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Aligning body and world: Stable reference frames improve young children's search for hidden objects

Lynn K. Perry^{a,*}, Larissa K. Samuelson^{a,b}, John P. Spencer^{a,b}

^aDepartment of Psychology, University of Iowa, E11 Seashore Hall, Iowa City, IA 52242, USA

^bIowa Center for Development and Learning Sciences, University of Iowa, Iowa City, IA 52242, USA

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ABSTRACT

This study investigated how young children's increasingly flexible use of spatial reference frames enables accurate search for hidden objects by using a task that 3-year-olds have been shown to perform with great accuracy and 2-year-olds have been shown to perform inaccurately. Children watched as an object was rolled down a ramp, behind a panel of doors, and stopped at a barrier visible above the doors. In two experiments, we gave 2- and 2.5-year-olds a strong reference frame by increasing the relative salience and stability of the barrier. In Experiment 1, 2.5-year-olds performed at above-chance levels with the more salient barrier. In Experiment 2, we highlighted the stability of the barrier (or ramp) by maximizing the spatial extent of each reference frame across the first four training trials. Children who were given a stable barrier (and moving ramp) during these initial trials performed at above-chance levels and significantly better than children who were given a stable ramp (and moving barrier). This work highlights that factors central to spatial cognition and motor planning—aligning egocentric and object-centered reference frames—play a role in the ramp task during this transitional phase in development.

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Introduction

Recent studies have revealed something quite striking: Older children sometimes fail to show competencies that infants have been thought to have. For example, researchers presented 2- and 3-year-olds with a ball that rolled down a ramp (Berthier, DeBlois, Poirier, Novak, & Clifton, 2000). The ball

* Corresponding author.

E-mail address: lynn-perry@uiowa.edu (L.K. Perry).

went behind an occluder with four doors and stopped at a barrier, visible above the occluder. The barrier could be placed beside any of the doors. Berthier and colleagues found that 2- and 2.5-year-olds were not able to select the correct door when asked to find the ball in this “ramp task.” In fact, only 3 of 16 2.5-year-olds performed at above-chance levels. The 3-year-olds were able to reliably choose the correct door at above-chance levels. This is surprising because infants in a related violation-of-expectancy task appear to understand that solid objects behind an occluder stop at solid barriers (see Spelke, Breinlinger, Macomber, & Jacobson, 1992). We are left to wonder how infants can demonstrate an understanding of hidden objects and solid barriers, whereas toddlers cannot.

One possibility is that this discrepancy reflects methodological issues. In particular, tasks used with infants rely on looking behaviors, whereas those with toddlers require reaching responses. It is possible that the added demands of generating a reaching response make the ramp task quite challenging for toddlers. In fact, toddlers have been shown to perform as infants do in a looking version of this task (Hood, Cole Davies, & Dias, 2003). Although this explains differences between infants' and toddlers' performances, such demands do not explain why 2-year-olds—but not 3-year-olds—have difficulty in the reaching task. To understand why 3-year-olds can solve this task, whereas 2-year-olds cannot, we must examine the changes between 2 and 3 years of age that enable successful performance.

Certainly, part of the answer must lie in the complex processes involved in reaching for a hidden object. For instance, in some versions of the ramp task, children must get up off a chair and walk to a table before reaching for a specific door (e.g., Perry, Smith, & Hockema, 2008). This requires coordinating movements of the body—eyes, head, arms, and legs—with visuospatial information in the task space specifying the location of the target door (Keen & Berthier, 2004). More specifically, as children approach the ramp, get close, and then ultimately reach for a door, they must track where they are relative to the ramp and barrier. Note that children face related challenges in tasks where they sit in a chair and the ramp is moved toward them (e.g., Berthier et al., 2000). Although such tasks do not require children to walk, children must still update their position relative to the ramp as it is moved toward them.

Seemingly, then, the ramp task sets up a challenging visuospatial coordination problem because the spatial frame of reference on which children should rely—the barrier—is small and flimsy and moves from trial to trial. It is well known that young children rely on large stable landmarks to establish their orientation in space (Learmonth, Newcombe, & Huttenlocher, 2001; Newcombe & Huttenlocher, 2000). Thus, as children prepare to reach toward the ramp, they are most likely to orient relative to the occluder affixed to the ramp. Young children's perseverative reaching in the ramp task is consistent with this idea. Specifically, children under 3 years of age have a strong tendency to open the same door they opened on the previous trial (Berthier et al., 2000). Indeed, considered together, it appears that two things conspire against young children in the ramp task. First, the barrier is small and moves from trial to trial and, therefore, is a poor spatial reference frame. Second, young children have a strong tendency to reach repeatedly to the same location in space (see Schutte, Spencer, & Schöner, 2003; Spencer, Smith, & Thelen, 2001).

If these two factors conspire against 2-year-olds in the ramp task, what changes around 3 years of age to enable better performance? Research in spatial cognition suggests that there are dramatic changes in how young children use spatial reference frames between 1 and 3 years of age. Evidence from reaching tasks indicates that children initially encode locations egocentrically (e.g., Acredelo, 1978). By 16 months of age, children can use a visible spatial reference frame—for example, the edges of a sandbox—to encode the location of a hidden object (Huttenlocher, Newcombe, & Sandberg, 1994), but it is not until 22 months of age that children encode the position of an object relative to external landmarks even when moved from one side of the sandbox to another (Newcombe, Huttenlocher, Drummey, & Wiley, 1998). Beyond 22 months of age, use of object-centered coding is still relatively inflexible. For instance, when 2.5-year-olds are shown a hiding event in a small dollhouse and are then asked to find a toy hidden in an analogous place in a larger scale model, they typically search either randomly or perseveratively, whereas 3-year-olds succeed (DeLoache, 1987; DeLoache, 1989). If, however, the dollhouses are similar in size and aligned in orientation, 2.5-year-olds succeed, suggesting that the ability to align reference frames may play a role in this task (DeLoache, 1987; DeLoache, 1989). Beyond 3 years of age, use of spatial reference frames continues to change. It is not until around 4 years of age, for example, that children start using more subtle spatial reference frames such as axes of symmetry in adult-like ways (Schutte & Spencer, *in press*).

This review suggests that developmental differences in children's ability to coordinate and select spatial reference frames may underlie changes in performance between 2 and 3 years of age. Specifically, we suggest that 3-year-olds perform accurately in this task because they are more skilled at aligning their responses to the barrier and not the occluding panel. However, 2-year-olds align responses to the occluder; they also have a strong tendency to reach perseveratively, creating additional challenges. If this view is correct, we may be able to boost younger children's performance via changes to the task that aid in reference frame alignment. We tested this possibility in two experiments by making the barrier a sturdy (i.e., larger and more stable) and highly salient reference frame and, in one condition, by moving the ramp while keeping the barrier fixed during training. Both manipulations should increase attention to the barrier—the appropriate spatial reference frame in the task.

Experiment 1

The goal of this experiment was to boost the performance of 2- to 2.5-year-olds in the ramp task by making the barrier more sturdy and salient (recall that only three 2.5-year-olds performed at above-chance levels in Berthier et al., 2000). In addition, we kept the barrier fixed in space during training for one group of participants. In particular, in a Moving Ramp condition, the barrier remained fixed at the table's midline while the ramp was moved from trial to trial as the object was hidden at different doors across the training trials (see Fig. 1). Children in a Stationary Ramp condition were trained using procedures from Berthier and colleagues' (2000) study such that the barrier moved from trial to trial (see Fig. 1). Critically, both groups of children were tested with the barrier moving from trial to trial—that is, both groups were tested in the same manner as in Berthier and colleagues' study. The central question was whether we could boost young children's performance to above-chance levels by calling attention to the critical reference frame in the task—the barrier.

Method

Participants

Participants were 40 2.5-year-olds (mean age = 2 years 6 months, range = 2 years 4 months to 2 years 7 months) and 40 2-year-olds (mean age = 2 years 1 month, range = 2 years 0 months to 2 years 3 months). Participants were recruited from local birth records. Children received a small prize as compensation.

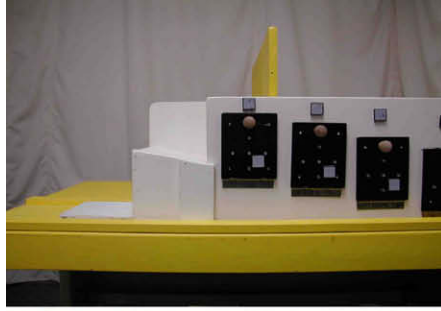
Apparatus

A wooden ramp, an occluder with four doors, a table, a small toy car, and a barrier were used. The ramp was 57.75 cm wide, 20.3 cm deep, and 28 cm tall at the tallest point and was painted white. The occluder was 27.94 cm tall and 57.15 cm wide. Each of the four black doors on the occluder was 10.75 cm wide and 14 cm tall.¹

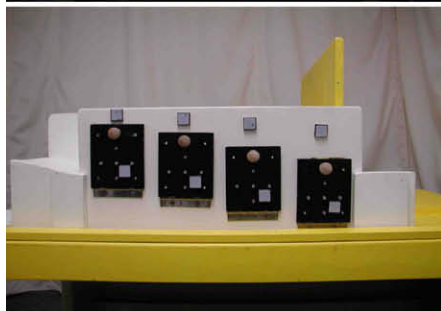
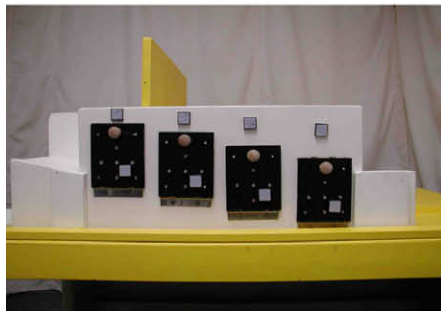
When the occluder was on the ramp, the car was visible for 15.24 cm before disappearing from view. The ramp was placed on a bright yellow table that was 25 cm tall, 49 cm wide, and 32 cm deep.

The sloped surface of the ramp had four slots into which a barrier (17.25 cm tall and 28.25 cm wide) could be placed to stop the car from rolling down the ramp. The barrier was thicker, wider, and more brightly colored than the barriers used in previous studies, and it was painted the same color as the table to facilitate the perception that both the barrier and table were stable features of the task space. In addition, the barrier was much larger than that in previous studies such that it fit inside a slot within the ramp and extended over the back of the ramp and across the back of the table. The slots in the ramp were positioned such that the car, when stopped, was directly behind one of the four doors on the occluder that could be attached to the front of the ramp.

¹ As can be seen in Fig. 1, each door had a small piece of Velcro above the knob and several small plastic lights around its surface. The apparatus had been previously used in other studies (Perry et al., 2008; Thelen & Whitmyer, 2005), and these details had been used to manipulate visual saliency and extra cues. Because these details were present in both of our experimental conditions, any effect that these details might have on children's spatial memory should be equal for both conditions.



Moving Ramp condition



Stationary Ramp Condition

Fig. 1. The top panels show how the ramp was moved such that the barrier remained aligned with the table's center during training in the Moving Ramp condition. The bottom panels show how the ramp remained stable and the barrier moved relative to the table in the Stationary Ramp condition.

Each child sat on a chair approximately 60 cm from the table and aligned so that the chair's midline lined up with the table's midline. A curtain was hung between the table and the child. The curtain was brought down between trials to prevent the child from seeing the barrier or ramp being moved. This was done to aid the perception that the barrier was fixed in space. The curtain was pinned out of the way during each trial. Note that the position of the child relative to the apparatus differed from that in the Berthier and colleagues' (2000) original study (a) to allow for a curtain to block the child's view of the apparatus between trials and (b) to allow the experimenter to stand behind the curtain and adjust the apparatus between trials.

Procedure

Our procedure closely followed that of Berthier and colleagues (2000). The session began with a *familiarization* period in which the child was introduced to the ramp and car and was shown that each door could open and close. The child was encouraged to approach the ramp and to open and close each door. After the child returned to his or her seat, the experimenter removed the occluder and doors to reveal the bare ramp and barrier. The barrier was positioned in the slot corresponding to the fourth door from the left. The experimenter then rolled the car down the ramp two times, commenting each time that it stopped at the barrier. The experimenter then replaced the occluder, opened all four doors, and rolled the car down the ramp two more times. On these trials, the experimenter drew the child's attention to the barrier by tapping it before releasing the car. The experimenter again commented that the car stopped at the barrier (which was still at the fourth slot).

Following familiarization, the child was given four open-door *training trials* and then four closed-door training trials. The child was told that the car was going to practice hiding and that it was the child's job to find it. The experimenter then brought down the curtain and positioned the barrier according to one of four pseudorandom orders. For the open-door training trials, only the correct door was left open. After reopening the curtain, the experimenter brought the child's attention to the barrier and rolled the car down the ramp. The child was then allowed to retrieve the car. This was repeated for a total of four trials (so that the car stopped once at each door). The closed-door training trials were identical to the open door trials except that all four doors were closed.

After training, there were 12 closed-door *testing trials*. The procedure for these was identical to that of the closed-door training trials and to the testing procedure of Berthier and colleagues (2000). The car stopped at each door once within a block of 4 trials so that it stopped at each door three times throughout testing in a pseudorandom order.

This same procedure was followed for both the Moving Ramp and Stationary Ramp conditions. The only difference was the placement of the ramp during the familiarization and training trials (see Fig. 1). In the Moving Ramp condition, the position of the ramp changed from trial to trial such that the barrier, directly to the right of the correct door, was always aligned with the table's and child's midline. In contrast, for the Stationary Ramp condition, the ramp and occluder remained centered on the table throughout the session as in Berthier and colleagues' (2000) study. Importantly, the closed-door testing trials were identical for both conditions; the ramp was positioned at the center of the table and did not move.

All sessions were videotaped and coded off-line to ensure accuracy of the procedure and to record the first reach that the child made on each trial.

Results

Average accuracy (proportion correct) on first reach during the test phase was calculated for each age group and condition. Four children—two 2.5-year-olds (1 in each condition) and two 2-year-olds (1 in each condition)—appeared to not understand the task. They failed to reach correctly on more than 1 of 12 testing trials. These children's data were not included in subsequent analyses.

Fig. 2A presents average accuracy for each age group in each condition during test trials. As can be seen in the figure, 2.5-year-olds in the Moving Ramp condition were more accurate than 2.5-year-olds in the Stationary Ramp condition and 2-year-olds in both conditions. In particular, *t* tests against chance showed that 2.5-year-olds in the Moving Ramp condition performed at significantly above chance (.25), $t(1) = 3.51$, $p < .003$, with an average of .36 trials correct. Average performance of 2.5-

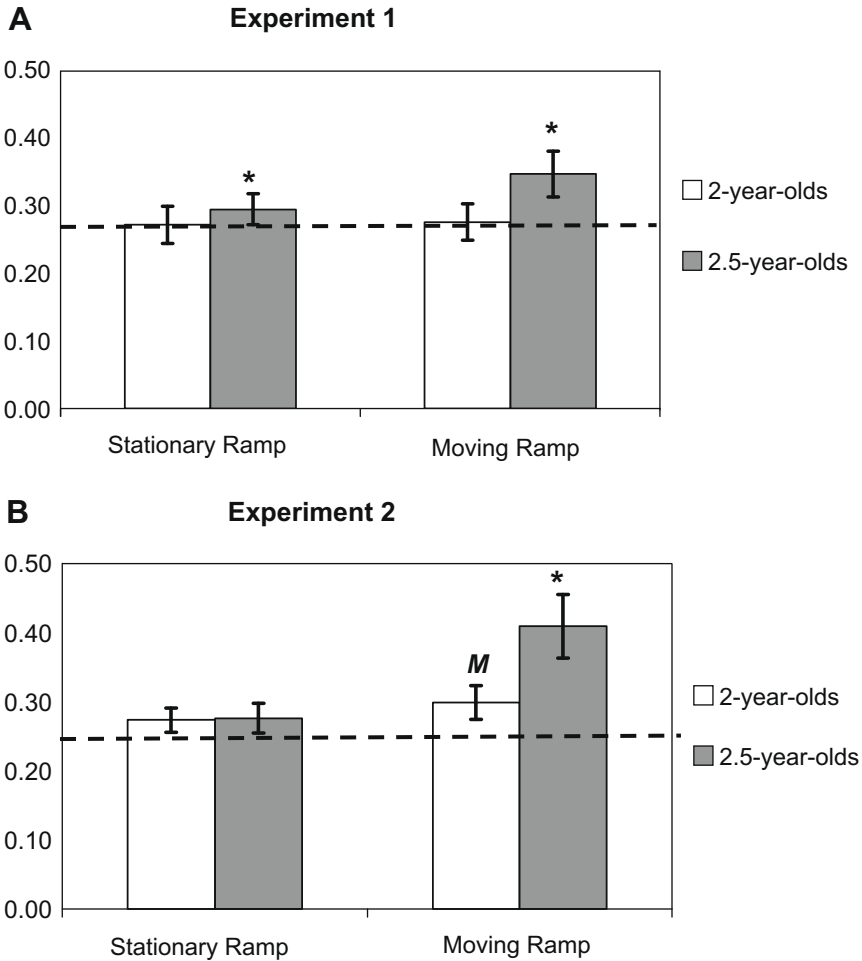


Fig. 2. Average accuracy for each age group in each condition of Experiment 1 (A) and Experiment 2 (B). Chance (.25) is indicated by a dashed line. In Experiment 1 (A), the 2.5-year-olds in both conditions performed significantly better than chance (indicated by *). In Experiment 2 (B), only the 2.5-year-olds in the Moving Ramp condition performed significantly better than chance (indicated by *). The 2-year-olds in the Moving Ramp condition showed a trend in this direction ($p < .07$, indicated by *M*).

year-olds in the Stationary Ramp condition was lower overall at .31 but was still significantly above chance, $t(1) = 2.65$, $p < .02$. The 2-year-olds in both the Moving Ramp and Stationary Ramp conditions did not perform at above-chance levels during testing, $p > .18$. Although both groups of 2.5-year-olds performed at above-chance levels, a two-way analysis of variance (ANOVA, condition by age) revealed only a marginal effect of age, $F(1, 72) = 3.00$, $p < .09$, $h^2 = .04$. There were no other significant effects or interactions.

Discussion

Making an important reference frame—the barrier—more salient had a significant impact on 2.5-year-olds' performance in the ramp task. Recall that only three 2.5-year-olds performed at above-chance levels in Berthier and colleagues (2000). Here 2.5-year-olds in both the Moving Ramp and Stationary Ramp conditions performed at levels significantly above chance. Specifically, as shown in

Fig. 3A, 12 of 20 2.5-year-olds in the Stationary Ramp condition and 14 of 20 in the Moving Ramp condition performed at above-chance levels, whereas 8 2-year-olds in each of the Moving Ramp and Stationary Ramp conditions did so. There was also evidence that our direct manipulation of the stability of the barrier from trial to trial had an impact on performance. In particular, 2.5-year-olds in the Moving Ramp condition did the best overall despite the fact that the testing trials were identical across conditions. Nevertheless, results from the ANOVA did not show a direct effect of this manipulation.

If the salience and stability of the barrier matters to young children's performance, why was there not a significant condition effect? Two factors may have attenuated the impact of our manipulation. First, although the barrier was fixed during training in the Moving Ramp condition, children were not always correct on the closed-door training trials where they simply needed to select the door to the left of the barrier and the table's midline on every trial (Stationary Ramp: 2-year-olds $M = .28$, 2.5-year-olds $M = .26$; Moving Ramp: 2-year-olds $M = .26$, 2.5-year-olds $M = .42$). Rather, children showed a strong tendency to perseverate, picking the door selected on the previous trial on 39% of the training trials. The group that was the most accurate during training—2.5-year-olds in the Moving Ramp condition—did the best during testing. This suggests that some of these children attended to the barrier during training and carried this tendency over into testing; however, this carryover was not sufficient to drive a significant difference across conditions.

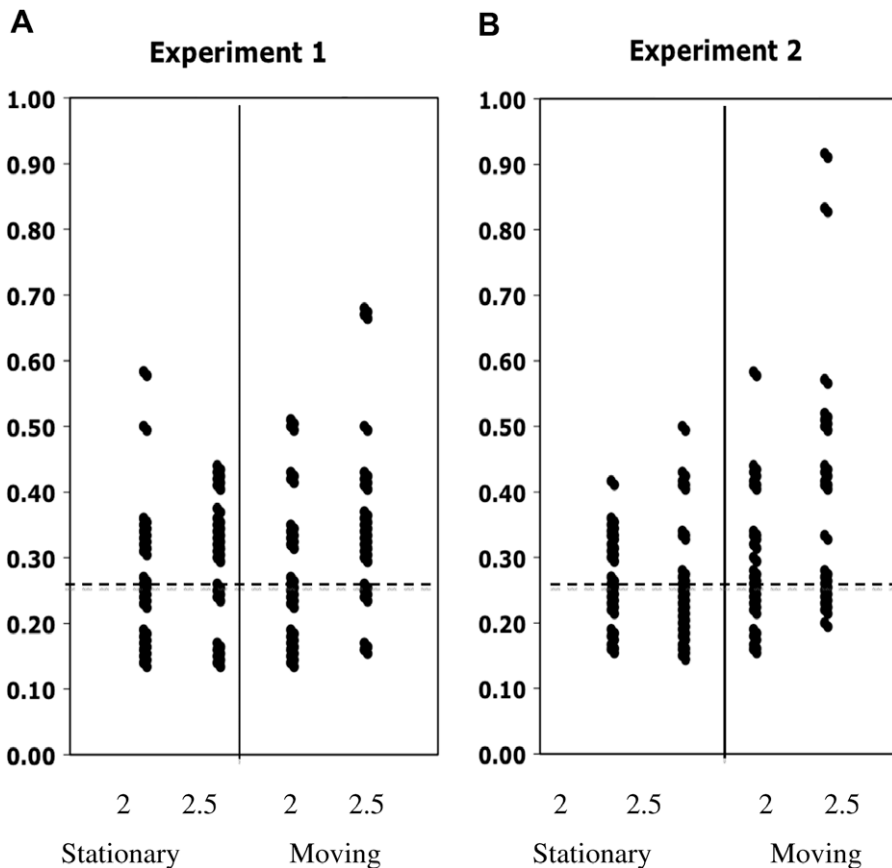


Fig. 3. Individual accuracy. Each circle represents one child's proportion correct within a given condition and age group. Panel A shows individual results from Experiment 1. As can be seen in the figure, 2.5-year-olds in the Moving Ramp condition had the most children—14 of 20—performing at above-chance levels. Panel B shows individual results from Experiment 2. As can be seen in the figure, 2- and 2.5-year-olds in the Moving Ramp condition had the most children—9 of 20 and 11 of 20, respectively—performing at above-chance levels.

The second factor that may have attenuated the impact of the Moving Ramp manipulation was the rather lengthy familiarization procedure used by *Berthier and colleagues (2000)*. This procedure takes great pains to draw attention to the information relevant to solving the ramp task; however, the procedure involves a lot of verbal instruction as the experimenter moves around different parts of the apparatus. Recently, *Perry and colleagues (2008)* used only four open-door training trials and did not report any detriment to either 2- or 3-year-olds' search accuracy. Thus, in Experiment 2, we implemented a new shortened familiarization phase. Moreover, we modified the familiarization and training phases in an attempt to boost the training performance of children in the Moving Ramp condition.

Experiment 2

The goal of this experiment was to boost the performance of children in the Moving Ramp condition by modifying the procedure from Experiment 1 in three ways. First, we shortened the familiarization phase. Second, we tried to highlight that the barrier was fixed and the ramp was moving during training in the Moving Ramp condition by maximizing the movement of the ramp across the first four training trials. In particular, instead of stopping once behind each door, the car was always hidden behind Doors 1 and 4 to maximize the distance that the ramp moved across these training trials (and, conversely, to maximize the distance that the barrier moved across training trials in the Stationary Ramp condition). If children have difficulty in attending to the barrier as a reference frame in this task, highlighting that the barrier is fixed by moving the ramp to the maximum extent possible should boost their performance. Note that this might impair children's performance in the Stationary Ramp condition by highlighting the fixed nature of the ramp and occluder.

Finally, to increase the likelihood that children would actually reach to the correct door on training trials and that, therefore, they would attend to the features of the apparatus (discussed above in our second manipulation), we modified the procedure on these first four training trials. Rather than conducting four open-door training trials here, we had children complete one open-door training trial and one closed-door training trial to the same location before moving the ramp or barrier. Thus, on the first training trial, children completed an open-door training trial with the barrier to the right of Door 1. This was followed by a closed-door training trial to the same door. Given that children tend to reach perseveratively, this should increase the likelihood that they would reach to the correct location—the same location—on the more challenging closed-door trial. We then moved the ramp (or barrier) such that the car was hidden behind Door 4 and repeated an open- and closed-door training trial. In this way, we capitalized on children's perseverative tendency to get them to reach correctly on the challenging closed-door trial while also highlighting what was stable and what was moving during this first set of four training trials. Thus, this training directs children's reaches to the spatial extremes (Doors 1 and 4), drawing their attention to the relevant reference frames. All children then completed the same set of closed-door training and testing trials as in Experiment 1. During closed-door training, the ramp moved between trials for children in the Moving Ramp condition while, importantly, the ramp remained stationary across testing trials for children in both conditions.

Method

Participants

Participants were 40 2.5-year-olds (mean age = 2 years 6 months, range = 2 years 4 months to 2 years 7 months) and 40 2-year-olds (mean age = 2 years 0 months, range = 1 year 11 months to 2 years 3 months). Children were randomly assigned to the Moving Ramp or Stationary Ramp condition. Children were recruited as in Experiment 1.

Apparatus and procedure

The apparatus and procedure were as in Experiment 1 except for the following. For familiarization, each child was shown the ramp, told that he or she was going to play a hiding and finding game, and then invited to open each door. This was followed by an open-door training trial with the barrier placed in the first position from the left. The child watched the car go down the ramp and was then

asked to retrieve it. This was followed by a closed-door training trial with the barrier again at this position. If the child did not successfully choose the first door on first reach, the experimenter repeated this sequence until the child succeeded. This was then repeated with the barrier in the fourth position from the left (one open-door trial followed by one closed-door trial). Again, if the child did not successfully choose the fourth door, the experimenter repeated this sequence.

These training trials were followed immediately by four closed-door training trials—either moving or stationary—as in Experiment 1 and then by 12 testing trials with the ramp in a fixed position across conditions. Note that, relative to Experiment 1, the modified training procedure on the first four trials did generally improve performance on the subsequent four closed-door training trials (Stationary Ramp: 2-year-olds $M = .26$, 2.5-year-olds $M = .36$; Moving Ramp: 2-year-olds $M = .38$, 2.5-year-olds $M = .39$).

Results

Average accuracy was calculated as in Experiment 1. We removed data from three participants who did not reach correctly on more than one test trial (two 2-year-olds in the Stationary Ramp condition and one 2.5-year-old in the Moving Ramp condition). Fig. 2B presents average accuracy for each age group in each condition during test. As can be seen in the figure, 2.5-year-olds ($M = .41$) and 2-year-olds ($M = .30$) in the Moving Ramp condition were more accurate than both 2- and 2.5-year-olds in the Stationary Ramp condition ($M_s = .27$ and $.28$, respectively). In particular, t tests against chance showed that 2.5-year-olds in the Moving Ramp condition performed significantly better than chance, $t(1) = 3.48$, $p < .003$, whereas 2-year-olds in the Moving Ramp condition showed a trend in this direction, $t(1) = 1.99$, $p < .07$. Average performance of 2- and 2.5-year-olds in the Stationary Ramp condition was not different from chance, $p > .20$.

A two-way ANOVA (condition by age) revealed a significant effect of condition on accuracy during testing, $F(1, 73) = 7.32$, $p < .01$, $h^2 = .08$, a marginal effect of age, $F(1, 73) = 3.762$, $p < .06$, $h^2 = .04$, and a marginal interaction between condition and age, $F(1, 73) = 3.225$, $p < .08$, $h^2 = .04$. Tests of simple effects revealed that in the Moving Ramp condition, 2.5-year-olds did significantly better than 2-year-olds, $F(1, 37) = 4.616$, $p < .04$, $h^2 = .11$, whereas in the Stationary Ramp condition, there were no differences between the age groups, $p > .88$. In addition, in the 2.5-year-old group, those in the Moving Ramp condition were significantly better than those in the Stationary Ramp condition, $F(1, 37) = 7.053$, $p < .02$, $h^2 = .16$, whereas in the 2-year-old group, there were no differences between conditions, $p > .38$.

Discussion

As in Experiment 1, 2.5-year-olds in the Moving Ramp condition performed at significantly above-chance levels. This contrasts with results from Berthier and colleagues (2000), where the majority of 2.5-year-olds performed at below-chance levels. Moreover, although there was a significant effect of age within the Moving Ramp condition, many of the 2-year-olds in this condition performed at above-chance levels and there was a group trend in this direction. Specifically, 9 of 20 2-year-olds and 11 of 20 2.5-year-olds in the Moving Ramp condition performed at above-chance levels, whereas 8 of 20 2-year-olds and 6 of 20 2.5-year-olds in the Stationary Ramp condition did so (see Fig. 3B). To our knowledge, this is the first study that has boosted the younger age group's performance to such levels during the standard testing. Finally, results showed a significant difference across conditions, revealing that a direct manipulation of barrier movement relative to the ramp and doors during training affects performance during standard testing trials. These data demonstrate that children's ability to select and align responses to a critical reference frame in the ramp task—the barrier—plays a role even when the barrier moves from trial to trial during testing.

In addition to boosting the performance of children in the Moving Ramp condition relative to Experiment 1, we also actually appear to have slightly impaired the performance of children in the Stationary Ramp condition; the 2.5-year-olds performed at above-chance levels in Experiment 1 ($M = .31$) but not here ($M = .28$). It is possible that when we highlighted the fact that the barrier was stationary, children in the Moving Ramp condition performed more accurately during testing;

when we highlighted the fact that the ramp was stationary, children in the Stationary Ramp condition performed less accurately.

General discussion

Much of the research using the ramp task has focused on the apparent discrepancy between infants' and toddlers' performances in looking and reaching versions of this task. It is now clear that this discrepancy reflects the different demands that looking versus reaching place on young children's search for hidden objects (Hood et al., 2003). But what changes underlie the transformation from failure at 2 and 2.5 years of age to success at 3 years of age? Research on spatial cognition suggests that children's ability to select spatial reference frames and use them to align experiences across trials or situations is changing during this period (DeLoache, 1987; DeLoache, 1989; Newcombe et al., 1998). Inspired by this work, we manipulated the salience and stability of the key spatial reference frame in the ramp task—the barrier—to examine whether we could improve the performance of toddlers.

This was indeed the case. The 2.5-year-olds in Experiment 1 performed at above-chance levels, exceeding the performance reported by Berthier and colleagues (2000). These data are consistent with results from Keen and colleagues (2008). These researchers boosted the performance of 2.5-year-olds to above-chance levels by making the barrier more salient. In Experiment 2, however, we showed that children's performance on test trials is also influenced by movement of the barrier and the spatial range of the training examples. When we maximized the spatial extent of ramp/barrier movement and capitalized on children's tendency to perseverate during training, we increased the accuracy of even 2-year-olds and found a significant difference between the Moving Ramp and Stationary Ramp conditions. Previous studies have successfully improved performance of 2.5-year-olds in this task during testing. Importantly, however, the manipulations that brought about the improvement in those prior studies were present during testing. In contrast, all children in our experiments were tested with the ramp fixed in position. Thus, our Moving Ramp manipulation was present only during training trials. This, then, suggests that our training manipulation helped children to learn how to search later during testing. In particular, our training manipulation increases children's ability to align their bodies with the relevant reference frame—the barrier—and thereby to successfully search in this task. In this way, then, our findings indicate that differences in performance between 2- and 3-year-olds in the ramp task are related to the emerging ability to flexibly align responses to specific spatial reference frames in the task space, including frames that move around from trial to trial.

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