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Brief article

Rich interpretation vs. deflationary accounts in cognitive development: the case of means-end skills in 7-month-old infants

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Abstract

Seven-month-old infants appear to learn means-end skills, such as pushing a button to retrieve a distant toy (*Psychological Review* 104 (1997) 686). The present studies tested whether such apparent means-end behaviors are genuine, or simply the repetition of trained behaviors under conditions of greatest arousal, as suggested by a dynamic systems reinterpretation. When infants were trained to repeat behaviors that did not serve as means to retrieving toys (pushing a button to light a set of distant lights), their button-pushing differed significantly from infants for whom button-pushing served as a means for retrieving toys. Further, infants demonstrated means-end skills with behaviors that they had not been trained to repeat. Implications for early means-end abilities and for debates surrounding the interpretation of infant behavior are discussed. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

A basic goal in studying cognitive development is to understand the origins of knowledge. To do so, we must assess what infants know. Researchers have designed numerous methods to test such preverbal populations, as well as non-verbal populations, with some experiments applied successfully to both human infants and monkeys (e.g. Hauser, MacNeilage, & Ware, 1996; Munakata, Santos, Spelke, Hauser, & O'Reilly, 2001; Wynn, 1992; Xu, Carey, & Welch, 1999). However, the interpretation of behavior in

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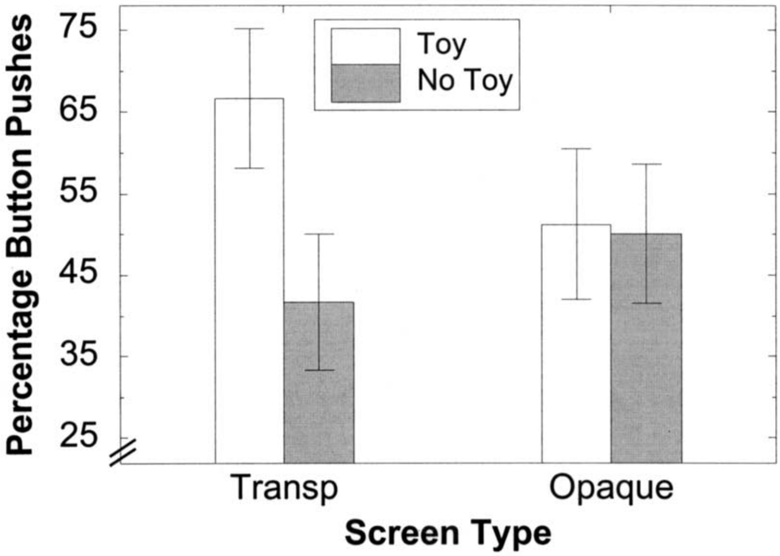

Fig. 1. Button-pushing by screen type and toy presence in Munakata et al. (1997), Experiment 3, in which pushing the button led to the retrieval of toys: infants distinguished Toy and No Toy conditions more in the Transparent condition than in the Opaque condition.

such experiments is controversial. Are researchers mistakenly forming “rich interpretations” (Haith & Benson, 1997) of behavior, casting simple responses in terms of overly complex abilities and cognitive processes, and falling prey in the case of infancy research to the “competent infant” movement (Bates & Elman, 1993)? Or are we underestimating the abilities of preverbal and non-verbal populations in “deflationary accounts” (Scholl & Leslie, 1999), mistakenly casting thoughtful behaviors in terms of simplistic processes?

The present work resolves one variant of this controversy. The studies explore means-end behavior, often defined in the study of infancy as the ability to link action on one object (the means) to its effect on other objects (the ends).[1] Infants appear to use means-end skills to retrieve toys. For example, 7-month-old infants can learn to pull a towel to retrieve a distant toy sitting on the towel, to push a button to make a distant ledge drop such that a toy sitting on the ledge slides to within reach, and to rotate a screen to retrieve a toy from behind it (Munakata, McClelland, Johnson, & Siegler, 1997; Shinskey & Munakata, 2001). Infants carry out these behaviors more often when there is a toy present than when there is not, and they distinguish toy presence and absence in their behaviors more when they can see whether or not there is a toy (behind a transparent screen) than when the area becomes occluded (by an opaque screen) (Fig. 1). This pattern suggests that 7-month-old infants understand that they can use one object (a button) as a means to the end of another object (a toy), but they have some difficulty remembering whether hidden toys are present.

[1] This notion of means-end behavior differs from the information-processing notion of determining the difference between the current and goal states and finding an operator to reduce this difference (Newell & Simon, 1972).

Are such apparent means-end behaviors genuine or is this instead rich interpretation? The dynamic systems framework provides an alternative account of these data, and alternative accounts of many other data currently interpreted in terms of infants' knowledge and abilities (e.g. Baillargeon, 1986; Diamond, 1985; Kellman & Spelke, 1983). In the dynamic systems framework (Smith & Thelen, 1993; Thelen & Smith, 1994), behaviors are viewed as emergent patterns of activity dependent on an individual's situation and history. According to the dynamic systems reinterpretation of the Munakata et al. (1997) means-end studies, infants simply repeated trained behaviors (e.g. pushing a button) without actually understanding the associated means-end links (Thelen, pers. commun., April, 1997). Infants were more likely to carry out the trained behaviors the more aroused they were; they were most aroused when they could see a toy, least aroused when they could see that there was no toy, and somewhere in between when they could not see whether there was a toy. Thus, what appeared to be meaningful means-end behaviors might instead have been simply the repetition of previously rewarded behaviors under conditions of greatest arousal. As with other dynamic systems and potentially deflationary reinterpretations, this alternative is appealing in its simplicity: it relies on factors known to affect infant behavior (reward, arousal), without attributing anything more. This dynamic systems reinterpretation is also consistent with a variety of theories positing limitations in the means-end actions of infants at this age (Baillargeon, Graber, DeVos, & Black, 1990; Diamond, 1991; Piaget, 1954; Uzgiris & Hunt, 1975; Willatts, 1990). Moreover, this dynamic systems reinterpretation is part of the greater controversy surrounding the interpretation of infant behavior, and it raises the opportunity to directly test factors relevant to this controversy.

We tested the dynamic systems and means-end interpretations of infant behavior in three studies that deconfounded the repetition of trained behaviors from means-end skills. In Experiments 1a and 1b, trained behaviors did not serve as a means to retrieving toys. In Experiment 2, the means to retrieving toys was not directly trained. The means-end account predicts that only infants in Experiment 2 will show the same pattern of behavior as infants in the original studies (Munakata et al., 1997), because only this behavior serves as a means to the end of the toys. In contrast, the dynamic systems account predicts that only infants in Experiments 1a and 1b will show the same pattern of behavior as infants in the original studies, because only this behavior is similarly rewarded and repeated during training, with similar conditions of visual arousal at test.

2. Experiments 1a and 1b

We trained infants on pushing a button that lit a string of lights along a distant ledge. This lighting effect was designed to be equivalent to the ledge-drop in the previous studies (similarly interesting, distant, contingent on the button-push, etc.), with the single difference that pushing the button no longer served as a means to retrieving toys. We then tested infants' button-pushing under the same conditions of toy presence and visibility used in the original studies. Experiments 1a and 1b differed only in whether infants saw the interesting movement of toys sliding down the ramp (as infants did in the original studies). As described in Section 2.1.4, infants in Experiment 1a were never exposed to this movement. Experiment 1b corrected for this.

The means-end account predicts that infants will show a different pattern of button-pushing from infants in the original studies (Munakata et al., 1997), because pushing the button is no longer a means to the end of the toys. In contrast, the dynamic systems account predicts that infants will show the same pattern of button-pushing as infants in the original studies, because pushing the button is similarly rewarded and repeated during training and the conditions of visual arousal are similar at test.

2.1. Method

2.1.1. Participants

Twelve full-term 7-month-olds (7-4 to 7-14, mean age = 7-9; seven males, five females) participated in Experiment 1a. Nineteen other participants were excluded from the sample due to apparatus malfunction (one infant), experimenter error (three infants), failing to pass the criteria to move into the testing phase (six infants), or fussiness during testing (nine infants).[2] Twelve full-term 7-month-olds (7-3 to 7-14, mean age = 7-9; four males, eight females) participated in Experiment 1b. Eleven other participants were excluded from the sample due to apparatus malfunction (two infants), sibling interruption (one infant), experimenter error (one infant), failure to pass the criteria to move into the testing phase (six infants) or fussiness during testing (one infant).

2.1.2. Stimuli and design

The stimuli were the same baby toys used in the original study (a toy phone, a toy hammer, etc.) presented in the same sequence. The experiments involved the same 2×2 within participants design as the original study, with screen type (Opaque or Transparent) crossed with toy presence (Toy or No Toy), with seven of each of the four types of trials randomly ordered by blocks of four trials.

2.1.3. Apparatus

The apparatus was the original button-pushing apparatus (Fig. 2), adapted with a string of ten small white lights aligned along the bottom edge of the ledge, with one light every 2.5 inches. Pushing the button lit the string of lights for 3 s.

2.1.4. Procedure

The single change to the procedure from the original studies was that pushing the button lit the lights rather than dropping the ledge, and did not lead to the retrieval of toys on the ledge.

During training, the experimenter tapped his or her hand along the ledge and then lowered the transparent or opaque screen. Infants were trained to push the button until they were able to do so on their own within 10 s, on two consecutive trials (one with each

[2] The number of infants failing to complete the present experiments is comparable to those from earlier studies using this apparatus. As noted in the earlier studies, infants' failure to complete the study could be due to many factors, so that it is difficult to draw conclusions from the behaviors of these infants. For example, the ledge drop in the earlier studies and the lights in the current study did not seem intrinsically interesting to several of these infants. Because the completion rate was similar across the current and original studies, we focus on the more interpretable comparison of the complete data.

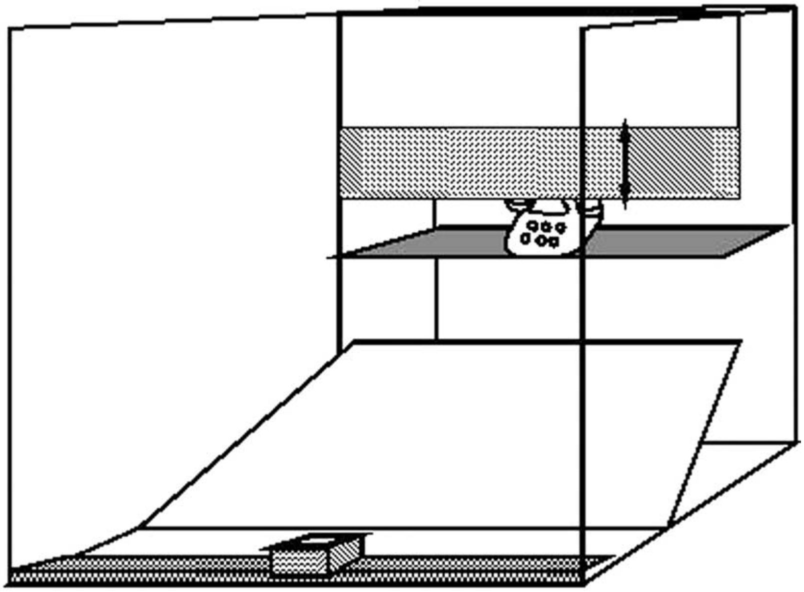

Fig. 2. The button-pushing apparatus used in Munakata et al. (1997) and in the present studies: a transparent or opaque screen could be lowered in front of the ledge. The apparatus was modified for Experiments 1a and 1b to include a string of lights along the front edge of the ledge; pushing the button lit the string of lights, but did not make the ledge drop. In Experiment 2, the string of lights was removed, pushing the button again made the ledge drop, and a large plastic ring could be attached to the button.

screen). Infants then received habituation trials until eight trials passed or they failed to push the button within 10 s on two consecutive trials. Parents then demonstrated the effects of the button-push with the toy present across four trials, two with each screen. The screen was lowered after the experimenter had placed the toy on the ledge and tapped the ledge.

Infants received breaks to play with toys following eight of the test trials, to parallel the toy breaks in the original study. The experimenter handed the toys to infants in Experiment 1a and dropped the shelf so the toys slid down the ramp to infants in Experiment 1b. In addition, in Experiment 1b, after the parent demonstrated the effects of the button-push with the toy present, the experimenter dropped the shelf so that the toy slid down the ramp to the infant. The experimenter waited a variable number of seconds before dropping the shelf (2 or 4, according to a specified schedule), so that the toy movement would not seem linked to the button-push.

2.1.5. Coding

Each trial was coded for whether the button was pushed, as measured by the illumination of the lights along the ledge. Coders blind to the purposes and hypotheses of the study coded half of the data. Inter-rater reliability was 0.99 for Experiment 1a, with coders agreeing on 167 out of 168 trials, and 1.0 for Experiment 1b, with coders agreeing on 168 out of 168 trials.

2.2. Results and discussion

As predicted by the means-end account, infants showed significantly different patterns of button-pushing (Fig. 3) than infants in the original study (Fig. 1). Specifically, there was a significant interaction between experiment, toy presence, and screen type, for both Experiment 1a vs. the original ($F(1, 22) = 6.5$, $P < 0.02$) and for Experiment 1b vs. the original ($F(1, 22) = 15.8$, $P < 0.005$). Infants showed similar overall levels of button-pushing in the present studies and in the original study (Fs < 1), indicating that infants across the studies appeared to be similarly engaged by the apparatus. Only the patterns of button-pushing differed across the studies. Infants' button-pushing in Experiment 1a was indiscriminate across the four conditions (all Fs < 1). Interestingly, Experiment 1b yielded a significant interaction between toy presence and screen type ($F(1, 11) = 5.3$, $P < 0.05$). This effect appears to have been driven largely by the low level of button-pushing in the Transparent Toy condition, perhaps because infants were more interested in looking at the toys than in pushing the button, given that the toys moved in interesting ways (occasionally sliding down the ramp) and the button did not serve as a means to retrieving toys.

Thus, infants behaved significantly differently when a button-push served as a means to a toy vs. lighting a string of lights, even though pushing the button was similarly rewarded and repeated during training, and the conditions of visual arousal were similar at test.

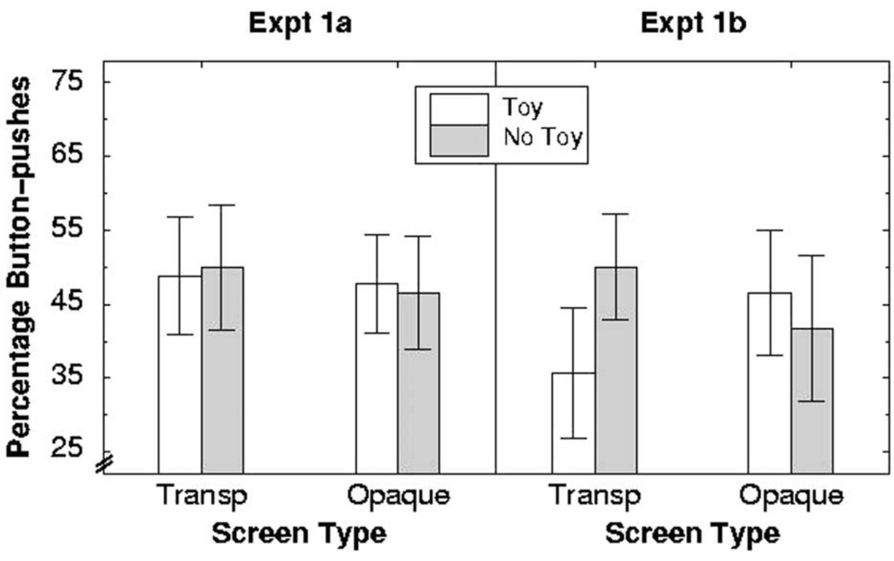

Fig. 3. Button-pushes by screen type and toy presence in Experiments 1a and 1b, in which pushing the button lit a set of lights: infants' button-pushing was significantly different from that in the original study (Fig. 1), in which pushing the button led to the retrieval of toys.

3. Experiment 2

We next tested whether infants could use means-end skills that had not been repeated or rewarded during training. We trained infants on one means for retrieving toys (pulling a ring attached to the button – which lowered the button to drop the ledge), and then tested them with a different means (pushing the button directly). The means-end account predicts that infants will show the same pattern of button-pushing as infants in the original studies (Munakata et al., 1997), because pushing the button serves as a means to the end of the toys. In contrast, the dynamic systems account predicts that infants will show a different pattern of button-pushing than infants in the original studies, because the very different action of ring-pulling (rather than button-pushing) is rewarded and repeated during training.

3.1. Method

3.1.1. Participants

Twelve full-term 7-month-olds (7-4 to 7-13, mean age = 7-7; ten males, two females) participated in the experiment. Eleven other participants were excluded from the sample due to failing to pass the criteria to move into the testing phase (four infants) or fussiness during testing (seven infants).

3.1.2. Stimuli and design

The stimuli and design were identical to those in Experiments 1a and 1b.

3.1.3. Apparatus

The apparatus was the original button-pushing apparatus (Fig. 2), without the string of lights, and with a removable plastic yellow ring that could attach to the front of the button and be used to pull the button down to drop the ledge.

3.1.4. Procedure

The single change to the procedure from the original studies was that infants were trained and habituated on pulling the ring down (which lowered the button) to drop the ledge. Infants were seated at a low height that allowed them to easily pull the ring but not push the button. After training and habituation with the ring, the ring was removed and infants were seated at the regular height that allowed them to easily push the button. As in the original studies, parents then demonstrated the effects of the button-push on the toy, and infants were then tested on button-pushing.

3.1.5. Coding

Each trial was coded for whether the button was pushed, as measured by the dropping of the shelf. Inter-rater reliability was 0.99, with coders agreeing on 167 out of 168 trials.

3.2. Results and discussion

As predicted by the means-end account, infants distinguished Toy and No Toy conditions more in the Transparent condition than in the Opaque condition (Fig. 4)

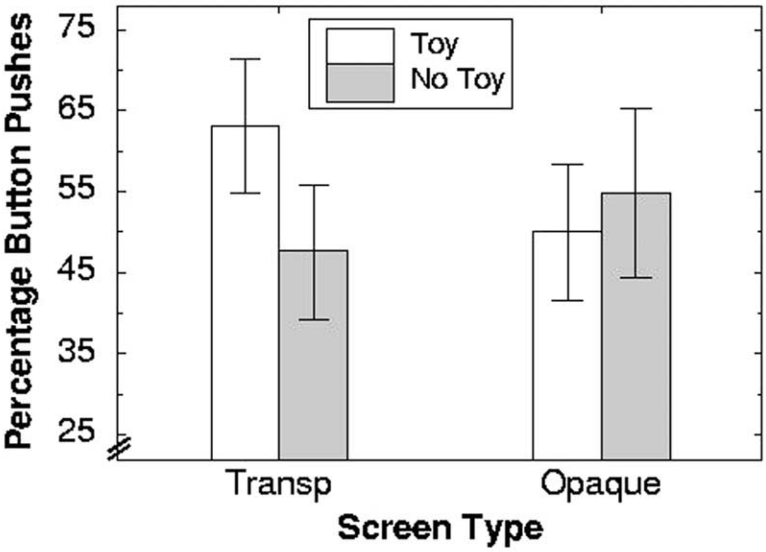

Fig. 4. Button-pushes by screen type and toy presence in Experiment 2, in which infants were trained on pulling a ring: as in the original study (Fig. 1), infants distinguished Toy and No Toy conditions more in the Transparent condition than in the Opaque condition.

($F(1, 11) = 7.6, P < 0.02$). Infants showed similar patterns of button-pushing as infants in the original study (all Fs < 1.5), even though this means-end behavior was not directly trained and was quite different from the repeated and rewarded behavior of ring-pulling.

The dynamic systems account might be revised to explain these results. Perhaps infants carry out non-trained behaviors whenever they are most aroused, if these behaviors have been observed (e.g. during the parent's demonstration of the button-push) or are afforded by the situation (e.g. by the button apparatus). However, this revised account predicts that infants should show the same patterns of button-pushing across all three of the current studies (because parents demonstrated button-pushing and the apparatus afforded button-pushing). Instead, infants showed meaningful patterns of button-pushing in the third study only, as predicted by the means-end account.

4. General discussion

Infants carry out genuine means-end behaviors, rather than simply repeating trained behaviors under conditions of greatest arousal. Infants push a button to retrieve visible toys, even when this means-end behavior has not been trained (Experiment 2). In contrast, infants show very different behaviors after being trained to push a button that lights a string of lights and does not serve as a means to retrieving toys (Experiments 1a and 1b). This work complements other studies demonstrating that young infants appear to recognize appropriate vs. inappropriate means-end behaviors (Baillargeon et al., 1990). Thus, the original interpretation of infants' means-end behaviors (Munakata et al., 1997) was not overly rich, whereas an account in terms of more basic processes may have been simplistic.

Some attempts to explore such controversies have failed to clearly distinguish competing hypotheses. Such attempts have focused on demonstrating that a given factor influences infant behavior, even though such demonstrations do not rule out contributions from other factors (such as those emphasized in competing theories). For example, the controversy surrounding interpretations of infant behavior may be fiercest around the preferential looking method, in which infants are presented repeatedly with a visual display until their attention to the display declines. Looking times to new displays are then measured, on the assumption that infants will look longer at displays they perceive to be novel or unnatural (Baillargeon, 1995; Fantz, 1964; Spelke, 1985). Researchers using this paradigm have attributed a variety of capacities to infants in the first year of life, including memory for hidden objects (Baillargeon, 1987), numerical understanding (Wynn, 1992), and notions of goal-directed action in others (Woodward, 1998). However, some findings from the preferential looking paradigm have been reinterpreted in terms of infants' basic preferences for the superficial familiarity or novelty of displays, rather than in terms of their conceptual understanding (e.g. Bogartz, Shinskey, & Schilling, 2000). Proponents have tested such perceptual process accounts in experiments that demonstrate that the familiarity of events influences infants' looking behavior (Schilling, 2000). However, demonstrating the importance of familiarity does not rule out potential contributions from other factors (such as an understanding of object permanence); thus, such experiments do not clearly distinguish the competing accounts.

A parallel example motivated the means-end studies that served as the basis for the present studies. One account of young infants' failures to search for hidden objects, despite demonstrating apparent sensitivity to them in preferential looking experiments, is that young infants have a concept of object permanence but lack the means-end skills required to retrieve hidden objects (Baillargeon et al., 1990; Diamond, 1991; Willatts, 1990). Proponents tested such accounts in experiments that demonstrated that simplifying means-end demands improved infants' performance (Kolstad & Aguiar, 1995). Again, demonstrating the importance of one factor (means-end demands) does not rule out the possibility of contributions from other factors, and so such experiments did not clearly distinguish potential competing accounts. Subsequent experiments demonstrated that infants fail to search for hidden toys despite using the necessary means-end skills to retrieve visible toys (Munakata et al., 1997; Shinskey & Munakata, 2001). These studies challenged the notion that infants' failures to search for hidden objects were due simply to means-end deficits, and instead suggested the role of other factors, such as graded object representations that are weaker for hidden objects than for visible ones (Munakata et al., 1997).

Future research will help to determine which interpretations have been too rich and which have been simplistic in other areas of this controversy (e.g. Clearfield & Mix, 1999; Smith, Thelen, Titzer, & McLin, 1999; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Wynn, 1996). Resolving these debates surrounding the interpretation of the behavior of preverbal and non-verbal populations will be critical for advancing our understanding of the origins of knowledge.

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