

Sharing and Comparing: How Comparing Shared Goals Broadens Goal Understanding in Development

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Gerson, S. A. (2014). Sharing and comparing: How comparing shared goals broadens goal understanding in development. *Child Development Perspectives*, 8, 24-29. doi: 10.1111/cdep.12056

Abstract

How we recognize the goals of others is a critical question for those interested in social, cognitive, and linguistic development. The origins of goal understanding exist early in life—that is, infants recognize the intentional relations (e.g., between actor and goal) that underlie intentional actions. In this article, I propose one mechanism through which these initially narrow goal representations can be generalized: comparison. I briefly review evidence that comparison facilitates detection of relational similarities across several domains, then address theoretical and neural findings consistent with the notion that comparison plays a role in social-cognitive development. I discuss more direct evidence that infants can and do expand their recognition of others' goals through comparison and then propose several hypotheses concerning the ways in which the benefits of comparison (and facilitative cues to compare) may influence the generalization of action understanding throughout development.

Social interactions drive learning and development across a variety of domains. We learn from and about others by observing and engaging with them. Recognizing others' goals and intentions is critical to this learning. Intentional relations, the links between actors and their goals, underlie and define intentional actions and are critical to recognizing the goals of others' actions (Barresi & Moore, 1996). Goal recognition begins early in development: Six-month-olds recognize the relation between an actor and the object for which she reaches as measured in a habituation paradigm (see Figure 1A; Woodward, 1998). By seven months, infants can act on this knowledge and imitate the choice of a reaching action by choosing the same toy as an experimenter in an imitation paradigm (Hamlin, Hallinan, & Woodward, 2008). And at 11 months, infants anticipate the target of intentional relations by looking to the expected goal (object) of a reach before the action occurs (Cannon & Woodward, 2012). Across these paradigms, infants' analysis of intentional relations is specific to the well-formed actions of agents. Infants recognize the intentional relations inherent in actions that involve using tools (Biro & Leslie, 2007; Jovanovic et al., 2007; Sommerville & Woodward, 2005) and anticipate goals in multistep sequences (Gredebäck & Kochukhova, 2010) later than they understand one-step instrumental actions such as grasps. Together, these findings suggest a broadening of infants' capacity to detect the intentional relations in various actions produced by humans across

development (see Woodward et al., 2009 for a summary) and raise a question: What are the developmental origins and the generalization mechanisms involved in broadening infants' capacity to apprehend the intentional structure of human actions?

One source of insight into intentional relations comes from infants' own actions. For example, 3-month-olds are not yet proficient at producing efficient object-directed reaches wherein they direct their actions toward an object and retrieve it. When 3-month-olds are given Velcro mittens to play with Velcro-covered toys, they produce more efficient, object-directed reaches. This exercise affects infants' perception of people (attention to faces; Libertus & Needham, 2011), events (causal perception; Rakison & Krogh, 2012), and intentional relations (Sommerville et al., 2005; Figure 1). Active training has yielded similar effects for means-end actions at 8 and 10 months (Gerson et al., under review; Sommerville, Hildebrand, & Crane, 2008). Neural evidence for the link between action production and perception is also growing. Shared neurocognitive representations (mirror systems) indicate that motor areas of the brain are activated both when a person produces and observes a motorically familiar, goal-directed action (Rizzolatti & Craighero, 2004).

Both behavioral and neural evidence highlight the role of one's specific motor repertoire in the perception of others' goal-directed actions. For example,

individual differences in pointing are related to recognizing pointing, but not gaze, as object directed (Brune & Woodward, 2007). The question of how we move beyond these initial ties is not negligible. However, the problem of generalization is not unique to this domain. Across a variety of fields, spanning verb learning to science education, specificity can sometimes be helpful and informative (e.g., the past tense of *run* is not *runned*), but it can also be limiting if never extended. In the domain of intention understanding, we must come to recognize the goals of actions we have never produced ourselves; generalization can help when applied appropriately (e.g., recognizing common goals across varying physical manifestations).

In studies of primates (e.g., Ferrari, Rozzi, & Fogassi, 2005) and apraxic patients (e.g., Gazzola et al., 2007), under certain circumstances, the mirror system is recruited when people observe actions that they have not produced. Monkeys who had never acted with tools themselves but retrieved food from tools using their hands (during daily feeding routines) later evidenced neural activity in the monkey ventral premotor area F5 when observing actions carried out with tools (Ferrari et al., 2005). One explanation for this finding is that the motor system adapted to the tool-use action through purely visual familiarity. Alternatively, the co-occurrence of the monkey's grasping action (a motorically familiar action) and the tool action (a motorically unfamiliar action) during feeding may have provided

an opportunity for the motor system to adapt to a broader array of actions--shifting from responses to the hand reach alone to both the hand and the tool-use actions. Such simultaneous perception of actions that babies have seen but not yet produced may play an important role in the generalizing intention understanding.

Comparison as a Mechanism of Change

Comparison, a domain-general mechanism that aids recognition of relational similarities across exemplars, may provide an avenue through which intentional relations can be generalized. Structure mapping, the mapping of relational similarities between exemplars, may occur via comparison processes and may facilitate the creation of inferences based on relational similarities (Gentner, 2003). The influence of comparison on adults' and preschoolers' identifying matching relations has been shown in domains of spatial representations (Loewenstein & Gentner, 2005), verb learning (Childers, 2011), and problem solving (Rittle-Johnson & Star, 2009). For example, when 3-year-olds played a hiding game in which they needed to map a spatial relation (e.g., the bone is under the chair next to the bed) from one exemplar to another, they were more proficient at extending the relation to a new scenario when they first compared two exemplars side by side (Loewenstein & Gentner, 2005; see Figure 2A). In the domain of intention understanding, interactions with others provide rich opportunities to compare the intentional relations structuring our own and others' actions, and allow us to seek

out similarities between them. Joint actions, in which two people act on a common goal, are one case in which comparing the intentional relations in two peoples' actions could facilitate intention understanding.

Comparison may similarly support learning during infancy. For example, in one study (Oakes & Ribar, 2005), infants were shown exemplars of a category (i.e., dogs and cats) either simultaneously or sequentially. Categorical extension was then tested in a paired comparison task. The 4-month-olds in the study detected the categorical information when exemplars from familiarization were presented simultaneously but not when presented sequentially. The young infants could compare simultaneously presented exemplars and abstract relevant information from these exemplars (see also Casasola, 2005; Pruden, Hirsh-Pasek, Maguire, & Meyer, 2004; Figure 2B).

Comparison in the Action Domain

Across a variety of perspectives concerning the emergence of intention understanding, a common theme is that comparisons between self and other support recognition of others' intentional actions. For example, the "like me" hypothesis (Meltzoff, 2005) suggests that the bodily mapping between an infant's actions and the actions of others provides the basis for extending knowledge about the self to others, and vice versa. Moreover, infants may learn about others' intentions via analogy to their own intentional states (Tomasello, 1999). Despite

these views, the role and nature of comparison processes in the domain of intention understanding has not been examined empirically in infants.

Imitation is important in understanding others' intentions because it may facilitate comparison between one's own and another's goals (Meltzoff, 2005). In addition, comparison during the physical alignment of one's own and others' actions during joint attention allows infants to form an analogy between self and other (Barresi & Moore, 1996). In shared attention, the infant's action and attentional state co-occur with the actions and attentional states of another individual; the infant can compare these states and infer that the other likely possesses attentional and intentional states that are similar to his or her own . However, joint attention is not the only context in which infants' and others' intentions are aligned. Alignment of one's own and others' actions could occur while acting on an object at the same time as another individual or engaging in a joint action with another; these scenarios may provide opportunities for comparison (see Reddy, Markova, & Wallot, 2013).

The benefits of comparison during simple joint actions have been examined using tool-use actions (Gerson & Woodward, 2012). Between 6 and 12 months, infants grasp objects, but do not use tools to achieve goals (e.g., as a means to retrieve another object; Sommerville & Woodward, 2005). Similarly, at these ages, infants recognize the relation between a person and her goal in a reaching action,

but do not recognize the goal of another person's tool use without extra cues or training (Biro & Leslie, 2007; Sommerville & Woodward, 2005). Woodward and I hypothesized that allowing infants to compare simultaneously produced grasping and tool-use actions would help them discern the similar intentional -relation (between actor and goal object) between the two actions. We assessed this possibility in a goal imitation paradigm.

In one study, 7-month-olds were familiarized with a set of toys, an experimenter, and a tool in one of several ways. In the critical case (*alignment condition*), infants reached for a toy at the same time the experimenter held the toy with a tool (see Figure 3A). In this way, infants could simultaneously perceive the familiar action they produced (the grasp) and the unfamiliar (tool-use) action produced by the experimenter. In the familiarization period of the control conditions, infants were given information about either the association between the tool and toys for which they reached or the functional properties of the tool, as both of these have been hypothesized to facilitate goal analysis (e.g., Biro & Leslie, 2007; see Figure 3D).

After familiarization, we assessed whether infants viewed the experimenter's tool-use actions as directed to a goal, using a method that assessed infants' propensity to imitate the goals of others' actions. Infants saw an experimenter act on one of two toys (see Figure 3C) and were then given a chance to choose a toy

themselves. In previous studies (e.g., Hamlin et al., 2008), 7-month-olds imitated the experimenter's toy choice (goal) when the experimenter previously acted on her goal in a manner the infant recognized as goal-directed (e.g., grasping) but not when she acted on it in an unfamiliar manner (e.g., touching with back of hand). In the current study, we expected that infants would imitate the experimenter's tool-use action if they recognized the intention of her action but would choose randomly if they did not. Only infants in the alignment condition chose the same toy as the experimenter more often than would be expected by chance (see Figure 3D). Lack of imitation in the control conditions, despite similar attentional patterns across all conditions, suggests that associations between the toys and tool, attention to the two toys, and functional information about the tool were insufficient to lead to imitation. Thus, without any experience using the tool, infants were able to discern the goal of the experimenter's tool-use action by comparing their own goal when grasping and the experimenter's goal when using a tool.

Implications of the Comparison Process in the Action Domain

The proposed perspective leads to several hypotheses concerning the emergence of action understanding and the mechanisms that facilitate this process. For example, the relational information to be transferred must be known for one of the exemplars being compared for the exemplar to be used as a basis of comparison (Gentner, 1988). Thus, active experience may act as a base for moving

beyond initially context-specific intentional-relations. That is, initial active experience may create portable knowledge about intentional-relations that can then be applied to new contexts via comparison. In the work described previously (Gerson & Woodward, 2012), being able to produce and understand the goal of the grasping action was necessary for infants to benefit from comparing this action with the novel tool-use action.

Additional indirect evidence for the hypothesis that active experience may act as a base of comparison comes from the studies that used Velcro mittens with 3-month-olds. When the infants played with toys without mittens and then observed mittened actions produced by an experimenter, infants did not later recognize the goal of an actor's mittened grasping action. However, infants who produced more unmittened object-directed activity prior to watching the mittened adult were more likely than their less active peers to later recognize the goal of the mittened action (Gerson & Woodward, under review). Unmittened activity was unrelated to goal recognition for infants who did not see the mittened adult's actions. Infants who were more proficient at acting without mittens may have used their initial representation about the intentional relations of grasps (gained through active experience) to compare their unmittened actions with the mittened actions seen during observational training and to extend their recognition of the intentional relation during the unmittened portion to the observed mittened actions. Research

should examine whether this mechanism can and does play a direct role in extending information about intentional relations to new contexts.

Perceptual similarity facilitates comparing and detecting relational similarities between exemplars (Gentner, 1988). Thus, comparison of perceptually similar objects and actions may facilitate recognition of a broader array of intentional relations independent of the particular compared objects. Similarity in perceptual features (i.e., matched objects/tools) helps infants compare relations between objects and tools across time, and facilitates efficient *production* of multistep actions. For example, perceptually matched tools or toys helped 10-month-olds transfer problem-solving solutions across multiple exemplars (Chen, Sanchez, & Campbell, 1997; see also Gerson & Woodward, 2013a). Whether this is also true for action perception has yet to be directly tested. However, additional findings from mittens training with 3-month-olds support this hypothesis. When infants in another mittens training study saw different objects in the habituation paradigm (a bear and ball) than those they had acted on during training (a smiley face and box), they did not, as a group, benefit from active training. However, as in the observational condition of the Gerson and Woodward (2013) study, the amount of unmittened activity produced with the smiley and box was related to individual differences in perceiving the goal-agent relation in the grasping action with the bear and ball (Gerson & Woodward, unpublished data). Again, comparison

between the unmittened and mittened actions (with the smiley and box toys) may have helped infants detect the intentional-relation independent of the specific objects involved (allowing infants to extend this relation from mittened reaches for boxes and smileys to mittened reaches for bears and balls).

Until now, comparison was most frequently studied in domains requiring comparison of two external exemplars (e.g., spatial relations of two rooms). In contrast, comparison in the social-cognitive domain emphasizes comparisons between oneself and another. For example, in the study described previously (Gerson & Woodward, 2012), 7-month-olds compared their own action (and goal) with an experimenter's action (i.e. second-person perspective). Given the importance of active experience in action perception, we examined whether comparing the tool-use action with a familiar action (grasp) produced by another actor would provide the same benefits as comparing the novel action with one's own (familiar) actions (see Figure 3B; Gerson & Woodward, 2013b). Ten-month-old infants initially benefited from engaging in but not from observing alignment (as measured through imitation). To examine whether cues that facilitate comparison in other domains play a similar role in the domain of intention understanding, we conducted the observational condition again, but with labels (e.g., Loewenstein & Gentner, 2005; Pruden et al., 2004). When infants saw the two actors reach for each toy (using a hand grasp or a tool), they also heard both

actors use the same label to identify their goal. Woodward and I hypothesized that this labeling would lead to increased attention to the relevant aspects of the aligned actions (i.e., the relation between the actors and their common goal) and facilitate recognition of the similar intentional relations. Infants imitated the experimenter's goals after observing the labeled alignment, consistent with work showing that labels facilitate comparison across exemplars (e.g., Fulkerson & Waxman, 2006). Thus, early support for comparison processes can take many forms: in simultaneous (vs. successive) presentation of exemplars, in active (vs. observational) engagement in the interaction, and in labels that promote comparison of the relevant aspects.

Comparison between intentional relations is *one* mechanism through which understanding of initial intention can be generalized. Comparison processes likely interact and work in parallel with a variety of other mechanisms throughout development. For example, statistical learning (Baldwin & Baird, 2001), language development (Astington & Baird, 2005), and explicit explanations are likely integrated with these processes in many ways. Furthermore, in this review, I focused on the broadening of intention understanding for specifically human actions. How this hypothesis can be integrated with findings suggesting ascription of intentionality to a broad array of agents early in life remains unanswered (e.g., Hamlin, 2013; Luo, 2011).

To uncover the intricacies of the role of comparison processes in intention understanding, research should examine the particular aspects of social interactions that are critical to learning and generalization, the role language plays in the development of intentional action knowledge, as well as how and when active and observational experience interact in development. Opportunities for comparison between the child's own and others' goals are ubiquitous in children's lives. Children's interactions with others through observation, joint attention, joint action, and shared activities provide rich opportunities to learn about others and their intentions throughout development.

Acknowledgments

I would like to thank Dr. Amanda Woodward for her supervision during my graduate career, and for her support in all of the empirical work cited (conducted during my time in her laboratory). I would also like to thank both Dr. Woodward and Dr. Sabine Hunnius for their helpful feedback on a previous version of this manuscript.

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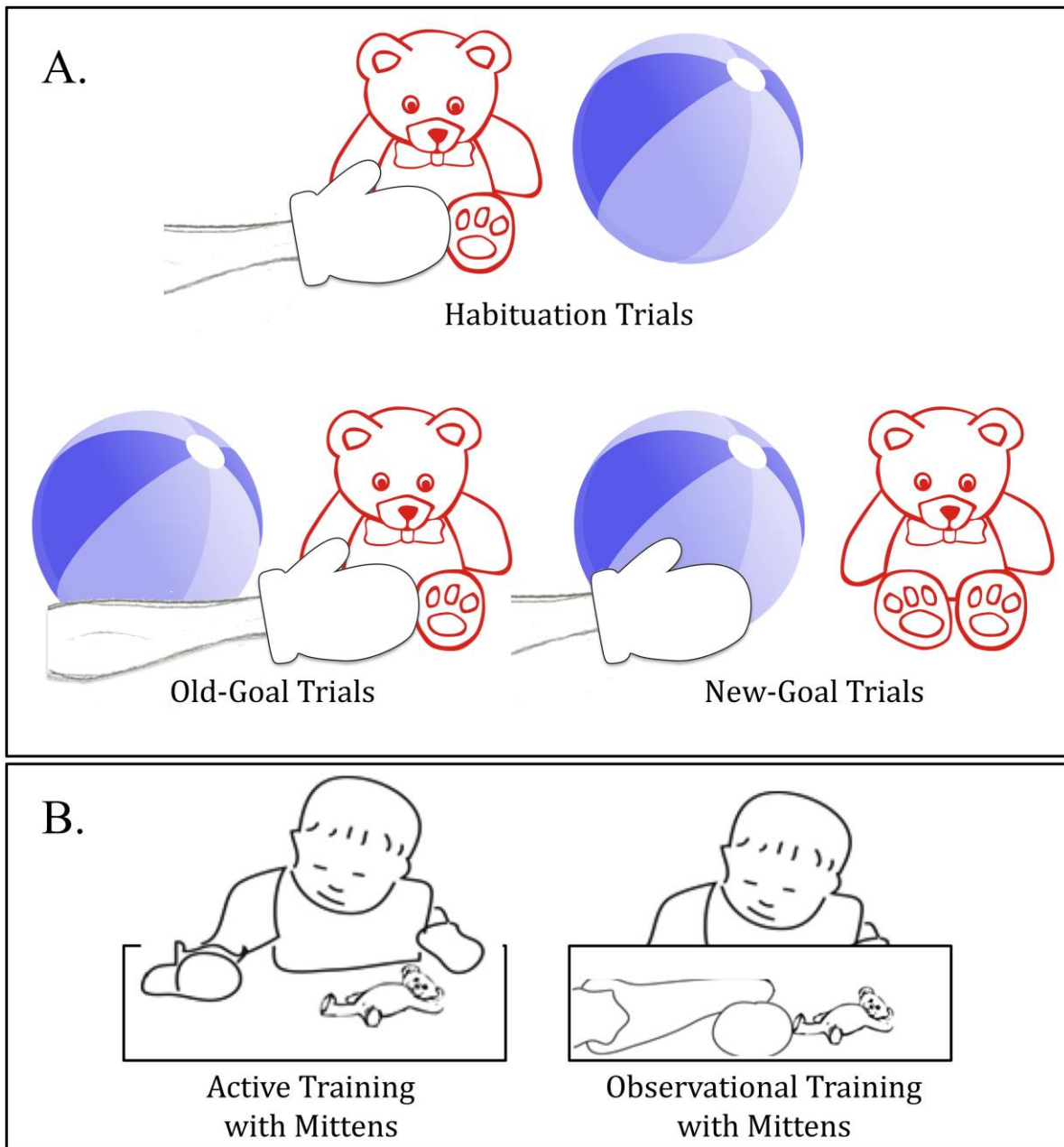


Figure 1. (A) In Gerson & Woodward (in press), infants were habituated to a hand reaching for and grasping one of two objects. In test trials, the placement of the objects was switched and the hand reached for the same toy in a new place (old-goal trials) or a new goal in the same place (new-goal trials). Both this study and Sommerville et al. (2005) used the same habituation procedure (adapted from Woodward, 1998). (B) Infants in Gerson & Woodward (in press) received either active or observational training.

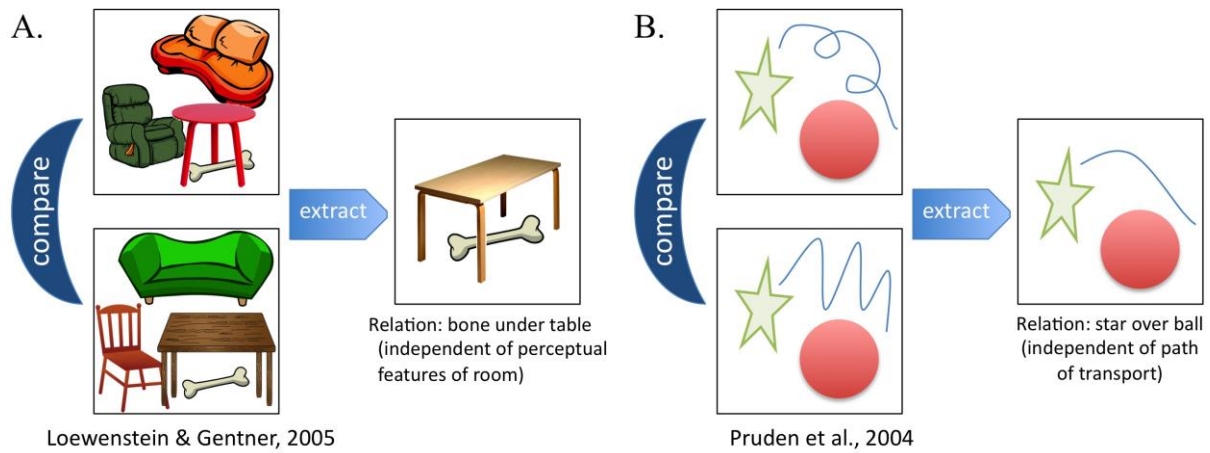


Figure 2. (A) In Loewenstein & Gentner’s (2005) experiments, children compared different model rooms with similar relations to extract the spatial relation of the bone under the table. (B) In Pruden and colleagues’ (2004) experiments, infants recognized the relation *over* via comparison of different movements following the same relational trajectory (over an object).

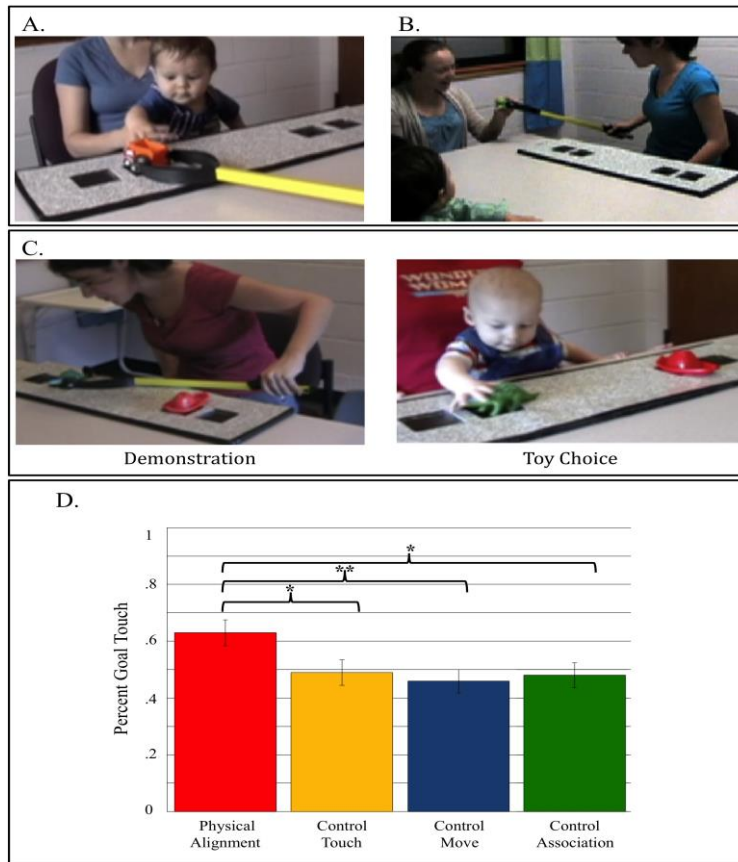


Figure 3. (A) Familiarization of active alignment condition in Gerson & Woodward (2012). (B) Observational condition in Gerson & Woodward (2012). This was visually identical to the labeling condition in Gerson & Woodward (2013). (C) In test trials for each of these studies, infants saw an experimenter reach for one of two toys using a claw (demonstration) and then chose between two toys themselves (toy choice). (D) In Gerson & Woodward (2012), infants in the alignment condition imitated the experimenter's toy choice at greater than chance levels (y-axis: average percentage of test trials on which infants imitated the experiment's toy choice). They were at chance in the three control conditions: Control touch (infant could reach for the claw without a toy present), control move (infant saw experimenter move each toy with the claw, demonstrating functional properties), and control association (infant could reach for each toy held by the claw but the experimenter did not hold the other end of the claw). The alignment condition was the only case in which infants could compare their own reach for the toy with the experimenter's reach for the toy. $**p < .02$, $*p < .05$.