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The Goal Trumps the Means: Highlighting Goals is More Beneficial than Highlighting Means in Means-End Training

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Means-end actions are an early-emerging form of problem solving. These actions require initiating initial behaviors with a goal in mind. In this study, we explored the origins of 8-month-old infants' means-end action production using a cloth-pulling training paradigm. We examined whether highlighting the goal (toy) or the means (cloth) was more valuable for learning to perform a well-organized means-end action. Infants were given the opportunity to both practice cloth-pulling and view modeling of the action performed by an adult throughout the session. Infants saw either the same toy or the same cloth in successive trials, so that the goal or means were highlighted prior to modeling of the action. All infants improved throughout the session regardless of which aspect of the event was highlighted. Beyond this general improvement, repetition of goals supported more rapid learning and more sustained learning than did repetition of means. These findings provide novel evidence that, at the origins of means-end action production, emphasizing the goal that structures an action facilitates the learning of new means-end actions.

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Adults plan actions with a goal in mind prior to initiating movement. Even when performing simple actions like reaching for an object, initiation of the reach is influenced by what the individual plans to do with the object afterward (Berthier, Clifton, Gullipalli, McCall, & Robin, 1996; Johnson-Frey, McCarty, & Keen, 2004; Marteniuk, MacKenzie, Jeannerod, Athenes, & Dugas, 1987; Rosenbaum, Vaughan, Meulenbroek, Jax, & Cohen, 2009). The same is true for infants. In a study by Claxton, Keen, & McCarty (2003), 10-month-old infants adapted their approach for a ball based on the subsequent action they planned to do with it once retrieved. Their approach was faster when they planned to throw it than when they planned to place it, presumably because placing takes more precision than throwing (see Gredebäck, Stasiewicz, Falck-Ytter, Rosander, & von Hofsten, 2009; Mash, 2007; McCarty, Clifton, & Collard, 2001 for similar findings; see Keen, 2011 for a review). Thus, throughout development, rather than being reactions, actions are structured by goals. In addition to performing simple grasping actions with goals in mind, at the end of the first year, infants are increasingly able to engage in means-end actions that require an individual to initiate an action on an object that is not his or her goal in order to retrieve a different object (particularly under supportive conditions involving training; Chen, Sanchez, & Campbell, 1997; Munakata, McClelland, Johnson, & Siegler, 1997; Sommerville, Hildebrand, & Crane, 2008; Willatts, 1999).

The acquisition of means-end actions requires learning at several levels, including becoming skilled at manual interactions with tools as well as learning about the affordances of novel objects (Barrett, Davis, & Needham, 2007; Lockman, 2000). The goal-based nature of infants' action production suggests that, in addition to these kinds of learning, goal representations may support infants' learning about new actions. Evidence from older infants, 24-month-olds, supports this hypothesis: In a study by Bauer, Schwade, Wewerka, & Delaney (1999), emphasis of the goal (the last step) of a sequence of actions was contrasted with emphasis of the means (the first step) to assess how these cues differentially influenced 2-year-old's action planning. Children first explored objects (without any instruction) that could be assembled through multiple steps (baseline). They were then shown the goal state (demonstration of the final step of the problem), the initial state (demonstration of the first step of the problem), or the first two steps of the problem. Both groups of children showed improvement in constructing the object from baseline, but children exposed to the initial state or the first two steps of the problem did not show the same level of improvement as children shown the goal state. These findings demonstrate the power of highlighting goals rather than means for problem solving at 2 years. An important question is whether goal highlighting is equally important in infancy, when means-end action production first emerges.

A study by Chen et al. (1997) suggests that goal highlighting may be no more important than means highlighting for infants less than 1 year. In this work, 10-month-old infants were given three structurally similar three-step problems to solve (involving a barrier, strings, cloths, and a toy). Across the three problems, either the goals (toys) were matched or the tools and context were matched. Infants learned equally well in these two conditions. The two conditions, however, differed in the number of elements that changed across problems. In the matched tools condition, only one feature (the goal) differed across problems and several features (e.g., strings, cloths, table) were consistent. In contrast, in the matched goals condition, all of these contextual features differed across problems and only the goal was consistent. Thus, it is difficult to know whether matched means or goals facilitated problem solving independent of differences in other elements, particularly because context is important for the generalization of learning during infancy (e.g., Rovee-Collier, Griesey, & Earley, 1985). An important open question, then, is whether highlighting the means versus the goal of a multi-step problem is particularly beneficial for problem solving when other contextual variables are held constant.

In this research, we recruited data from a series of training studies conducted in our laboratory in order to conduct a more systematic test of whether highlighting goals or means is most effective for problem solving in young infants. We address the benefits of cueing the goal versus the means in a simple problem-solving task: cloth-pulling. In our task, we assess 8-month-old infants who are at the cusp of learning to perform means-end actions but, as a group, are unable to effectively pull on a cloth to retrieve a toy in a well-organized manner. This age allows us to train infants to engage in problem solving before they otherwise would examine the origins of this ability. The training session involved both practice producing the action and modeling of the action. Infants were first given the opportunity to pull a cloth to retrieve a toy without assistance during four pretraining trials. During training trials, an experimenter demonstrated how to retrieve the toy and allowed the infant to imitate her actions. Posttraining trials were identical to the pretraining session.

All infants engaged with the same two toys and two cloths during pretraining and posttraining and saw all combinations of these cloth and toy pairs. One set of infants (*goal-repeat condition*), however, always saw the same goal twice in a row and then the other goal twice in a row (see Figure 1). In contrast, other infants (*cloth-repeat condition*) saw the same cloth twice in a row and then the other cloth twice in a row. We examined whether infants in these two groups differentially improved in performing well-organized means-end actions throughout the session. We hypothesized that highlighting the goal would be more helpful early in the development of problem solving and that goal-repeat infants would show more rapid improvement.

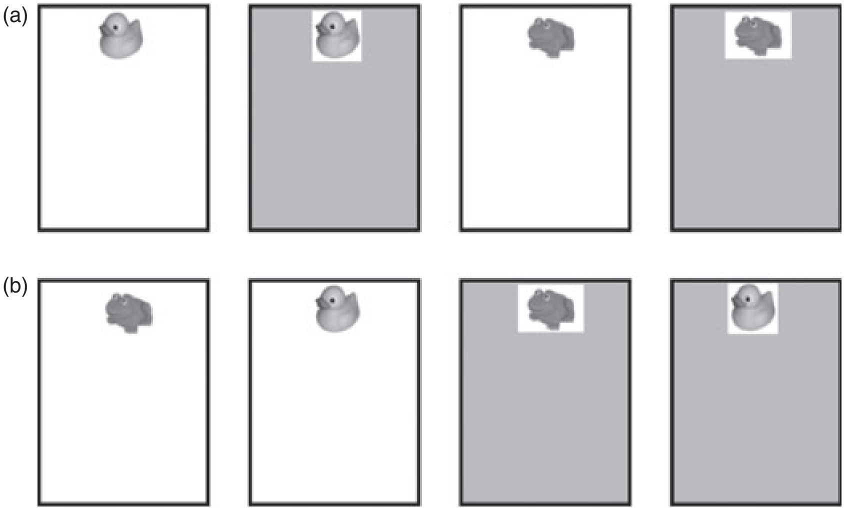

Figure 1 Examples of goal-repeat (a) and cloth-repeat (b) pre- and posttraining orders. *Note*. White cloths in this figure were blue and gray cloths were red.

METHODS

Participants

Seventy 8-month-old infants (mean age = 7.83 months) were selected from two previously conducted studies. All infants from these studies who received one of two particular orders of pretraining and posttraining trials were included in the current analysis: those who viewed cloth repeats during training ($n = 38$; M age = 7.8 months; 15 boys) and those who viewed goal repeats ($n = 32$; M age = 7.87 months; 15 boys). Infants in the original training studies were selected from a database recruited from the Washington, DC, metropolitan area through mailings and advertisements. The sample of infants was 20% African American, 6% Asian, 42% Caucasian, 16% Hispanic, 6% multiracial, and 10% unknown.

Because we were interested in improvement upon training and not how training interacted with existing capabilities, infants who were capable of producing the cloth-pulling action in a well-organized manner prior to any training (coding scheme described below) were excluded from further analyses. The set of infants who remained in the study consisted of 56 infants, similar to the original set of infants in age, gender, and number in each condition (cloth repeat: $n = 30$; M age = 7.8 months; 13 boys; goal repeat: $n = 26$; M age = 7.83 months; 11 boys).

Procedure

Infants sat on a parent's lap at a light gray table, and parents were asked not to influence their infants. An experimenter sat next to the infant. A camera recorded the session for offline coding. During four pretraining trials, the experimenter placed a felt cloth (blue or red, approximately 30 × 20 cm) on the table a few inches away from the infant but within the infant's reach. She then placed a small toy (a green frog or a yellow duck, approximately 5 × 6 cm) at the end of the cloth (see Figure 2a) and looked down so as not to influence the infant. If the infant did not attend to the stimuli, the experimenter tapped near the toy. If the infant retrieved the toy, the experimenter immediately removed the cloth and allowed the infant to play with the toy while she set up the next trial. If the infant did not retrieve the toy, the experimenter removed the cloth and toy and set up the next trial after approximately 30 sec. All infants saw each combination of cloths and toys. Infants in the goal-repeat condition always saw the same goal twice in a row, and infants in the cloth-repeat condition always saw the same cloth twice in a row (see Figure 1). Whether infants saw the blue or red cloth first and/or the frog or duck first was counterbalanced. Infants in the each condition could see one of eight different combinations, resulting from the various toy and cloth pairs and orders.

Immediately following, infants underwent five training trials. In each training trial, the experimenter placed a cloth and toy in front of her and ensured the infant was watching. She then said "look" as she looked at the toy and pulled the cloth toward herself while gazing at the toy and saying "ooh" excitedly. She picked up the toy, looked at it, and said "ooh" again (see Figure 2b). She then placed the same cloth and toy in front of her, said "Let's see that again!," and performed a second demonstration. Then, the experimenter said "Now it's your turn!" and placed the cloth and toy in

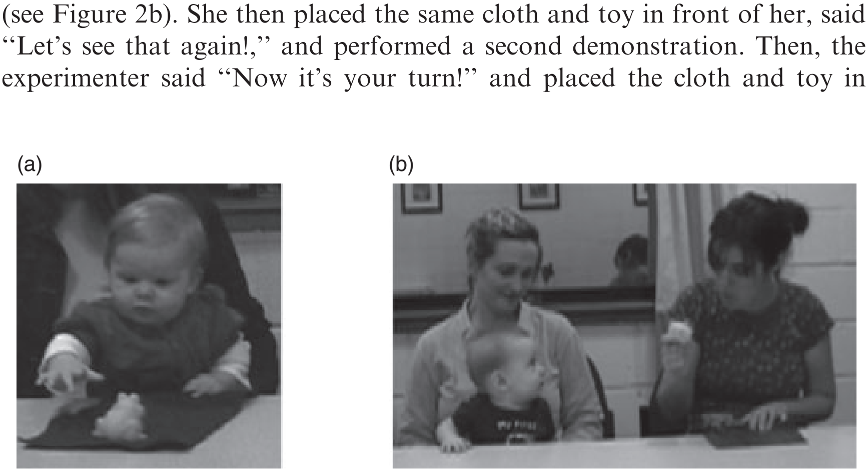

Figure 2 Pretraining and posttraining trails (a) and training trails (b).

front of the infant (as in pretraining trials). The infant again had approximately 30 sec to act. Infants saw five different pairs of cloths and toys (e.g., a turtle on a pink cloth, a whale on a yellow cloth; all were approximately the same size as toys and cloths in pretraining) in pseudorandom order throughout training trials.

Following training trials, infants underwent four posttraining trials that were identical to the pretraining trials. Infants saw the toy and cloth pairs in the same order as they had in pretraining.

Coding

A trained coder assessed whether infants' actions during each trial were *planful* or *unplanful* offline using a digitized video of the session. Actions were coded as planful if the infant maintained focus on the toy while using the cloth to attain the toy and quickly and immediately touched the toy once it was within reach. If the infant did not touch the toy, waited more than 3 sec to retrieve it once within reach, or did not focus on the toy throughout the pull, the trial was coded as unplanful. If the infant knocked the toy out of reach, the trial was coded as a mistrial. In these cases, the coder defined the trial "could have been planful" if the infants' actions appeared planful until the mishap or "could not have been planful" if the infant had already played with the cloth or lost attention to the toy before the mishap. In the analyses, mistrials that could not have been planful were considered unplanful. Mistrials that could have been planful were left out of analyses because it was impossible to determine whether infants' action would have been fully carried out in a well-organized manner (this consisted of 10 trials out of the 910 total).

All coders were blind to hypotheses presented in this paper during coding. A second independent coder recoded all sessions (except for three sessions that could not be double coded due to technical error). The reliability coder agreed with the original coder on 90% of the trials ($\kappa = .80$).

ANALYSES AND RESULTS

Analyses

In our initial analyses, we examined changes in infants' planfulness across trials. Because planfulness was a binary, repeated code, we were unable to examine changes in planfulness across trials using a repeated measures analysis of variance. A more appropriate analysis technique that accounts for potential correlations among repeated observations, accounts for missing data, and is not restricted to normally distributed data sets is the generalized estimating equation (GEE; Ballinger, 2004; Hardin & Hilbe, 2003; Zeger, Liang, & Albert, 1988). GEEs are an extension of generalized linear models that are particularly well suited to analyzing binary or ordinal repeated measures. Using this form of analysis allowed us to estimate predicted probability of changes in planfulness across trials for each condition. Because each participant received a binary code (planful or not) for each trial, predicted probability in each trial translated to the estimated percent of infants within each condition (cloth repeat or goal repeat) who were predicted to be planful in their actions. The output of a GEE consists of Wald χ^2 values for main effects and interactions within a given model and estimated marginal means that can then be examined with pairwise comparisons.

Our second set of analyses assessed how planfulness during pretraining and training sessions influenced infants' actions in posttraining. In these analyses, we used a generalized linear model (GLZM). In order to include all variables of interest, we examined the number of planful trials within each session or portion of a session. In the training session, for example, infants' scores ranged from zero to five, depending on the number of trials during which they produced a planful action. Because count values are not normally distributed, a poisson GLZM was conducted. To examine both main effects and interactions, we centered each covariate before entering it into the analysis.

RESULTS

In an initial GEE, we examined improvements in planfulness within the pretraining trials. In this way, we explored immediate benefits of goal or cloth repeats prior to any modeling during the training phase. Time (first half of pretraining [preA] versus second half [preB]) and condition (cloth versus goal repeats) were entered as predictor variables, and we examined both the main effects and the interaction between these two factors. Importantly, these time periods (preA and preB) compare performance before and after exposure to the first repeat of either the goal or the cloth. Prior to further analyses, we verified that age did not differ between conditions ($p = .53$) or relate to planfulness ($p = .14$), so age did not drive any possible effects.

We specified an unstructured correlation matrix and probed significant interactions using the least significant differences method for pairwise comparisons of estimated marginal means. A main effect of time (Wald χ^2 (1) $= 4.89, p = .027, \beta = 1.43, \eta^2 = .086$) indicated that infants improved in planfulness from the first to the second half of pretraining. No main effect of condition across pretraining emerged (Wald χ^2 (1) $= 0.079$, $p = .78$, $\beta = 0.79$, $\eta^2 = .0015$), but a Time × Condition interaction was revealed

(Wald χ^2 (1) = 4.25, p = .039, β = 1.38, η^2 = .076; see Figure 3). Paired comparisons demonstrated that infants in the goal-repeat condition significantly improved in planfulness from the first to the second half of pretraining (md = 0.24, SE = 0.09, p = .007, d = 0.55). In contrast, infants in the cloth-repeat condition did not improve during pretraining (md = 0.01, SE = 0.065, p = .90, d = 0.029). Infants in the two conditions did not differ in planfulness during PreA (md = 0.08, SE = 0.062, p = .25), so improvement was not due to initial differences in the groups' planfulness. These findings indicate that infants who saw two consecutive goals repeated in the first two problems improved more rapidly in their planfulness than infants who saw two repeats of the same means.

In a second GEE, we examined the improvement between pretraining and posttraining trials to evaluate whether the learning differences evident during pretraining persisted over the entire session. This GEE examined the main effects of time (pre or post) and condition and the interaction between these two factors. As expected, a main effect of time emerged: Planfulness increased from pretraining to posttraining (Wald χ^2 (1) = 56.47, $p < .001$, β = 1.73, η^2 = .52). Infants in the two conditions did not differ from one another in planfulness during pretraining or posttraining (md = 0.04, SE = 0.057, p = .49, d = 0.10 and md = 0.11, SE = 0.084, p = .18, d = 0.20, respectively; see Figure 4). Thus, the training was effective in improving all infants' abilities to planfully carry out the cloth-pulling action. An additional GEE also indicated that infants in both the cloth-repeat and goal-repeat groups improved from PreB to PostA (md = 0.32, p = .001 and md = 0.23, p = .010, respectively). There was no main effect of condition or Time × Condition interaction (Wald χ^2 (1) = 1.71, p = .19, β = 0.47, η^2 = .032, and Wald χ^2 (1) = 0.29, p = .59, β = 0.23, η^2 = .0055, respectively).

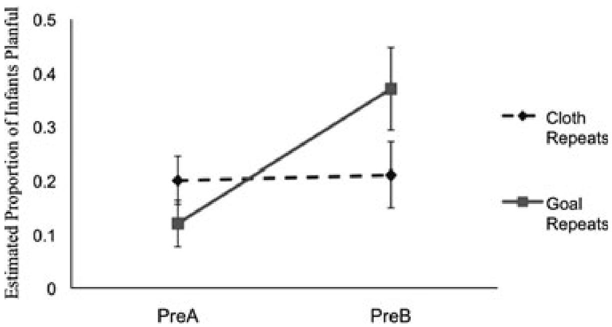

Figure 3 Estimated marginal means for planful infants during the first two (PreA) and last two (PreB) trails of pretraining.

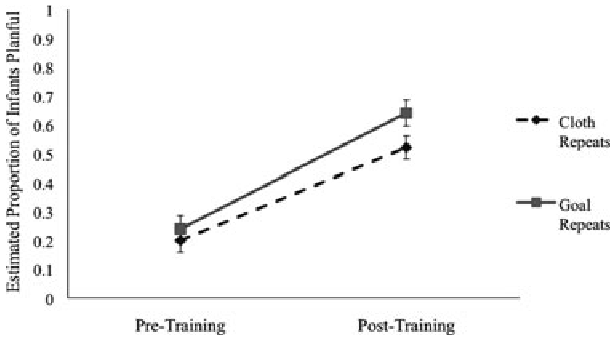

Figure 4 Estimated marginal means for planful infants during pretraining and post-training.

The above analyses indicate that the two groups differed in their improvement in producing cloth-pulling actions prior to viewing modeled demonstrations of the actions (also see Table 1 for raw data). After training, however, infants were comparable in their ability to successfully complete the means-end action. We next address whether infants in the two groups reached this level of success through the same path. That is, we examined the role of pretraining and training phases on infants' planfulness in post-training within each condition. The number of planful trials in posttraining was entered as the dependent variable in a poisson generalized linear model (GLZM). Improvement during pretraining (defined as PreB–PreA) and planfulness during training trials (i.e., infants' own actions immediately following modeled examples) were centered and entered as covariates. Importantly, planfulness during training did not differ between conditions ($t(68) = 0.68, p = .50$).

In the goal-repeat condition, a significant interaction between training responses and pretraining improvement emerged (Wald χ^2 (1) = 6.63,

TABLE 1
Raw Means and Standard Errors of Infants' Planfulness in Each Portion of Each Condition

Portion of session	*Cloth-repeat condition M (SE)*	*Goal-repeat condition M (SE)*
PreA	0.20 (0.045)	0.12 (0.042)
PreB	0.35 (0.076)	0.48 (0.085)
Training 12	0.45 (0.080)	0.42 (0.082)
Training 45	0.48 (0.085)	0.48 (0.085)
PostA	0.65 (0.080)	0.69 (0.084)
PostB	0.65 (0.080)	0.71 (0.079)

p = .010, β = −0.38, η^2 = .23). Analysis of simple slopes indicated that the effect of training was significant for infants one standard deviation below the mean in pretraining improvement ($t(3)$ = 3.58, p < .01, β = 0.66, d = 0.34) but not significant for infants one standard deviation above the mean ($t(3)$ = −0.79, p > .43, β = −0.16, d = 0.028; see Figure 5a). In contrast, in the cloth-repeat condition, no interaction or effect of pretraining improvement was revealed (Wald χ^2 (1) = 0.12, p = .73, β = −0.073, η^2 = .0046 and Wald χ^2 (1) = 0.075, p = .78, β = −0.11, η^2 = .0029, respectively). A conditional effect of training responses, however, was significant (Wald χ^2 (1) = 9.35, p = .002, β = 0.16, η^2 = .26; see Figure 5b). This suggests that the benefits infants achieved during pretraining differed for cloth- versus goal-repeat infants. Goal-repeat infants who improved during pretraining seemed to sustain this improvement independent of subsequent training trials. Goal-repeat infants who did not improve during pretraining were influenced by training trials. In contrast, cloth-repeat infants' actions during posttraining were a function of actions during training regardless of improvement during pretraining.

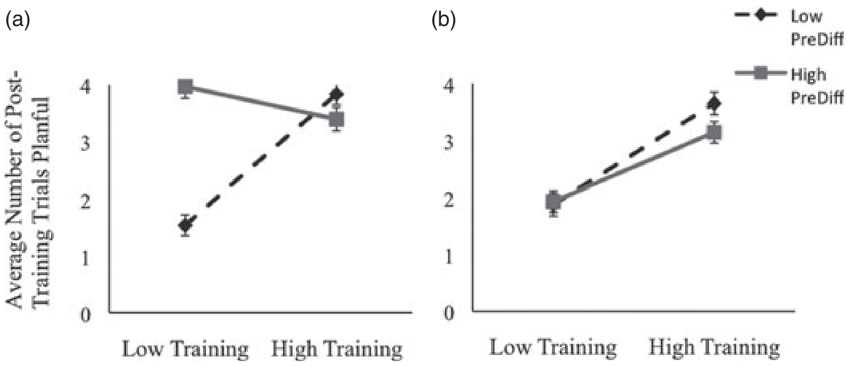

Figure 5 Post-training planfulness based on improvement during pre-training (prediff) and planfulness during training for goal-repeat (a) and cloth-repeat (b) infants.

DISCUSSION

In this study, we explored the origins of infants' production of means-end actions. We examined which aspect of cloth-pulling actions (the goal or the means) was most valuable for improvement in problem solving across a training session. Infants improved with practice regardless of condition. Beyond this general improvement, repetition of goals supported more rapid learning and more sustained learning than did repetition of means. That is, infants who viewed two examples with matched goals in the first two pretraining trials were faster to improve in solving the cloth-pulling problem than infants who viewed two matched cloths. Further, those infants who improved during pretraining in the goal-repeat condition seemed less reliant on training experience than did other infants. Thus, even in very young infants just beginning to engage in problem solving, highlighting goals improves the performance of simple means-end actions.

The current findings are in accordance with Bauer et al.'s (1999) work in demonstrating a benefit of attention to (or priming of) the goal versus the means. As in Bauer et al.'s (1999) study, groups primed with either cue improved in carrying out a sequence of actions (throughout time or relative to a baseline), but the goal was a more effective prime. In addition, the current study indicates that, over a year earlier than revealed in Bauer et al.'s (1999) study, a subtle manipulation of the order in which infants saw problems presented was enough to drive a change in behavior. That is, all infants in the current study saw the same goal toys presented throughout the training session (an equal number of times). The only difference between conditions was whether or not they saw the same goal twice in a row.

These findings add to previous research suggesting that infants are responsive to means-end training in the first year (e.g., Chen et al., 1997) and are consistent with the hypothesis that several factors support means-end learning. Infants in the current study underwent training in both conditions that allowed them to manipulate the cloth, practice performing the action, and view modeling of well-organized means-end actions. Previous studies have demonstrated that these three factors (exploration of the means [i.e., tool], experience producing the action, and viewing examples of a well-organized solution to the problem) all aid infants in performing means-end actions earlier than they would without training (e.g., Barrett et al., 2007; Chen et al., 1997; Lockman, 2000; Sommerville et al., 2008). In the current study, the amount of experience with tools, opportunities to practice the action, and exposure to modeling were held constant across conditions. In accord with the previous research, all infants seemed to benefit from these factors. Our findings add to this literature in isolating a particularly salient effect of experiencing problems with common goals. Because infants were given equal information about the mean or goal in cloth- versus goal-repeat conditions, the current study provides a clearer test of the effects of goal versus means highlighting than the prior study by Chen et al. (1997). Our findings imply that highlighting goals shapes infants' action learning and that goals play a role not only in the production of established action plans, but also in the acquisition of new actions.

In the current study, we contrasted highlighting of the goal with highlighting of the means. Given this design, we cannot be sure whether the differences in infants' learning in these two conditions reflected positive effects of priming the goal, negative effects of priming the means, or a combination of both of these factors. Given the importance of goals in carrying out actions, it is possible that infants have a natural tendency to focus on the goal of a means-end action and that the cloth-repeat condition reduced the salience of the goal, thus leading to worse performance than would be seen at some baseline. Our hypothesis was that priming goals would improve performance more rapidly than priming means. We confirmed this hypothesis, but this leaves open the question of whether these two conditions differ from infants' initial propensities.

Even so, prior findings make it seem unlikely that priming the means would impair infants' learning. For one, in their study with 2-year-olds, Bauer et al. (1999) found that although showing children the goal state was most effective in supporting problem solving, showing them the first step in the sequence also improved performance relative to a baseline phase with no priming. Further, Barrett et al. (2007) found that when 13- to 18-month-old infants were trained to use a novel tool for a function that required a specific hand position, they showed the strongest learning for new uses of the tool that involved the same hand position, and little learning in tasks that required them to adopt a new hand position. Barrett et al. (2007) presented infants with only novel functions in test, and so their study did not provide a measure of the effectiveness of priming goals per se, but their findings clearly indicate the importance of interaction with the tool in means-end learning. Taken together, these studies suggest that priming the means supports infants' problem solving, at least in older infants. Further research is needed to investigate the effects of goal- and means-priming relative to unprimed experience in younger infants.

This issue aside, our findings add to a growing body of research indicating that, in both adults (e.g., Berthier et al., 1996; Johnson-Frey et al., 2004; Marteniuk et al., 1987; Rosenbaum et al., 2009) and infants (e.g., Claxton et al., 2003; Gredebäck et al., 2009), early stages of action planning are influenced by later goals. Our results supplement the previous research indicating that infants in the first year of life are capable of engaging in well-structured actions directed at a distal goal with sufficient training (e.g., Sommerville et al., 2008; Willatts, 1999). Further, they are in accord with the research by Munakata et al. (1997) indicating that infants were more likely to engage in a means-end action if they could see a toy (goal) present than if the toy was absent or hidden. Although the authors did not interpret this finding as related to infants' action plans, our findings suggest that the presence of the goal may have aided infants' action planning in this work. Consistent with these earlier findings, our results provide novel evidence that the saliency of goals affects the production of means-end actions and is present at the earliest points in means-end learning.

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