations between our outcome variables (Table 1, Figure 1). Neural correlates of give-me gesture perception as indexed by P400 (Bakker et al. 2015) and evaluation of give-me gesture interactions as indexed by pupil dilation (difference score) correlate at 9 months. Infants with a greater P400 amplitude when viewing the give-me gesture compared with a control hand-shape had significantly greater pupil dilation when viewing an inappropriate give-me gesture response than an appropriate response (Figure 3).

Nine months and two years. Neural correlates of give-me gesture perception at 9 months correlated with giving behavior at two years (Table 1). Participants showing stronger neural processing of the give-me gesture had a greater proportion of trials with giving and decreased latency to giving.

Evaluation of give-me gesture interactions at 9-months-old correlated with giving behavior at two years (Table 1). Children with a greater difference in pupil dilation during observation of an appropriate and inappropriate give-me gesture response had a greater proportion of trials with giving and decreased latency to giving.

Correlations with, and between, other variables. None of the giving-related variables correlated with any of the non-giving related variables at any age, except that giving and non-giving helping production correlated negatively at two years, which is to be expected as the behaviors are mutually exclusive within each trial (Table 1). Performance on the gaze-following task correlated positively with language ability at 9 months, indicating that children with greater accuracy in the gaze-following task had greater reported language ability at 9 months. Performance on the gaze-following task was unrelated to any of the other variables at 9 months or two years of age. There was continuity in language ability from 18 months to two years, suggesting validity of the measure. Neither gaze following nor language at 9 months correlated with language at 18 months or two years – we suggest that the lack of these correlations is simply due to attrition in the later language measures which reduced power (Table S1).

Our relatively small sample sizes raise the issues of potential undetected correlations between giving-related variables and non-giving-related variables. However, correlations between the three giving-related variables were stronger or marginally stronger than comparable potential undetected correlations between these three giving-related variables and non-giving related variables (four *p*s $<= .1$, three *p*s $<= .05$, one $p < 0.01$, see supplementary materials for details).

Discussion

When two individuals engaged in giving and receiving interactions, 9-month-old infants were able to evaluate actions that violated their understanding of basic giving behavior, as indicated by greater pupil dilation in response to inappropriate as compared to appropriate actions. As previously demonstrated (Bakker et al., 2015), infants show increased neural processing in the P400 in response to a give-me gesture compared to a control hand-configuration. The same infants that showed greater pupil dilation also showed an increased sensitivity to the give-me gesture, and later in development, the same infants were more likely and quicker to comply with a give-me gesture by giving. Importantly, none of the individual differences in giving perception and performance were associated with non-giving helping behavior or other non-giving-related socio-cognitive measures. However, the association between gaze-following and language, in accordance with previous empirical results (Brooks &

Meltzoff, 2005), supports the validity of these particular non-giving related socio-cognitive measures.

These findings provide the first strong evidence for early maturing cognitive mechanisms for processing and producing giving-related behaviors that generalize across different giving-related tasks and show continuity through the early years. Furthermore, these cognitive mechanisms for the perception and understanding of giving develop before overt responses to other people's give-me gestures: at the same age, none of these infants themselves produced giving in response to the give-me gesture (Bakker et al. 2015). It is interesting to note that this study therefore represents an example of early passive understanding being important for later action ability, rather than early action-experience driving the understanding of others' actions (Gredebäck & Falck-Ytter, 2015; Gottwald, Achmermann, Marciszko, Lindskog, & Gredebäck, 2016).

The nature of these cognitive mechanisms, however, cannot be established more precisely than that they appear specialized in some way for giving-related behavior. One possibility is that these mechanisms relate specifically to give-me gesture processing – all tasks involved understanding of the give-me gesture and this explanation is therefore parsimonious. However, fundamental to performance in both the eye-tracking task and the behavioral task is an appreciation of the connection between this gesture and the appropriate response of giving, so the understanding demonstrated here relates not only to the gesture but also to giving itself, including the tendency to produce it. Future work should include giving-related tasks not involving the give-me gesture, to establish continuity of understanding of giving independent to gesture understanding.

A further possibility requiring consideration is that the variation in give-me gesture understanding evidenced here may reflect the operation of more general gesture processing mechanisms not specifically related to the give-me gesture. This is one example of a broad category of alternative hypotheses suggesting that the associations between understanding and production of giving-related behavior may be due to individual variation in mechanisms not specific to giving-related behavior. However, we found no associations between giving-related measures and any other variables, and analyses showed that any such associations that were undetected would be smaller than comparable within-giving-related variable associations. Explanations for the associations between giving-related measures based on individual differences in more general social cognition therefore do not suffice to explain the data. This is most obviously demonstrated by the two measures in the giving task: giving and non-giving helping. Explanations based on individual differences in general social cognition could account for the correlation between giving understanding at 9 months and giving at 2 years. However, they would also predict a similar correlation between giving understanding and non-giving helping, which was not found. It is further notable that the giving-related measures at 9 months did not correlate with language at 9 months, despite the language measure at this age including gestures.

Because the pupil dilation task involves a physiological measure relatively new in infant research, further consideration of the interpretation is merited. An alternative explanation for increased pupil dilation when viewing an inappropriate response to the give-me gesture could be that the behavior is simply unfamiliar. There are two reasons why this interpretation is unlikely. Firstly, it cannot explain why the degree of dilation difference between appropriate and inappropriate conditions clearly correlates with other giving-related variables, but not other socio-cognitive variables. Secondly, although we did not directly control for this alternative here, another infant study using a very similar design included a relevant control (Gredebäck & Melinder, 2010). The stimuli involved a pair of actors, with one responding to the other's food request by feeding them with a spoon to the mouth or by using the spoon to place food on their hand. Control conditions demonstrated that placing food on the hand resulted in significant pupil dilation, but only if it was an inappropriate response given the context of the request. Unfamiliarity alone did not result in pupil dilation when the context meant placing on the hand was an appropriate response to the request. This suggests that infant pupil dilation is not driven simply by unfamiliarity, but by incongruity between an action and the context in which it takes place – in line with our interpretation here.

The chief limitation of this study is that each task involved the give-me gesture – as discussed, it is therefore difficult to separate infants' understanding of giving behavior from understanding of the give-me gesture, although understanding of the connection between the gesture and giving is clear. A further important limitation is that active giving behavior was not measured before two years of age, although such behavior could have been revealing – as reviewed above, giving is easily elicited throughout the second year, and anecdotal reports suggest it is possible to elicit in the first year. Attempts to elicit giving at nine months were unsuccessful with the current cohort (Bakker et al. 2015), but future studies may have more success using more naturalistic methods to elicit giving at this age. Furthermore, standard caveats concerning the generalizability of results from a culturally homogenous sample apply. Although giving appears culturally universal (Godbout & Caillé, 1998; Mauss, 1954; Rochat, 2009; Tatone et al., 2015), the forms in which infants are exposed to it may differ in ways that could influence the current measures.

However, in discussing previous infant data and the major roles that giving plays in human development and evolutionary history, it has been concluded that "the claim that humans possess an early conceptual knowledge of social goals should be extended to include basic social interactions based on giving" (Tatone et al., 2015). Our results further support this conclusion. The existence of cognitive mechanisms for giving in infancy that continue through childhood is consistent with the great importance of giving in all human cultures (Godbout & Caillé, 1998; Mauss, 1954; Rochat, 2009). Giving is important not only in humans (Dunfield, Kuhlmeier, O'Connell & Kelley, 2011; Yarrow et al., 1976) but also our closest relatives, the chimpanzees and bonobos, who also beg using the give-me gesture (Genty, Breuer, Hobaiter, & Byrne, 2009; Hobaiter & Byrne, 2011; Pollick & de Waal, 2007; Roberts, Roberts, & Vick, 2014; Warneken & Tomasello, 2006). A parsimonious suggestion is therefore that communicative gestures may be homologous between the species (Gillespie-Lynch, Greenfield, Feng, Savage-Rumbaugh, & Lyn, 2013). Giving behavior is much more reliably elicited than other forms of helping in chimpanzees (Warneken & Tomasello, 2006). Paralleling this comparative data, observation of human infants indicates that giving behavior emerges earlier than other forms of instrumental helping (Warneken & Tomasello, 2007) or other prosocial behavior such as comforting (Dunfield & Kuhlmeier, 2013). Comparative and developmental data therefore converge to suggest that giving may be distinct to and possibly more fundamental than other types of helping. Together, these results allow the highly speculative suggestion that the early developing giving mechanisms may represent an evolutionarily ancient specialized cognitive system.

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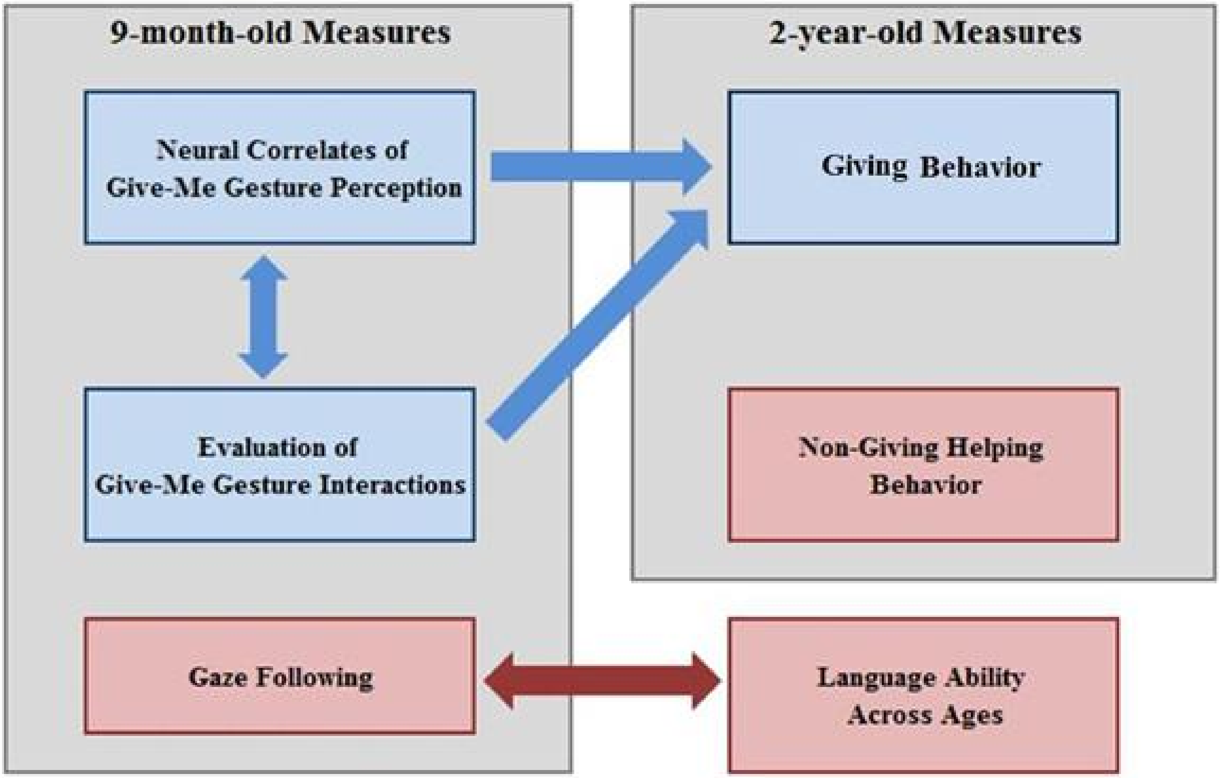

Figure 1. *Predictions based on the hypothesis of early developing and continuous cognitive mechanisms for giving-related behavior, showing giving-related (blue boxes) and non-giving related (red boxes) mechanisms. Arrows indicate predicted associations across measures and ages, while importantly, the absence of arrows indicates measures that are not predicted to be associated.*

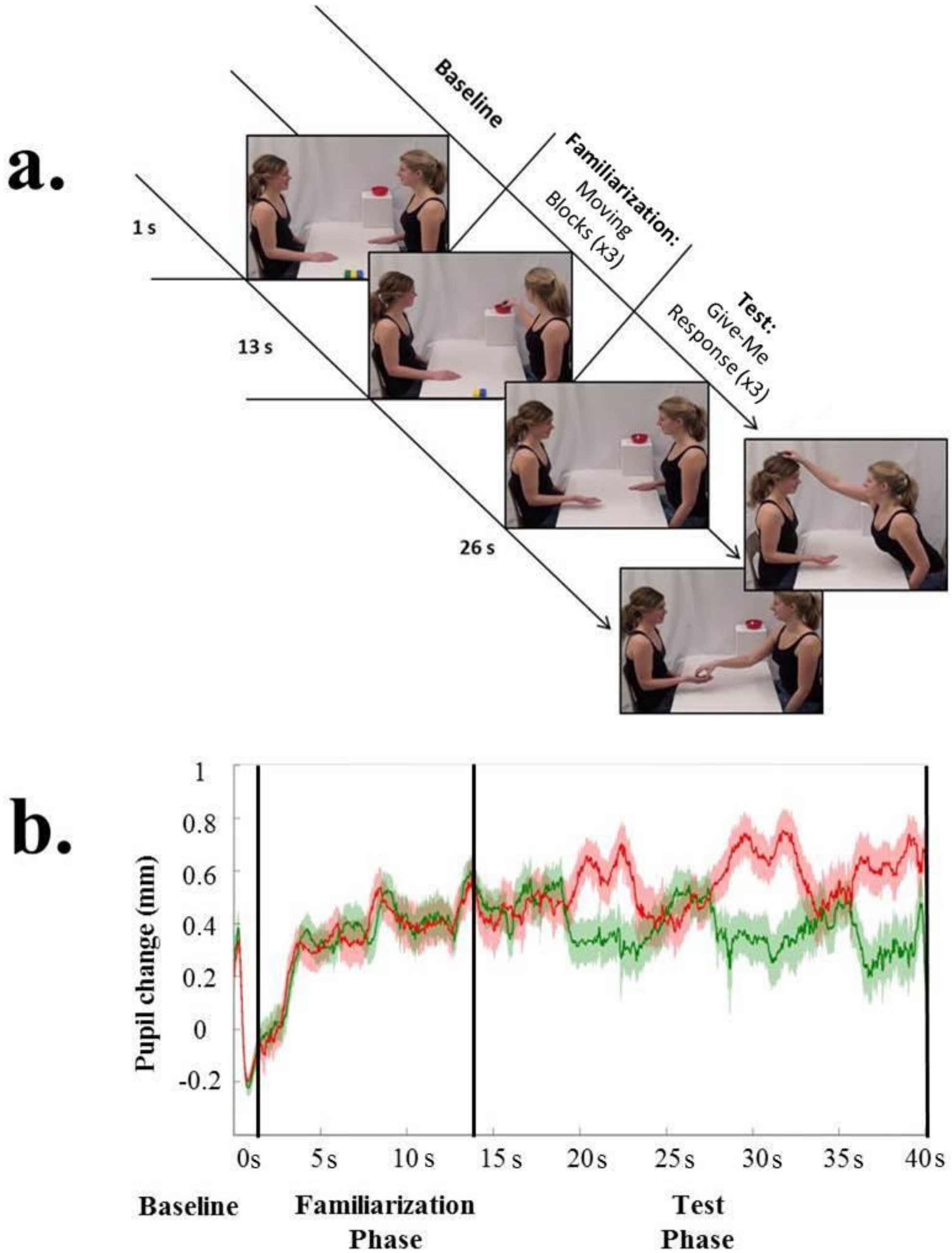

Figure 2. *Time series of one evaluation of give-me gesture interaction trial, illustrating (a) the sequence of actions in the video stimuli with two conditions: an appropriate response to the give-me gesture (object being passed to the hand; green line), or an inappropriate response to the give-me gesture (object being passed to the head; red line), and (b) the mean pupil change across the time sequence. Note that each phase consisted of three separate actions.*

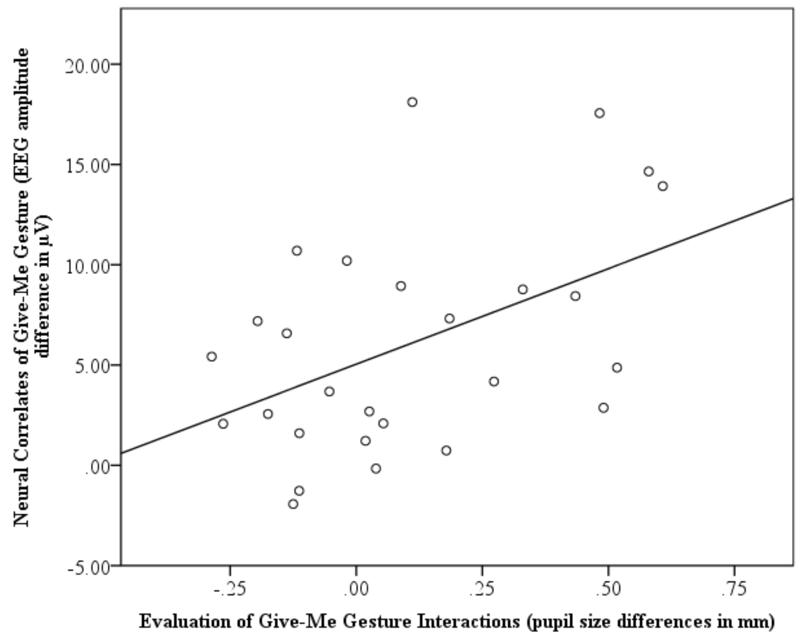

Figure 3. *Difference scores in P400 mean amplitude in the neural correlates of give-me gesture perception task is positively correlated with difference scores in pupil size between the appropriate and inappropriate conditions in the evaluation of give-me gesture interactions task.*

Table 1
Correlations between Non-Giving Helping (placing in the box) and Giving at Two Years, P400 Amplitude, Pupil Difference Scores and Gaze Following at 9-months, and Language Scores at 9 months, 18 months, and Two Years of Age.

Age (months)		Measure	1	2	3	4	5	6	7	8	9	10
24	1	Non-giving helping (proportion trials)	-	-.84**	-.47**	-0.42**	-.19	-.16	.09	.13	.03	-.12
24	2	Non-giving helping (latency)		-	.45**	-.41**	.13	.25	-.10	-.07	-.01	.07
24	3	Giving (proportion trials)			-	-.97**	.51*	.42*	-.10	-.07	-.05	.19
24	4	Giving (latency)				-	-.53*	-.45*	.07	.09	.03	-.26
9	5	P400					-	.47*	-.02	-.23	-.09	-.21
9	6	Pupil						-	-.09	.11	-.11	-.19
9	7	Gaze following							-	.30*	-.04	-.02
9	8	Language								-	.17	.09
18	9	Language									-	.57**
24	10	Language										-

Note: All coefficients are Pearson's r, except for proportion and latency correlations, for which Spearman's rho is used due to heavy skew. **p* < .05, ***p* < .01