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When the body reveals the mind: Children's use of others' body orientation to understand their focus of attention

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ABSTRACT

A considerable amount of research has examined children's ability to rely on explicit social cues such as pointing to understand others' referential intentions. Yet, skillful social interaction also requires reliance on and learning from implicit cues (i.e., cues that are not displayed with the explicit intention to teach or inform someone). From an embodied point of view, orienting movements and body orientation are salient cues that reveal something about a person's intentional relations without being explicit communicative cues. In three experiments, the current study investigated the development of the ability to use body information in a word learning situation. To this end, we presented 2-year-old children, 3.5-year-old children, and adults with movies on an eye-tracking screen in which an actor oriented her upper body to one of two objects while uttering a novel word. The results show that the 3.5-year-old children and adults, but not the 2-year-old children, related the novel word to the referred object (Experiments 1 and 2). Yet, when the actor oriented her body to one object while pointing to the other object, children of both age groups relied on the pointing cue (Experiment 3). This suggests that by 3.5 years children use another's body orientation as an indicator of her intentional relations but that they prioritize explicit social cues over the implicit body posture cues. Overall, the study supports theoretical views that an appreciation of others' intentional relations does not emerge as an all-or-nothing ability but rather emerges gradually during the course of early development.

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Introduction

Following others' social cues and understanding others' referential intentions plays a pivotal role in successful social interaction and social learning, for example, in early language acquisition (e.g., Tomasello, 2003). During the last two decades, developmental research has investigated the ontogenetic origins and development of young children's understanding of others' intentional relations. These studies have provided converging evidence that already in their first year of life infants become able to follow others' explicit cues, particularly eye gaze and pointing (e.g., Deák, Flom, & Pick, 2000; Moore, 2008; Paulus, 2011; Sodian & Thoermer, 2004). Likewise, studies on the social basis of early word learning have provided ample evidence that infants rely on these social cues to acquire novel words (e.g., Baldwin, 1993; Brooks & Meltzoff, 2005; Fenell & Waxman, 2010; Hollich et al., 2000; Houston-Price, Plunkett, & Duffy, 2006; Paulus & Fikkert, 2014). This ability is fragile until the end of the second year of life (Moore, Angelopoulos, & Bennett, 1999), easily disturbed in persons with autism spectrum disorders (Aldaqre, Paulus, & Sodian, 2015), and an explicit understanding of these cues develops during the third year of life (Doherty, Anderson, & Howieson, 2009). Nonetheless, a large set of studies shows that already infants appreciate others' referential intentions in pedagogical contexts, suggesting an early ability to learn from others.

Notwithstanding the relevance of learning from explicit social cues (i.e., cues that are used with the intention to communicate with or teach others), humans are very proficient in reading others' intentional relations (i.e., physical or mental activities directed at real or imagined objects; Barresi & Moore, 1996) from a variety of other cues. These include gait characteristics, body movements, and involuntary facial expressions (e.g., Sebanz & Shiffrar, 2009; van't Wout & Sanfey, 2008). Indeed, research has provided ample evidence that adults show a high proficiency in reading others' body language (de Gelder, 2009; de Gelder et al., 2010). For example, they integrate facial and body information, and in the case of conflict body information affects their ratings of facial information (Meeren, van Heijnsbergen, & de Gelder, 2005). Moreover, it has been shown that adults are able to infer others' beliefs (Grezes, Frith, & Passingham, 2004b) and intentions to deceive (Grezes, Frith, & Passingham, 2004a; Sebanz & Shiffrar, 2009) from cues inherent in their body movements. These cues are commonly not shown with the explicit intention to inform or teach the other; rather, they are bodily expressions of an actor's intention, hence also called "embodied intentions" (cf. Johnson, 2007). Consequently, we refer to these cues as being implicit (social) cues. Note that this conceptual differentiation between explicit and implicit social cues focuses on the role of these cues in communicative contexts and does not presuppose how the cues are processed by the perceiving agent (i.e., it does not map to the implicit–explicit knowledge distinction advocated by, for example, Apperly & Butterfill, 2009). Particularly from an embodied perspective on deictic reference, orienting movements such as body posture orientation are, therefore, excellent examples for implicit cues that show something about a person's mind and intentions (e.g., Ballard, Hayhoe, Pook, & Rao, 1997). The ability to appreciate these cues and react to them in social interaction constitutes an important part of skilled interpersonal communication and social competence (e.g., Hargie, 2011). Consequently, for a full understanding of the development of social competence, it is important to study young children's developing appreciation of implicit cues such as body postures.

From a theoretical perspective, it would be highly interesting to explore the development of young children's ability to understand others' body posture cues. Theories on the developmental origins of early social cognition make different predictions with respect to the developmental timeline of children's developing appreciation of others' social cues. Some researchers (e.g., Baron-Cohen, 1995; Leslie, 1994) presume that a general cross-situational understanding of others' intentional relation is present at the end of the first year of life (as indicated by terms such as "intention reading" and "intention understanding"; see also Tomasello, Carpenter, Call, Behne, & Moll, 2005). Thus, some scholars have argued that the different forms of joint attention show tight synchrony, emerge together, and are indicative of a general understanding of others' intentionality. This perspective predicts that an understanding of others' body orientation should—given that there is no principled difference between the different kinds of social cues assumed—develop in parallel with their understanding of other cues. If this were true, already infants should appreciate the body postures expressing others' intentions.

Another line of developmental theorizing assumes that social–cognitive knowledge is acquired in a more constructivist developmental process that works along a longer timescale, is diversified, and depends on multiple mechanisms (e.g., Moore, 2006; Uithol & Paulus, 2014; see also Racine & Carpendale, 2007). For example, Moore (2006) proposed that the development of social understanding starts out from "intentional islands." Initially, infants' understanding of others centers around a limited number of prominent actions and social cues that are prevalent in their daily experiences (e.g., grasping; Woodward, 1998) and/or may also be subject to training (e.g., point following; Palmquist, Burns, & Jaswal, 2012). Starting from these islands, social understanding proceeds gradually to a full appreciation of others' intentionality. This theoretical perspective would predict developmental differences in young children's understanding of others' intentional relations, whereby an understanding of others' body posture cues should show a later developmental onset than an understanding of explicit cues. Taken together, the developmental timeline of children's understanding of the body posture expressing others' intentions is, thus, an excellent touchstone for current developmental theories on the origins of human social cognition.

Unfortunately, little is known about young children's understanding of others' body postures and their ability to learn from them. One line of evidence comes from research on emotion perception (e.g., Mondloch, 2012). It has been shown that by elementary school age children's sorting of sad and fear faces is impaired by body postures that are incongruent with respect to the facial expressions. Moreover, 3-year-olds are not able to accurately sort isolated body postures according to their emotional expressions (Mondloch, Horner, & Mian, 2013). Although this line of research focused on emotion perception (whereas the current study examined body orientation per se), it suggests important developmental changes in preschool children's processing of others' body postures.

There is ample evidence that children under 2 years of age already use a variety of explicit cues—such as gaze and pointing—in word learning and to process others' actions (Gräfenhain, Behne, Carpenter, & Tomasello, 2009; Houston-Price et al., 2006; for a review, see Deák & Holt, 2008). This is even true for third-party or observational contexts in which infants witness a demonstration by another person that is not directed at them (e.g., Akhtar, 2005; Nielsen, Moore, & Mohamedally, 2012). Given that 2-year-olds' word learning system is quite flexible (e.g., Altvater-Mackensen & Mani, 2013a, 2013b), it would be particularly interesting to see whether 2-year-olds are equally proficient in employing implicit posture cues.

Interestingly, if studies on early word learning or early social understanding have presented body posture cues (i.e., body orientation) at all, it has always been confounded with other social cues such as face direction and pointing (i.e., orienting the body in the direction of one's own pointing gesture or gaze direction; e.g., Bakker, Kochukhova, & von Hofsten, 2011; Fawcett & Gredebäck, 2013; Gräfenhain et al., 2009; Over & Carpenter, 2009; Paulus & Fikkert, 2014). Consequently, we do not know whether body cues played a role in these situations. Thus, it remains an open question whether young children can use implicit body posture cues to understand others' intentional relations.

The current study

To this end, we examined the behavior of 2-year-old children, 3.5-year-old children, and adults during word learning in a situation where an actor uttered a novel word while she oriented her upper body toward one of two objects. More concretely speaking, our procedure followed established paradigms (e.g., Houston-Price et al., 2006; Mani & Plunkett, 2008; Paulus & Fikkert, 2014). In Experiment 1, during a learning phase comprising 10 trials, participants observed an actor orienting toward one of two novel objects. This display was presented on an eye-tracker. We decided to use body posture orientation as an implicit cue not only because it has been suggested to be a prototypical example of embodied deictic reference (Ballard et al., 1997) but also because it is clearly visible on a screen, thereby preventing perceptual problems in detecting the implicit cue. To control for the impact of head and gaze information, only the upper body—but not the face—was visible (for similar displays, see Falck-Ytter, Gredebäck, & von Hofsten, 2006; Woodward, 1998). The actor referred to the posture-cued object using a novel word. During the test phase, participants were presented with both objects again and were asked to look at the target.

Based on findings that language comprehension modulates looking behavior (e.g., Houston-Price et al., 2006; Houston-Price, Plunkett, & Harris, 2005; Swingley, Pinto, & Fernald, 1998), we analyzed participants' looking times to the two objects during the learning phase and test phase of the experiment. If children's ability to appreciate implicit cues is based on a general ability to perceive others' intentions (e.g., Baron-Cohen, 1995), we would expect that participants of all age groups would rely on body orientation to learn the novel word. Yet, if children's understanding of others' intentional relations develops rather gradually, we might expect that only the older children and adults, but not the 2-year-old children, would use body orientation to learn the novel word.

In addition, comparing participants' behavior in the learning trials and test trials also allows for a more detailed understanding of participants' appreciation of others' body posture cues. In particular, such an analysis could reveal whether participants merely orient reflexively toward the cued object or whether they also process the intention relation between person and object (see Gliga et al., 2012). If participants understand intentional relations from body orientation, they should orient toward the named object in the learning trials and test trials. If body posture cues merely cue attention to an object without involving an understanding of the underlying intentional relation, we should find a preferential looking to the cued object only in the learning trials (as a direct consequence of perceiving the body orientation) but not in the test trials (where no body posture cue is present). Finally, if participants do not appreciate the body posture cue at all, there should be—across both trial types—no preferential looking to the cued object.

We also conducted two further control experiments. Experiment 2 aimed at showing that the findings generalize to a new set of targets. Experiment 3 investigated children's word learning in a situation where a conflict between the body orientation cue and a pointing cue was presented (i.e., the two cues referred to different targets). By demonstrating that in such a situation both child age groups relied on the pointing cue to map the novel word to a referent, we provide empirical evidence for the validity of our experimental paradigm.

Experiment 1

Method

Participants

Participants were 24 2-year-old children (*M* = 27.2 months, *SD* = 2.3; 14 boys), 22 3.5-year-old children (*M* = 42.4 months, *SD* = 1.3; 10 boys), and 19 adults (*M* = 26.1 years; *SD* = 7.8; 7 men). Participants came from a large European city. An additional 3 2-year-old children, 2 3.5-year-old children, and 1 adult were excluded due to technical problems, insufficient data collection, or restlessness. The child participants were recruited from public birth records and came mainly from middle-class families. Children were largely Caucasian and monolingual. Only children without any known medical problems or sensory limitations participated in the study. Informed consent for participation was given by the children's caregivers. Parents received monetary compensation for travel expenses, and children received a gift for their participation. The adult participants were students and were credited with course points for their participation in the study.

Stimuli

The stimulus material consisted of two types of short movies: learning movies and test movies (see Fig. 1 for screenshots of the key phases).

The learning movies displayed a female model sitting at a table. On the left and right sides of the table were two toy objects. The toys were characters from children's television series prominent in the United States but unknown in Europe. The learning movies displayed the upper body, but not the head, of the actor. We decided to occlude the head instead of, for example, blurring the face to (a) ensure that no gaze and head information was available to guide participants' looking responses, to (b) not attract participants' visual attention to the face region, and to (c) disentangle the impact of body orientation from head/gaze following. Similar displays have successfully been used even with 6- to 12-month-old infants (e.g., Falck-Ytter et al., 2006; Woodward, 1998). Initially, the actor was ori-

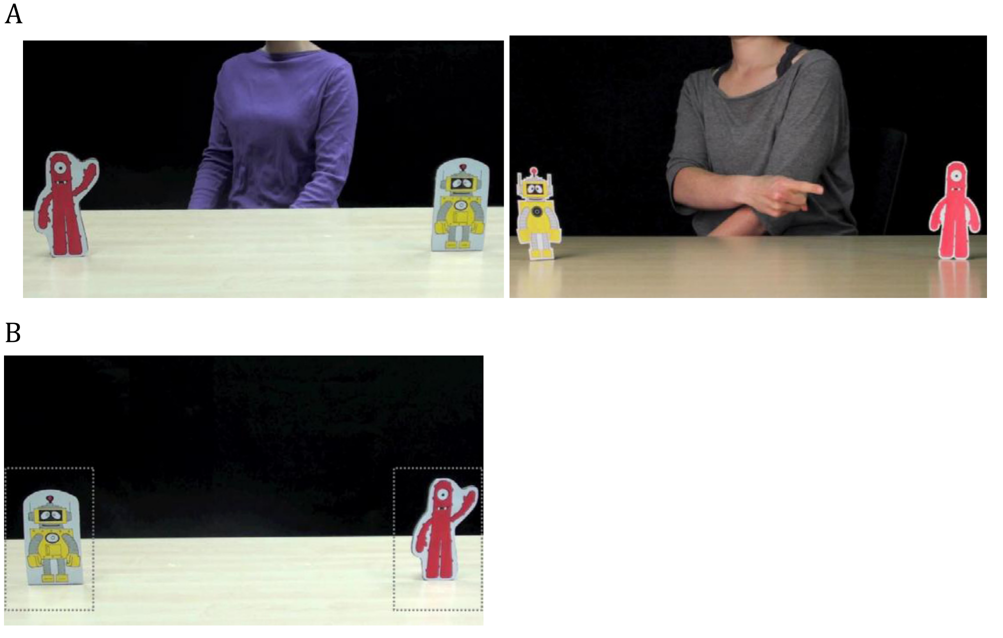

Fig. 1. Key frames of the stimulus movies in Experiments 1 and 3. Panel A gives key frames from the learning trials in Experiment 1 (first picture) and Experiment 3 (second picture). Panel B shows a frame from a test trial in Experiment 1. The rectangles illustrate the approximate positions and sizes of the areas of interest.

ented toward the viewer. To draw the observer's attention to the screen, the actor uttered "Oh" after 2 s. Approximately 6 s after stimulus onset, she oriented her body toward one of the two objects on the table. Following this, she said with an engaging voice "Look!" and approximately 2.5 s thereafter "A *faap*!" (first teaching phase). After approximately another 3 s, she repeated "A *faap*!" (second teaching phase). The word *faap* was chosen as a non-word, its properties being characteristic of typical words yet without being similar to known words. The whole sequence lasted 20 s. To control for direction and object biases within participants, we balanced the position of the objects at the left and right sides of the table (two possibilities), and to do so between participants, we balanced which object the model was orienting toward (two possibilities). Thus, four different learning movies were constructed. In all learning movies, the same novel word (*faap*) was taught.

In addition, there were test movies in which only the two objects were shown. Approximately 2.5 s after stimulus onset (baseline phase), infants were addressed by the model's voice: "Look! A *faap*!" (naming phase); approximately 7 s after stimulus onset, infants were again addressed with "A *faap*!" (naming phase). The whole test movie had a duration of 12 s. There were two versions of the test movies to balance which objects were presented at the left- and right-hand sides of the table.

We included the baseline phase in the test movies to control for saliency effects. If a possible effect (i.e., more attention to the named object) during the naming phase were to be due to saliency effects (i.e., the target would generally receive more attention as it was primed during the learning movies), we would expect the same effect to be present during the baseline phase. If the effect were time-locked to the naming of the word (i.e., naming phase), this would support our claim that infants used the model's cues to map a novel word form to a referent.

Ten learning movies (learning trials), repeatedly teaching participants the same word, and four test movies (test trials) were combined and presented to the participants. This number of learning trials was chosen in line with previous work (Paulus & Fikkert, 2014). To prevent monotony during presentation of the movies, we first presented six learning trials and two test trials, followed by four additional learning trials and finally the last two test trials. Fig. 2 gives an overview on the design and timeframe of the trials.

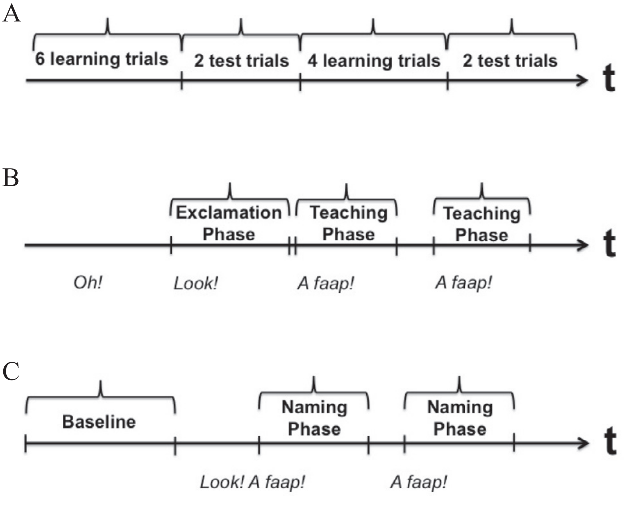

Fig. 2. Panel A shows the order of the learning trials and test trials during the entire experimental session. Panel B depicts the timing of events during the learning trials. Panel C depicts the timing of events during the test trials.

Experimental setup and procedure

Participants sat 60 cm away from the monitor of a corneal reflection eye-tracker (Tobii T60, Tobii Technology, Stockholm, Sweden). Stimuli were shown on a 17-inch TFT flat-screen monitor, and gaze was recorded at 60 Hz with an average accuracy of 0.5° visual angle. After successful calibration, the experimenter started the experiment. The stimuli were automatically presented by Tobii Studio (Tobii Technology) in a predefined order (see "Stimuli" section above).

Data analysis

Participants' looking behavior was recorded using Tobii Studio. A predefined I-VT fixation filter was activated so that only a gaze with a velocity threshold of 30°/s and a minimum duration of 60 ms was counted as a fixation. Two equally sized areas of interest (AOIs) were defined around the two objects (see Fig. 1B), and participants' fixations to both objects were analyzed with the help of Tobii Studio. The main analysis of both test trials and learning trials focused on participants' looking time to the respective AOIs. To this end, looking time duration was calculated by summing up all fixations on each AOI. The relative proportion of looking times to each target was computed separately for the different phases of each test trial and subsequently averaged across trials for every participant. We decided to statistically analyze the proportion of looking times because we were interested in participants' (relative) preference for one object over the other independent of their overall amount of looking at the objects (cf. Houston-Price et al., 2006; Paulus & Fikkert, 2014; Wu & Kirkham, 2010).

In addition, to provide a more comprehensive picture of participants' looking behavior, we report analyses on participants' absolute amount of looking and the number of fixations. For this analysis, we also included the actor's body as an additional AOI as well as participants' looking at the whole screen (i.e., the whole scene formed another AOI, including the other AOIs).

Learning trials. Data from the learning movies were separated into three phases. The first phase started with the onset of the exclamation "Look!" (exclamation phase). The critical teaching phases (two per learning trial) started with the naming of the novel word *faap* (teaching phase). Because participants' looking behavior was (in contrast to the test trials) not exclusively triggered by language processing but also potentially affected by the model's body orientation, data were analyzed over 2000 ms after the onset of the exclamation or the novel word. For the analysis that focused on proportion looking times at both targets, we needed to omit phases during which no target was fixated (e.g., as participants kept fixating the person). Thus, phases during which no eye gaze at one of the target objects was registered were omitted from further analysis (exclamation phase: 43%; teaching phase: 22%). For the analyses on participants' overall looking times and number of fixations, no phases were omitted from analysis. Data were analyzed using a two-way analysis of variance (ANOVA) with the within-participants factor phase (exclamation or teaching) and the between-participants factor age group (2-year-old children, 3.5-year-old children, or adults).

Test trials. Data from the test stimuli were separated for analysis into the baseline phase, including the first 2000 ms after stimulus onset, and two naming phases of exactly 1500 ms. The naming phase included data over 400 to 1900 ms after the onset of the target word *faap* (cf. Swingley & Aslin, 2002). Phases during which no eye gaze at one of the target objects was registered (16.9%) were omitted from further analysis, as were infants from whom no data at all in either the baseline phase or naming phases were obtained (see "Participants" section above). No phases were omitted for the analyses of the overall amount of looking or the number of fixations. Data were statistically analyzed using a two-way ANOVA with the within-participants factor phase (baseline or naming) and the between-participants factor age group (2-year-old children, 3.5-year-old children, or adults).

Results

Learning trials

Main analysis of proportion looking time. The two-way ANOVA on proportion looking time to the body posture-cued object (between the two objects) revealed a significant effect of age group, $F(2, 62) = 22.08$, $p < .001$, $\eta_p^2 = .42$. There was no effect of phase (all *ps* > .18). To explore the main effect in greater detail, we averaged data across phases. Independent samples *t*-tests revealed that the looking behavior of the 2-year-old children ($M = 50\%$, $SE = 4.7$) differed significantly from that of the 3.5-year-old children ($M = 62.6\%$, $SE = 2.9$), $t(44) = 2.26$, $p = .029$, and the adults ($M = 86.7\%$, $SE = 3.6$), $t(41) = 5.97$, $p < .001$. There was also a significant difference between the latter two age groups, $t(39) = 5.24$, $p < .001$. Simple *t*-tests against chance confirmed that the 3.5-year-old children's and adults' looking behavior differed from chance, $t(21) = 4.35$, $p < .001$, and $t(18) = 10.31$, $p < .001$, respectively, whereas 2-year-old children showed no systematic preference during the learning trials, $t(23) = 0.004$, $p = .997$.

This finding was supported by nonparametric analyses. Of the 19 adults, 18 showed a preference for the cued object (i.e., looking > 50% of the time). A chi-square test revealed that this was different from chance, $\chi^2(1, 19) = 15.211$, $p < .001$. Of the 22 3.5-year-old children, 19 showed a preference for the correct object. A chi-square test revealed that this was different from chance, $\chi^2(1, 22) = 11.636$, $p = .001$. Again, only 10 of the 24 2-year-old children showed such a preference. This pattern was not different from chance, $\chi^2(1, 24) = 0.667$, $p = .41$.

Participants' overall looking time and number of fixations. To obtain a more comprehensive overview on participants' looking behavior during teaching, we examined participants' overall looking time (in seconds) during the teaching phases of the learning trials (see Fig. 3A). A paired samples *t*-test for each age group confirmed that the adults and 3.5-year-old children looked longer at the cued object than at the uncued object, $t(18) = 7.81$, $p < .001$, and $t(21) = 4.25$, $p < .001$, respectively. The 2-year-old children, in contrast, showed no difference, $t(23) = 0.04$, $p = .966$.

In addition, to rule out the possible objection that the younger children might have shown an effect during the very first trials that regressed to the mean during the course of the study, we checked the 2-year-old children's looking behavior during the teaching phases of the first two learning trials separately. They looked on average 124 ms ($SE = 31$) to the cued object and 141 ms ($SE = 43$) to the uncued object. This difference was not significant, $t(23) = 0.38$, $p = .709$, demonstrating that there was no effect of the actor's body orientation during the first two learning trials.

Likewise, an analysis of participants' number of fixations (see Fig. 3B) yielded that the adults and 3.5-year-old children looked more at the cued object than at the uncued object, $t(18) = 8.01$, $p < .001$, and $t(21) = 3.54$, $p = .002$, respectively. The 2-year-old children, in contrast, showed no difference, *t*

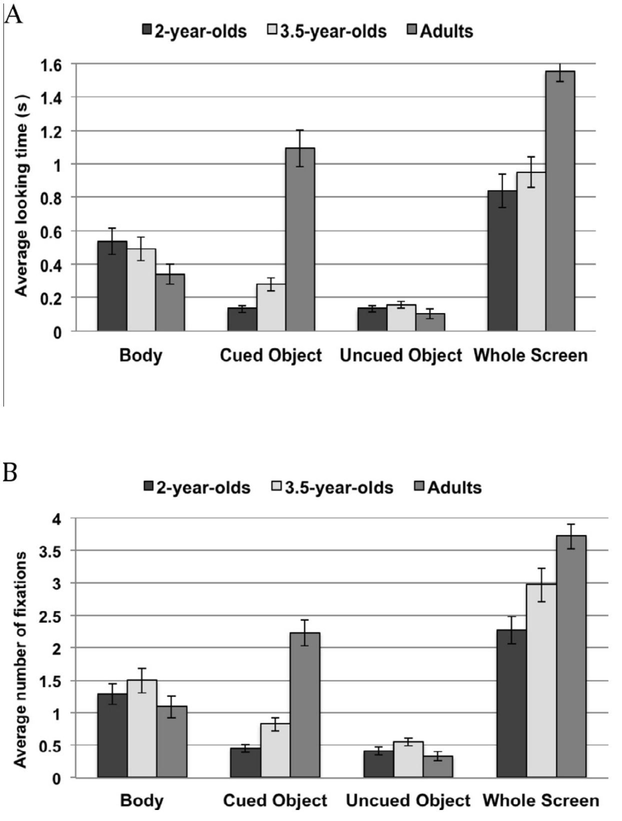

Fig. 3. Participants' looking behavior during the teaching phases of the learning trials in Experiment 1. Panel A shows the average looking time (in seconds). Panel B shows the average number of fixations. The "Whole Screen" category includes all other categories. Error bars indicate the standard errors of the means.

(23) = 0.83, p = .416. Thus, both analyses paralleled the findings of the main analysis on relative proportion of looking times.

Post hoc analysis. To examine whether participants actually looked at the body during the learning trials (and thus had a chance to perceive the change in body orientation), we conducted an additional post hoc analysis. We analyzed participants' looking behavior to the actor's body during the first few seconds before body orientation took place (body baseline phase: duration ~ 6.5 s) and the actual phase of body orientation (body change phase: duration ~ 2.5 s) (see Fig. 4).

Given the different overall duration of each phase, we performed two separate one-way ANOVAs with age group as the between-participants factor. The ANOVA on the body baseline phase revealed no significant effect, $F(2, 62) = 2.88$, $p = .064$, $\eta_p^2 = .09$. Likewise, the ANOVA on the more critical body change phase revealed no significant effect, $F(2, 62) = 1.24$, $p = .297$, $\eta_p^2 = .04$. Thus, the analyses indicate no significant looking time differences to the actor's body among the age groups.

Test trials

Main analysis of proportion looking time. The two-way ANOVA on proportion looking time to the "correct" object revealed a significant main effect of phase, $F(1, 62) = 13.38$, $p = .001$, $\eta_p^2 = .18$, and a significant main effect of age group, $F(2, 62) = 11.48$, $p < .001$, $\eta_p^2 = .27$ (see Fig. 5). The main effects were qualified by a significant interaction, $F(2, 62) = 4.74$, $p = .012$, $\eta_p^2 = .13$.

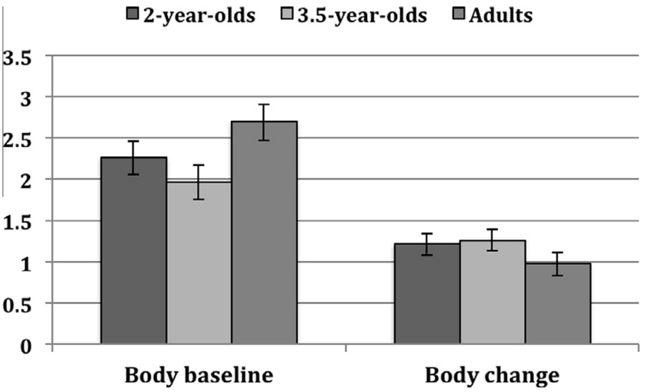

Fig. 4. Mean looking times on the actor's body during the learning phase of Experiment 1. Error bars indicate the standard errors of the means.

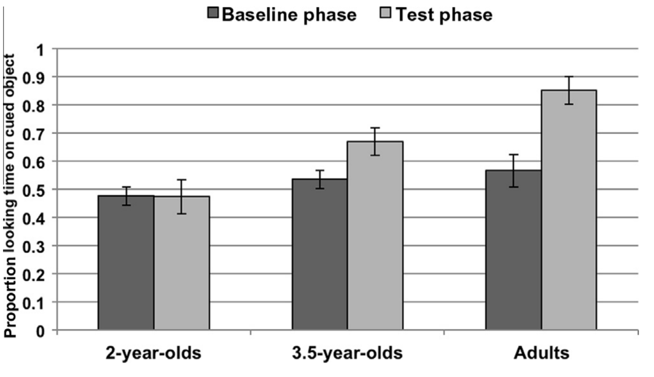

Fig. 5. Average proportions of looking times directed to the cued object during the baseline phase (dark gray) and test phase (light gray) of Experiment 1. Error bars indicate the standard errors of the means.

To follow up on the interaction, we conducted a one-way repeated measures ANOVA for each group with phase (baseline or naming) as the within-participants factor. The ANOVAs for the 3.5-year-old children as well as the adults yielded significant effects of phase, $F(1, 21) = 5.93$, $p = .024$, $\eta_p^2 = .22$, and $F(1, 18) = 14.81$, $p = .001$, $\eta_p^2 = .45$, respectively, demonstrating that both age groups looked more at the cued object during the naming phase than during the baseline phase. There was no effect for the 2-year-old children, $F(1, 23) < .01$, $p = .969$, $\eta_p^2 < .001$.

Additional post hoc tests against chance demonstrated that the adult participants looked longer at the cued object during the naming phase, $t(18) = 7.25$, $p < .001$, but not during the baseline phase, $t(18) = 1.14$, $p = .269$. Likewise, the 3.5-year-old children looked longer at the cued object during the naming phase, $t(21) = 3.47$, $p = .002$, but not during the baseline phase, $t(21) = 1.10$, $p = .284$. Yet, the 2-year-old children showed no such preference in either the baseline phase, $t(23) = 0.73$, $p = .472$, or the naming phase, $t(23) = 0.43$, $p = .670$.

To assess whether the 2-year-old children might have shown an effect during the early test trials that regressed to the mean during the course of the study (e.g., due to becoming tired), we also analyzed younger children's looking behavior during the first two test trials only. The 2-year-old children looked 45% ($SD = 29.2$) of the time at the cued object. This was not different from chance, $t(23) = 0.88$, $p = .386$, thereby corresponding to the results of the overall analysis.

In addition, to examine whether only a few participants drove the effects, we conducted an individual-level analysis for each age group. To this end, we analyzed for each participant whether he or she looked on average more at the correct object during the test phase (see Fig. 6). Here, 18 of the 19 adults, 16 of the 22 3.5-year-old children, and 10 of the 24 2-year-old children showed such a preference. The older two age groups performed different from chance, $\chi^2(1, 19) = 15.211$, $p < .001$, and $\chi^2(1, 22) = 4.545$, $p < .05$, respectively, but not the 2-year-old children, $\chi^2(1, 24) = 0.667$, $p = .41$.

Participants' overall looking time and number of fixations. To further examine participants' looking behavior during the test trials, we analyzed the number of participants' fixations on both objects and the whole scene (see Fig. 7A). Given that the durations of the baseline phase and naming phase were different and thus not comparable, and given that we analyzed the number of fixations in absolute numbers, we analyzed both phases separately. A two-way mixed-model ANOVA on the number of fixations for the baseline phase with object (cued or uncued) as the within-participants factor and age group (2-year-old children, 3.5-year-old children, or adults) as the between-participants factor yielded no significant effect (all *p*s > .10), indicating that during the baseline phase there was no preference for one object over the other. A two-way mixed-model ANOVA on the number of fixations for the naming phase with object (cued or uncued) as the within-participants factor and age group (2-year-old children, 3.5-year-old children, or adults) as the between-participants factor yielded a main effect of object, $F(1, 62) = 38.80$, $p < .001$, $\eta_p^2 = .39$, and a main effect of age group, $F(2, 62) = 15.93$, $p < .001$, $\eta_p^2 = .34$. Importantly, the main effects were qualified by an interaction between object and age group, $F(2, 62) = 21.29$, $p < .001$, $\eta_p^2 = .41$. To follow up on the interaction effect, a post hoc paired samples *t*-test was conducted for each age group. The *t*-tests showed that the adults and the 3.5-year-old children looked significantly longer at the previously cued object than at the uncued object, $t(18) = 6.02$, $p < .001$, and $t(21) = 2.87$, $p = .009$, respectively. Yet, there was no difference in the 2-year-old children, $t(18) = 0.35$, $p = .733$. An inspection of participants' overall looking time yielded an analogous pattern

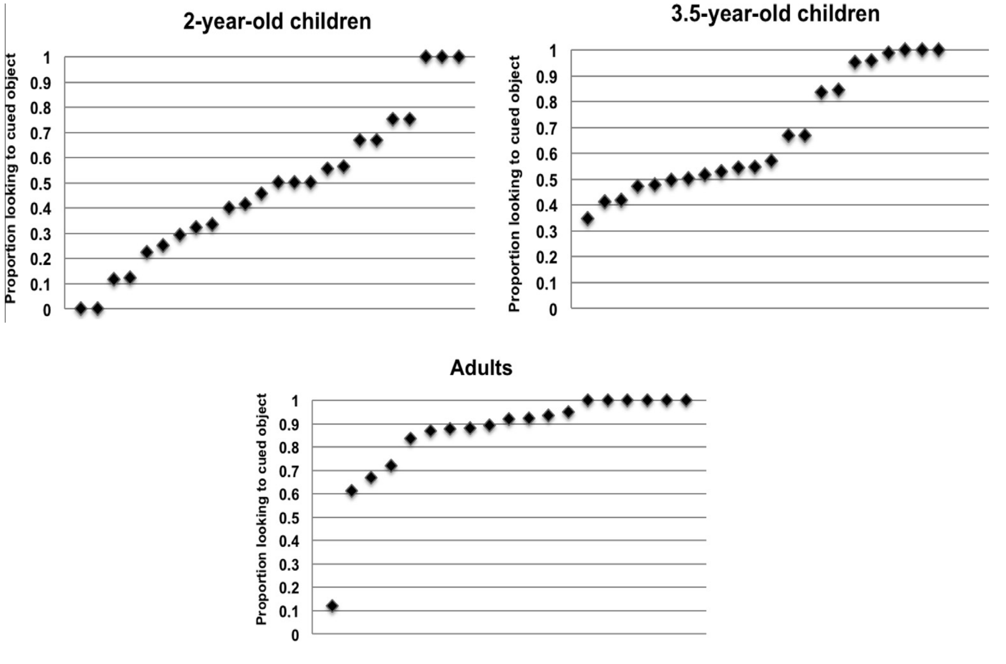

Fig. 6. Individual-level analyses of participants' looking behavior during the test trials in Experiment 1. The *y*-axis represents proportion looking time to the correct object. The black diamonds represent individual participants. Participants are ordered (on the *x*-axis) following their performance. The three panels show the data of the three different age groups.

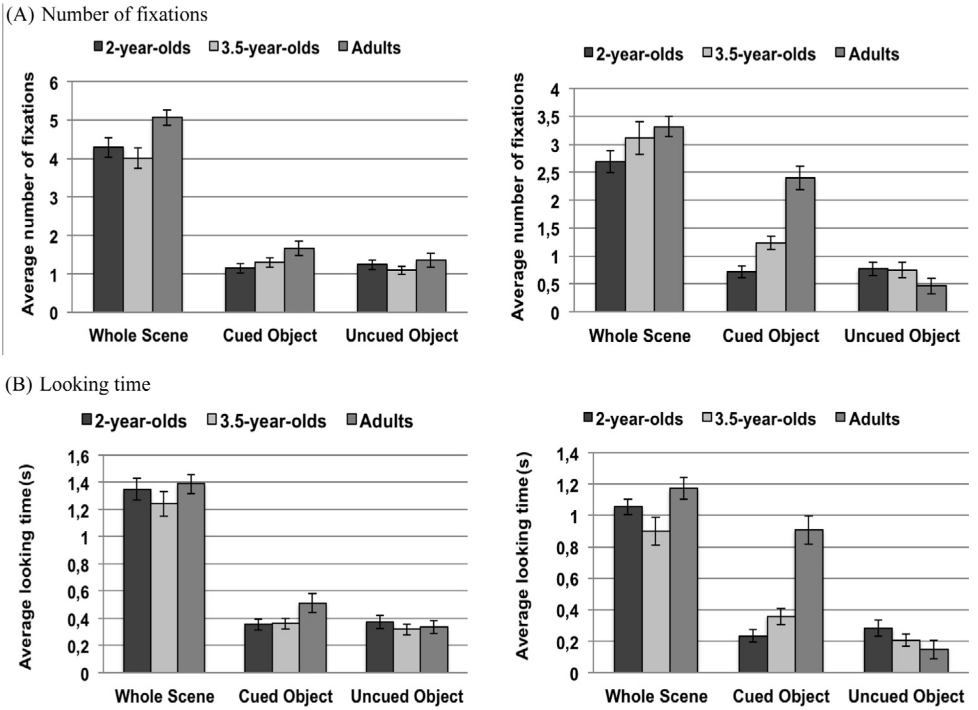

Fig. 7. Participants' looking behavior during the baseline phase and naming phase of the test trials. Panel A shows the number of fixations. Panel B shows the overall looking time (in seconds). Note that the baseline phase lasted 2000 ms, whereas the naming phase lasted 1500 ms. The left graphs of Panels A and B give the results of the baseline phase, and the right graphs give the results of the naming phase. Error bars indicate the standard errors of the means.

of results (see Fig. 7B). Thus, the findings of the additional analyses mirror the results on the proportions of looking times.

Correlational analyses

To assess possible relations between participants' perception of the model's body orientation in the learning trials and their test performance, we computed correlations between participants' looking behavior to the cued object during the teaching phase of the learning trials and during the naming phase of the test trials. These analyses yielded significant correlations for the adult participants ($r = .86$, $p < .001$) and the 3.5-year-old children ($r = .57$, $p < .001$) but not for the 2-year-old children ($r = .10$, $p = .66$).

Discussion

Experiment 1 examined children's ability to understand others' intentional relations by taking into account an actor's body orientation in a word-learning scenario. The results show that 3.5-year-old children and adults, but not 2-year-old children, related a novel word to the referred object when they observed the actor orienting toward one of two objects. Moreover, analyses of the learning trials indicated that the adults and 3.5-year-old children, but not the 2-year-old children, followed the person's body posture cue to the target. Therefore, the findings suggest that the ability to appreciate body posture cues develops during toddlerhood.

An additional post hoc analysis on participants' looking behavior at the actor's body indicated no differences among the three age groups. That is, during the time phase when the actor changed her body orientation (body change phase), the three age groups spent the same amount of time looking at the body. This suggests that the age differences in participants' performance cannot be explained by one age group not noticing the actor's movement. It also rules out the concern that the head-occluded display was not social enough for the young children to perceive the relevant information. In addition, we separately analyzed the younger children's looking behavior during the first two learning trials and the first two test trials. The results of these analyses mirrored the results of the overall analyses. Therefore, we can rule out the possibility that the younger children might have shown an effect during the very first trials that was washed out during the entire course of the study (e.g., due to becoming tired or bored). Thus, the additional analyses support the notion that the 3.5-year-old children and adult participants, but not the 2-year-old children, appreciate another person's body posture cue.

In addition, we also found a correlation between 3.5-year-old children's and adults' preference for the cued object during the learning trials and test trials. There was no such relation for the younger participants. This suggests a relation between the extent to which their attention was affected during the teaching situation and their performance in the test trials. An alternative interpretation, however, could be that the correlation merely indicates individual differences in participants' baseline preferences for the objects. Yet, the fact that we did not find such a correlation for the 2-year-old children renders such an explanation unlikely.

Before interpreting the results of this study in greater detail, in particular the developmental differences found between the 2- and 3.5-year-old children, it was important to exclude the possibility that the younger children's failure might be due to the specific stimuli employed in Experiment 1. In particular, given that already infants differentiate among humans, animals, and artifacts (e.g., Mareschal & Quinn, 2001), one could argue that the use of toy figures that had some similarity to humans might have hampered word learning of a generic name (but see Axelsson & Horst, 2014, and Diesendruck, 2005, for the use of pictures of animate creatures in word-learning studies). Moreover, one could argue that the stimuli were of different salience, with the red figure being more interesting to the young children and, therefore, masking a word-learning effect. To exclude this possibility, we tested another group of 2-year-old children in Experiment 2, where we replaced the toy figures with line drawings of artificial objects similar to ones successfully employed in other studies on early word learning (e.g., Mani & Plunkett, 2008).

Experiment 2

Method

Participants

Participants were 21 2-year-old children (M = 27.0 months, SD = 1.5; 12 boys). During the experiment, 1 participant needed to be excluded due to technical problems. Sample characteristics were the same as in Experiment 1.

Stimuli, setup, and procedure

Stimuli, setup, and procedure were the same as in Experiment 1 with two differences. First, we replaced the two toy figures by line drawings of artificial objects. Second, to make the learning movies more interesting, we shortened them so that each movie lasted 16 s. The line drawings were taken from a test for language assessment (Grimm, 2001).

Data analysis and results

Given that the analyses of the different dependent variables of Experiment 1 yielded the same pattern of results, we analyzed only proportion looking time during the test trials. During the baseline phase, participants looked 46.7% (SE = 4.3) at the previously cued object and 53.3% (SE = 4.3) at the uncued object. During the naming phase, participants looked 45.7% (SE = 5.3) at the previously cued object and 54.3% (SE = 5.3) at the uncued object. A one-way repeated measures ANOVA with the within-participants factor phase (baseline or naming) did not reveal a significant effect, $F(1, 19) = 0.02$, p = .878, η_p^2 = .001, suggesting no differences in looking to both objects during the two phases.

Discussion

Experiment 2 replicated the main finding with 2-year-old children of Experiment 1 with a different object set. This suggests that 2-year-old children's failure to appreciate others' body posture cues cannot be attributed to the toy figures employed in Experiment 1.

Yet, one could argue that the nature of the stimuli, particularly the no-head display, was confusing and might have interfered with an appreciation of another person's social cues. Moreover, to draw strong conclusions with respect to the theoretical claim that children prioritize explicit cues over implicit cues, a direct comparison of the impact of explicit and implicit cues within the same experiment would be desirable. Experiment 3 was conducted to address these issues. This experiment closely followed Experiment 1 with the crucial difference that the model simultaneously cued one object with an explicit cue, a pointing gesture, while she oriented her body to the other object, thereby creating a conflict between an implicit cue and an explicit cue.

The theoretically most interesting, and for the current study most important, predictions concerned the behavior of the younger children. If the 2-year-old children's failure to appreciate body posture cues in Experiments 1 and 2 was due to a general problem with processing the no-head display, one would expect chance performance also in this experiment. However, if their lack of reliance on the body posture cue was due to a developmental decalage in their reliance on implicit and explicit cues, one would expect that the 2-year-old children would map the novel word to the object the model has been pointing to.

The predictions for the 3.5-year-old children were more open. One might argue that an increasing appreciation of implicit cues would lead to a preferential reliance on the body posture cue during the course of development. However, the theoretical notion that an appreciation of implicit cues develops later than an appreciation of explicit cues does not automatically lead to the conclusion that implicit cues overtake explicit cues during the course of development. Indeed, given assumptions that explicit cues such as pointing are a clear indicator of someone's referential intention (e.g., Clark, 2003), and given that previous research demonstrated that 3- and 4-year-old children demonstrate a strong reliance on explicit cues—particularly the pointing gesture—even when the person who is pointing is not knowledgeable (Palmquist & Jaswal, 2012), we also predicted that the 3.5-year-old children would preferentially rely on another person's pointing gesture.

Experiment 3

Method

Participants

Participants were 18 2-year-old children (M = 27.8 months, SD = 0.65; 10 boys) and 19 3.5-year-old children (M = 44.5 months, SD = 0.26; 8 boys). During the experiment, 4 2-year-old children and 4 3-year-old children needed to be excluded due to technical problems, insufficient data collection, or restlessness. Population and consent form were the same as in Experiment 1.

Stimuli, setup, and procedure

Stimuli, setup, and procedure followed Experiment 1 with the crucial difference that the model oriented her body toward one of the two objects (body–object) on the table while simultaneously pointing with her index finger to the other object (point–object) (see Fig. 1 for a screenshot).

Data analysis

Data analysis of the test stimuli followed closely Experiment 1 with one exception. During the second naming phase of the last test trial, children became so upset and fussy that less than 50% delivered any data for analysis of this particular phase. Therefore, we decided to remove the second naming phase of the last test trial altogether from analysis.

Given that the analyses of the different dependent variables of Experiment 1 yielded the same pattern of results, we analyzed only proportion looking time to both objects during the test trials. On average, 20.1% of trials were omitted as no eye gaze was registered during the critical phases. We coded as the dependent variable the proportion of looking time to the object that was cued by the actor's body orientation. Thus, looking times below chance level indicate preferences for the object the actor has been pointing to.

Results

Following Experiment 1, the main test was a two-way ANOVA with the within-participants factor phase (baseline or naming) and the between-participants factor age group (2-year-old children or 3.5-year-old children). Given that the processing of conflicting social cues could be more difficult for young children, resulting in a greater number of learning trials, we first separately analyzed for each age group whether there was a change in children's looking behavior from the first block of test trials to the second block. If our concern were true, we would expect a better performance in the second block than in the first block. We thus first averaged performance for each block separately. Because this analysis revealed no effect of block (all $ps > .30$), data were averaged across the two blocks. On average, the 2-year-old children looked at the body-cued object during a mean of 56.3% ($SE = .04$) of the baseline phase and 41.0% ($SE = 0.05$) of the naming phase. The 3.5-year-old children looked at the body-cued object during a mean of 56.9% ($SE = .04$) of the baseline phase and 42.4% ($SE = 0.05$) of the naming phase.

The ANOVA on proportion looking time revealed only a significant main effect of phase, $F(1, 35) = 9.62$, $p = 0.004$, $\eta_p^2 = .22$ (all other $ps > .83$), indicating that across age children spent relatively more time looking at the body posture-cued object during the baseline phase than during the naming phase. Importantly, there was no effect of age group. Data were pooled across age, and post hoc *t*-tests were conducted to examine whether children's looking behavior differed from chance. The *t*-test on the baseline phase showed that children looked longer at the body posture-cued object than expected by chance ($M = 0.57$, $SE = 0.03$), $t(36) = 2.26$, $p = .030$. The *t*-test on the naming phase showed that children looked less long at the body posture-cued object than expected by chance ($M = 0.42$, $SE = 0.04$), $t(36) = 2.23$, $p = .032$, thereby indicating a preference for the object the actor has been pointing to.

Discussion

Experiment 3 presented 2- and 3.5-year-old children with a model who was pointing at one object and orienting her body toward another object while she was teaching a novel word. When both objects were presented and children were asked to look at the target, children of both age groups looked longer at the object the model has been pointing to. This suggests that the 2- and 3.5-year-old children relied on the explicit cue to map the novel word to a referent.

Whereas the analysis of the naming phases demonstrated a preference for the point–object, children showed the opposite looking preference during the baseline phase. One possible interpretation of this finding is that—given that children's attention was directed toward the point–object during the naming phase—it constitutes an inhibitory aftereffect (inhibition of return; e.g., Klein, 2000). Another interpretation could be that during the learning situation the body motion was more salient than the arm motion (e.g., because the body is larger than the arm) so that initial attention was primed to the body–object. Regardless of how to explain this baseline preference, when children perceived the word during the naming phase, they looked at the point–object, indicating that they related the novel word to the object.

General discussion

The current study examined the development of children's ability to use body orientation as a cue to another person's intentional relations in a word-learning situation. To this end, 2- and 3.5-year-old children, as well as a group of adults, were presented with movies on an eye-tracker screen. The movies displayed the upper body of an actor who oriented herself toward one of two objects while uttering a novel word. During a subsequent test phase, participants' looking times to the named object revealed that the 3.5-year-old children and adults, but not the 2-year-old children, looked longer to the previously referred object. This suggests that the older two age groups were able to relate the novel word to the referred object. Thus, the findings show that the ability to use body orientation as a cue to an actor's intentional relation develops during the course of toddlerhood. Note that Experiment 3 provided evidence that the 2-year-old children were able to use an explicit cue (i.e., pointing) to understand another person's intentional relation. Thus, our study also indicates that children's ability to use explicit pedagogical cues precedes and overtakes their tendency to use implicit cues (i.e., cues that are not displayed with the intention to inform others). Overall, three findings are noteworthy and require deeper discussion.

First, our results show that 3.5-year-old children, but not 2-year-old children, relied on body posture cues to map a novel word to a referent. The fact that the 2-year-old children's failure did not depend on the stimulus material (Experiment 2), as well as the fact that they were able to rely on an explicit cue in the same paradigm (Experiment 3), renders it unlikely that the failure was due to the nature of stimuli employed in our study. It is also important to note that the visual preferences for one object over the other were found only during the naming phases. No such preference was found during the baseline phase. This excludes the possibility that the naming effect could be due to a general object enhancement effect. This suggests that it was the naming of the novel word that directed the participants' attention to one of the objects and that participants successfully matched a novel word form to a referent.

Thus, the current results indicate substantial developmental changes in preschool children's ability to rely on implicit body posture cues to understand another person's intentional relations. From a theoretical point of view, this finding adds to research on humans' processing of others' body posture cues (de Gelder, 2009; de Gelder et al., 2010) and informs theories on the basis of people's ability to read "embodied intentions" (cf. Ballard et al., 1997). Our study suggests that the ability to read body language emerges during the toddler years, with 3.5-year-old children not only showing cueing effects but also understanding the intentional relations associated with body orientation.

Second, Experiment 3 demonstrated that the 3.5-year-old children relied on the pointing cue rather than on the other person's body orientation. That is, even though they were in principle able to appreciate others' body posture cues (Experiment 1), they prioritized the explicit pedagogical cue over the implicit cue (Experiment 3). This finding relates to proposals that explicit cues, such as pointing, are seen as more reliable cues for referential intentions than are other cues (Deák et al., 2000). Therefore, our finding provides empirical evidence that during the early preschool years children weigh explicit cues more than implicit cues.

Third, the finding that the 2-year-old children could use the pointing cue but not the body posture cue suggests a developmental decalage in their appreciation of implicit and explicit social cues. Indeed, the results of the third experiment are supported by other studies demonstrating that 1- and 2-year-old infants rely on explicit social cues during word learning in similar paradigms (e.g., Akhtar, 2005; Hollich et al., 2000; Parise & Csibra, 2012). It is important to note that not only did the 2-year-old children show no appreciation of the intentional relations that were indicated by the body posture cue, but there was also no indication that their attention was drawn to the cued object during the learning situation. This points to a fundamental lack of processing of body posture cues in this age group.

This apparent developmental decalage is highly informative for the current theoretical debate on the early development of social cognition (e.g., Carpendale & Lewis, 2004; Chapman, 1987; Deák & Triesch, 2006; Moore, 2006; Uithol & Paulus, 2014). Is the ability to understand others' intentional relations already present during the first year of life? Some researchers (e.g., Baron-Cohen, 1995; Tomasello et al., 2005) presume that a general cross-situational understanding of others' intentional relation is present at the end of the first year of life. In contrast, other researchers have argued that social–cognitive knowledge is acquired during a longer lasting developmental process. For example, following Tomasello's (2003) notion of "verb islands," Moore (2006) proposed that the development of social understanding starts out from "intentional islands" that center around a limited number of prominent actions and social cues and proceeds gradually to a full appreciation of others' intentionality. The current study on children's understanding of others' body posture cues constitutes a critical touchstone of these developmental perspectives. The finding that 3.5-year-old children, but not 2-

year-old children, who were able to rely on pointing for word learning relied on another person's body posture directly informs this theoretical debate. The results are not in line with views suggesting that a general understanding of others' intentional relations develops at the end of the first year of life (e.g., Baron-Cohen, 1995; Tomasello et al., 2005). It provides empirical support for theoretical notions that an appreciation of others' intentional relation does not emerge as an all-or-none ability but rather emerges gradually.

How to explain this developmental effect? We offer two not mutually exclusive answers. One possibility is that learning about the reliability of cues could be subserved by children's domain-general abilities to detect regularities (e.g., Namy, 2012; Smith, 2000). One could argue that—as young children's attention is strongly drawn to faces and moving hands (e.g., Paulus & Fikkert, 2014)—children learn first about the reliability of head and gaze cues before they learn to take body orientation into account. Yet, given that already infants demonstrate fascinating statistical learning abilities (e.g., Smith, 2000), one could assume that young children should quickly rely on body posture cues. Consequently, another difference might also play a role in explaining this developmental decalage. It is likely that explicitly communicative cues are treated differently than implicit cues by infants' caregivers. For example, in social interaction we are more insistent when someone does not respond adequately to the explicit social cue with which we provided him or her. Likewise, parents put special emphasis on their explicitly communicative gestures and language (cf. "motherese") when interacting with young children (Moore, 2006). Thus, the explicit cues acquire their meaning at least partly in and through social interactions with others (Carpendale & Carpendale, 2010; Carpendale & Lewis, 2004; Racine & Carpendale, 2007), whereas the appreciation of implicit cues might be subject to subsequent learning about their reliability and meaning. Such learning might be guided by bottom-up processes, such as statistical learning of regularities, but also by top-down processes, such as knowledge about the intentionality of other agents and active search for relevant cues. Future research is necessary to examine these possibilities in greater detail.

Overall, our results relate to a greater picture according to which the human ability to rely on social and movement cues to understand others' behavior continues to develop over the course of toddlerhood and the preschool period. The first instances of action understanding have been shown as early as 3 to 9 months of age when it concerns others' object-directed interactions (e.g., Woodward, 1998). Moreover, an understanding of the referential nature of explicit gestures such as ostensive gazing and pointing has been reported for children at around 1 year of age (Caron, Kiel, Dayton, & Butler, 2002; Sodian, Thoermer, & Metz, 2007; Woodward & Guajardo, 2002), although this ability is not yet robust until the end of the second year of life (e.g., Moore et al., 1999). By the second year, toddlers become able to understand others' object-directed behavior by observing failed attempts (Brandone & Wellman, 2009; Meltzoff, 1995) and intentions-in-actions (Poulin-Dubois & Forbes, 2002). Our study extends these findings by showing that children's understanding of implicit cues develops between 2 and 3 years of age. This suggests a developmental timeline according to which the early understanding of others' intentional relations to the physical world begins with concrete object-directed actions and continues with an appreciation of explicit social cues, followed by an understanding of implicit cues.

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