Familiarity of Actions Leads Infants to Privilege Goals in Their Imitation of Others' Acts

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During observational learning of goal-directed action, infants tend to simplify the form of action to ensure that the goal is copied. As recent findings suggest that infants' sensitivity to the goal structure of action is reliant on their own experience with particular actions, the present study further examines whether the precedence of goal in infants' imitation is susceptible to the familiarity of the presented action. Eighteen-month-old infants observed an adult hop or slide a toy animal into one of two boxes (box condition) or to a final location (no-box condition). The toy moved along either a straight-line path familiar to infants (Experiment 1) or a novel turning-line path (Experiment 2). Overall, in the box condition, infants were more likely to copy the goal box while ignoring the hopping and sliding motion; in the no-box condition, they produced the opposite pattern of imitation. However, further analyses of the tendency to put the toy into boxes showed that infants' choice of the adult's goal was significantly higher than chance only in Experiment 1, suggesting that familiar actions determines whether infants privilege goals in their imitation of others' acts. To identify the goal of an agent's action requires not only the perceivable outcome, but it also requires a perception-action transduction that transfers observed acts into infants' own motor patterns. Familiar actions that infants are able to perform directly activate the equivalent body movements in their own motor repertoire. The results are consistent with the notion of direct mapping, suggesting that infants gain insight into goals through action experiences.

Keywords: Action familiarity; Direct mapping; Goal; Goal-directed; Imitation

Extended Abstract

It has been suggested that imitation involves the attribution of goals to others. This is manifested in infants' tendency to selectively reproduce the goal-relevant aspects of acts that they have observed. In a seminal study, Carpenter et al., (2005) showed that after seeing an adult sliding or hopping a toy mouse along the shortest path into a toy house, both 12- and 18-month-old infants directly placed the mouse into the same house as the adult had done, ignoring the exact movement. In contrast, when there was no house at the end location, infants reproduced the adult's action. This result has been interpreted as support for the goal-directed theory of imitation (GOADI), which posits that infants may ignore an adult's specific action because they encode the action's outcome as the important goal to reproduce (Bekkering et

al., 2000; Gattis et al., 2002; Wohlschläger et al., 2003). According to this interpretation, selectively copying goals rests on the ideomotor principle that actions and effects are represented in the motor repertoire as action-effect associations. Perceivable effects provide the idea of goals, which activates the motor program with which they are most strongly associated. However, while GOADI emphasizes that goals dominate the selection of actions, the ideomotor principle presupposes that goals elicit associated actions in an individual's motor repertoire.

In this study, we explored infants' imitation of goal-directed actions in light of their own action experience to challenge to GOADI's claim that perceivable outcomes are sufficient to identify action goals. Evidence that infants rely on action experience to understand actions as

goal-directed comes from a series of visual habituation studies by Woodward and her colleagues. Woodward (1999) demonstrated the presence of goal attribution in young infants. In contrast to their reaction to an unfamiliar action (i.e., touching a toy with the back of the hand), 5- and 9-month-olds interpreted an action familiar to them (i.e., grasping the toy) as goal-directed, showing dishabituation to a subsequent change in the grasped object rather than to a change in the path to reach the object. In another experiment, even if 3-month-old infants did not readily encode the goal of a demonstrated reach and grasp, they dishabituated to a change in grasped object after brief training in which they were allowed to perform goal-directed reaches by wearing Velcro-covered mittens and interacting with Velcro-covered objects (Sommerville et al., 2005). They did not benefit from the opportunity to observe an experimenter perform the trained actions (Gerson & Woodward, 2014). These findings raise the question of whether, when infants begin to imitate others' actions by the end of their first year (Meltzoff, 1988), familiarity with some actions continuously imposes constraints on the imitation of goals. The results of the Carpenter et al. (2005) study are thus subject to another interpretative problem: the shortest path used by the adult to move the mouse to the end location is also the strategy that 12- and 18-month-olds typically perform in their goal-directed reaches, leading them to efficiently recognize goal-directedness.

In this paper, we replicate and extend the Carpenter et al. (2005) study with a novel path of motion, examining the influence of familiarity of actions on infants' selective imitation of action goals. In two experiments, 18-month-old infants watched as an adult hopped or slid a toy animal into one of two boxes (box condition) or to a final location (no-box condition). In Experiment 1, as in the Carpenter et al. (2005) study, the experimenter moved the toy along the shortest path between two points; in Experiment 2, he moved the toy through a novel turning-line path. If infants encode the box as the goal of the demonstrated action, they should be more likely to choose the same box as the experimenter while ignoring the exact movements. However, if familiarity of actions imposes constraints on understanding of actions as goal-directed,

the unfamiliar path presented in Experiment 2 should detract from infants' identification of action goals. When no box is present at the end location, infants in both conditions should be more likely to copy observed non-goal directed actions than in the box condition.

Experiment 1

The aim of Experiment 1 was to replicate the findings of Carpenter et al. (2005). The participants were 24 18-month-old infants (12 boys, 12 girls; $M = 18.60$ months, $SD = 0.81$). Six additional infants were excluded because of loss of interest in the test (5) and procedural error (1). The infants watched as an adult hopped or slid a toy animal into one of two boxes (box condition) or to a final location (no-box condition). As in the Carpenter et al. (2005) study, the adult adopted a strategy supposedly familiar to the infants by moving the toy along the shortest path (the solid arrow in Figure 1). Each condition consisted of four demonstration trials; during each trial, following the demonstration, the adult presented the toy to the infant and waited until 30 s passed or the infant made a relevant response. We scored whether infants copied the adult's action style and choice of end location. Inter-rater reliabilities were 96% (*kappa* = .91) for action style and 95% (*kappa* = .84) for location, based on 50% of videotaped test sessions. In addition, we recorded the infants' anticipatory looks at the goal in the box condition by coding whether they looked at the box prior to the arrival of the toy. Inter-rater reliability for anticipatory looking was 91% (*kappa* = .71) based on 33% of videotaped test sessions.

Figure 2 shows the mean percentages of trials in which infants matched the adult's action style or choice of location. In the box condition, infants matched the box ($M = .50$, $SD = .26$) more often than they copied the action style ($M = .20$, $SD = .24$), $t(23) = 3.73$, $p = .001$; in the no-box condition, they produced the opposite pattern of matching (action style: $M = .66$, $SD = .28$; location: $M = .03$, $SD = .09$), $t(23) = 10.76$, $p < .001$. Further analyses revealed that the infants' choice of the same box as the adult (number of trials in which they copied the adult's goal box/number of trials in which they placed the toy in the box) was significantly greater than chance ($M = .62$,

Figure 1

Box (left) and no-box (right) conditions. The solid arrow depicted the familiar (straight-line) path presented in Experiment 1; the dashed arrow depicted the unfamiliar (turning-line) path presented in Experiment 2.
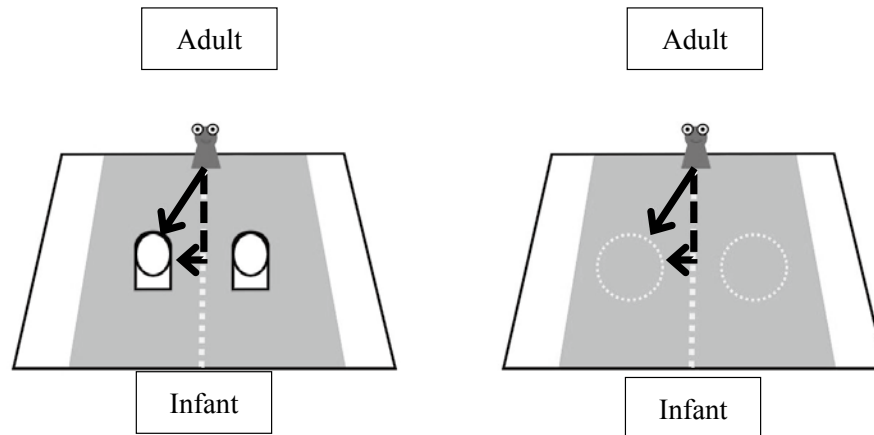

Figure 2

Mean percentages of matching location and matching action style in
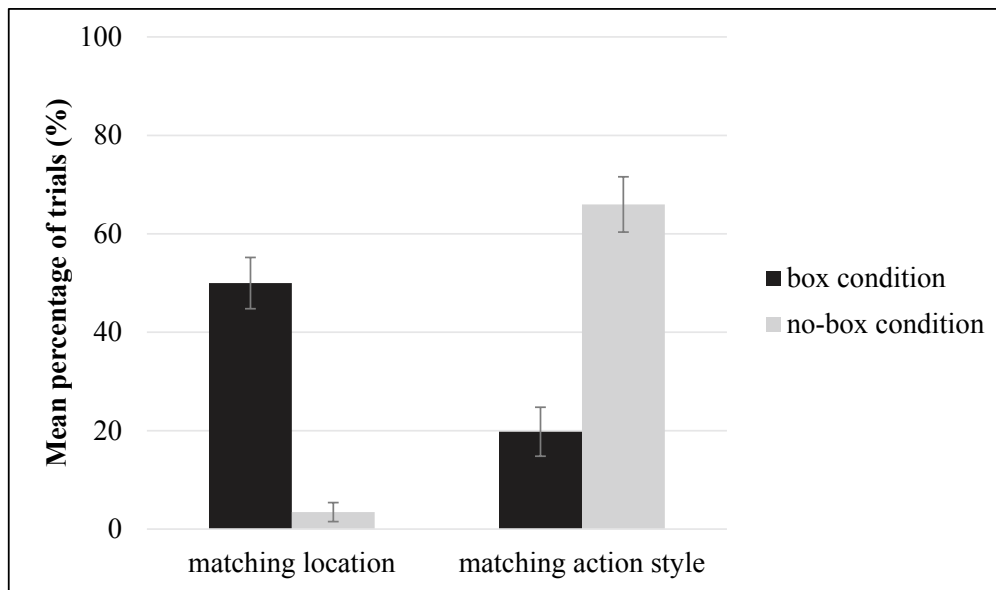
$SD = .21$, $t(21) = 2.65$, $p = .015$), suggesting that they recognized the adult's goal in their selective imitation. Although the infants shifted their gaze to the goal box before the toy arrived ($M = 1.38$ s, $SD = 0.75$, $t(23) = 9.03$, $p < .001$), there was no significant correlation between the mean proportion of trials in which the infants showed anticipatory looking ($M = .78$, $SD = .24$) and the mean proportion of trials in which they copied the adult's goal, $r = -.05$, $p = .835$.

Figure 3

Mean percentages of matching location and action style in Experiment 2
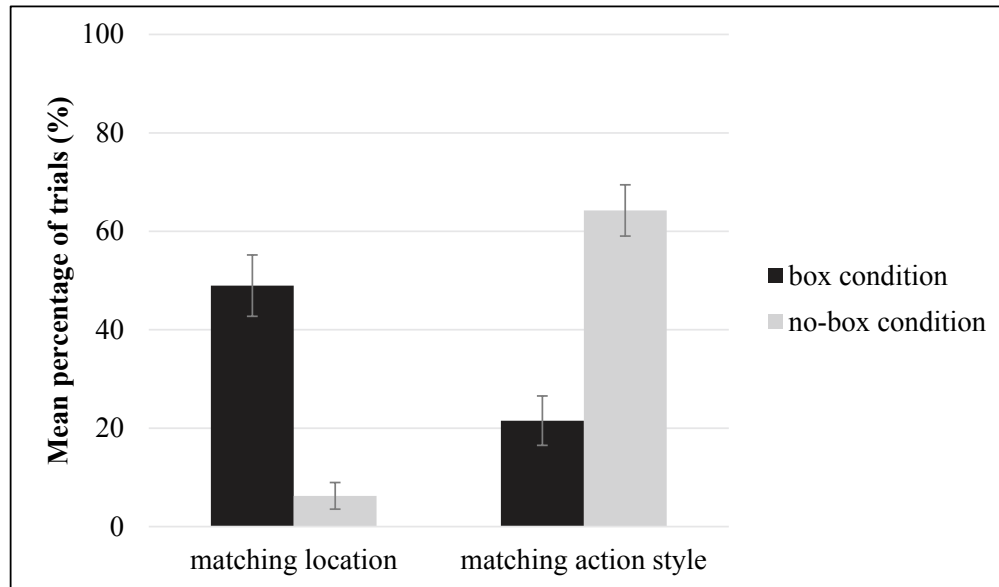
Experiment 2

In Experiment 2, the Experiment 1 task was modified by presenting a novel turning-line path. The participants were 24 18-month-old infants (12 boys, 12 girls; $M = 18.69$ months, $SD = 0.94$). Seven additional infants were excluded because of loss of interest in the test (5) and procedural error (2). The procedure and scoring were identical to those in Experiment 1, except that the adult moved the toy along the midline and did not choose the goal until it arrived between the two end locations (the dashed arrow in Figure 1). Inter-rater reliabilities were 97% (*kappa* = .94) for action style, 94% (*kappa* = .80) for location, and 91% (*kappa* = .71) for anticipatory looking. As shown in Figure 3, the infants produced a pattern of imitation similar to that obtained in Experiment 1. In the box condition, they copied the goal box ($M = .49$, $SD = .31$) more often than the action style ($M = .21$, $SD = .25$), $t(23) = 3.02$, $p = .006$; in the no-box condition, they produced the opposite pattern of imitation (action style: $M = .64$, $SD = .25$; location: $M = .06$, $SD = .13$), $t(23) = 11.31$, $p < .001$. However, unlike in Experiment 1, the infants' choice of the adult's goal ($M = .56$, $SD = .31$) was not significantly greater than chance, $t(23) < 1$, indicating

no evidence of goal recognition. As in Experiment 1, there was no significant correlation between the mean proportion of trials in which infants showed anticipatory looking ($M = .16$, $SD = .19$) and the mean proportion of trials in which they copied the adult's goal, $r = .14$, $p = .524$.

General Discussion

In both experiments, the infants differentially reproduced the goal or action style depending on whether the action ended in an observable outcome. They were more likely to copy the goal while ignoring the movements when the toy was moved and placed in a box and to copy the movements when there was no box at the end location. However, further analyses revealed that the goal box was significantly preferred only in Experiment 1, in which the path of motion was familiar to the infants, suggesting that familiarity of actions plays a privileged role in identifying goal-directedness.

GOADI, which maintains that goals dominate action processing, is not supported by the results of this study. According to GOADI, in both experiments the infants should have identified the goal equally efficiently, because

they observed the same outcome (the toy in the box). Nevertheless, the goal box was not significantly preferred in Experiment 2, in which a novel turning-line path was presented. Thus, ignoring the behavioral means does not guarantee that the endpoint of a person's action will be accurately copied.

Our data also rule out the possibility that the infants' success in copying goals in Experiment 1 was due to the direction of movement of the path that directed their attention to the goal box at the start of each demonstration, given that they showed greater anticipatory looking toward the goal box during observation but it was not related to the accuracy of copying goals. Similarly, given that the infants showed similar levels of copying movements in the no-box condition in both experiments, it is unlikely that they paid more attention to the manner of action in Experiment 2 because the turning-line path did not cue them to attend to the goal box at the start of the demonstration.

The results of this study are consistent with the notion that understanding of goals is related to the ability to match observed actions with one's own motor repertoire. The hypothesis of direct mapping presupposes a perception-action transduction that transfers observed acts into infants' motor patterns (Bekkering et al., 2005; van Elk et al., 2008). According to this view, infants benefit from seeing actions that they can perform, because familiar actions directly activate the equivalent body movements in their own motor repertoires. Support for the direct mapping hypothesis comes from infants' understanding of goal-directed actions (Gerson & Woodward, 2014; Hamlin et al., 2008; Sommerville et al., 2005; Woodward, 1999) and object concept (Boyer & Bertenthal, 2016; Longo & Bertenthal, 2006). For example, Longo and Bertenthal (2006) tested 9-month-old infants in an observational version of the A-not-B paradigm and found that they were equally likely to make perseverative errors following active search by themselves or following observation of the experimenter's

reach, in the latter of which they perseverated after seeing an ipsilateral (but not contralateral) search by the experimenter. As the 9-month-olds typically reached ipsilaterally, the findings suggest that a motor mapping mechanism underlies infants' encoding of others' actions.

More broadly, the results of this study lend support to recent research on the mirror neuron system (MNS). The MNS plays a prominent role in both imitation (Iacoboni et al., 1999) and goal understanding (Fogassi et al., 2005). Although the MNS is typically triggered by observing familiar actions on objects (grasping, placing, manipulating, etc.), it can be modified by experience and develops sensitivity to actions produced through tool use or in the absence of objects (Brass & Heyes, 2005; Ferrari et al., 2005; Iacoboni et al., 2005; Rizzolatti et al., 1996). For example, observation of crawling compared to walking videos elicited stronger mu- and beta-desynchronizations in infants who had more experience with crawling than with walking, suggesting that understanding of actions is closely related to infants' own motor experience (van Elk et al., 2008). Similarly, observation of piano playing finger movements elicited stronger mirror activation in pianists than in musically naïve persons (Haslinger et al., 2005). The evidence suggests that the motor mapping mechanism continuously develops from early childhood to adulthood.

Our findings present a challenge to the GOADI interpretation of the Carpenter et al. (2005) paradigm. Under the GOADI framework, this paradigm has been used to assess the ability of young children to understand the goals underlying actions (Sakkalou et al., 2013; Yu & Kushnir, 2020). We suggest that researchers should consider the relation between familiarity of actions and goal understanding and remain cautious when interpreting the differential imitation of ends and means across conditions. A follow-up study will investigate whether self-produced and observational training experience can lead infants to privilege goals in imitating unfamiliar actions on objects.