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Infants' online perception of give-and-take interactions

Claudia Elsner [a,*], Marta Bakker [a], Katharina Rohlfing [b], Gustaf Gredebäck [a]

[a] Uppsala Child and Baby Lab, Department of Psychology, Uppsala University, 751 42 Uppsala, Sweden
[b] Center of Excellence Cognitive Interaction Technology, Bielefeld University, 33615 Bielefeld, Germany

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ABSTRACT

This research investigated infants' online perception of give-me gestures during observation of a social interaction. In the first experiment, goal-directed eye movements of 12-month-olds were recorded as they observed a give-and-take interaction in which an object is passed from one individual to another. Infants' gaze shifts from the passing hand to the receiving hand were significantly faster when the receiving hand formed a give-me gesture relative to when it was presented as an inverted hand shape. Experiment 2 revealed that infants' goal-directed gaze shifts were not based on different affordances of the two receiving hands. Two additional control experiments further demonstrated that differences in infants' online gaze behavior were not mediated by an attentional preference for the give-me gesture. Together, our findings provide evidence that properties of social action goals influence infants' online gaze during action observation. The current studies demonstrate that infants have expectations about well-formed object transfer actions between social agents. We suggest that 12-month-olds are sensitive to social goals within the context of give-and-take interactions while observing from a third-party perspective.

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Introduction

From birth, human infants are sensitive to social information, and they begin to communicate before becoming verbal (Bruner, 1977; Tomasello, 2008). Even newborns show sensitivity to different

* Corresponding author.
E-mail address: claudia.elsner@psyk.uu.se (C. Elsner).

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communicative cues such as preference for face-like patterns (e.g., Valenza, Simion, Cassia, & Umiltà, 1996) and sensitivity for mutual and direct gaze (Farroni, Csibra, Simion, & Johnson, 2002). From early on, infants are receptive to turn-taking structures and signals in mother–infant (Kozak-Mayer & Tronick, 1985; Nadel, Prepin, & Okanda, 2005; Trevarthen, 1979, 1993) and stranger–infant (Melinder, Forbes, Tronick, Fikke, & Gredebäck, 2010) face-to-face interactions during both dyadic and triadic interactions (Brooks & Meltzoff, 2005; Bruner, 1983; Carpendale & Lewis, 2004; Gredebäck, Fikke, & Melinder, 2010; Moore & Dunham, 1995). Such early experiences in interpersonal communication are seen as a foundation for social communication skills later in life (Brownell & Carriger, 1990; Mundy & Newell, 2007; Tomasello, 1999).

Besides referential cues from faces (e.g., gaze directions, facial expressions), observing other people's actions plays a crucial role in communication and cultural learning. It also facilitates understanding and prediction of other people's goals during social interactions (Baldwin, 2000; Sebanz, Bekkering, & Knoblich, 2006). However, one limitation of prior studies on infants' action understanding is their focus on manual actions performed by a single individual (e.g., Daum, Prinz, & Aschersleben, 2008; Falck-Ytter, Gredebäck, & von Hofsten, 2006; Woodward & Sommerville, 2000). Consequently, it is not well understood how infants perceive manual actions in a social context. One exception is a study by Gredebäck and Melinder (2010), who presented infants with two actors feeding each other (for a recent exception, see also Thorgrimsson, Fawcett, & Liszkowski, 2014). The current study aimed to address this gap by focusing on infants' understanding of a simple social interaction. In the following, we refer to a specific type of social interaction that consists of an exchange of an object between two individuals (see also Fawcett & Gredebäck, 2013).

In the current study, goal-directed eye movements of 12-month-olds were recorded as the infants observed a give-and-take interaction in which an object is passed from one individual to another. We investigated whether infants are able to exhibit goal-directed gaze shifts toward the action goal of an observed social interaction. More specifically, the current study examined whether there is a difference in the latencies of infants' goal-directed gaze shifts that are directed toward a give-me gesture — an extended hand with palm up formed when requesting and receiving an object (Mundy, Sigman, Ungerer, & Sherman, 1986) — compared with an inverted hand shape that was identical in shape but different in orientation (a downward-facing palm, hereafter labeled as inverted hand shape). This research topic is new to the field of developmental psychology in that it combines knowledge from studies targeting both the development of gestural communication and online action understanding. Even though it is still unclear how social properties of observed action goals influence infants' early action understanding from a third-party perspective, they play an important role in our social world where we constantly observe and encode social interactions. Because gestures are a key component of human social communication, the current study focused on infants' online perception of a give-me gesture as a part and goal of an observed interaction.

Gestural communication can be found across many contexts, cultures, and species (Call & Tomasello, 2007; Cartmill & Byrne, 2010; Goldin-Meadow, 2011). In essence, gestures are perceived as conveying specific meanings, intentions, goals, interpersonal information, and emotions from one individual to another, typically with fingers, hands, and arms (Crais, Douglas, & Campbell, 2004). On a theoretical level, researchers have made a distinction between deictic and representational gestures (Goldin-Meadow, 1999; Iverson & Thal, 1998; McNeill, 1992). The former are gestures that refer to objects or events, for example, through pointing or showing (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). The latter can stand on their own (i.e., without speech) because its form or motion conveys a specific semantic meaning that can be either object related or convention based (Crais et al., 2004). The give-me gesture, which is the target of the current experiments, is referential because it often involves an invitation to collaborate or a request to comply.

Prior studies investigating give-me gestures have primarily relied on observational paradigms, focusing on infants' ability to produce give-me gestures during give-and-take interactions (Carpenter, Nagell, & Tomasello, 1998; Crais et al., 2004; Messinger & Fogel, 1998). For instance, Messinger and Fogel (1998) examined infants' gesturing and corresponding communicative behaviors (e.g., vocalization, gazing at the mother) during mother–infant play sessions from 9 to 15 months of age using a longitudinal design. Over the investigated time range, the proportions of infants both offering and requesting objects increased. These changes were accompanied by increasing communicative signals such as vocalization and smiling while gazing at the mother. This increase in offering and requesting occurs at roughly the same time that infants begin to produce declarative gives (i.e., giving objects to share and direct attention) as well as imperative gives (i.e., giving as a means to direct others' behavior) at around 13 months of age (Carpenter et al., 1998). In another longitudinal study, Crais and colleagues (2004) found an earlier emergence of declarative giving (around 9 months) than imperative giving (around 12 months).

These studies provide helpful information about the developmental trajectories of give-me gesturing; however, they do not inform us about how infants perceive these gestures from a third-person perspective, that is, during observation of other people interacting with each other. However, one electroencephalogram (EEG) study performed on adults addressed this issue. Shibata, Gyoba, and Suzuki (2009) assessed how adults processed give-and-take actions while they observed either appropriate (shape of receiving hand matching the giving action) or inappropriate (shape of receiving hand not matching the giving action) receiving actions. In their study, inappropriate receiving actions elicited larger N400 components than appropriate receiving actions, demonstrating that semantic processing and prediction of interpersonal action sequences occurs in adults. Similarly, Reid and colleagues (2009) found neurophysiological evidence that even at 9 months of age, infants may use similar semantic processing systems as adults to predict goals of others' actions. In their EEG study, they showed that 9-month-olds, but not 7-month-olds, produce similar N400 responses as those of adults while observing unexpected completions of eating action sequences such as bringing a spoon to the head instead of to the mouth. Of note is that the action sequences used in their study did not involve a social interaction but rather were always performed by a single individual.

As mentioned above, the comprehension of others' gestures is related not only to gesture production but also to action understanding at large and the ability to infer and understand other people's action goals (Crais et al., 2004; Sebanz et al., 2006). Looking time paradigms have shown that by 6 months of age, infants begin to perceive observed human actions as goal directed (e.g., Luo & Baillargeon, 2005; Woodward & Sommerville, 2000). In these studies, infants are surprised when they observe an unexpected action outcome rather than an expected one (Woodward, 1998). At the same age, infants also rely on environmental cues to infer others' goals even when they see incomplete actions (Daum, Vuori, Prinz, & Aschersleben, 2009; see also Brandone & Wellman, 2009). Using the same technique, Henderson and colleagues demonstrated that infants' ability to understand the common goal structure of an observed joint action between two collaborating individuals develops between 10 and 14 months of age (Henderson, Wang, Matz, & Woodward, 2013; Henderson & Woodward, 2011).

Whereas looking time studies show that infants react to changes that have already occurred, anticipatory gaze shifts measure infants' ability to make sense of ongoing events online as they unfold. The ability to anticipate the goals of others' actions (i.e., fixating on the goal of an observed action before it is completed) is seen as a marker of predictive action understanding (Elsner, Falck-Ytter, & Gredebäck, 2012; Flanagan & Johansson, 2003; Gredebäck, Johnson, & von Hofsten, 2010). Numerous studies have used this technique to investigate how online action understanding emerges and expands after the first 6 months of life. Prior findings show that infants' ability to look at the goal of an action before that action is completed is closely linked to infants' own ability to perform the same action (e.g., Cannon & Woodward, 2012; Falck-Ytter et al., 2006; Kanakogi & Itakura, 2011; Kochukhova & Gredebäck, 2010). Moreover, previous studies have also demonstrated that the properties of the goal influence the latency of goal-directed gaze shifts (Ambrosini, Costantini, & Sinigaglia, 2011; Gredebäck, Stasiewicz, Falck-Ytter, Rosander, & von Hofsten, 2009; Henrichs, Elsner, Elsner, & Gredebäck, 2012). The majority of these studies focused on presenting actions in which one agent performed an action in isolation. Consequently, there have been few attempts to explore how infants' goal-directed gaze shifts are expressed during social interactions. One notable exception is a study by Gredebäck and Melinder (2010) in which infants observed two adults feeding each other. In this study, they demonstrated that 1-year-old infants fixate on the recipient of the food significantly earlier when the feeding action is performed in a rational action manner (food is brought to the person's mouth during feeding action) than when the feeding is performed in an irrational manner (food is placed on top of the recipient's hand while the recipient later leans forward and eats it from the back of her hand).

Together, prior literature provides support to the existence of a link between infants' own action proficiency and action understanding as measured with latencies of goal-directed gaze shifts (e.g., Cannon, Woodward, Gredebäck, von Hofsten, & Turek, 2012; Falck-Ytter et al., 2006). Given that infants begin to produce and respond to give-me gestures during interactions with others from around 9 to 12 months of age (Crais et al., 2004), it is possible that infants will also demonstrate sensitivity to observed social interactions, including give-me gestures, at 12 months of age. In addition, recent studies have demonstrated that latencies of goal-directed gaze shifts are modulated by properties of the goal (Ambrosini et al., 2011; Gredebäck et al., 2009; Henrichs et al., 2012). This would suggest that latencies of goal-directed gaze shifts might also be influenced by properties of a social goal such as the receiving hand in a give-and-take interaction. However, information about how infants perceive give-me gestures as goals of observed social actions is limited. This limitation is notable in both anticipation studies and studies of early gestural communication, which focused primarily on pointing (e.g., Butterworth, 2003; Rohlfing, Longo, & Bertenthal, 2012; Tomasello, Carpenter, & Liszkowski, 2007) or on infants' production of give-me gestures (e.g., Crais et al., 2004; Messinger & Fogel, 1998).

The current study addressed this gap within the developmental literature by investigating whether the social properties of a give-me gesture as a goal of an observed give-and-take interaction affect online gaze behavior in 12-month-old infants. In the following article, we first present an experiment testing differences in latency of goal-directed gaze shifts toward a receiving hand that forms either a meaningful and functional gesture (the give-me gesture) or a non-functional hand shape (the inverted hand shape). Finding faster gaze shifts to the give-me gesture as the receiving hand would be consistent with the hypothesis that infants are sensitive to the social properties of the gesture as a part of the give-and-take interaction. Three subsequent experiments are presented to rule out alternative explanations of gaze shift differences, such as affordance- and attention-based explanations.

Experiment 1

In Experiment 1, we presented 12-month-olds with movies of a manual give-and-take transaction between two people in which one hand grasps a ball and passes it to another hand, forming either a give-me gesture or an inverted hand shape. As a dependent variable, we measured the latency of infants' goal-directed gaze shifts, that is, how fast they shifted their gaze from the passing hand to the receiving hand (shaped as a give-me gesture or an inverted hand shape). If infants are sensitive to the social properties of the give-me gesture in the context of this social interaction, we hypothesized faster gaze shifts to the receiving hand when it has formed as a give-me gesture than when the presented action ends with an inverted hand shape.

Method

Participants

The sample consisted of 34 12-month-olds (15 boys and 19 girls), with 17 infants in the Give-Me Gesture condition and 17 infants in the condition showing the inverted hand shape (Inverted Hand Shape condition). The mean age was 377 days ($SD = 8$) in the experimental condition and 380 days ($SD = 10$) in the control condition. An additional five infants were excluded from the analysis because of failure to fulfill the inclusion criteria (not enough valid gaze shifts over all trials due to fussiness) or technical problems with the eye tracker. All parents gave their written consent prior to the experiment. All families received a gift certificate (approximately 10 euros) as compensation for their participation. The study was approved by the regional ethics committee and in accordance with the 1964 Declaration of Helsinki.

Stimuli and apparatus

Gaze was measured with a Tobii T120 near infrared eye tracker (sampling rate = 60 Hz, accuracy = 0.5 degrees, monitor size = 17 inches; Tobii, Stockholm, Sweden). The stimulus movie was recorded from a live scene and edited in Adobe Premiere (Adobe Systems, San Jose, CA, USA). The final movie (29.3×24.2 visual degrees) contained an everyday give-and-take interaction. The movie was from a lateral perspective and showed two social agents, including only their hands and arms. The stimulus presentation started with a still frame of a hand forming a fist that was positioned on the right or left side of the screen and an object (white ball with colorful flowers) that was placed in the middle of the scene. After approximately 100 ms, a second hand entered the scene from the side (opposite to the first hand) and grasped and lifted the ball (average duration = 1875 ms). After squeezing the ball accompanied by a sound (average duration = 1555 ms), the other hand subsequently formed either a give-me gesture (average duration = 1700 ms) or an inverted hand shape (average duration = 1600 ms) [Fig. 1A(I)]. After the ball was squeezed a second time (average duration = 1625 ms) to ensure that infants attended to the object, the ball was passed to the receiving hand on the other side of the screen (average duration in the Give-Me Gesture condition = 1680 ms; average duration in the Inverted Hand Shape condition = 1720 ms) [Fig. 1A(II)]. The stimulus movie ended with a still frame for 1 s showing the ball touching the receiving hand [Fig. 1A(III)]. All reaching actions of the four different stimuli versions (alternating reaching from right or left side with either a give-me gesture or an inverted hand shape as the goal) had approximately the same length (10.12, 10.24, 11.28, and 11.56 s, respectively).

Procedure

Before the experiment, infants were seated approximately 60 cm in front of the eye tracker on a caregiver's lap. After a standard 5-point calibration (Gredebäck et al., 2010), infants were presented with movies of the give-and-take interaction, alternating giving from the right or the left between consecutive trials. Each infant was then shown 10 trials with either the give-me gesture or the inverted hand shape as the goal of an observed action (between-subject design) intermixed with various attention-grabbing movies between stimuli presentations to maintain infants' attention. Each family spent approximately 20 min in the lab.

Data reduction and analysis

All data analyses were performed in MATLAB (MathWorks, Friedrichsdorf, Germany). Infants' latencies of goal-directed eye movements in two areas of interest (AOIs) were analyzed. The first AOI covered the position of the "giving" hand holding the ball (+ 1 visual degree in each direction). The AOI around the action goal covered the area around the receiving hand (+ 1 visual degree in each direction) [see Fig. 1A(I)].

We measured gaze shifts from the AOI around the giving hand to the goal AOI during the passing action. Data were included in the analysis if infants fixated first on the AOI around the hand with the ball and subsequently on the goal AOI (each for more than 200 ms) during a time period between the end of the second ball squeezing and 1 s after the ball touched the receiving hand. The duration of the reaching action, from the onset of the hand movement until the hand entered the goal AOI, lasted

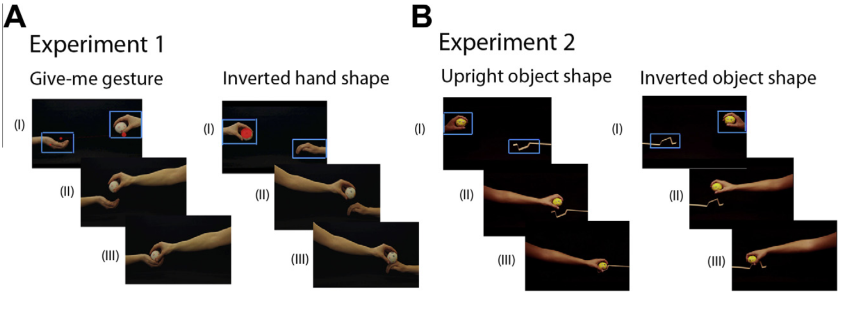

Fig. 1. Snapshots of the action sequences presented in Experiments 1 and 2 separately for the different conditions showing either a give-me gesture or an inverted hand shape (A) or an upright or inverted object shape (B). Depicted for both experiments are the time point when the hand/object postures are formed (I), the passing action toward the receiving hand/object shape (II), and the time point when the ball was placed (III). Note that the object shape in Experiment 2 is three-dimensional and, thus, allows a ball to be physically placed on it in both conditions. AOIs (covering the passing hand and the action goal) used in the analysis are marked by blue rectangles, and recorded gaze is plotted in red. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

approximately 1400 ms (average duration in the Give-Me Gesture condition = 1440 ms; average duration in the Inverted Hand Shape condition = 1380 ms). In this experiment, 72.4% of all presented trials were classified as valid data points and were included in the analyses. Latencies of goal-directed gaze shifts were calculated by subtracting the time when participants first fixated on the goal AOI from the point in time when the first part of the hand entered this AOI. Positive numbers refer to gaze arriving at the goal AOI before the hand passing the ball, and negative values refer to gaze fixations after the arrival of the hand. All included infants exhibited gaze shifts in at least 4 of 10 presented trials. An outlier analysis with *z*-transformations was performed for each condition. No data point in the Give-Me Gesture condition was classified as an outlier. Four data points with *z*-scores less than −3 or greater than 3 were classified as statistical outliers and removed in the condition showing the inverted hand shape. Mean latencies of goal-directed gaze shifts were aggregated and averaged over all valid trials for each infant.

Statistical analyses were performed in SPSS. Mean latencies of goal-directed gaze shifts were compared with an independent *t*-test to assess whether gaze performance differed between conditions. An additional independent *t*-test examined whether there is a difference in latencies of goal-directed gaze shifts between the two conditions already at the first trial.

Results

On average, infants fixated on the area around the give-me gesture before the passing hand entered the goal AOI (M = 73.71 ms, SE = 52.52, 95% confidence interval [CI] [−38, 185]). In the control condition, on average, 12-month-olds fixated on the goal AOI after the hand had entered it (M = −278.77 ms, SE = 57.58, CI [−401, −157]). A between-subject comparison of mean latencies revealed that gaze latencies were significantly earlier during observation of the give-me gesture than when infants were presented with the inverted hand shape, $t(32) = 4.523$, $p < .001$, $d = 1.60$ (see Fig. 2). Moreover, mean gaze arrival times differed significantly between the two conditions even at the first trial ($M_{\text{Give-Me Gesture}}$ = −97.75 ms, SE = 71.09, $M_{\text{Inverted Hand Shape}}$ = −317.33 ms, SE = 59.29), $t(29) = 2.36$, $p = .025$, $d = 0.87$.

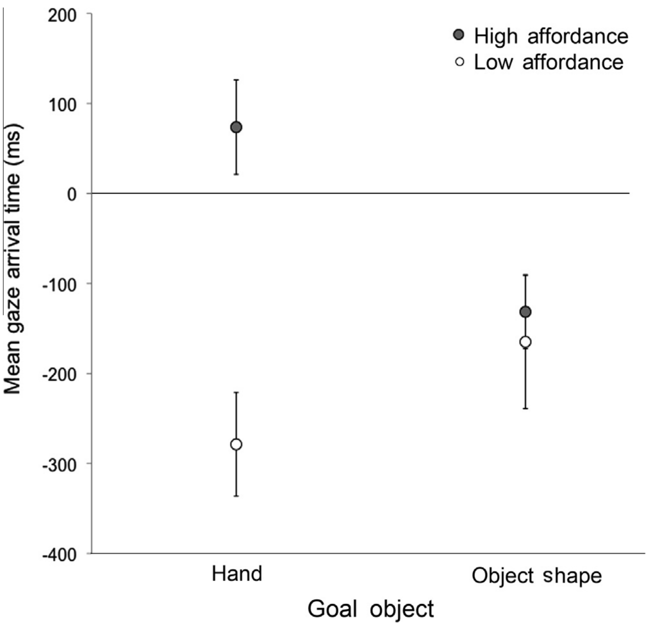

Fig. 2. Aggregated mean gaze arrival time of Trials 1 to 10 for each of the four conditions presented in Experiments 1 and 2 (Goal Object: Hand vs. Object shape; Affordance: Low vs. High). Error bars depict standard errors. Values above 0 ms correspond to earlier arrival of gaze at the goal area relative to the arrival of the hand.

Discussion

The aim of Experiment 1 was to assess how 12-month-olds perceive a give-me gesture in the context of a give-and-take interaction between two individuals. We hypothesized that infants would fixate on the give-me gesture earlier than they fixated on the inverted hand shape. Experiment 1 demonstrates that the latencies of infants' goal-directed gaze shifts are significantly shorter when the receiving hand formed a give-me gesture relative to when the hand formed an inverted shape. It is also noteworthy that the difference in infants' gaze behavior was evident from the first trial onward, demonstrating that infants' sensitivity to give-me gestures was not based on learning the consequences of the passing hand within the experimental session. In sum, these results suggest that 1-year-olds are able to differentiate give-me gestures from other visually similar but non-functional hand shapes when observing a give-and-take interaction.

However, it is also possible that infants' anticipatory gaze was mediated by affordance differences between the two hands receiving the ball, that is, by the quality of an object, such as shape or orientation, which conveys readily perceivable action possibilities (Chemero, 2003; Costantini & Sinigaglia, 2012; Gibson, 1979). In the same way as the shape of a chair affords sitting (Gibson & Pick, 2000, p.15), the upright container-like shape of a hand in a give-me gesture may afford containing the ball and not the social action of receiving. Concurrently, the inversion of the give-me gesture could decrease the affordance of the hand. It is possible that differences in affordances (i.e., the fact that children expect objects of a particular shape to be related to each other) rather than infants' sensitivity toward social goals and actions could account for different latencies of goal-directed gaze shifts found in Experiment 1. In other words, if a give-me gesture conveys a higher affordance due to its dispositional properties (shape or orientation), shorter gaze latencies towards this receiving gesture may not be related to its social properties, but by simply perceiving the function of the gestural shape which is to contain another object. To test this possibility, in Experiment 2 we examined whether infants' goal-directed gaze shifts are modified by the affordance of a goal object.

Experiment 2

In Experiment 2, we presented infants with the same transaction as in Experiment 1 except that the hand was replaced by an unfamiliar u-shaped object as the goal of the action. We varied the affordance by the orientation of the goal object; the final position of the object shape was upright in the High Affordance condition (similar shape and orientation as a give-me gesture) and was inverted in the Low Affordance condition (similar shape and orientation as the inverted hand shape). Both the upright object shape in the High Affordance condition and the inverted object shape in the Low Affordance condition represent goal objects without apparent social properties. Thus, if infants' gaze is mediated by affordances, goal-directed gaze shifts should occur earlier during observation of the upright object shape as the goal object (High Affordance condition) compared with when the ball is passed toward the inverted object shape (Low Affordance condition). Alternatively, if the social properties of the give-me gesture rather than its affordance mediate differences in the latency of infants' goal-directed gaze shifts, as observed in Experiment 1, latencies of goal-directed gaze shifts should not differ during observation of passing actions toward goal objects with high or low affordances, as presented in Experiment 2.

Method

Participants

The final sample consisted of 34 12-month-olds (19 boys and 15 girls) and was divided into two conditions: 17 infants in the High Affordance condition (mean age = 367 days, *SD* = 6; 9 boys and 8 girls) and 17 infants in the Low Affordance condition (mean age = 367 days, *SD* = 6, 10 boys and 7 girls). An additional 8 infants were tested but excluded because of fussiness or lack of attention. An additional 5 exclusions were due to calibration failure. All families were given a gift certificate (approximately 10 euros) for their participation.

Stimuli and apparatus

The apparatus was identical to that used in Experiment 1. Stimuli movies were created in Adobe Premiere. The final movie (29.3 × 24.2 visual degrees) showed the same action sequence from a lateral perspective against a black background as in Experiment 1 except that the hand was replaced with a three-dimensional object shape. The object was a skin-colored (with metallic paint) u-shaped metal bar (like the form of a give-me gesture, 230 × 25 × 3 mm) (see Fig. 1B). We chose a novel object shape rather than a familiar object to avoid potential confounds of the object's familiarity with its affordance and their respective effects on the latency of goal-directed gaze shifts.

The stimulus presentation began with the object shape turned to the side (no shape visible) and positioned on the right or left side of the screen, whereas the ball (yellow with colorful flowers) was placed in the middle of the scene. Next, a hand entered the scene from the side opposite of the object shape and grasped and lifted the ball (average duration = 2800 ms). The following action sequences were identical to those in Experiment 1. After the hand had squeezed the ball accompanied by a sound (average duration = 1900 ms), the object shape was turned 90 degrees up or down to either an upright (High Affordance condition) or inverted (Low Affordance condition) position (average duration = 3000 ms) [Fig. 1B(I)]. After the ball was squeezed a second time (average duration = 1800 ms), the hand passed the ball to the object shape on the other side of the screen (duration High Affordance condition = 1967 ms; duration Low Affordance condition = 1934 ms) [Fig. 1B(II)]. The stimulus movie ended with a still frame for 1 s when the ball touched the object shape [Fig. 1B(III)]. All four stimuli versions (upright vs. inverted object shape, reaching from right or left side) lasted 14.1 s in total.

Procedure

Infants were tested in the same laboratory settings as in Experiment 1. After successful calibration of their eyes, infants were presented with 10 trials of the stimulus movie from either the High Affordance or Low Affordance condition (altering showing reaching from the right or from the left), interleaved with different attention-grabbing movies. The whole experiment lasted approximately 20 min.

Data reduction and analysis

All data reduction was performed in the same manner as in Experiment 1. The first AOI covered the position of the "giving" hand holding the ball (+ 1 visual degree in each direction). The goal AOI covered the area around the object shape in its final position (+ 1 visual degree in each direction) [see Fig. 1B(I)]. Both the AOI around the hand (7.8 × 7.3 visual degrees) and the goal AOI (8.2 × 4.8 visual degrees) were the same size in each condition.

Data were included in the analysis if infants fixated first on the AOI around the hand with the ball and subsequently on the goal AOI (each for more than 200 ms) during the time between the end of the second ball squeezing and 1 s after the ball touched the object shape. The time period when anticipations were measured (2934 ms) and the duration of the reaching action (from the start of the reaching until the hand entered the goal AOI) were the same in both conditions (1534 ms). In the current experiment, 67% of all presented trials were classified as valid data points and included in the analyses. Mean latencies of goal-directed gaze shifts were calculated in the same manner as in Experiment 1. All included infants exhibited gaze shifts in at least 4 of 10 presented trials. Four data points in the High Affordance condition and 1 data point in the Low Affordance condition were classified as statistical outliers and removed. Data analysis was conducted in the same way as in Experiment 1.

Results

On average, 12-month-olds in both the High Affordance condition ($M = -131.51$ ms, $SE = 40.91$, 95% CI [−218, −45]) and the Low Affordance condition ($M = -164.85$ ms, $SE = 74.17$, CI [−322, −8]) fixated on the goal after the passing hand entered the goal AOI. A corrected t-test (Welch-test for heterogeneous variances) revealed that there was no significant difference in mean gaze latencies between the two conditions, $t(24.91) = 0.394$, $p = .697$, $d = 0.14$ (see Fig. 2). No evidence of learning effects was found in the High Affordance condition; that is, infants did not show improvement of performance over the course of trials.

Comparison between Experiments 1 and 2

To compare gaze latencies between Experiments 1 and 2, an additional analysis including all four conditions (Give-Me Gesture, Inverted Hand Shape, Upright Object Shape, and Inverted Object Shape) was performed. A 2×2 analysis of variance (ANOVA) with the factors Goal Object (Hand vs. Object shape) and Affordance (High vs. Low) as independent variables was conducted to examine gaze latencies between the different goal objects across experiments. The analysis showed a significant main effect for Affordance, $F(1,67) = 11.24$, $p = .001$, $\eta^2 = .15$, no significant main effect for Goal Object, $F(1,67) = 0.63$, $p = .431$, $\eta^2 = .01$, but a significant Goal Object by Affordance interaction, $F(1,67) = 7.69$, $p = .007$, $\eta^2 = .11$. Post hoc comparisons (Fisher's LSD [least significant difference]) indicated that infants fixated on the goal AOI significantly earlier when they observed the give-me gesture compared with the other High Affordance condition showing the upright object shape (mean difference [*MD*] = 205.22, *SE* = 81.39, $p = .014$), but there was no significant difference between the inverted hand shape and the inverted object shape in the Low Affordance condition (*MD* = 113.91, *SE* = 81.4, $p = .166$) (see Fig. 2).

Discussion

The purpose of Experiment 2 was to test the alternative explanation that a higher affordance of the give-me gesture rather than its relatedness to social action may account for shorter latencies of goal-directed gaze shifts compared with gaze behavior observed in the Inverted Hand Shape condition. The findings of Experiment 2 demonstrate that affordances alone do not explain the difference in latencies of goal-directed eye movements observed in Experiment 1. The 12-month-olds did not exhibit significantly earlier gaze shifts toward a non-social goal object with a high affordance compared with a goal object with a low affordance. Interestingly, the comparison between Experiments 1 and 2 revealed that latencies of infants' goal-directed gaze shifts were significantly shorter when the receiving hand formed a give-me gesture relative to when the upright object shape with a comparable high affordance was presented as the goal of the observed action. At the same time, there was no significant difference in infants' gaze behavior between observing the inverted hand shape and observing the inverted object shape that also conveys similar affordances (Low Affordance condition). Together, the findings are also consistent with the hypothesis that properties of a social goal, in this case a receiving hand, influence how fast infants shift their gaze during observation of other people's actions and not its affordance.

However, another possible interpretation of Experiment 1 is that give-me gestures attract more of infants' attention than the inverted hand shape and that this increase of attention facilitates goal-directed gaze shifts through priming (Daum & Gredebäck, 2011). According to this suggestion, shorter latencies of goal-directed gaze shifts in the condition showing the give-me gesture might be attributed only to attentional mechanisms and not to the social goal of an action. This issue was addressed in Experiment 3.

Experiment 3

In Experiment 3, we presented infants with the two hand postures from Experiment 1 simultaneously while measuring looking times at the give-me gesture and at the inverted hand shape. To be as consistent as possible with the original context, a moving ball was also presented in the scene. However, no action of receiving the ball was presented. We reasoned that if infants generally pay more attention to the give-me gesture, they should look more at this gesture than at the inverted hand shape.

Method

Participants

A sample of 14 12-month-olds participated in this experiment and were included in the analysis (mean age = 365.4 days, *SD* = 9.5; 5 boys and 9 girls). An additional 3 infants were tested but excluded due to fussiness or lack of attention. All families were given a gift certificate (approximately 10 euros) for their participation.

Stimuli and apparatus

The apparatus was identical to that in Experiment 1. The stimuli were live recordings of a wooden stick, a ball, and two human hands placed across from each other. All versions of the stimuli movies (29.3 × 24.2 visual degrees) were created in Adobe Premiere. They started with a still frame showing two fists positioned on the left and right and a ball on a wooden stick positioned at the top middle of a black screen (Fig. 3A). After 400 ms, the stick with the attached ball (orange with colorful flowers) moved once like a pendulum back and forth (Fig. 3A). The swing lasted 1.8 s — approximately the same amount of time as the hand took to reach for, grasp, and lift the ball from the floor in Experiment 1. Subsequently, the ball wiggled two times while a squeezing sound identical to that in Experiment 1 (average duration = 2000 ms) was presented. The wiggle and sound were intended to present the same amount of audio–visual information as was presented when the hand squeezed the ball in Experiment 1. In response to the wiggle and sound and with similar timing, one hand formed a give-me gesture and the other one formed the inverted hand shape (same hand postures as in Experiment 1; average duration = 2600 ms) (Fig. 3A). Both hands were matched in their size as well as their respective distance to the ball. After the wiggle and sound were again presented (2000 ms), the pendulum swung a second time back and forth (1740 ms) (Fig. 3A). During the last 2.72 s of the stimulus movie, a still frame of the two hand postures and the pendulum in the middle of the screen were shown (see Fig. 3A). Both the position of the hand postures and the direction of the first pendulum swing (to the left or right) were randomized and counterbalanced over all trials. All versions of the stimulus movies lasted 14.48 s.

Procedure

Infants were tested in the same laboratory settings as in Experiment 1. After successful calibration of their eyes, infants were presented with 12 trials of the stimulus movie interleaved with different attention-grabbing movies. The four different stimuli versions were shown in a randomized order. The whole experiment lasted approximately 20 min.

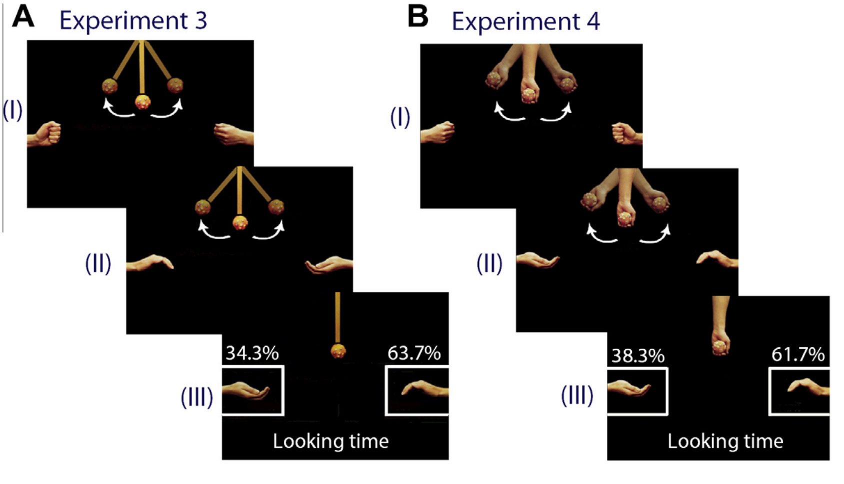

Fig. 3. Snapshots of the action sequences presented in Experiment 3 (A) and Experiment 4 (B) depicting the fisted hands at the beginning of the movie (I), the two hand positions after the hand postures were formed (II), and the pendulum motion from the ball either attached to a stick (A) or held by a human hand (B), with motion directions indicated by arrows (I + II). AOIs (covering the two hand postures) used in the looking time analysis are marked by blue [A(III)] or yellow [B(III)] rectangles. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Data reduction

Overall looking times around each hand were measured to assess whether infants prefer to look at one of the two hand postures. Looking time analyses were performed in MATLAB. Within this preferential looking experiment, infants' looking time in two AOIs was measured: one AOI covering the give-me gesture (+ 1 visual degree) and the other equal-sized AOI covering the inverted hand shape (+ 1 visual degree). Looking time was included in the analysis if infants fixated on an AOI for at least 200 ms during the time period when the hands started to form the hand posture until the end of the movie (9.88 s in total). The total amount of infants' looking time in each AOI was aggregated and averaged over all included trials. Individual trials were excluded from the analysis if infants were not attentive enough and did not look at either AOI during 1 trial. Every infant with at least 4 valid trials out of 12 total trials was included in the analysis. The individual proportion of looking time in each AOI in relation to the overall looking time in both AOIs was calculated as a percentage score. Statistical analyses were conducted in SPSS. One-sample *t*-tests assessed whether percentages of looking time into the AOI showing the inverted hand shape was significantly different from chance (tested against 50%). Given this, a second *t*-test for the other AOI was unnecessary because its value depended on the percentage of looking time in the first AOI.

Results

On average, infants spent 19.4 s (SD = 9.0) looking in both of the AOIs over all included trials (average number of valid trials = 10.86, SD = 1.6). Infants looked preferentially to the AOI surrounding the inverted hand shape. More specifically, infants spent 63.7% (SD = 10.7) of the time looking at the AOI around the inverted hand shape and only 34.3% of the time looking at the AOI around the give-me gesture. A one-sample *t*-test of average looking times against 50% revealed that the average percentage of looking time into the AOI covering the inverted hand shape was significantly different from chance, $t(13) = 4.82$, $p < .001$.

Discussion

Experiment 3 demonstrates that in the absence of a social give-and-take interaction, 12-month-olds did not pay more attention to the give-me gesture than to the inverted hand shape when both were presented side by side. Instead, we found an attentional preference for the inverted hand shape. One possible explanation is that the data reflect a novelty preference, indicating differential processing for the two gestures.

The findings from Experiment 3 indicate that shorter gaze latencies found in Experiment 1 were not due to a priming effect based on an attentional bias for the give-me gesture. It is, of course, possible that the attentional preference suggested above is present only in even more complex social situations when there is a human holding the ball. That is, there might be an attentional preference toward give-me gestures when there is another human agent holding an object that could be transferred. To investigate the possibility of an attentional preference more thoroughly, a fourth experiment was conducted. Here the two hands (give-me gesture and inverted hand shape) were once more presented simultaneously in the presence of a moving ball; however, this time a hand moved the ball back and forth. Experiment 4 investigated whether the presence of a human holding the ball triggers more attentional load to the give-me gesture relative to the inverted hand shape. As in Experiment 3, looking times at the two hands were the dependent variables.

Experiment 4

In a second preferential looking experiment, infants were presented with the same action sequence as in Experiment 3, but the stick used in Experiment 3 was replaced by a human hand. We aimed to assess whether infants prefer to fixate on the give-me gesture when presented in a more social context compared with Experiment 3.

Method

Participants

The sample consisted of 14 12-month-olds (mean age = 363.9 days, *SD* = 7.8; 8 boys and 6 girls). An additional 4 infants participated but were excluded from the analyses (3 due to fussiness and 1 for looking to only the left side of the screen during the entire experiment).

Stimuli and apparatus

The apparatus and presented stimuli were identical to those used in Experiment 3 except that, instead of a wooden stick, a human hand held the ball and the visible arm moved like a pendulum. The ball lay in the palm of the hand, and the fingertips were visible below the ball [see Fig. 3B(II)]. The presented action sequence was exactly the same as in Experiment 3. In half of the movies the thumb was shown on the left side of the hand, and in the other half the thumb was shown on the right side of the hand. That is, in half of the movies participants observed the left hand holding the ball with the thumb pointing to the left (palm toward the observer), and in the other half they observed the right hand with the thumb pointing to the right holding the ball. Both the position of the hand postures and the location of the thumb, as well as the direction of the first pendulum motion (to the left or right), were randomized and counterbalanced over all trials. All versions of the stimulus movies lasted 14.4 s.

Procedure and data reduction

The procedure was identical to that in Experiment 3. All data reduction and analyses were performed in the same manner as in Experiment 3.

Results

Over all valid trials, infants looked on average 21.3 s (*SD* = 9.6) in the two AOIs covering the two hand postures (average number of valid trials = 10.92, *SD* = 1.3). In this second control experiment, we found the same effect as in the previous preferential looking study — an attentional preference for the more inverted hand shape. Of the aggregated overall looking time, 12-month-olds spent 61.7% (*SD* = 7.2) of the time looking at the AOI around the inverted hand shape and spent only 38.3% of the time looking at the AOI covering the give-me gesture. Their preferential looking to the inverted hand shape was significantly different from chance level, $t(13) = 6.11$, $p < .001$.

Discussion

In Experiment 4, we replicated the preference for the inverted hand shape found in Experiment 3. In the absence of a social action (i.e., one person receiving an object from another person), infants did not look more at the give-me gesture than at the inverted hand shape. This finding provides evidence that goal-directed gaze shifts as demonstrated in Experiment 1 cannot be attributed to an attentional preference.

General discussion

This research investigated infants' online perception of give-me gestures during observation of a give-and-take interaction between two individuals. Experiment 1 demonstrated that 12-month-olds' gaze shifts from a passing hand to a receiving hand are significantly faster when the receiving hand forms a give-me gesture relative to when the goal is presented as an inverted hand shape. Experiment 2 showed that affordances between the two receiving hands cannot account for the difference in gaze latencies observed in Experiment 1. Two additional control experiments demonstrated that differences in infants' predictive gaze behavior were not mediated by a general attentional preference for the give-me gesture in the absence of the social action of receiving.

Together, the current experiments provide evidence that 12-month-olds perceive an object transfer action between two social agents that includes a give-me gesture as a more well-formed goal-directed action than when the same action is completed with an inverted hand shape. This set of experiments extends prior research, which has shown that properties of physical goals affect latencies of infants' goal-directed gaze shifts during action observation (e.g., Gredebäck et al., 2009; Henrichs et al., 2012). The current study suggests that 1-year-olds are sensitive to the properties of social action goals (e.g., of a give-me gesture) and that these social properties influence infants' goal-directed gaze shifts during observation of a give-and-take interaction. These conclusions are discussed more extensively below.

Findings from Experiment 1 provide evidence for two possible alternative cognitive processes that might explain the observed latency differences. One possibility is that infants do not perceive the social interaction but rather react to the give-me gesture as a more likely place to put an object given that the palm-up hand shape has a higher affordance. According to this interpretation, infants might match the transferred object to the form of the give-me gesture due to its shape, resulting in earlier gaze arrival times in the upright "matching" condition compared with the inverted "non-matching" condition. However, the findings from Experiment 2 argue against this possibility, showing that latencies of goal-directed gaze shifts observed in Experiment 1 were not driven by different affordances of the two goals because affordances did not influence goal-directed gaze shifts when the action was directed to objects.

Another possibility is that infants' gaze behavior observed in Experiment 2 was influenced by action familiarity (Southgate, 2013). Indeed, prior studies have shown that infants' understanding of goal-directed actions performed by an unfamiliar agent, such as a mechanical claw, improves after a brief familiarization (Boyer, Pan, & Bertenthal, 2011; Hofer, Hauf, & Aschersleben, 2005). The influence of novel agents could potentially apply to novel goal objects as well. Thus, it is possible that infants exhibited later gaze shifts to the unfamiliar object shape, especially in the High Affordance condition, due only to its novelty. Although most prior studies dealt with the potential effect of novelty by a brief training period, it needs to be acknowledged that the current study did not include a pre-test familiarization. Nonetheless, both goal objects were novel, and yet there was no evidence of learning for the upright goal object in the High Affordance condition. This does not support the assumption that infants needed to learn about the new goal object in order to exhibit goal-directed gaze shifts.

In addition, it is important to acknowledge that the current set of studies cannot completely disentangle whether infants perceived the presented object transfer event as an action or as a segment of a social interaction. One possibility is that infants were faster in exhibiting online goal-directed gaze shifts to a palm-up hand without necessarily encoding the give-me gesture as an integral part of the observed social interaction. Another richer interpretation of infants' gaze behavior would suggest that infants are sensitive to the communicative information of the give-me gesture (i.e., the conveyed request), the compliant reaction to pass the object to the recipient's hand forming the give-me gesture, and the give-me gesture as an appropriate gesture to receive the object. However, the current data do not permit inferences about how much infants' goal-directed gaze shifts were based on encoding the social context of the give-and-take interaction such as that the passing hand provides some benefit for the receiving hand. One possibility to test this hypothesis in future research would be to disambiguate a social goal from a social action, for example, to present the give-me gesture in a non-social context where it does not convey any social information. For instance, comparing latencies of goal-directed gaze shifts to a palm-up versus palm-down hand receiving an object that was moving down a slide (non-social context) would allow testing whether infants in the current study encoded the social nature of the give-me gesture as an integral part of the interaction.

Other future directions for this research would be to investigate infants' gaze performance during social interactions within richer social contexts that include faces and language. In addition, future studies should also examine in more detail the extent to which familiarity of observed action goals affects infants' action understanding. Finally, future research would benefit from investigating the relationship between infants' active experience in social interactions and their understanding of the common goal structure underlying joint actions. Furthermore, finding neural correlates of give-me gesture perception might shed some light on the underlying processes of our current investigation.

By presenting infants with a simple dyadic interaction between two individuals, the current study aimed to provide insight into infants' very early online perception of give-and-take actions from a third-party perspective. Together, the current experiments indicate that already by 12 months of age, infants' goal-directed gaze behavior differs between observed object transfer actions that involve a give-me gesture and those that involve an inverted hand shape. These findings are consistent with the interpretation that infants, by their first year of life, are sensitive to the communicative properties of a give-me gesture in the context of a give-and-take social interaction and that, therefore, these properties are likely to play an important role in infants' action understanding from a third-party perspective.

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