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Unifying Representations and Responses: Perseverative Biases Arise From a Single Behavioral System

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Research Article

Unifying Representations and Responses

Perseverative Biases Arise From a Single Behavioral System

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ABSTRACT—A dominant account of perseverative errors in early development contends that such errors reflect a failure to inhibit a prepotent response. This study investigated whether perseveration might also arise from a failure to inhibit a prepotent representation. Children watched as a toy was hidden at an A location, waited during a delay, and then watched the experimenter find the toy. After six observation-only A trials, the toy was hidden at a B location, and children were allowed to search for the toy. Two- and 4-year-olds' responses on the B trials were significantly biased toward A even though they had never overtly responded to this location. Thus, perseverative biases in early development can arise as a result of prepotent representations, demonstrating that the prepotent-response account is incomplete. We discuss three alternative interpretations of these results, including the possibility that representational and response-based biases reflect the operation of a single, integrated behavioral system.

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The demonstration of a behavioral dissociation is often used to infer the presence of multiple, separable systems (e.g., Goodale & Milner, 1992; Milner, 1963; Robertson & Marshall, 1993). Recently, however, connectionist and dynamic systems models have demonstrated that such dissociations can arise from single systems that operate in different ways in different situations (e.g., Munakata, 2001; Thelen, Schöner, Scheier, & Smith, 2001; Van Orden, Pennington, & Stone, 2001). This debate is particularly germane to the field of early development, in which several developmental dissociations between knowing and acting have been reported (e.g., Zelazo, Frye, & Rapus, 1996; Zelazo & Reznick, 1991). For instance, when tested in violation-of-expectancy paradigms, 3.5-month-old infants appear to know that objects continue to exist when out of sight (Baillargeon, 1987). In the Piagetian A-not-B task, however, 8- to 10-month-old infants perseveratively reach to one location after seeing a toy clearly hidden at a second location (e.g., Piaget, 1954; Smith, Thelen, Titzer, & McLin, 1999). Related perseverative errors persist into early childhood (e.g., DeLoache & Brown, 1983; Schutte & Spencer, 2002; Spencer, Smith, & Thelen, 2001). Does this dissociation between knowing and acting reflect the operation of two systems or one? Answering this question provides a unique window onto the organization, use, and development of behavioral systems.

One dominant account of this striking developmental pattern relies on a two-systems view: Children have an accurate representation of the hiding locations in the A-not-B task; however, they err because of a failure to inhibit a prepotent response to A (e.g., Zelazo, Reznick, & Spinazzola, 1998; for related ideas, see Diamond, 1990, 1991). Thus, A-not-B-type errors arise because a response system dominates an accurate but weak representational system. In time, children come to rely more on representations and can more effectively regulate the response system; consequently, A-not-B-type errors decline (Marcovitch & Zelazo, 1999; Zelazo et al., 1998).

Strong support for the prepotent-response view comes from a recent study by Zelazo and his colleagues (1998). In this A-not-B-type experiment, 2-year-olds watched as the experimenter hid an object at an A location. Next, they watched the experimenter engage in a multistep sequence to retrieve the object; the last step in this sequence required the selection of an object in a location spatially aligned with A. This set of events was repeated several times. Then, an object was hidden at a B location, and the children were allowed to retrieve the object by repeating the multistep sequence. If perseverative errors are caused by a failure to inhibit a prepotent response, then during these B trials, children should have selected the object in the location aligned with B in the last step of the multistep sequence because they never overtly responded to the location aligned with A. This was indeed the case. In contrast, a control group that retrieved the object on all trials selected the location aligned with A. The authors concluded that overt responding is a necessary component of perseverative search behaviors (but see Jacques, Zelazo, Kirkham, & Semcesen, 1999, for an alternative interpretation of performance in a nonsearch task).

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The underlying logic of this observation-only methodology assumes that children construct the same representations in both observation only and respond conditions. This may not be the case. Children might, for instance, construct a relatively weak representation of A in observation-only conditions as they passively watch the experimenter hide and find an object. Recent connectionist models suggest that if this is the case, children might fail to perseverate not because representational states are immune from perseverative biases in early development, but because the weak representation of A does not effectively compete with the more recent, stronger representation of the B location on B trials (Munakata, 1998, 2001). This suggests that, under some conditions, perseverative biases might occur in observation-only conditions. Such a result would call into question the prepotent-response account and, more generally, whether two systems—versus a single system—are needed to account for perseverative biases.

In the present study, we sought to provide the first direct evidence that A-not-B-type biases in early development can arise from a failure to inhibit a prepotent representation, rather than from a failure to inhibit a prepotent response. Previous research has demonstrated that after 2-year-olds search for hidden toys at an A location in a sandbox, their responses to a B location are biased in the direction of A (Spencer et al., 2001). We examined whether such biases occur when 2-year-olds observe events at A on A trials, but respond on B trials. Our task differed in two key ways from the task used by Zelazo et al. (1998). First, we eliminated the multistep sequence. Instead, when children were allowed to search, they searched directly for the hidden object. With this procedure, children should create a strong representation of the target location, because the memory for the target does not have to compete with the memory for the sequence. However, the sandbox task is still challenging enough to observe significant A-not-B-type biases: Young children find it difficult to find hidden—but unmarked—objects in the sand. Second, we encouraged the children to construct a strong representation of A by preventing them from knowing whether they would have to respond until after the memory delay. We assumed that given this ambiguity, children would form a strong representation of the target location on all trials just in case they were asked to respond.

Our predictions were as follows. If perseverative errors in early development are caused by a failure to inhibit a prepotent response, 2-year-olds—as in the study by Zelazo et al. (1998)—should search correctly on B trials in our observation-only condition. If, however, perseverative errors can arise from strong but competing representations—as connectionist models suggest—children should show biases toward A on B trials even when they only observed events at A.

EXPERIMENT 1

Method

Participants

Eighty 2-year-olds (M = 2 years 5.1 months, SD = 1.2 months) participated. Data from 10 participants were not analyzed because either the children failed to complete the task (n = 7) or there was an experimenter error (n = 3). In addition, data from 13 children assigned to the observation-only condition were excluded because they reached on one or more of the A trials. Participants were recruited from a database at the University of Iowa and were given a small gift for participating. The parents of all participants gave informed consent.

Materials

A circular sandbox (17-in. diameter, 5 in. deep) was used on training trials; a long, rectangular sandbox (60 in. long, 16 in. wide, 20 in. high) was used for the A-not-B task (see Fig. 1). A video camera was mounted on the ceiling above the rectangular sandbox to record children's responses. Before each session, the video image was aligned with a grid on a video monitor. Curtains hung from the ceiling eliminated all external landmarks. The training task took place outside the curtained area, and the A-not-B task took place within the curtained area (see Fig. 1). During the A-not-B task, the child stood on an outline of feet taped to the floor 12 in. from the child's side of the rectangular sandbox and aligned with the center of this sandbox. The child stood on the feet from the start of each trial through the memory delay, but was allowed to move when searching for the toy. The experimenter sat opposite the child, and the parent sat in a chair behind the child.

Procedure

Each session began with six training trials conducted in the circular sandbox. On the first trial, the experimenter half-buried a toy (1 in. tall, 1 in. wide, 1 in. thick) in the center of the circular sandbox, counted to 5, and encouraged the child to reach for the toy. The second trial was the same except the experimenter buried the toy such that only the very top was showing. Next, the experimenter introduced a card game and explained that he or she would turn over a flash card after counting to 5. If the card was green, the child was allowed to reach for the toy, dig it up, and hold it until the next trial began. If, however, the card was red, the experimenter would say, "It's my turn," reach for the toy, dig it up, and give it to the child. The flash cards were used on the final four training trials. On these trials, the

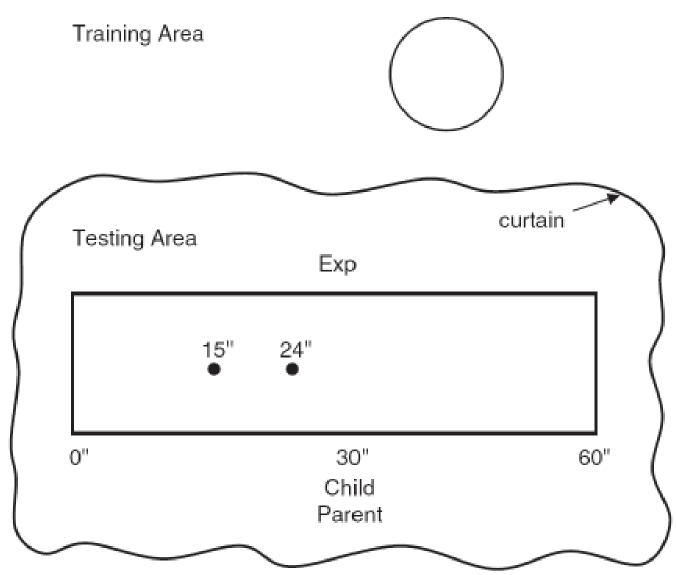

Fig. 1. Schematic of the training and testing areas viewed from above. During testing, the experimenter (Exp) sat on one side of the rectangular sandbox, with the child and parent on the other. In Experiment 1, hiding locations were at 15 and 24 in. from the left edge of the sandbox.

experimenter buried the toy completely, counted to 5, and turned over a flash card. The flash card on Trial 3 was green, and the card on Trial 4 was red. The colors on Trials 5 and 6 were randomized such that one card was green and one card was red.

After training, the child, parent, and experimenter moved into the curtained area. The child completed nine test trials that were identical to the last four training trials except for the hiding locations and memory delay. During the first six test trials, the experimenter buried the toy at an A location, counted to 3, and then turned over a flash card. In the observe conditions, the flash cards on the A trials were always red. Consequently, the experimenter searched for the toy. In the reach conditions, the flash cards on the A trials were always green. Thus, the child was allowed to search for the toy. The final three test trials—the B trials—were identical in all conditions. On these trials, a toy was hidden at a B location, the experimenter counted to 10, and then the experimenter turned over a green card. Thus, all children were allowed to search on these trials.[1]

Experimental Design

The children were randomly assigned to one of four conditions. In each condition, toys were hidden at locations in the left half of the sandbox: 15 in. or 24 in. from the left edge (from the child's perspective; see Fig. 1). For 14 children in the observe condition and 15 children in the reach condition, A was at 15 in. and B was at 24 in. For the remaining 14 children in each condition, A was at 24 in. and B was at 15 in. The counterbalancing of location was necessary because, in addition to showing biases toward A in this task, 2-year-olds show a bias toward the midline of the sandbox (i.e., toward 30 in.; e.g., Huttenlocher, Newcombe, & Sandberg, 1994). Consequently, when A is in the direction of the midline relative to B, a bias toward A could reflect an A-not-B-type bias or a midline bias. By counterbalancing the A and B locations, we were able to verify whether children's responses were biased toward A regardless of the layout of A and B. Note, however, that we expected biases toward A to be larger when A was in the direction of the midline relative to B, because the A-not-B-type and midline biases "pulled" memory in the same direction in this case.

Behavioral Scoring

All sessions were scored from videotapes. Scorers coded where each child first contacted the sand on the reach trials. If the child reached with both hands, the hand that touched the sand first was scored. If both hands touched the sand at the same time, the hand closest to the hiding location was scored. Responses were coded to the nearest 1/2 inch. A second scorer scored 15% of the sessions. The mean deviation (absolute value) between the two scorers was 0.70 in. (SD = 0.98 in.). The initial scorer's values were used in all analyses.

Results and Discussion

To examine whether children showed a bias toward A on the B trials in the observe and reach conditions, we coded children's response errors such that positive errors were in the direction of A relative to B, whereas negative errors were away from A. Thus, when B was at 15 in., rightward errors were scored as positive because A was at 24 in. By contrast, when B was at 24 in., leftward errors were scored as positive. As can be seen in Figure 2, children's responses on the B trials were

[1]The short delay on the A trials encouraged children to encode and remember these locations robustly, whereas the longer delay on the B trials taxed memory. Note, however, that A-not-B-type errors occur even with a 10-s delay on both A and B trials (Schutte, Spencer, & Schöner, 2003).

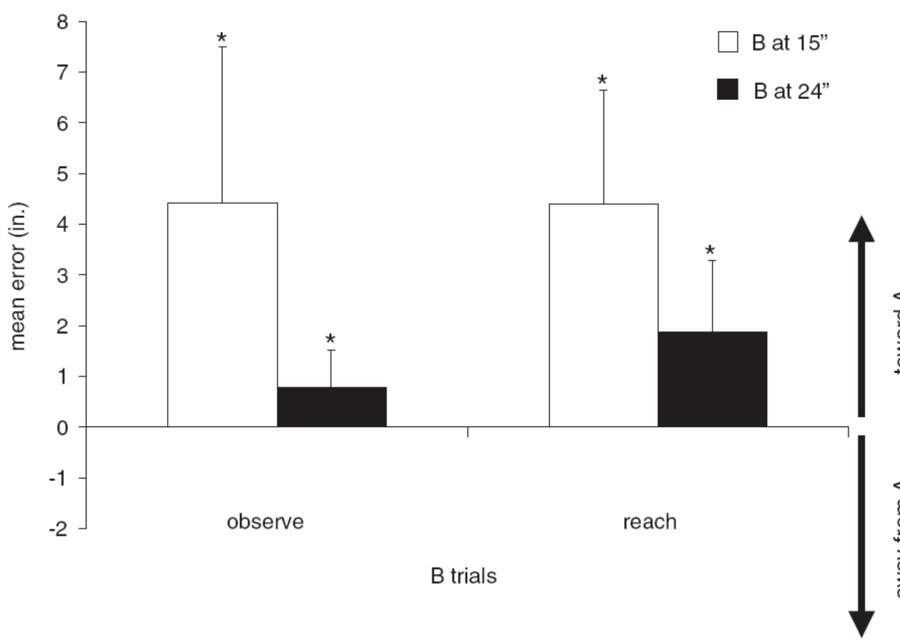

Fig. 2. Two-year-olds' mean error (in inches) on the B trials in both the observe and the reach conditions when B was located 15 in. from the left edge of the sandbox and when B was located 24 in. from the left edge. Positive errors indicate errors toward A; negative errors indicate errors away from A. Asterisks indicate that responses differed significantly from zero error. Error bars show $SD/2$.

biased toward A in all conditions, although biases toward A were stronger when A was in the direction of the midline of the sandbox relative to B (i.e., B at 15 in.), rather than the other way around (see also Spencer et al., 2001). Data from each condition were analyzed separately by comparing mean responses on the B trials to zero error. These t tests indicated that responses were significantly biased toward A in the observe conditions, $t(13) = 2.68$, $p < .01$, when B was at 15 in. and $t(13) = 2.00$, $p < .025$, when B was at 24 in., as well as in the reach conditions, $t(13) = 3.68$, $p < .005$, when B was at 15 in. and $t(14) = 2.62$, $p = .01$, when B was at 24 in.[2]

Next, we examined whether children's perseverative biases differed between the observe and reach conditions. A two-way analysis of variance (ANOVA) examining mean error on the B trials, with response type (observe, reach) and location (B at 15 in., B at 24 in.) as between-subjects factors, revealed a significant main effect of location, $F(1, 53) = 7.99$, $p < .01$. This indicated that biases toward A were significantly larger when A was in the direction of midline than when it was not. No other effects reached significance. Thus, biases toward A on the B trials did not differ significantly between the observe and reach conditions.

Finally, we examined whether errors on the B trials differed from errors on the A trials in the reach condition, to verify that biases on the B trials differed from midline biases that might arise on the A trials. Errors on the A trials were biased toward midline both when B was at 15 in. ($M = 1.12$ in. toward midline) and when B was at 24 in. ($M = 2.28$ in. toward midline). Moreover, t tests indicated that errors on the B trials differed significantly from these errors, $t(13) = 3.27$, $p < .01$, when B was at 15 in. and $t(14) = 6.54$, $p < .001$, when B was at 24 in.[3]

These results demonstrate—for the first time—that overt responding is not a necessary component of young children's perseverative biases in search tasks. Two-year-olds' responses on the B trials were significantly biased toward A even when the children had never searched for toys at the A location, suggesting that A-not-B-type biases can emerge from a failure to inhibit a prepotent representation. It is possible that 2-year-olds failed to show perseverative biases in the study by Zelazo et al. (1998) because they constructed a weak memory of A in observation-only conditions. In the present experiment, when children were encouraged to construct a strong memory of A, they showed equally strong perseverative tendencies in the observe and reach conditions.

EXPERIMENT 2

Results from Experiment 1 demonstrate that perseverative biases can arise because of competition between the representation of a previously remembered location and the representation of a current hiding location. These data challenge the proposal that perseveration in early development is due to response-based processes. Nevertheless, they do not speak to a second claim of the two-systems account: Over development, children come to rely more on an accurate representational system and less on a response system.

Data from a recent study allowed us to examine this proposal directly. In that study (Schutte, Spencer, & Schöner, 2003), 4-year-olds made robust A-not-B-type errors in the sandbox task when A and B were separated by 6 in. Thus, in Experiment 2, we tested 4-year-olds in observe and reach conditions. If an accurate representational system is becoming more dominant over a response system as development takes place—as proponents of the two-systems view have suggested—observation-only errors like the ones reported in Experiment 1 should not occur later in development. By contrast, if perseveration is a general phenomenon that can occur whenever strong representations are pitted against one another, perseverative biases should occur in observation-only conditions even at 4 years of age. Such a result would extend the results of Experiment 1, and would call into question the utility of the two-systems view for explaining developmental change.

Method

Participants

Sixty 4-year-olds (M = 4 years 3.1 months, SD = 1.8 months) participated. Data from 4 participants were not analyzed because either these children did not complete the task or there was an experimenter error. Participants were recruited and compensated as in Experiment 1, and their parents gave informed consent.

Materials and Procedure

The materials and procedure were the same as in Experiment 1 except that the child sat on a small chair aligned with the center of the rectangular sandbox, and the parent sat on a chair behind and to the left of the participant. The design was the same as in Experiment 1 with one exception: Toys were hidden 18 or 24 in. from the left edge of the sandbox. There were 14 children in each experimental condition. All sessions were scored as in Experiment 1. The mean deviation (absolute value) between the two scorers was 0.37 in. ($SD = 0.55$ in.).

Results and Discussion

Our previous study with 4-year-olds showed that children of this age make robust A-not-B-type errors on the first B trial and, further, that such errors weaken on the second and third B trials (Schutte et al., 2003). Thus, we focused on performance on Trial B1. As can be seen in Figure 3, 4-year-olds' responses on the first B trial were biased toward A in all conditions. Data from each condition were analyzed by comparing responses on the first B trial to zero error. These t tests indicated that responses were significantly biased toward A in the observe conditions, $t(13) = 2.89$, $p < .01$, when B was at 18 in. and $t(13) = 2.06$, $p < .05$, when B was at 24 in., as well as in the reach conditions, $t(13) = 2.97$, $p < .01$, when B was at 18 in. and $t(13) = 4.24$, $p < .001$, when B was at 24 in. In addition, a two-way ANOVA with response type and location as between-subjects factors revealed no significant effects on Trial B1. Therefore, the children made significant A-not-B-type errors regardless of whether they reached or observed on the A trials.

It is possible that differences between reach and observe conditions emerged over B trials. Therefore, we conducted an ANOVA with trial (B1, B2, B3) as a within-subjects factor and response type and location as between-subjects factors. There was a significant main effect of trial, $F(2, 104) = 9.32$, $p < .001$, but no other significant effects. As

[2] It is important to note that biases toward A were significant in all conditions, because previous studies of prepotent representations failed to find perseverative biases in respond conditions (for a discussion of this issue, see Zelazo et al., 1998).

[3] Although the magnitudes of error on the A and B trials when B was at 24 in. were similar, errors on the A trials were biased toward midline, whereas errors on the B trials were biased away from midline and toward A.

expected, the bias toward A was smaller on Trials B2 and B3 than on Trial B1 (B1: $M = 2.34$; B2: $M = 0.90$; B3: $M = 0.96$). Responses on all three B trials, however, were significantly biased toward A, $t(55) = 6.10$, $p < .001$, for Trial B1; $t(55) = 2.59$, $p < .01$, for Trial B2; and $t(55) = 3.09$, $p < .005$, for Trial B3.

Last, we investigated whether errors on the first B trial differed significantly from errors on the final A trial in the reach condition. Errors on the last A trial were near zero both when B was at 18 in. ($M = 0.02$) and when B was at 24 in. ($M = 0.11$). The *t* tests comparing errors on this trial and errors on Trial B1 revealed a significant increase in error toward A on the B trial both when B was at 18 in., $t(13) = 2.80$, $p < .025$, and when B was at 24 in., $t(13) = 3.58$, $p < .005$.

In summary, 4-year-olds—like 2-year-olds—showed significant biases toward A even when they simply observed hiding events on the A trials. Thus, overt responding is not a necessary component of A-not-B-type biases for this age group.

GENERAL DISCUSSION

Data from the present study suggest that the two-systems account of A-not-B-type errors does not fully explain the origin of perseveration in search tasks in early development. In particular, the prepotent response account is incomplete. But is it also incorrect? For instance, given that A-not-B-type biases can arise from a failure to inhibit a prepotent representation, is it the case that all A-not-B-type effects arise from this cause (for related ideas, see Fox, Kagan, & Weiskopf, 1979; Harris, 1973; Schacter, Moscovitch, Tulving, McLachlan, & Freedman, 1986)? We suspect that the answer is no. That is, although the A-not-B-type biases observed in some studies might have been due to failure to inhibit a prepotent representation, such failure is not always the cause of these biases, just as failure to inhibit a prepotent response is not always the cause. For instance, Smith and her colleagues (1999) have demonstrated convincingly that some perseverative biases are indeed caused by prepotent responses. In particular, infants are less likely to make the A-not-B error if they are in a seated position during the A trials and are moved to a standing position before the first B trial than if they remain seated throughout the session. Thus, a change in body posture that alters the specifics of the reaching response can reduce perseveration, even though infants must represent the same two hiding locations before and after the postural change.

Given that an extreme representational view seems incomplete, a second possibility is to retain the two-systems perspective, but allow for perseverative biases to arise from both systems. This would require rethinking the meaning of knowing-acting dissociations in early development. In particular, researchers would need to chart the developmental trajectory of each system, and how the two systems coevolve under different task constraints. Such a goal would create a variety of empirical challenges. For instance, we went to great effort to develop a task that would encourage 2-year-olds to strongly represent A even in observation-only conditions. It is not clear how one would achieve the same goal with young infants, although doing so seems necessary to track the development of the representational system.

More generally, we question whether it is possible to completely isolate and track the development of representational and response-based systems. Although we used a relatively common methodology to investigate the characteristics of these systems (e.g., Hofstadter & Reznick, 1996; Zelazo et al., 1998), recent data reveal that representations and responses are more intricately connected than was previously thought. For instance, humans and nonhuman primates represent locations in many ways, including relative to the actions needed to move to locations (e.g., di Pellegrino & Wise, 1993;

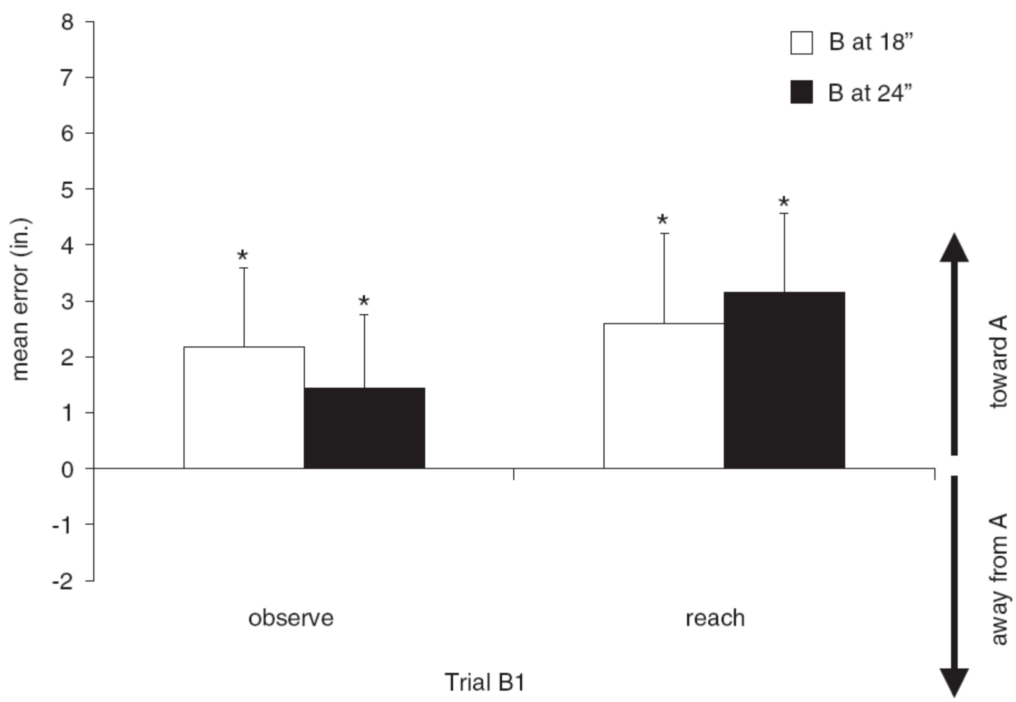

Fig. 3. Four-year-olds' mean error (in inches) on the first B trial in both the observe and the reach conditions when B was located 18 in. from the left edge of the sandbox and when B was located 24 in. from the left edge. Positive errors indicate errors toward A; negative errors indicate errors away from A. Asterisks indicate that responses differed significantly from zero error. Error bars show *SD*/2.

Georgopoulos, Taira, & Lukashin, 1993; Smyrnis, Taira, Ashe, & Georgopoulos, 1992). Thus, it is difficult to distinguish behaviorally between representational and response-based processes because one can generate representations of responses. Moreover, it is difficult to separate representations and responses in time because they are continuously coupled and interdependent. Studies with adults have demonstrated that even after a reaching movement has started, there is continuous updating of the represented target location (van Sonderen, Gielen, & Denier van der Gon, 1989). Furthermore, at any point during movement, actions can be continuously updated on the basis of newly represented information (Erlhagen & Schöner, 2002; Ghez et al., 1997). Thus, it is not the case that response-based processes start and representational processes stop the moment an overt response begins. Finally, data suggest that representations—far from being isolated from perceptual-motor processes—are largely contained within perceptual-motor cortical areas (e.g., Barsalou, 1999; Damasio & Damasio, 1994).

In light of these data, we conclude by raising a third possible interpretation of our results that moves beyond the modified two-systems view. Specifically, we propose that perseverative biases reflect the operation of a single system. For instance, recent connectionist and dynamic systems models show that knowing-acting dissociations can arise from a single, dynamic, integrated system that acts differently in different situations (e.g., Spencer & Schöner, 2003; Thelen et al., 2001). We contend that this view raises exciting new questions for future study, questions that are empirically tractable. From this perspective, the challenge is not to try to further isolate representations and responses, but rather to understand how infants and children encode locations, maintain location-related information during delays in the context of ongoing movements and changes in the environment, and use represented information—including representations of actions—to generate a response (for related ideas, see Newcombe & Huttenlocher, 2000). And, most relevant to this study, it will be necessary to understand how children's trial-to-trial experience is integrated with and affects these processes. Thus, a more complete understanding of perseverative biases might lie beyond dichotomous thinking in a single-system perspective that embraces the complexity of "simple" behaviors like reaching to a remembered location.

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