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Goal saliency boosts infants' action prediction for human manual actions, but not for mechanical claws

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ABSTRACT

Previous research indicates that infants' prediction of the goals of observed actions is influenced by own experience with the type of agent performing the action (i.e., human hand vs. non-human agent) as well as by action-relevant features of goal objects (e.g., object size). The present study investigated the combined effects of these factors on 12-month-olds' action prediction. Infants' (N = 49) goal-directed gaze shifts were recorded as they observed 14 trials in which either a human hand or a mechanical claw reached for a small goal area (low-saliency goal) or a large goal area (high-saliency goal). Only infants who had observed the human hand reaching for a high-saliency goal fixated the goal object ahead of time, and they rapidly learned to predict the action goal across trials. By contrast, infants in all other conditions did not track the observed action in a predictive manner, and their gaze shifts to the action goal did not change systematically across trials. Thus, high-saliency goals seem to boost infants' predictive gaze shifts during the observation of human manual actions, but not of actions performed by a mechanical device. This supports the assumption that infants' action predictions are based on interactive effects of action-relevant object features (e.g., size) and own action experience.

During their first year of life, infants develop the ability to predict the goals of observed actions, which is a prerequisite for more sophisticated skills such as successful interactions with other people. To illustrate, infants as young as 6 months start to predict the goals of observed highly familiar everyday actions (Hunnius & Bekkering, 2010; Kanakogi & Itakura, 2011; Kochukhova & Gredebäck, 2010), whereas 12-month-olds predict the goals of more complex actions, such as transporting objects into containers (Cannon, Woodward, Gredebäck, von Hofsten, & Turek, 2012; Falck-Ytter, Gredebäck, & von Hofsten, 2006).

Recently, several factors have been identified that impact infants' action prediction. Many studies indicate a close relationship between infants' own motor experience and their ability to predict the actions performed by others (Cannon et al., 2012; Gredebäck & Kochukhova, 2010; Gredebäck & Melinder, 2010). For example, infants' emerging ability to grasp objects at the age of 6 months is strongly correlated with their ability to predict the goal of human reaching and grasping actions (e.g., Kanakogi & Itakura, 2011). Similarly, 12-month-old infants' performance in a behavioural task consisting of placing

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toys into containers is linked to their predictive gaze shifts during the observation of transporting actions (Cannon et al., 2012). And, at the same age, infants' experience with feeding actions correlates with their anticipatory gaze performance during the observation of feeding actions (Gredebäck & Melinder, 2010).

The assumption that infants' goal anticipation is connected to their own action experience is further corroborated by findings that infants encode and predict the goals of grasping actions performed by human hands, but do not do so when observing the same actions performed by mechanical claws (e.g., Cannon & Woodward, 2012; Kanakogi & Itakura, 2011). These results are in line with the idea that there is a link between infants' action experience and their action perception, leading to enhanced cognitive processing of an observed action when own agentive experience with that action is stored as motor information in the brain (e.g., Falck-Ytter et al., 2006; Gerson & Woodward, 2014; Rizzolatti & Craighero, 2004).

The properties of (goal) objects also influence how infants distribute, organize, and hold their visual attention (e.g., Cohen, 1972; Guan & Corbetta, 2012; Newman, Atkinson, & Braddick, 2001) or how they predict observed actions (Henrichs, Elsner, Elsner, & Gredebäck, 2012). For instance, 12-month-olds exhibited goal-directed gaze shifts earlier when observing a human hand reaching for a large object, compared to when the hand reached for a small object (Henrichs et al., 2012). Different grip apertures used for grasping large vs. small objects were not responsible for the differences in gaze performance, because the same results occurred when the grip aperture was kept constant in both conditions. Ambrosini et al. (2013) also found effects of goal size on younger infants' predictive gaze shifts for human-hand actions: 6-, 8-, and 10-month-old infants exhibited significantly earlier gaze shifts when the hand reached for a large object using a whole-hand grasp compared to using a closed-fist configuration. In contrast, when the hand reached for a small object, significantly earlier gaze shifts for a precision grasp than for the closed-fist occurred only from 8 months onwards, and infants' gaze-shifts were predictive (i.e., gaze arrived at the goal object before the moving hand did) at 10 months. This corroborates first, that action prediction interrelates with infants' ongoing motor development and/or action experience. Second, together with the overall finding that more action predictions occurred for the large compared to the small goal object, these results support an impact of goal size on infants' anticipatory gaze performance.

Taken together, there is evidence that infants' action prediction is connected to their own ability to perform actions (e.g., Gredebäck & Melinder, 2010; Kanakogi & Itakura, 2011), and that properties of the goal object influence infants' predictive gaze-shifts (Ambrosini et al., 2013; Henrichs et al., 2012). What remains unclear is whether effects of goal size on predictive gaze-shifts interact with factors such as own action-experience or familiarity of the agent, or if they reflect general attention processes that operate independently of action processing (Henrichs et al., 2012). Evidence for the latter comes from findings that large objects automatically capture adults' attention in object-search tasks, simply due to their increased perceptual saliency compared to small objects (e.g., Proulx, 2010). In this perceptual context, saliency is defined as the presence of perceptual properties of goal objects that attract infants' and adults' focus of attention, such as shape, size, orientation, or colour (e.g., Cohen, 1972; Guan & Corbetta, 2012; Sorrows & Hirtle, 1999; Treisman & Gelade, 1980; Wolfe & Horowitz, 2004). Along this line, the perceptual saliency of the goal object might enhance infants' predictive gaze-shifts independently of the observed action, with large objects making it relatively easier to disengage visual attention from the moving hand and to shift gaze to the goal. Indeed, Henrichs et al. (2012) and Ambrosini et al. (2013) found an overall advantage for shifting gaze to a large goal object, the former even after controlling for grip size (large vs. small aperture), the latter independently from the shaping of the reaching hand (whole hand/precision grasp vs. closed fist).

However, in the action context, effects of saliency may emerge from the important role of goal size for action planning and execution. During grasping actions, the size of the target object is rapidly processed, determining grip aperture already during the reaching phase (Santello & Soechting, 1998). Here, large goals may exhibit more saliency than small goals because planning movements to the former require relatively less effort (e.g., Park, 2002). Indeed, already infants reach faster and preshape their grasp earlier when their actions are directed towards large compared to small goal objects (Zaal & Thelen, 2005). If infants' action prediction relies on their own action experience (Ambrosini et al., 2013; Kanakogi & Itakura, 2011), goal size may therefore produce action-specific saliency effects. Accordingly, Ambrosini et al. (2013) found earlier predictive gaze shifts to a large object for a pre-shaped hand, compared to a closed-fist configuration, in 6- to 10-month-olds. However, for a small object, this condition difference occurred only from 8 months onwards, with predictive gaze shifts occurring only at 10 months, indicating that effects of goal size on action prediction interacted with infants' emerging ability to use the precision grasp. By presenting a human hand in all conditions, Ambrosini et al. varied only the functionality of the action and kept the familiarity of the agent constant. It has been argued that infants predict human actions more readily than movements of non-human agents, because the former allow for better mapping on own sensorimotor experience (Kanakogi & Itakura, 2011). If so, the size of the goal object should influence infants' predictive gaze shifts only for observed familiar human manual actions, but not for non-human actions which infants have no previous experience with.

To test this idea, we presented 12-month-old infants with either a human hand or a mechanical claw repeatedly reaching for a goal object in a small or large goal area (Low-saliency vs. High-saliency goal condition). This age group was chosen because previous research has demonstrated well-established predictive-gaze performance for observed human manual actions in 1-year-olds (e.g., Falck-Ytter et al., 2006; Gredebäck & Melinder, 2010). The kinematic information was kept constant between the saliency conditions (see Henrichs et al., 2012), in that the hand or claw always reached for one small goal object, which was presented either alone (small goal area; Low-saliency condition) or as one out of four small objects that established a large goal area (High-saliency condition). If the size of the goal area, as a perceptual feature, had a general impact on 12-month-olds' predictive gaze shifts, then infants in the High-saliency condition should exhibit significantly earlier gaze shifts than infants in the Low-saliency condition, irrespective of the type of agent or familiarity of the action, respectively. If,