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Baby do–baby see! How action production influences action perception in infants

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Abstract

With a series of four experiments we show that self-produced actions influence infants' perception of actions performed by others. After having played with an object, 7–11-month-olds simultaneously watched two videos presenting adults who act on either the same object or a different one. The 9- and 11-month-old preferred to watch the same-object video indicating an influence of action production on action perception at this age. Follow-up studies showed that this influence was restricted to object-related actions. Agentive experience enhanced interest in actions with objects, but not in watching objects or persons per se. These findings indicate that infants are not only interested in acting on objects themselves, but that this experience increases their interest in the actions of other people with the same object.

Keywords: Infants; Action production; Action perception; Like-me; Agentive experience

1. Introduction

The importance of actions for our everyday life is obvious. Human beings act in and interact with their social environment. Accordingly, it is of special importance not only to control one's own actions but also to understand other individuals' actions. Over the last decade, the issue of how the understanding of actions develops during infancy has increasingly been investigated. How does it come about that infants learn to control their own actions as well as to understand other persons' actions? And what impact does this have on the ontogeny of action production and action

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perception, respectively? There is ample evidence that infants learn by observation efficiently and even flexibly. They learn about themselves and their action possibilities through observing others' actions. Infants also learn about actions by analogy to self-produced actions. Nevertheless, there are only a few studies addressing the question of how the infant's own previous actions influence his/her subsequent perception and understanding of others' actions. Our interest in this issue is motivated in a three-fold way.

First, it is well known that the production of actions by the self has a strong impact on action memory. In research with adults, there has been a growing interest in memory processes that are intimately connected to action (Zimmer, 2001). This interest is reflected in research on prospective memory, that is, remembering to perform actions in the future, and in work involving the monitoring of one's own actions. Furthermore, current research also focuses on the memory of self-performed actions (Engelkamp, 1997; Nilsson et al., 2000; Zimmer, 2001). In adults, enactment clearly enhances memory quantity and memory accuracy (Koriat & Pearlman-Avnion, 2003). To produce actions helps to remember actions. It has recently been demonstrated that this applies not only for adults but also for infants. Hayne, Barr, and Herbert (2003) tested 18-month-old infants by using an imitation paradigm in which an adult demonstrated an action sequence with objects. The infants were given the opportunity to reproduce the target action following delay. Those infants who practised the action sequence before the retention interval reactivated the target action more often and more accurately. They also generalized it to novel test stimuli. These results suggest that actively produced actions influence the accessibility and generality of infants' memories by enhancing both the content and the strength of the underlying memory representation.

Second, the influence of action production on action perception requires cross-modal coordination. Proprioceptive information (perception of self) must be mapped onto the perception of others. Cross-modal recognition of shape from hand to eyes is already evident in human newborns. Streri and Gentaz (2003, 2004) demonstrated that neonates are able to process and encode shape information about manually experienced objects and to discriminate between subsequently presented visual objects. Moreover 5.5-month-old infants coordinate information from the tactile and visual modalities of objects and use these intermodal object representations to interpret physical events (Schweinle & Wilcox, 2004). Furthermore, tactile perception is enhanced by active production of surface motion (Streri, Spelke, & Rameix, 1993). Like adults, 4.5-month-old infants appear to perceive the boundaries of tactilely presented objects more clearly from patterns of relative motion that infants produced themselves than from patterns of relative motion produced by others. Related findings in adults using neuroimaging methodology demonstrated that the active performance of a concurrent action influenced the perception of an observed action, whereas this was not the case in a passive condition (Hamilton, Wolpert, & Frith, 2004).

Third, the common contemporary view in infant research claims that human beings need agentive experiences to understand others as actors. Infants first have to acquire a specific level of reasoning about their own actions, in order to be able to understand other people's actions (e.g., Barresi & Moore, 1996; Carpenter, Nagell, & Tomasello, 1998; Meltzoff, 1995; Moore & Corkum, 1994; Tomasello, 1995, 1999). Recent findings indicate that by 6–9 months of age, infants represent certain single actions as directed at goals, rather than as purely physical trajectories through space (Woodward, 1998). As these results were not found with mechanical devices (Woodward, 1998; but see Hofer, Hauf, & Aschersleben, 2005) and with unfamiliar actions (Woodward, 1999; but see Hofer, Hauf, & Aschersleben, in press) it was assumed that agentive experience plays a crucial role for the understanding of goal-directed actions performed by others. This is a core assumption in the literature on the understanding of goal-directedness as well as on

the understanding of intentional actions (Carpenter, Akthar, & Tomasello, 1998; Meltzoff, 1995, in press).

During the first year of life infants contingently increase their production of goal-directed actions. By doing this they acquire increased knowledge about actions. This action knowledge seems to provide a valuable source for a broader understanding of actions performed by them and by others (cf. Meltzoff, 2002, in press). Nevertheless, only few studies have addressed the question of how preceding action performance influences later action perception in infants (cf. Hauf & Prinz, 2005; Sommerville, Woodward, & Needham, 2005). Experimental approaches to date have focused on other aspects of agentive experiences like the experience of contingencies between self-performed movements and environmental events (Rovee-Collier & Hayne, 2000), the input of object exploration on the development of explorations skills (Needham, 2001; Needham & Baillargeon, 1997, 1998; Needham, Barrett, & Peterman, 2002), or the power of manual exploration on reaching behaviour (Hauf & Baillargeon, 2005).

These considerations, along with the fact that infants' interest in objects increases dramatically once they develop the ability to reach for objects (Gibson, 1988; Gibson & Pick, 2000; Kaye & Fogel, 1980) emphasize the importance of agentive experience for the development of action understanding. Recent findings utilizing an enhancement procedure and a habituation task in 3-month-old infants indicate that action experience may facilitate action perception (Sommerville et al., 2005). Furthermore, 10-month-old only understood that the initial step of a cloth-pulling sequence was directed toward the ultimate goal of attaining a toy if they were able to solve a similar sequence by own action production (Sommerville & Woodward, 2005). Overall, these findings indicate a close developmental link between infants' action production and their perception of actions performed by others. Additionally, the idea of a functional equivalence of self-performed actions and perceived actions performed by others (Hauf & Prinz, 2005; Meltzoff, 2002, in press) highlights the similarity between produced and perceived actions even in very young infants. It seems that action knowledge is used both by the motor system in order to perform actions and by the perceptual system in order to perceive and understand the actions of other people.

Extending this line of argument, in the present study we tested the assumption that acting on objects directly influences further observation of other persons' acting on the same objects. To act on objects is a prominent mechanism for infants not only to learn about object features but also to learn about the capacities of their perceptual and motor systems as well as to learn about the effects produced in their environment while acting. Therefore, it could be assumed that acting on objects motivates them additionally to acquire more knowledge about actions through further observation of other persons' acting on the same object. To investigate this, infants first played with a real object and subsequently watched videos, which showed two adults acting on either the same object or a different one (Experiment 1). Further experiments were conducted to ensure that any increased interest was related to perceived actions and not to the presented objects per se (Experiment 2/Experiment 3). Finally, Experiment 4 investigated whether attention towards an object – without handling the object by oneself – leads to an increased interest in actions performed by others as well. In order to track developmental changes the present experiments investigated 7-, 9-, and 11-month-old infants.

2. Experiment 1

The purpose of this experiment was to test, if and how self-produced actions influence his/her interest in other person's actions. The infant first played with a toy at a table. Afterwards he/she

simultaneously watched two videos. One video showed two adults sitting at a table and acting on the same toy the infant had played with before. The other video showed the same two adults sitting at the table but now acting on a different toy. The two toys were carefully chosen to make sure that the kind of toys that were used had no effects on the results. Therefore, both toys were multi-coloured with moving parts. One of the toys was very popular and it could be assumed that all infants know this type of toy (car), whereas none of the infants were familiar with the other toy (ribbons). Although the toys differed in familiarity this was not the case for the presented movements. The movements applied to the two objects, sliding (the car) and shaking (the ribbons), were equally familiar to infants at this age.

2.1. Method

2.1.1. Participants

The final sample consisted of 36 healthy, full term infants, who were recruited from public birth records and by word of mouth. All infants scored within their age range in selected tasks of the Bayley Scales of Infant Development (BSID-II, 1993). Participants were seven male and five female 7-month-olds (mean age: 7 months, 1 day; range: 6;21 to 7;09), seven male and five female 9-month-olds (mean age: 9 months, 9 days; range: 8;27 to 9;20), and seven male and five female 11-month-olds (mean age: 11 months, 3 days; range: 10;20 to 11;10). In order to make sure that the infants had enough time to perform actions and to encode the object features, only those infants were included in further data analysis that acted and/or looked at the object for at least 45 s. Accordingly, five additional 7-month-olds (two males, three females) and three additional 11-month-olds (one male, two females) were tested but not included in the final sample due to refusal to remain seated or inattentiveness.

2.1.2. Test environment, apparatus and stimuli

The test room was unfurnished except for the test equipment. For the first part of the experiment (production phase, see Fig. 1A), the parent and experimenter faced each other across a small (60 cm × 90 cm) table, with infants on their parents' laps. A camera to the right of the infant and parent was focused to include the experimenter's hands, the infant's torso, head and hands

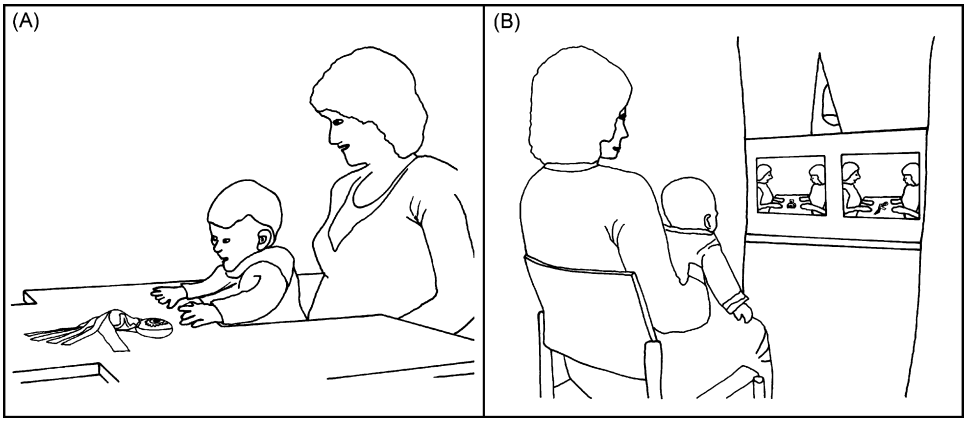

Fig. 1. Experimental setting during the production phase (A) and the subsequent perception phase (B).

as well as most of the table top. The objects used during the experiment were a multi-coloured toy car (length: 12 cm; width: 8 cm; height: 5/9 cm), and multi-coloured ribbons (50 cm × 4 cm) attached to a soft grasping part (length: 12 cm; width: 7 cm; height: 3 cm). For the second part of the experiment (perception phase, see Fig. 1B), the infants were placed on their parents' laps and seated centered in front of two video screens (each 21″) with a distance of 80 cm. A camera above the video screen was focused to include the infant's torso and head. A second camera to the infant's and parent's right recorded the video movies shown on the screens. The two videos showed the same two adults sitting at a table face to face and alternately performing an action (either sliding the car or shaking the ribbons). Person A acted upon the toy, whereas Person B kept an eye on that action and repeated it immediately. Subsequently, Person A repeated the same action, and so on. The whole sequence lasted for 90 s. The two adults were situated face to face in order to create a situation more similar to social interactions in everyday life where infants are often watching other peoples' actions without being the focus of attention for those people.

2.1.3. Procedure

Infants were tested in our lab at a time of day when they were likely to be alert and playful. Each participant and parent was escorted to a reception room. For approximately 10 min the infant was allowed to explore the room, while the experimenter described the test procedure to the parent. Next, the infant and parent were brought to the test room and the infant was given approximately 2 min to become accustomed to the environment. As soon as the infant seemed comfortable, the experiment began. The experiment consisted of one session that was divided into the production phase and the perception phase.

During the production phase, all infants played with a toy for a 90 s interval. Half of the infants played with the car, the other half with the ribbons. The perception phase followed immediately after the production phase. The infant watched simultaneously two short videos on the two screens, which both showed the same two adults sitting at a table and playing alternately with one toy (either sliding the car or shaking the ribbons) for 90 s. In one video clip, the two adults were acting on the same toy the infants had played with during the production phase. The other video showed the same two adults acting on the other toy. Thus, the only difference between the two videos was the toy used and the action produced during the action sequence. The side of video presentation was counterbalanced across infants.

2.1.4. Data analysis

Each videotaped session was scored by an observer, who was blind to the infants' group assignment. During the production phase, it was coded how long the infant played with the toy as well as how long the infant looked at it during a 90 s interval (acting time and looking time). Furthermore, infant spontaneous production of the target actions presented during the subsequent perception phase was also coded (sliding the car or shaking the ribbons). During the perception phase, the looking time at the two videos in the 90 s interval was scored. In addition, a randomly selected 25% of the data set was coded by a second independent observer. Interobserver reliability was high in all experiments and for all age groups ($.92 < r < .97$). Preliminary analyses of the data revealed no significant effects of sex and side of presentation in any experiment (all p-values $> .20$); the data were therefore collapsed across these factors. Further examination yielded no differences in whether the familiar car or the unfamiliar ribbons were the same or the different toys during the perception phase in any experiment (all p-values $> .20$); therefore, the looking time data were collapsed across the two toys.

Table 1
Mean acting and looking time during the production phase (90 s) subdivided into the different age groups and the two toys plotted for Experiment 1–4

	Mean acting time		Mean looking time	
	Car	Ribbons	Car	Ribbons
Experiment 1				
7-Month-old	69.1 (S.E. = 7.9)	73.9 (S.E. = 4.7)	70.7 (S.E. = 4.0)	66.6 (S.E. = 3.1)
9-Month-old	76.2 (S.E. = 9.5)	67.0 (S.E. = 9.9)	65.4 (S.E. = 2.5)	62.9 (S.E. = 2.0)
11-Month-old	71.4 (S.E. = 10.6)	63.7 (S.E. = 10.0)	69.7 (S.E. = 4.0)	67.4 (S.E. = 1,7)
Experiment 2				
9-Month-old	78.8 (S.E. = 2.6)	74.6 (S.E. = 7.8)	66.6 (S.E. = 3.2)	64.7 (S.E. = 1.6)
11-Month-old	67.9 (S.E. = 6.6)	65.0 (S.E. = 8.9)	60.8 (S.E. = 3.1)	68.8 (S.E. = 3.6)
Experiment 3				
9-Month-old	79.8 (S.E. = 4.8)	72.8 (S.E. = 5.4)	62.9 (S.E. = 2.6)	65.9 (S.E. = 3.1)
11-Month-old	72.0 (S.E. = 4.4)	69.4 (S.E. = 2.3)	64.2 (S.E. = 4.1)	64.1 (S.E. = 4.2)
Experiment 4				
9-Month-old	No self-performed actions		79.2 (S.E. = 2.2)	72.6 (S.E. = 3.8)
11-Month-old	No self-performed actions		73.5 (S.E. = 2.0)	77.5 (S.E. = 2.2)

2.2. Results and discussion

2.2.1. Production phase

All infants started the session by acting on one toy, either the car or the ribbons. The 7-month-old infants acted equally long on both toys, $t(10) = 0.526$, $p = .61$. They also looked equally long at both toys, $t(10) = 0.827$, $p = .43$. Moreover, there were no differences in acting and looking time data in 9-month-olds [acting: $t(10) = 0.671$, $p = .52$; looking: $t(10) = 0.82$, $p = .43$] as well as in 11-month-olds [acting: $t(10) = 0.533$, $p = .61$; looking: $t(10) = 0.515$, $p = .62$]. Furthermore, no age differences occurred in acting time data, $F(2, 0.14) = 0.869$, or in looking time data, $F(2, 1.51) = 0.235$ (see Table 1).

All infants showed deliberate exploratory behaviour, like touching the toy, banging it on the table, holding it in front of their eyes, rotating it or putting it into the mouth. This was the case with both the car and the ribbons. In addition, three of the 7-month-old, six of the 9-month-olds, and four of the 11-month-olds spontaneously produced the target actions "sliding the car" and "shaking the ribbons", respectively. However, corresponding χ^2-tests based on the number of infants performing the target actions yielded no significant differences between the age groups (all p-values $> .527$). The results obtained in the production phase indicate that the presented objects were of equal interest to the infants and that the objects could be considered suitable for all investigated age groups. Therefore, any differences obtained in the perception phase were not related to any a-priori preference during the production phase.

2.2.2. Perception phase

Preliminary analysis of the looking time data revealed no significant differences between infants who had produced the target actions during the production phase and those who had not (all p-values $> .20$). Therefore, mean looking time data (see Fig. 2) were analyzed by a 3×2 analysis of variance (ANOVA) with the between-subjects factor age (7, 9, and 11 months) and the within-subject factor toy (same and different). The analysis yielded a significant main effect

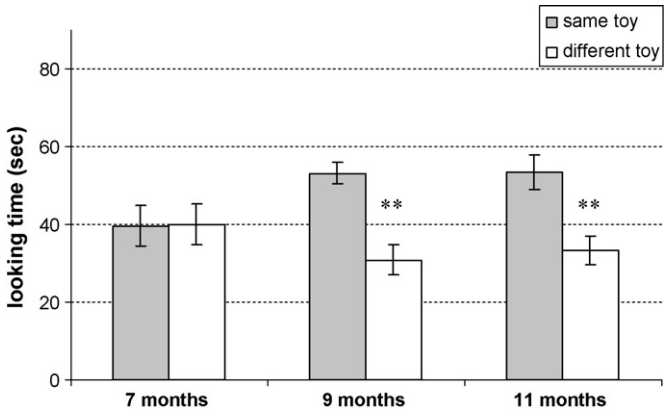

Fig. 2. Mean looking time during the perception phase while infants watched two adults either acting on the same toy or a different toy (Experiment 1).

of toy, $F(1, 33) = 8.62$, $p = .006$, $\eta^2 = .207$ and no significant main effect of age ($p = .224$) or interaction between age and toy ($p = .117$). Separate t-tests revealed no differences in looking time between same ($M = 39.73$, S.E. = 4.89) and different toy ($M = 39.95$, S.E. = 5.03) in 7-month-old infants, $p = .982$. However, the 9-month-old infants looked reliably longer at the video with the same toy ($M = 53.03$, S.E. = 2.61) than at the video with the different toy ($M = 30.89$, S.E. = 3.70), $t(11) = 3.675$, $p = .004$. The same significant difference occurred in the 11-month-olds (same: $M = 51.49$, S.E. = 4.22; different: $M = 33.35$, S.E. = 3.50), $t(11) = 2.392$, $p = .036$.

These results indicate that self-performed actions influence the subsequent perception of the actions of other people. The 9- and 11-month-old infants – but not 7-month-olds – preferred to watch other people acting on the toy they had played with before. This demonstrates that infants at this age are interested in objects, specifically in object features and actions with the same object. The 7-month-old infants were also highly interested in acting on objects and in perceiving other peoples' actions on objects, but they did not show a preference for one of the two videos. Even though the 7-month-olds spontaneously produced the target actions as often as the older infants and did not differ in the amount of explorative behaviour, it may be possible that the lack of preference was due to less progressed manual skills. Infants at the age of 7 months are able to reach for and grasp objects (Gibson, 1988) and that was what they did in the present experiment. Nevertheless, their play behaviour was less sophisticated, precise and structured. In contrast, 9-month-old are capable of performing means-ends tasks (Willatts, 1999) indicating that they have acquired knowledge about movements, actions, and end states. This knowledge is even more elaborate in 11-month-old infants (Behne, Carpenter, Call, & Tomasello, 2005; Carpenter, Call, & Tomasello, 2005). By using these capacities the 9- and 11-month-old explored the objects in a much more deliberate way. Possibly these infants were particularly motivated to acquire increased knowledge about actions. They did this through further observation of other peoples' actions on the same toy and therefore also preferred to watch the same-toy video.

In order to ensure that the observed effects are due to self-performed actions we have to rule out various alternative explanations. Firstly, one could argue that the effects observed in Experiment 1 fit into an increased interest with the toy with which the infant had previously played. The observed effects would thus not be related to the performed action. In order to rule out this explanation, Experiment 2 and 3 examined the influence of agentive experience on watching

non-acting (looking) persons as well as on watching only objects. Secondly, one could argue that the preference for the same-toy video is not prompted by agentive experience, but by having a real object and actions live during the production phase. Therefore, Experiment 4 investigated the influence of non-agentive experience with a real object on subsequent watching of other peoples' actions.

3. Experiment 2

The results of Experiment 1 indicate that self acting influences the following perception of other persons' actions in 9- and 11-month-old infants. To ensure that the preference for the same-toy video was indeed related to the perceived actions, we conducted the following experiment. The infants again started with acting on a toy for 90 s. During the following perception phase, two videos were simultaneously presented with the same two adults sitting at the table as in Experiment 1. In contrast to Experiment 1, however, the two adults were looking at instead of playing with the toy (the same toy in one video and a different toy in the other video). No action was shown at any time during this 90 s perception phase. As the 7-month-old did not show a preference for any of the two videos in the first experiment, we ran Experiment 2 only with 9- and 11-month-old infants.

3.1. Method

3.1.1. Participants

The final sample consisted of 24 healthy, full term infants, who were recruited from public birth records and by word of mouth. All infants scored within their age range in selected tasks of the Bayley Scales of Infant Development (BSID-II, 1993). Participants were seven male and five female 9-month-olds (mean age: 8 months, 24 days; range: 8;16 to 9;06), and six male and six female 11-month-olds (mean age: 10 months, 27 days; range: 10;16 to 11;13). Seven additional 9-month-old infants (three males and seven females) and six additional 11-month-old infants (four males and two females) were tested but were not included in the final sample due to refusal to remain seated or inattentiveness during the perception phase.

3.1.2. Test environment, apparatus, stimuli, and procedure

The test environment, apparatus, and procedure were identical to those described in Experiment 1 with the following exception; the videos presented two adults looking (without acting) at the toy for 90 s. In one video the two adults were looking at the same toy, in the other video at a different toy. No acting took place at any time. The side of presentation was counterbalanced across infants.

3.2. Results and discussion

3.2.1. Production phase

All infants started the session by acting on one toy, either the car or the ribbons. The 9-month-old infants acted equally long on both toys during the production phase, $t(10) = 0.508$, $p = .62$. They also looked equally long at both toys, $t(10) = 0.516$, $p = .62$. Similarly, there were no differences in acting and looking time in 11-month-olds [acting: $t(10) = 0.266$, $p = .80$; looking: $t(10) = 1.673$, $p = .13$]. Furthermore, no age differences occurred in acting time, $t(22) = 1.540$, $p = .14$, or in looking time, $t(22) = 0.276$, $p = .79$ (see Table 1). All infants showed highly structured explorative

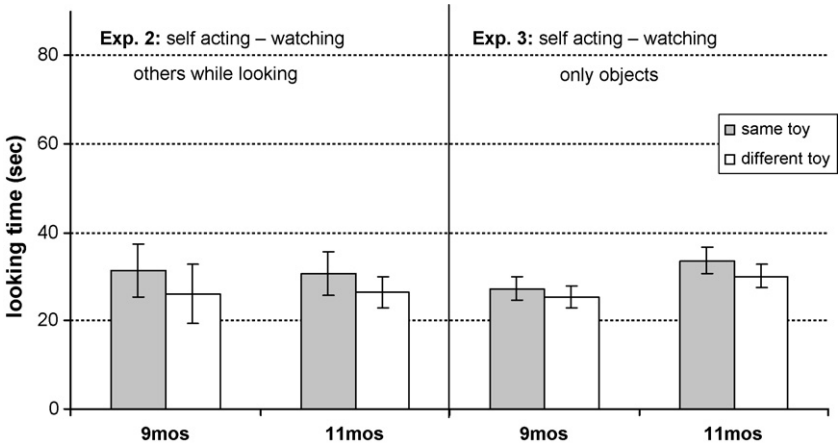

Fig. 3. Mean looking time during the perception phase while infants watched two adults either looking at the same toy or at a different toy (Experiment 2) and when watching a close-up view of either the same toy or a different toy (Experiment 3).

behaviour; six of the 9-month-olds and three of the 11-month-olds were spontaneously sliding the car or shaking the ribbons.[1] The results obtained in the production phase replicated the results of Experiment 1, where the presented objects were equally explored by the infants.

3.2.2. Perception phase

The infants' mean looking time data (see Fig. 3) were analyzed by a 2 × 2 ANOVA with age (9 and 11 months) as the between-subjects factor and toy (same and different) as the within-subject factor. The analysis yielded no significant differences. There was no main effect of toy ($p = .307$), or age ($p = .652$) or interaction between age and toy ($p = .727$). Even though there is a slight numerical difference between the two conditions, no significant difference occurred in either age group. The 9-month-old infants looked equally long at the video with the same toy ($M = 31.39$, S.E. = 5.85) and at the video with the different toy ($M = 26.02$, S.E. = 6.69). The same result pattern occurred for the 11-month-olds (same: $M = 30.70$, S.E. = 4.81; different: $M = 26.48$, S.E. = 3.38).

In order to test the assumption that agentive experience enhanced only the interest in actions but not in objects, the infants' looking time data in Experiment 1 and 2 were analyzed by a 2 × 2 × 2 ANOVA with Experiment (1 and 2) and age (9 and 11 months) as between-subjects factors and toy (same and different) as the within-subject factor. The analysis yielded no significant main effect of age ($p = .744$) but significant main effects of experiment, $F(1, 44) = 33.72$, $p < .001$, $\eta^2 = .434$ and toy, $F(1, 44) = 11.58$, $p = .001$, $\eta^2 = .208$. A significant toy-by-experiment interaction, $F(1, 44) = 7.55$, $p = .009$, $\eta^2 = .148$, indicated that the looking time data of the same-toy video varied in both experiments. Infants looked reliably longer at the same-toy video in Experiment 1 ($M = 52.26$, S.E. = 2.43) than in Experiment 2 ($M = 32.73$, S.E. = 3.85, $t(46) = 4.292$, $p < .001$) and they looked equally long at the different-toy video in both experiments ($p = 126$). No further interactions reached significance (all p-values > .596).

[1] The number of infants spontaneously producing the target actions is reported for better comparability with Exp.1, even though no actions were presented in the videos here.

The infants in Experiment 2 as in Experiment 1 initially performed actions on a toy by themselves. In contrast to Experiment 1, the adults in the subsequently presented videos did not act at any time. If agentive experience increased only the interest in the object per se, but not in the actions related to this object, one would expect the same differences as in Experiment 1. However, the preference for the same-toy video was not found in the Experiment 2. As the videos did not involve actions, the infants were not able to compare their own actions with others' actions or to learn something new about the use of the object that they were interested in. As a consequence they looked equally long at both videos. In addition, the fact that we obtained the same looking time data for both videos ruled out the argument that infants were just interested in the fact that a toy they played with was now involved in the video on the screen. This was clearly not the case.

4. Experiment 3

The preceding experiment supports the interpretation given for Experiment 1 that agentive experience in particular has an impact on the subsequent perception of actions. The following experiment should yield further evidence for such an interpretation. One could argue that two adults sitting at a table and looking at a toy for 90 s is a more or less unnatural condition. Potentially the infants looked equally long at both videos, as they were wondering where and when actions will occur. Therefore, in this control experiment we showed two videos simultaneously presenting the objects in a close-up view. Thus, there were no people present at the video. If the increased interest is only related to the object a preference for the same-toy video should occur. But if – as we would like to argue – action production enhances the interest in actions, then there is no reason for a preference.

4.1. Method

4.1.1. Participants

The final sample consisted of 24 healthy, full term infants, who were recruited from public birth records and by word of mouth. All infants scored within their age range in selected tasks of the Bayley Scales of Infant Development (BSID-II, 1993). Participants were five male and seven female 9-month-olds (mean age: 8 months, 28 days; range: 8;25 to 9;11), and seven male and five female 11-month-olds (mean age: 11 months, 06 days; range: 11;01 to 11;12). Two additional 9-month-olds (males) were tested but were not included in the final sample due to refusal to remain seated during the perception phase.

4.1.2. Test environment, apparatus, stimuli, and procedure

The test environment, apparatus, and procedure were identical to those described in Experiment 1 with the following exception. In contrast to Experiment 1, the infants simultaneously watched two short videos which both showed a close-up view of the toy on a table (car or ribbons) for 90 s. In one video the same toy was visible, in the other video the different toy. The side of presentation was counterbalanced across infants.

4.2. Results and discussion

4.2.1. Production phase

The 9-month-old infants acted equally long on both toys during the production phase, $t(10) = 0.968$, $p = .36$. They also looked equally long at both toys, $t(10) = 0.733$, $p = .48$. There

were also no differences in acting and looking time in 11-month-olds [acting: $t(10) = 0.519$, $p = .62$; looking: $t(10) = 0.025$, $p = .98$]. Furthermore, no age differences occurred in acting time, $t(22) = 1.294$, $p = .21$, or in looking time, $t(22) = 0.083$, $p = .94$ (see Table 1). All infants showed advanced explorative behaviour; two of the 9-month-olds and three of the 11-month-olds were spontaneously sliding the car or shaking the ribbons.[1] These results support the findings of the former experiments indicating that infants were equally interested in exploring both toys.

4.2.2. Perception phase

The infants' looking time data (see Fig. 3) were analyzed by a 2 × 2 ANOVA with age (9 and 11 months) as the between-subjects factor and toy (same and different) as the within-subject factor. The analysis yielded no significant differences. There was no effect of toy ($p = .312$), age ($p = .652$) or interaction between age and toy ($p = .772$). The 9-month-old infants looked equally long at the same-toy video ($M = 27.34$, S.E. = 2.52) and at the different-toy video ($M = 25.39$, S.E. = 2.41). The same result patterns occurred for the 11-month-olds (same: $M = 33.58$, S.E. = 3.00; different: $M = 30.08$, S.E. = 2.63).

In the present experiment the infants first acted on the toy and explored it. Afterward they watched videos. Watching a close-up video of a toy is like watching a picture. The object features are clearly visible. In Experiment 1 infants as young as 9 and 11 months preferred the same-toy video. Thus, they were able to recognize the toys in the video. But here infants looked equally long at both videos. Obviously, agentive experience increased the interest in actions, but during this perception phase the videos only showed objects. Thus, the missing preference in the present experiment is additional evidence for the argument that the differences in looking time data observed in Experiment 1 are related to actions.

This interpretation was confirmed by a 2 × 2 × 2 ANOVA with Experiment (1 and 3) and age (9 and 11 months) as between-subjects factors and toy (same and different) as the within-subject factor revealing significant main effects of experiment, $F(1, 44) = 77.22$, $p < .001$, $\eta^2 = .637$ and toy, $F(1, 44) = 17.20$, $p < .001$, $\eta^2 = .281$. A significant toy-by-experiment interaction, $F(1, 44) = 9.97$, $p = .003$, $\eta^2 = .185$, showed that infants looked reliably longer at the same-toy video in Experiment 1 ($M = 52.26$, S.E. = 2.43) than in Experiment 3 ($M = 30.46$, S.E. = 2.02, $t(46) = 6.899$, $p < .001$) and that they looked equally long at the different-toy video in both experiments ($p = .043$). These results suggest that infants are particularly interested in perceiving other peoples' actions following their own agentive experience and that this interest is mainly related to actions and not to objects or persons per se.

5. Experiment 4

In the former experiments, we were able to demonstrate that agentive experience enhanced the interest in actions but not in watching objects or persons per se. Thus, we argue that infants who have agentive experience with an object are particularly interested in other peoples' actions with the same object. However, there is one remaining alternative interpretation. One could argue that agentive experience is not the crucial factor, but rather that seeing a real object and actions live during the production phase is critical. To exclude this possibility, we conducted the following experiment. During the production phase the infant was sitting at a table facing an experimenter, like in the former experiments. However, in this case, not the infant, but the experimenter was acting on the toy for 90 s. The experimenter was instructed to perform those actions that infants had shown in the former experiments during the production phase; namely touching the toy, banging it on the table or exploring it by rotating it in front of the eyes. But she never showed any part

of the action sequence that followed in the videos during the perception phase (sliding the car and shaking the ribbons). Thus, the infants saw actions on real objects live, but did not perform these actions themselves. If the results exhibit different looking times for both videos, this would indicate that the preference for the same-toy video obtained in Experiment 1 was not related to agentive experience.

5.1. Method

5.1.1. Participants

The final sample consisted of 24 healthy, full term infants, who were recruited from public birth records and by word of mouth. All infants scored within their age range in selected tasks of the Bayley Scales of Infant Development (BSID-II, 1993). Participants were seven male and five female 9-month-olds (mean age: 8 months, 23 days; range: 8;18 to 8;29), and five male and seven female 11-month-olds (mean age: 10 months, 27 days; range: 10;15 to 11;09). Three additional 9-month-olds (one male, two females) and two additional 11-month-olds (one male, one female) were tested but were not included in the final sample due to their refusal to remain seated or to touch the toy during the production phase.

5.1.2. Test environment, apparatus, stimuli, and procedure

The test environment, apparatus, and procedure were identical to those already described with one exception. During the 'production phase'[2] all infants were sitting on their parents' laps at a table, however, they never played with a toy. Rather, the experimenter acted on the toy (car or ribbons) for a 90 s interval. Again, the perception phase immediately followed. The infants simultaneously watched the same two videos as in Experiment 1 on the two screens. The side of presentation was counterbalanced across infants.

5.2. Results and discussion

5.2.1. Production phase

All infants started the session by watching an experimenter acting on one toy, either the car or the ribbons. The 9-month-old infants watched the performed actions on both toys for an equal amount of time, $t(10) = 1.483$, $p = .17$. The 11-month-olds also did not show a difference in looking time, $t(10) = 1.360$, $p = .20$. Furthermore, no age differences occurred, $t(22) = 0.135$, $p = .89$ (see Table 1). The results obtained in the production phase indicated that the infants were equally interested in the actions performed with both toys. Furthermore, the results suggest that the infants were interested in the toys, even though they did not perform any actions during this time interval.

5.2.2. Perception phase

The infants' looking time data (see Fig. 4) were analyzed by a 2×2 ANOVA with age (9 and 11 months) as the between-subjects factor and toy (same and different) as the within-subject factor. The analysis yielded no significant differences. There was no main effect of toy ($p = .955$), age ($p = .880$) or interaction between age and toy ($p = .552$). The 9-month-old infants looked equally

[2] In order to stress the comparability between the procedures of all experiments, we used the term 'production phase' again, even though the infants were never acting on the objects themselves during Experiment 4.

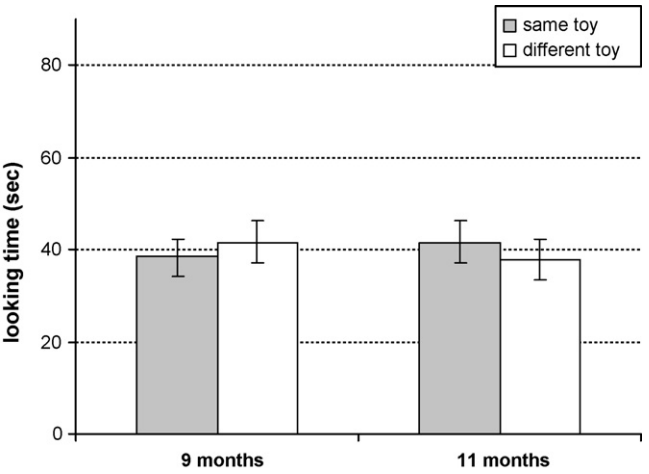

Fig. 4. Mean looking time during the perception phase while infants watched two adults acting either on the same toy or on a different toy (no self-performed actions during the production phase).

long at the video with the same toy ($M = 38.58$, S.E. = 3.40) as at the video with the different toy ($M = 41.59$, S.E. = 4.38). The same result pattern occurred for the 11-month-olds (same: $M = 41.61$, S.E. = 4.40; different: $M = 37.97$, S.E. = 4.26).

These results support the assumption that self-performed actions have an important impact on the subsequent perception of others' actions and that this effect occurs only after agentive experience. To watch others' actions on real objects in a live context seems not to be the main factor. The infants were highly attentive during the "production phase" (about 75 s). Therefore, it could be assumed that they had enough time to encode the relevant object features—even without agentive experience. Nevertheless, infants did not show any preference during the subsequent perception phase. They attentively watched the actions of the experimenter at the table as well as the actions presented in both videos. As the infants did not require knowledge about objects and movements based on their own experience there is no increased interest in other peoples' actions with one particular object. As a consequence they looked equally long at both videos.

In order to confirm this statement, infants' mean looking times were analyzed by a $2 \times 2 \times 2$ ANOVA with Experiment (1 and 4) and age (9 and 11 months) as between-subjects factors and toy (same and different) as the within-subject factor. The analysis yielded no significant main effects of age ($p = 947$) and experiment ($p = .065$), but a significant main effect of toy, $F(1, 44) = 7.78$, $p = .008$, $\eta^2 = .150$, as well as a significant toy-by-experiment interaction, $F(1, 44) = 7.31$, $p = .010$, $\eta^2 = .142$. Infants looked reliably longer at the same-toy video in Experiment 1 ($M = 52.26$, S.E. = 2.43) than in Experiment 4 ($M = 40.10$, S.E. = 2.74, $t(46) = 3.322$, $p = .002$) and they looked equally long at the different-toy video in both experiments ($p = .311$).

These results highlight the fact that the infants looked longer at the same-toy video only in Experiment 1, which was not the case in all other experiments. Only in the first experiment agentive experience had an impact on the subsequent perception of actions, indicating that handling an object increased the interest in further actions with the same object. From doing oneself to seeing others seems to be a critical factor for the development of action understanding.

6. General discussion

The present findings demonstrate that infants' interest in other peoples' actions is increased by agentive experience. After acting with an object, 7 to 11-month-old infants simultaneously watched two videos that presented adults acting on the same object or on a different one. The 9- and 11-month-olds – but not the 7-month-olds – preferred to watch the same-object video, indicating an influence of action production on action perception at these ages (Experiment 1). It is important to note that this influence was restricted only to those conditions in which self-performed actions and actions of others took place. Only then were infants more interested in watching people acting on the same object instead of a different one. By doing this, infants were able to compare their own way of using objects with others' modes of using the same object. This explains why agentive experience enhanced infants' interest only when observing actions but not when watching objects or persons per se (Experiment 2/Experiment 3); if no actions took place during the perception phase, no preferences occurred. Furthermore, this influence only appeared after agentive experience. Even if infants attentively watched actions on real objects performed by an experimenter, they showed no preference for one of the two subsequently presented videos. Watching others' actions on real objects in a live situation was not enough (Experiment 4). These findings indicate that infants are interested in acting with objects by performing actions themselves and that they use this experience while watching others' actions.

However, there is one major issue that has to be addressed. The presented experiments differed not only due to the actions involved, but also due to the attention attracted by the presented objects and movements. The impact of attention on action understanding (Tomasello, 1995; Tomasello & Haberl, 2003) is as well known as the role of action production for object exploration (e.g., Needham, 2001; Needham et al., 2002). Also, previous research indicates that infants show a visual preference for moving over stationary visual objects (e.g., Volkmann & Dobson, 1976). In line with this, Experiment 1 was the only situation in which both attributes were simultaneously present, manual exploration and actions with moving objects. As a result, infants may have looked longer at the same-object video only in Experiment 1. At first glance this seems to be an adequate explanation in line with what is known about infants' attention and active cognitive processing during object exploration. However, in contrast to object recognition, focusing on attention and related object representation is not sufficient to explain the reported influence of agentive experience on action perception. In order to partially account for this apparent contradiction we will focus on the nature of actions. Actions not only draw attention to objects (e.g., Tomasello, 1995), but self-performed actions also help to encode object features (e.g., Needham, 2001) and enhance the understanding of perceived actions (Sommerville & Woodward, 2005; Sommerville et al., 2005). When producing actions, infants build up a specific action representation that includes object features as well as features about the movements and action outcomes. These representations are used both for action production (Elsner & Aschersleben, 2003; Hauf & Aschersleben, in press; Hauf, Elsner, & Aschersleben, 2004; Klein, Hauf, & Aschersleben, in press) and action perception (Hofer et al., 2005, in press; Király, Jovanovic, Prinz, Aschersleben, & Gergely, 2003). In addition, infants are also interested in actions per se and not only in movements related to objects (Carpenter et al., 2005). Accordingly, the infants in Experiment 1 were able to build up a stable object representation and on the basis of agentive experience, an additional action representation about self-performed actions. These representations were subsequently used for action perception. As a result, one could assume that the infants preferred to look at the same-toy video as they had already fully encoded the relevant object features, but not all relevant

action features. Potentially, the infants were detecting the differences of their own actions and the actions demonstrated by the adults. This may cause infants to look longer when adults act on the same object so that they may compare their actions with the actions of the adults. As most of the infants did not spontaneously produce the target actions on their own, it is possible that the preference for the same-toy video occurred due to perceiving new actions (adults sliding or shaking), new object motions (objects sliding or shaking), or a combination of both (adults sliding or shaking objects). Based upon our results we speculate that the combination of particular actions with particular objects is of special importance. Nevertheless, additional research is needed to specify in more detail which aspects of actions and objects are critical to perceptual processing.

It is essential to emphasize the necessity and importance of agentive experience. An experimenter acting live in front of the infant would provide the infant with information about the behavioural regularities that typically accompany an action, e.g., eye gaze, bodily trajectory, bodily orientation (Baldwin, Baird, Sayler, & Clark, 2001). Nevertheless, infants in the present study showed only enhanced interest in the same-object video after self-performed actions. The joint results show that when infants increased interest in other persons' actions, it appeared to be tied to self-performed actions as well as to perceived actions. One possibility is that agentive experience is functioning like a catalyst for action perception. It primes infants' interest not only in objects but – even more importantly – also in other persons' actions. The efficiency of priming processes for infants' knowledge acquisition is well known. Wilcox and Chapa (2004) demonstrated the effectiveness of visual priming and event mapping for learning processes in early infancy. Our findings additionally indicate that the idea of "action priming" could be helpful for the development of action understanding.

The present study aimed to demonstrate a direct connection of self-performed actions with subsequent perceived actions in infants in a new experimental paradigm. This link was strongly shown, providing further evidence for the impact of agentive experience on action perception and – more generally – on the development of action understanding during infancy. However, the question of how infants come to understand their own actions and the actions of others could be answered more specifically by investigating the bi-directional influence of both, namely action production *and* action perception. There is ample evidence for a functional equivalence in adults (for an overview see Hommel, Müsseler, Aschersleben, & Prinz, 2001; Prinz, 1997). Moreover, cognitive neuroscientists have demonstrated that common brain regions serve both the perception and the production of actions (e.g., Decety, 1996; Decety & Sommerville, 2003; Grèzes & Decety, 2001; Iacoboni et al., 1999; Meltzoff, 2002; Meltzoff & Decety, 2003). This approach also seems to be of increasing significance in recent infant studies (c.f. Agnetta & Rochat, 2004; Hauf & Prinz, 2005; Meltzoff, 2002, in press; Sommerville et al., 2005). Further research must show how mental representations develop very early in infancy and whether the establishing of these representations requires input from both perception and motor systems.

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