



Infancy, 20(1), 115–125, 2015

© 2015 The Authors. *Infancy* published by

Wiley Periodicals, Inc. on behalf of International Society on Infant Studies

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

ISSN: 1525-0008 print / 1532-7078 online

DOI: 10.1111/infa.12062

WILEY Blackwell

Eighteen-Month-Olds, but not 14-Month-Olds, Use Social Context to Bind Action Sequences

Christine Fawcett and Gustaf Gredebäck

Uppsala Child and Baby Lab

Department of Psychology

Uppsala University

We demonstrate that 18-month-olds, but not 14-month-olds, can anticipate others' actions based on an interpretation of shared goals that bind together individual actions into a collaborative sequence. After viewing a sequence of actions performed by two people who socially interact, 18-month-olds bound together the socially engaged actors' actions such that they later expected the actors to share the same final goal. Eighteen-month-olds who saw nonsocially engaged actors did not have this expectation and neither did 14-month-olds when viewing either socially or nonsocially engaged actors. The results are discussed in light of the possibility that experience in collaborations could be necessary for understanding collaboration from a third-person perspective.

Recognizing the goals behind others' actions is one of the fundamental achievements of early social cognitive development. Previous research shows

Correspondence should be sent to Christine Fawcett, Uppsala Child and Baby Lab, Department of Psychology, Uppsala University, Box 1225, 751 42 Uppsala, Sweden. E-mail: Christine.fawcett@psyk.uu.se

The copyright line in this article was changed on 22 September 2015 after online publication.

that at 18 months, infants can use social engagement between individuals to subsequently infer that their actions are bound by a shared goal into a collaborative sequence (Fawcett & Gredebäck, 2013). In that study, one actor moved a block from one location to another, and then a second actor moved the same block to a final location. These movements could either be interpreted as individual actions based on individual goals for where the block should be, or as a collaborative action sequence based on a shared goal for the block to move to the final location. In later test trials, infants' spontaneous action anticipations revealed that those who saw the social actors were more likely than those who saw the nonsocial actors to anticipate that the first actor shared the second's goal and would complete it by moving the block to the final location.

A further question is when action binding based on social cues develops. The basic social cognitive abilities underlying action binding, which include recognizing interaction cues (e.g., Augusti, Melinder, & Gredebäck, 2010; Beier & Spelke, 2012; Handl, Mahlberg, Norling, & Gredebäck, 2013), recognizing goals (e.g., Behne, Carpenter, Call, & Tomasello, 2005; Phillips, Wellman, & Spelke, 2002), and anticipation of individual (e.g., Falck-Ytter, Gredebäck, & von Hofsten, 2006) and joint (Gredebäck & Melinder, 2010) actions, are typically observed before 12 months (though see Uithol & Paulus, 2014). Looking time studies also indicate that at 14 months, infants recognize that causally linked actions performed by two individuals are based on a shared goal (Henderson & Woodward, 2011) and that with trained experience in the observed activity, even 10-month-olds recognize shared goals between others (Henderson, Wang, Matz, & Woodward, 2013). While these looking time studies indicate that infants have some understanding of the shared goals in collaboration after the actions are complete, only action anticipation can demonstrate whether infants can apply this understanding as actions unfold; and this more demanding ability could additionally require more natural, varied experience (e.g., Gredebäck & Melinder, 2010 for object placement).

At 14 months, infants have begun to achieve coordination in joint activities with adults, but are less coordinated than 18-month-olds (Warneken & Tomasello, 2007). In fact, infants are not successful in collaborating with peers, who cannot scaffold the interaction the way an adult might, before at least 18 months (Brownell & Carriger, 1990). Further, 14-month-olds make few communicative attempts to reengage an uncooperative adult, suggesting that their understanding of the shared goal and its action implications is still in its early stages at 14 months (Warneken & Tomasello, 2007).

Together, the current literature suggests that at 14 months, infants have some understanding of shared goals, but that they are only just developing the ability to carry out coordinated activities based on those goals. Examin-

ing developmental differences in action binding between 14 and 18 months will give insight into the role of active experience in collaborations for developing action binding. That is, if we observe a transition in action binding ability between 14 and 18 months, then a probable reason for that age difference is infants' increasing experience acting together with others in collaborations. Thus, the current study examined both 18- and 14-month-olds in a procedure similar to that of Fawcett and Gredebäck (2013), described above. We expect to replicate previous findings that 18-month-olds show an action binding effect only for actors who engage socially with each other. Whether 14-month-olds show the same pattern of performance is an open question and will give insight into whether action binding is dependent on sufficient experience in collaboration or whether basic recognition of goals and social interaction cues alone can support this skill.

METHOD

Participants

Forty-eight 18-month-olds ($M = 18$ months 18 days, $SD = 10$ days, 24 girls) and 49 14-month-olds ($M = 14$ months 12 days, $SD = 7$ days; 24 girls) were quasi-randomly assigned to either the Social or Nonsocial condition, ensuring nearly equal gender distribution in each condition. An additional eight infants were excluded: 3 14-month-olds for fussiness, 1 18-month-old and 3 14-month-olds for watching less than 50% of the Demonstration, and 1 18-month-old for experimenter error. Participants were recruited from a list of parents who indicated interest in participating in research with their child. Infants were primarily from white and middle-class backgrounds, living in a medium-sized European city. Parents received a gift voucher worth approximately 10 euros.

Apparatus

Infants' eye movements were recorded using a Tobii T120 remote eye tracker. It has a reported accuracy of 0.5 visual degrees and freedom of head movement within $30 \times 22 \times 30$ cm. Gaze was recorded at 60 Hz. An initial 5-point calibration was used with the requirement that all points were successfully calibrated before beginning the experiment.

Stimuli

Infants viewed a series of videos showing two adult female actors sitting at a table. The actors wore sunglasses to avoid having their gaze influence

infants' looking. There were two location objects that could hold a block. One was in the center of the table (Center-location object), and the other was at the far left of the table (Left-location object).

In the first video (15 sec), Actor 1 sat to the right of the Center-location object and Actor 2 sat between the Center and Left-location objects. A single block sat on the right side of the table (see Figure 1). The two actors began facing forward, then turned either toward (Social condition) or away from (Nonsocial condition) each other. Actor 1 said "I'm going

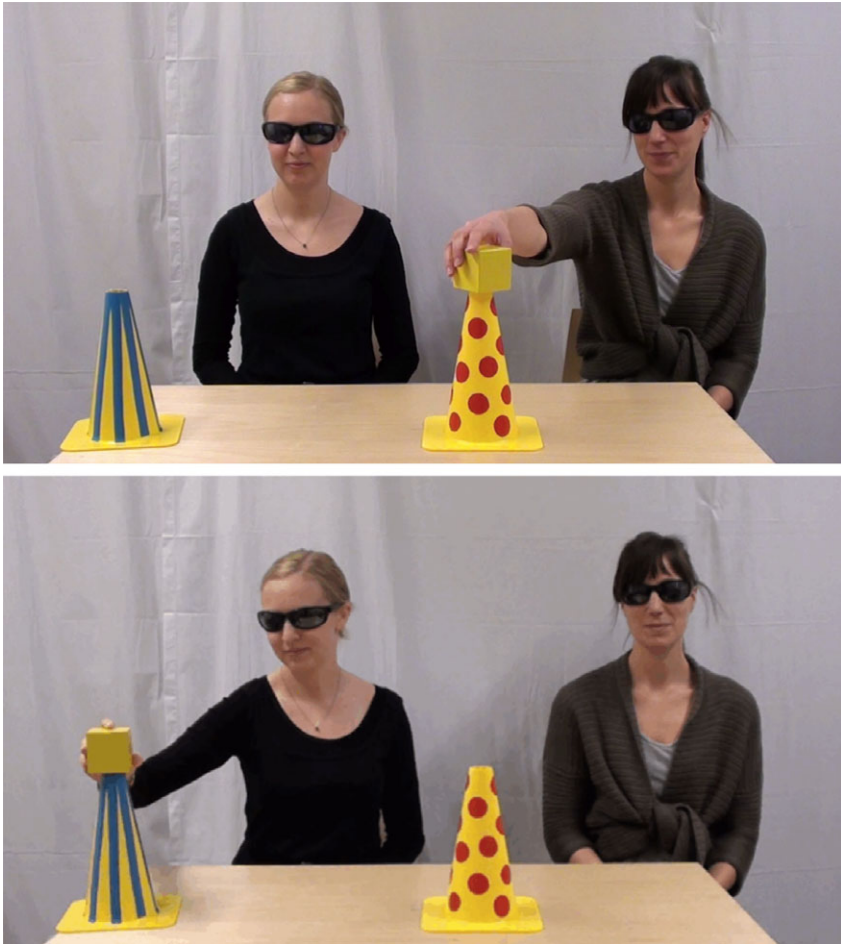


Figure 1 The actors and location objects in the Familiarization. Here, Actor 1 places the block on the Center-location object (top), and Actor 2 places the block on the Left-location object (bottom).

to play with blocks today” and Actor 2 said “I like to play with blocks”. Importantly, the timing of their utterances differed across conditions. In the Social condition, Actor 2 spoke directly after Actor 1, and then both paused for one-second before turning to face forward again. In the Non-social condition, the one-second pause was in between the two statements, making it sound as if the actors were not talking to each other in a contingent manner.

In the next five identical Familiarization videos (26 sec each), the actors began facing forward, briefly turned toward (Social condition) or away from (Nonsocial condition) each other and smiled before facing forward again. Then, Actor 1 grasped the block from the right side of the table, counted to three aloud, and moved it to the Center-location object. When the block was placed, a chime was heard and a spinning light was seen on the location object. Then, Actor 1 said “yes”. Actor 2 grasped the same block, counted to three aloud, and moved it to the Left-location object. The same sound was heard, and an identical spinning light was seen on the Left-location object. Finally, Actor 2 said “yes”.

The following Exit video (11 sec) showed Actor 2 leaving and Actor 1 taking her seat.

Finally, infants viewed four identical Test Trial videos (14 sec each). Actor 1 was sitting in between the two location objects. She looked down and picked up another block with both hands saying, “I found another block”. She then held the block in front of her, centered between the two location objects, while she said, “I wonder where I should put it”. She then counted to three aloud as she had in the Familiarization videos. Importantly, as she began to say, “I wonder where I should put it”, a rectangular occluder expanded from a center point outward to cover her arms and the tops of the location objects (see Figure 2b). This served to occlude any information about where she actually placed her block. Finally, infants heard the same chime as in the Familiarization (with the same 2-sec gap in time between her finishing counting and the chime), but no corresponding light was seen, again serving to conceal the block placement.

Video sequences were counterbalanced across infants for which individual played Actor 1 and Actor 2, and for the locations of the red and blue objects.

Procedure

Infants sat on their parent’s lap approximately 50 cm from the screen. Following a 5-point calibration, infants viewed the series of videos lasting approximately 3 min and 35 sec total.

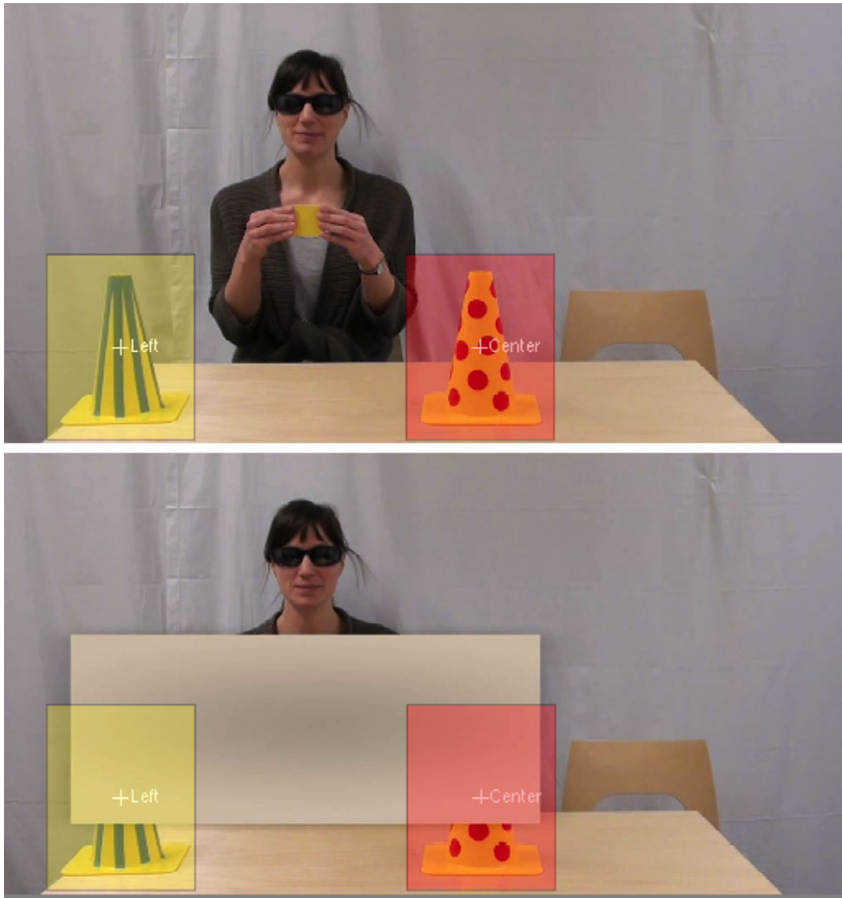


Figure 2 The AOIs for the Left and Center-location objects before and after the appearance of the occluder during test trials.

Data reduction

After raw data were exported from the Tobii eye tracker, they were processed in Time Studio (<http://timestudioproject.com/>) to create areas of interest (AOIs) and to calculate gaze durations in those AOIs. For the test trials, rectangular AOIs (4.1 by 5.7 visual degrees) that left a border of at least .5 visual degrees were created around each of the location objects to account for variations in the eye tracker's accuracy (see Figure 2). The amount of gaze to the AOIs was calculated as a difference score between gaze during the time before the actor finished counting to

three (9 sec) and the time afterward (5 sec), that is, indicating whether they increase looking in expectation of the light cue (see Table 1 for descriptive statistics). Using difference scores helps to account for individual preferences to look at one object and individual differences in overall looking during particular trials. As the time periods used in the difference scores were not equal, the scores do not have a meaningful zero (e.g., that one could compare to chance looking). However, for making comparisons across the two conditions as we do in the current study, this is not necessary.

RESULTS

To examine infants' looking to the location objects in the test trials, the calculated difference scores were analyzed using a mixed-effects model with age, condition, trial, and location (Center- or Left-location object) as fixed effects and trial number, object color, and subject as random effects (Baayen, Davidson, & Bates, 2008). The model was fit using the lmer function of the R package Lme4 (Bates & Sarkar, 2007; R Development Core Team, 2005). This initial model revealed an interaction between age and trial number ($\beta = 0.022$, $SE = 0.009$, $t = 2.505$; Model Comparison $X^2(1) = 6.273$, $p = .012$); thus, we examined each age group separately using models which included fixed effects for condition, trial, and location; as well as random effects for trial, object color, and subject.

TABLE 1
Amount of Gaze (ms) to the AOIs Before and After the Actor's Counting

	<i>Precounting Phase</i>		<i>Postcounting Phase</i>	
	<i>Left-Location object</i>	<i>Center-Location object</i>	<i>Left-Location object</i>	<i>Center-Location object</i>
18-month-olds				
Social	<i>M</i> = 25 <i>SE</i> = 123	<i>M</i> = 86 <i>SE</i> = 266	<i>M</i> = 316 <i>SE</i> = 526	<i>M</i> = 328 <i>SE</i> = 539
Nonsocial	<i>M</i> = 58 <i>SE</i> = 190	<i>M</i> = 70 <i>SE</i> = 236	<i>M</i> = 260 <i>SE</i> = 457	<i>M</i> = 269 <i>SE</i> = 419
14-month-olds				
Social	<i>M</i> = 22 <i>SE</i> = 92	<i>M</i> = 84 <i>SE</i> = 221	<i>M</i> = 180 <i>SE</i> = 370	<i>M</i> = 334 <i>SE</i> = 506
Nonsocial	<i>M</i> = 50 <i>SE</i> = 175	<i>M</i> = 138 <i>SE</i> = 294	<i>M</i> = 246 <i>SE</i> = 457	<i>M</i> = 282 <i>SE</i> = 447

18-month-olds

For the 18-month-olds, there was an interaction between location object and trial ($\beta = -0.116$, $SE = 0.047$, $t = -2.479$; Model Comparison $X^2(1) = 6.136$, $p = .013$); thus, the following analyses were performed separately for each location object. For the Left-location object, where infants should look if they expect the actor to fulfill a shared goal, condition was significant with infants showing a greater increase in looking from the pre- to postcounting phase in the Social than the Nonsocial condition (Social: $M = 0.193$, $SD = 0.506$, Nonsocial: $M = -0.043$, $SD = 0.617$; $\beta = 0.192$, $SE = 0.096$, $t = 2.007$; Model Comparison $X^2(1) = 3.938$, $p = .047$; see Figure 3). For the Center-location object, there was no effect of condition on difference scores (Social: $M = 0.073$, $SD = 0.590$, Nonsocial: $M = -0.070$, $SD = 0.582$; see Figure 3), but there was an overall trend for the difference in looking from the pre- to postcounting phase to increase over the trials ($\beta = 0.063$, $SE = 0.033$, $t = 1.898$; Model Comparison $X^2(1) = 3.632$, $p = .057$). Together, this suggests that 18-month-olds in the Social condition increased their looking to the Left-location object in expectation of the light effect, indicating an

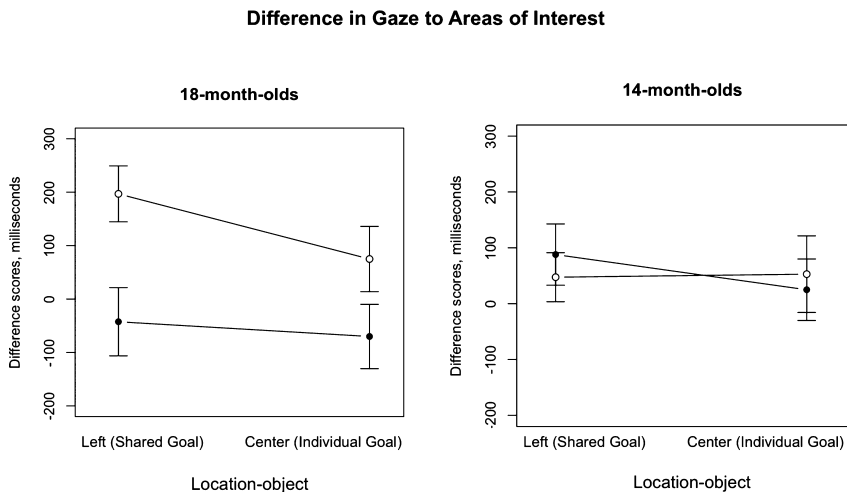


Figure 3 Difference scores (looking in the post- minus precounting phases) for each age group to the Center (individual goal) and Left (shared goal) location object AOIs by condition (Social: open circles, Nonsocial: filled circles). Bars indicate standard error. Eighteen-month-olds looked more to the Left (shared goal) location object in the Social than the Nonsocial condition. 14-month-olds had no significant differences.

awareness of the shared goal, but infants in the Nonsocial condition did not show a similar expectation for either location object.

14-month-olds

For the 14-month-olds, no significant effects were found (see Figure 3), suggesting that their expectations did not differ based on the social context they observed. However, this younger group anticipated the light effect outcome as well as the 18-month-olds did, as indicated by a lack of age effect in overall difference scores in a regression model with only age group as a fixed effect and the same random effects as above ($\beta = -0.005$, $SE = 0.013$, $t = -0.426$; Model Comparison $X^2(1) = 0.170$, $p = .680$).

DISCUSSION

The current study revealed that 18-, but not 14-month-olds, are able to rely on prior social cues to infer a shared goal and to bind together an ambiguous action sequence to anticipate future actions. Both 14- and 18-month-olds anticipated the action effect by looking for it when it should have appeared, suggesting that the ability to predict social events is not a main limiting factor for the younger infants. What does this developmental transition tell us about action binding?

While we cannot be certain why infants' performance improved during this time period (e.g., attention, memory, or the need for more salient social cues could be involved), a likely basis for the difference is increasing amount and variety of experience in collaborative actions. Action experience is related to action perception and anticipation in many areas, including reaching (Sommerville, Woodward, & Needham, 2005), placing objects (Cannon, Woodward, Gredebäck, von Hofsten, & Turek, 2012; Gredebäck & Kochukhova, 2010), and feeding (Gredebäck & Melinder, 2010). Behavior during collaboration may even be related to understanding of individual goals (Hunnus, Bekkering, & Cillessen, 2009), yet research has not directly examined whether naturally encountered experience in collaboration is necessary for understanding others' shared goals. The current study suggests that action experience may indeed play a role in shared goal understanding. One main difference in the social cognitive abilities of 14- and 18-month-olds is their skill in coordinating actions with others based on shared goals (e.g., Warneken & Tomasello, 2007). Recent research suggests that short-term, trained experience in a particular collaborative task facilitates recognition of third-party collaboration (Henderson et al., 2013). Thus, it is quite possible that building up general, active experience in collaborations

is necessary for the ability to recognize shared goals in others' collaborations and to anticipate actions that will fulfill those shared goals. This is certainly an important question for future research.

ACKNOWLEDGMENTS

The research was supported by the European Research Council StG (CACTUS – 312292).

REFERENCES

- Augusti, E. M., Melinder, A., & Gredebäck, G. (2010). Look who's talking: pre-verbal infants' perception of face-to-face and back-to-back social interactions. *Frontiers in Psychology, 1*, 161.
- Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*(4), 390–412.
- Bates, D., & Sarkar, D. (2007). lme4: Linear mixed-effects models using S4 classes. R package, version 0.9975-13.
- Behne, T., Carpenter, M., Call, J., & Tomasello, M. (2005). Unwilling versus unable: infants' understanding of intentional action. *Developmental Psychology, 41*(2), 328.
- Beier, J. S., & Spelke, E. S. (2012). Infants' developing understanding of social gaze. *Child Development, 83*(2), 486–496.
- Brownell, C. A., & Carriger, M. S. (1990). Changes in cooperation and self–other differentiation during the second year. *Child Development, 61*(4), 1164–1174.
- Cannon, E. N., Woodward, A. L., Gredebäck, G., von Hofsten, C., & Turek, C. (2012). Action production influences 12-month-old infants' attention to others' actions. *Developmental Science, 15*(1), 35–42.
- Falck-Ytter, T., Gredebäck, G., & von Hofsten, C. (2006). Infants predict other people's action goals. *Nature Neuroscience, 9*(7), 878–879.
- Fawcett, C., & Gredebäck, G. (2013). Infants use social context to bind actions into a collaborative sequence. *Developmental Science, 16*(6), 841–849.
- Gredebäck, G., & Kochukhova, O. (2010). Goal anticipation during action observation is influenced by synonymous action capabilities, a puzzling developmental study. *Experimental Brain Research, 202*(2), 493–497.
- Gredebäck, G., & Melinder, A. (2010). Infants' understanding of everyday social interactions: a dual process account. *Cognition, 114*(2), 197–206.
- Handl, A., Mahlberg, T., Norling, S., & Gredeback, G. (2013). Facing still faces: what visual cues affect infants' observations of others? *Infant Behavior & Development, 36*(4), 583–586.
- Henderson, A. M., Wang, Y., Matz, L. E., & Woodward, A. L. (2013). Active experience shapes 10-month-old infants' understanding of collaborative goals. *Infancy, 18*(1), 10–39.
- Henderson, A. M., & Woodward, A. L. (2011). “Let's work together”: what do infants understand about collaborative goals?. *Cognition, 121*(1), 12–21.
- Hunnius, S., Bekkering, H., & Cillessen, A. H. (2009). The association between intention understanding and peer cooperation in toddlers. *International Journal of Developmental Science, 3*(4), 368–388.

- Phillips, A. T., Wellman, H. M., & Spelke, E. S. (2002). Infants' ability to connect gaze and emotional expression to intentional action. *Cognition*, 85(1), 53–78.
- R Development Core Team (2005). *R: A language and environment for statistical computing*. Vienna, Austria: Foundation for Statistical Computing.
- Sommerville, J. A., Woodward, A. L., & Needham, A. (2005). Action experience alters 3-month-old infants' perception of others' actions. *Cognition*, 96(1), B1–B11.
- Time Studio (2013). <http://timestudioproject.com/>
- Uithol, S., & Paulus, M. (2014). What do infants understand of others' action? A theoretical account of early social cognition. *Psychological Research*, 78, 609–622.
- Warneken, F., & Tomasello, M. (2007). Helping and cooperation at 14 months of age. *Infancy*, 11(3), 271–294.