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REPRESENTATIONAL MOMENTUM IN CHILDREN: DYNAMIC INFORMATION AND ANALOGUE REPRESENTATION[1]

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Summary.—Two groups of children and a control group of adults completed a visual memory task previously shown to produce representational momentum in adults. In the task, a computer-animated target was shown moving either horizontally or vertically, and the target vanished without warning. After the target vanished, observers indicated the location at which it had vanished. Both children and adults exhibited representational momentum, i.e., indicated locations slightly beyond where the target actually disappeared, and the magnitude of representational momentum was larger for younger children than adults. Implications of the results for issues of sensitivity to dynamics and for reliance on analogue representation are discussed.

Memory for the final position of a moving target is often displaced in the direction of that target's anticipated motion, and this displacement has been referred to as *representational momentum* (for review, see Hubbard, 1995, 1998). Freyd and Finke (1984; also Finke, Freyd, & Shyi, 1986) have suggested that representational momentum resulted from an internalization of the principles of momentum by the representational system. For example, just as a person cannot stop a moving automobile immediately after applying the brakes but continues forward some distance because of the momentum of the automobile, so too the mental representation of that motion does not stop immediately but continues forward some distance because the representational system mimics the physical properties of momentum. Representational momentum has been suggested to result from analogue (Kelly & Freyd, 1987) and dynamic (Freyd, 1987; Hubbard, 1995) properties of representation, and so an examination of the developmental course of representational momentum may provide insight into age-related changes in the structure and format of mental representation.

In the only previously published study of representational momentum in children, Futterweit and Beilin (1994) presented third-grade children, fifth-grade children, and adults with pairs of action photographs, e.g., a per-

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[1] Portions of these data were presented at the 1997 Biennial Meeting of the Society for Research in Child Development in Washington, DC (April, 1997). Address correspondence to Timothy Hubbard, Department of Psychology, Texas Christian University, Fort Worth, TX 76129 or e-mail (thubbard@gamma.is.tcu.edu).

son walking. When the photographs were shown in actual temporal order, observers of all ages were more likely to respond that the second picture was the same as the first than when the pictures were shown in the opposite temporal order, and there were no differences in representational momentum as a function of age. This suggested that memory for the action portrayed in the first photograph was shifted in the direction of implied motion and that there were no age-related differences in sensitivity to the direction of implied movement in the photographs. In a control experiment, Futterweit and Beilin presented pairs of nonaction photographs, e.g., a person standing still, and the probability of a *same* response by children or adults was not influenced by whether the photographs were presented in actual or opposite temporal order.

The similarity of children's and adults' responses in Futterweit and Beilin (1994) seems to contradict other studies which suggest that children may not be as sensitive as adults to the dynamic information implied in static stimuli. For example, Kaiser and Proffitt (1984) tested the sensitivity of children to dynamic information by presenting kindergarten, second-grade, and fourth-grade children, and adults with either static (i.e., snapshot) or dynamic (i.e., apparent motion) depictions of two colliding balls, and some of the depictions had been altered to portray dynamically anomalous events. Observers of all ages were able to use the dynamic information explicit in moving displays to identify correctly the anomalous moving displays, whereas only older children and adults were able to use the dynamic information implicit in static displays to identify correctly the anomalous static displays. Kaiser and Proffitt concluded that, if a stimulus is moving, children may be relatively more sensitive to dynamic information, whereas if a stimulus is not moving (e.g., consists of a series of static and discrete pictures), children may be relatively less sensitive to dynamic information.

If adults are capable of extracting dynamic information from both static and moving stimuli, then presentation of either static pictorial stimuli or moving stimuli could indicate sensitivity to dynamic information and representational momentum. If children are more capable of extracting dynamic information from moving than from static stimuli, then the presentation of static pictorial stimuli would not show the full extent of children's sensitivity to dynamic information, nor would such stimuli evoke the full extent of possible representational momentum. It could therefore be predicted that, if both children and adults are presented a moving stimulus, then the children should subsequently exhibit even greater representational momentum than adults. Accordingly, the following experiment presented a horizontally or vertically moving target that smoothly translated across the display, and representational momentum for the target was assessed.

METHOD

Participants

There were three groups of participants: younger children ($n = 13$, $M = 6.7$ yr., range = 5.3–8.6 yr.), older children ($n = 13$, $M = 10.7$ yr., range = 9.1–12.9 yr.), and adults ($n = 13$, $M = 21.4$ yr., range = 19.1–24.0 yr.). Younger and older children were recruited from a pool of children who had participated in previous developmental studies (unrelated to the current study) at Texas Christian University. Adults were undergraduates recruited from introductory psychology courses at Texas Christian University who received partial course credit for participation.

Apparatus

The stimuli were presented upon and responses collected by an Apple Macintosh IIsi microcomputer equipped with an Apple RGB color monitor.

Stimuli

The target stimulus was a filled black square presented on a white background. The target was 20 pixels (approximately 0.83°) in diameter. The target emerged from either the top, bottom, left, or right of the screen and traveled in a straight line toward the opposite side of the screen. The target vanished without warning within the middle one-third of the screen. Target velocity was controlled by shifting the target either 1 or 3 pixels per screen refresh, resulting in an approximate target velocity of either 5 or 15°/sec. Target motion appeared smooth and continuous. Each observer was presented with 40 trials (4 directions × 2 velocities × 5 replications) in a different random order.

Procedure

The observer initiated each trial by pressing a designated key. One second after the key to begin the trial was pressed, the target emerged from either the top, bottom, left, or right edge of the screen. The target traveled in a straight line toward the opposite side of the screen, and the target vanished without warning after crossing between one-third and two-thirds of the distance across the screen. After the target vanished, the cursor appeared in the form of a crosshair (i.e., a "+" sign) near the center of the screen, and observers positioned the center of the crosshair over where the center of the target had been when the target vanished. The cursor was positioned by movement of a computer mouse; observers were instructed to be as accurate as possible and were given as much time as they required. After the cursor was properly positioned, observers clicked a button on the mouse (to record the screen coordinates of the cursor). Observers completed six practice trials that were randomly drawn from the experimental trials.

RESULTS

The differences between the true vanishing point and the judged vanishing point (in pixels) along the axis of motion were calculated for each direction and velocity condition for each observer. Following Hubbard and Bharucha (1988), the differences along the axis of motion (the x axis for horizontal motion, and the y axis for vertical motion) were referred to as *M displacement.* Positively signed M displacements indicated judged vanishing points beyond the true vanishing point (e.g., left of a leftward moving target) above an ascending target, and negatively-signed M displacements indicated judged vanishing points behind the true vanishing point (e.g., right of a leftward moving target) below an ascending target. The magnitude of positive M displacement provided a direct estimate of the magnitude of representational momentum.

An analysis of variance with Direction and Velocity as within-subjects variables and Age as a between-subjects variable was carried out on the M displacements. Age was significantly associated with the magnitude of M displacement ($F_{2,36}=3.18$, $MSE=671.57$, $p=.05$), and *post hoc* Newman-Keuls tests ($p<.05$) of all pairwise comparisons between younger children ($M=22.94$), older children ($M=17.75$), and adults ($M=13.91$) indicated that the magnitudes of M displacement were larger for younger children than for adults. Direction influenced M displacement ($F_{3,108}=31.08$, $MSE=209.74$, $p<.001$); orthogonal planned comparisons indicated larger M displacements for horizontal motion than for vertical motion ($F_{1,36}=98.63$, $p<.001$), larger M displacements for descending motion than for ascending motion ($F_{1,36}=11.47$, $p<.01$) but no differences between rightward and leftward motion ($F_{1,36}=1.20$, ns). Faster ($M=26.01$) velocity produced greater M displacement than slower ($M=10.38$) velocity ($F_{1,36}=79.81$, $MSE=238.65$, $p<.001$), and velocity also interacted with direction ($F_{3,108}=20.30$, $MSE=73.57$, $p<.001$). As shown in Fig. 1, M displacement increased more rapidly with increases in velocity for horizontal motion. The observed direction and velocity effects were consistent with those of previous studies.

The average M displacements for each age and velocity condition were compared to a null hypothesized mean of zero (using a Bonferroni correction of $.05/6=.008$). For younger children, M displacements were greater than zero for slow ($t_{12}=8.61$, $p<.001$) and fast ($t_{12}=7.16$, $p<.001$) velocities. For older children, M displacements were greater than zero for slow ($t_{12}=8.62$, $p<.001$) and fast ($t_{12}=9.21$, $p<.001$) velocities. For adults, M displacements were greater than zero for slow ($t_{12}=2.78$, $p<.008$) and fast ($t_{12}=5.66$, $p<.001$) velocities.

DISCUSSION

Younger children, older children, and adults all exhibited representational momentum, but the magnitude of representational momentum was

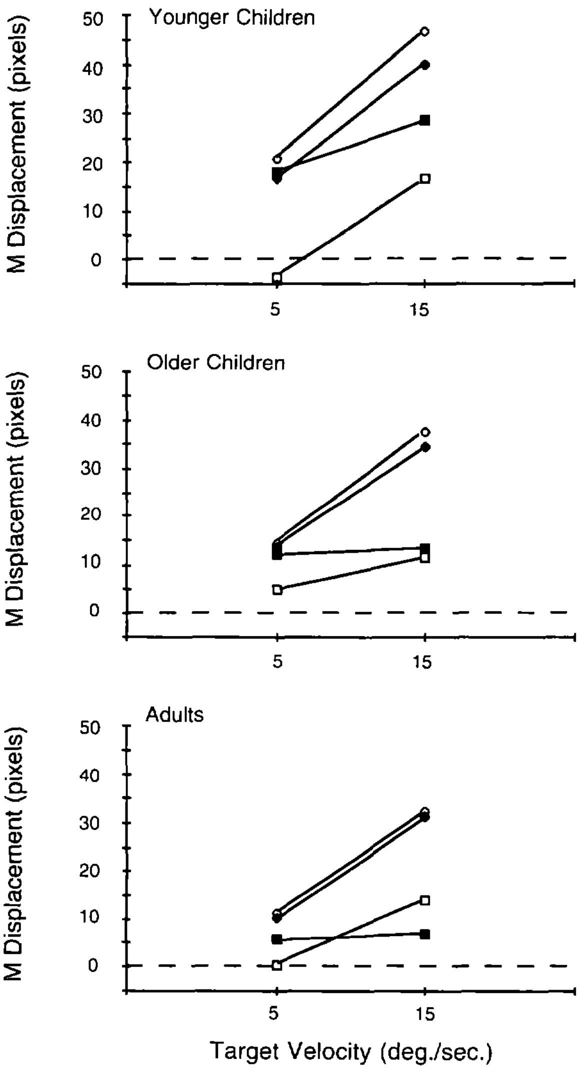

FIG. 1. M displacement as a function of target velocity. Data for younger children are displayed in the top panel, data for older children are displayed in the middle panel, and data for adults are displayed in the bottom panel. Data for rightward motion (◆), leftward motion (◇), descending motion (■), and ascending motion (□) are displayed.

larger in younger children than in adults. This pattern is consistent with the suggestion that children may be more sensitive to dynamic information within moving displays than to the implied dynamics within static pictures. Why might such a difference in sensitivity occur? One possibility is that children may rely more on a concrete and sensory analogue representation than on a propositional or abstract representation (e.g., Bruner, Olver, & Greenfield, 1966; Kosslyn, 1978; but see Mandler, 1983), whereas adults may rely more on a propositional or abstract representation than on a concrete or sensory analogue representation. Given that representational momentum may rely on or reflect properties of analogue representation (Kelly & Freyd, 1987), a greater reliance on analogue representation by the younger children could subsequently result in a greater magnitude of representational momentum.

There are several possible explanations for the differences between the current data and that reported in Futterweit and Beilin (1994). One explanation involves differences in ages: Futterweit and Beilin's youngest subjects had a mean age of 8.9 yr. of age, and this age is closer to that of the older children than to that of the younger children in the current study. Although the older children exhibited somewhat more M displacement than the adults (and less than the younger children), the *post hoc* comparison between the older children and adults was nonsignificant. Had Futterweit and Beilin used a younger group of observers, they might have been more likely to obtain significant effects of age. Such an explanation suggests that differences in the surface form of the stimuli (e.g., whether static pictures or animated displays were used) would not have necessarily influenced representational momentum, and this is consistent with Freyd's (1993) notion that it is the structure of the underlying dimension rather than the structure of the specific stimuli that determines whether representational momentum occurs (but see Brehaut & Tipper, 1996).[2]

A second explanation for the differences between the data of Futterweit and Beilin (1994) and the data of the current study involves differences in the types of motion that were presented. Futterweit and Beilin used static pictures of complex motions (e.g., a person tossing or bouncing a ball, a person walking, running, or jumping) whereas the current study used relatively simple horizontal and vertical translation. It may be the case that extrapolation for such complex motion is more difficult than extrapolation for simple translation, so children experienced more difficulty in representing the path of anticipated future motion. In a related point, the pictorial stimuli used by Futterweit and Beilin contained much richer ecological information than the simple animations used in the current experiment. This additional information may have partially compensated for the use of static

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[2] Freyd (1993) suggested that, if the underlying dimension is continuous (e.g., orientation, spatial position), then stimuli along that dimension should exhibit representational momentum regardless of whether those stimuli are discrete and separated samples (e.g., as in implied motion) or are more continuously varying (e.g., as in apparent motion). However, if the underlying dimension is discrete (e.g., integers), then stimuli along that dimension should not exhibit representational momentum. Thus, it is the structure of the underlying dimension rather than the structure of a specific stimulus that determines whether representational momentum for a given stimulus is obtained.

stimuli and allowed children to exhibit representational momentum more comparable to that exhibited by adults.

The primary finding was that, when children and adults were shown stimuli undergoing apparent motion, the younger children exhibited greater magnitudes of representational momentum than did adults. This pattern is consistent with previous claims that children are more likely than adults to rely on analogue representation. This pattern is also consistent with previous claims that children are more sensitive to the dynamics within animated displays than within static displays. Researchers should examine representational momentum in younger children with a series of static targets that imply motion (e.g., as in Freyd & Finke, 1984). Given that children should be less sensitive to the implied dynamics of such a display and that such stimuli might be less likely to evoke analogue representation, we predict that younger children's memory for such stimuli would exhibit less representational momentum than would the memory of adults. The data presented here offer a first step toward an understanding of the developmental course of representational momentum and a useful addition to theories of representational momentum and of sensitivity to implied dynamics.

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