Movement Coding and Memory in Retarded Children

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Three experiments on the coding and retention of movement-generated information were performed on two groups of mildly retarded children varying in MA. The cue to be reproduced in each case was the terminal position of the limb that studies with adults have shown to require central processing activity for maintained performance. In Experiment 1, although the older MA group was superior, both groups showed similar decrements in performance over a 15-second retention interval. In Experiment 2 the procedures were adopted in an attempt to overcome performance deficits. Subjects were allowed to choose (preselect) their own movements voluntarily in addition to performing constrained, experimenter-defined movements. Preselected reproduction was superior to constrained at all three retention intervals (0, 7, and 15 seconds) but was not statistically different among age groups. Also, performance was maintained for both groups over 7 seconds but deteriorated over 15 seconds. These results were replicated in Experiment 3, which also showed that an interpolated motor task designed to block rehearsal processes interfered with reproduction at the 7- and 15-second retention-interval conditions. The findings indicated that mildly retarded children could maintain motor information over brief time periods and also illustrated the important contribution of the planning component in facilitating the coding of motoric information.

Although there has been a good deal of research on retarded children's short-term memory for verbal and visual materials (for reviews see Brown, 1974; Flavell, 1970; Spitz, 1973), there is a paucity of work dealing with memory for movement information. This somewhat surprising situation prevails in spite of the fact that developmental theorists in general have assumed that the kinesthetic modality relaying movement and position information to the central nervous system (CNS) is important for the detection and correction of movement errors (see Connolly, 1970). Bruner (1973), for example, argued that the "synchrony" developed between an intended action signalled within the CNS and the kinesthetic information arising as a result of

that action is a major determinant of skilled performance.

Although it is generally agreed that mentally retarded children lag behind those of "normal" intelligence in the development of both fine- and gross-motor skills (e.g., Rarick, Dobbins, & Broadhead, 1976), we have little information as to why this is the case. In fact, much of the research on the motor behavior of retarded individuals has been descriptive and product-oriented (e.g., Bruininks, 1974; Malpass, 1963; Rarick, Widdop, & Broadhead, 1970). In contrast, the area of adult motor performance has shifted towards a process approach to understanding the underlying mechanisms involved in the acquisition of skills and the control of movement (e.g., Kelso & Stelmach, 1976). Congruent with this approach, we asked the following empirical questions in this set of experiments: (a) How efficiently can retarded children remember motoric information? (b) Are there age-related differences in this ability? (c) What procedures might facilitate main-

tenance of movement-produced information in memory?

Our experimental method was quite simple. Two groups of retarded children made linear movements involving adduction of the shoulder joint to a location defined by an experimenter (termed *constrained*) or to one chosen by themselves (termed *preselected*). They then reproduced the final location from a new starting position. We chose final location as an important source of information based largely on research findings with adults, which show that it is not subject to retention deficits over short periods of time (Keele & Ells, 1972; Laabs, 1973; Posner, 1967).

Laabs (1973) has developed a model of kinesthetic memory postulating dual storage codes, one of which (location) is rehearsable (i.e., can be maintained over time), while the other (distance) is not. A point to emphasize here is that this view of rehearsal is not restricted to situations where processing is verbal, but rather is extended to include any situation in which the materials to-be-remembered require central processing. Whether movement-produced information is subject to the same type of rehearsal deficits as has been found for verbal materials in retarded children (see Brown, 1974, for review) is unknown. Thus, in the present experiments we sought to establish the generality of the hypothesis that developmentally young people are unable to generate spontaneous rehearsal strategies by utilizing motoric information as the input to-be-remembered.

EXPERIMENT 1
Method
Subjects

Thirty-five right-handed educable mentally retarded (EMR) children from self-contained special-education classes served as the experimental subjects. The older group consisted of 15 subjects between the ages of 10 years, 10 months (10–10) and 13–1 (mean = 12–2), with a mean mental age (MA) of 8–10 years (range = 8–4 to 9–8), as calculated from a recent administration of standardized individual intelligence tests. The younger group was composed of 20 subjects between the ages of 8–0 and 10–9 years (mean = 9–4), with a mean MA of 5–9 years (range = 4–7 to 6–11).

Apparatus

Two steel rods (1.0 m long, 1.6 cm diameter) were mounted horizontally and parallel to each other, 9.5 cm apart on a wooden frame that rested on a 60 cm high table. Two fitted aluminum tubes, which ran on the steel rods, were set in a block of wood (7.5 cm × 15.5 cm × 5.0 cm) and comprised the main frame of the slide. The freely moving slide had a handle (9.0 cm long × 1.3 cm diameter) set vertically in the center of the slide. A pointer attached to the experimenter's side of the slide moved along a metric scale so that the subject's criterion and reproduction movements could be recorded to the nearest .1 cm. Moveable stops allowed for three starting positions (backward, at the 23 cm mark; middle, at the 33 cm mark; forward, at the 43 cm mark) and two end positions to be defined at the 55 cm and 65 cm positions (termed *short* and *long*, respectively). Timing of movements was controlled by an 8-bank Lafayette programmable electronic timer.

Procedure and Design

All subjects in this and the following experiments were tested individually. When the subjects entered the testing room, they were told that the task involved remembering movements. Each subject was seated facing the slide such that the midline of the body was opposite the 45 cm mark on the linear positioning device. The subjects were instructed to grasp the handle of the slide with the right hand and attempt to move it from right to left through the full range of movement (0 to 70 cm). They then performed one practice trial in which, with vision available and after hearing the command to start, they moved the handle until it contacted a stop designating the criterion movement. After remaining at the stop for 2 seconds, the subjects, on a release com-

mand, removed their right hand while the experimenter returned the handle to the starting position. The subjects were encouraged to remember the location ("remember that spot") during the 2 seconds at the stop and in the ensuing retention interval. The stop was then removed, and the subjects were instructed to regrasp the handle and reproduce the criterion movements, an action designated as the reproduction movement. This task was accomplished easily by all subjects. To make the "game" a little harder, the subjects were blindfolded, and an additional practice trial was given. We should note that no knowledge of results as to response accuracy was given at any point during the experiment. The sequence for 36 trials that were performed in the absence of vision then commenced, presented in a block of 18 trials at each retention interval (immediate and 15 seconds), with a rest of approximately 30 seconds after 9 trials and a rest of approximately 1 minute between the two blocks. Each criterion movement started at the middle starting position and terminated at one of the two end locations, while each reproduction movement started at one of the three starting positions. Starting position and end location for each trial were randomized, with the constraint that no two adjacent trials have the same starting position or end location. One-half of the subjects performed in the immediate retention interval first, while the other half initially performed in the 15-second retention interval. The intertrial interval was 10 seconds.

Reproduction errors for each separate condition were collapsed for inspection of signed or constant error and absolute or unsigned error. In addition, an estimate of variability was obtained by calculating the standard deviation (SD) around each subject's mean constant error (variable error). The data were thus analyzed using a 2 (groups: developmental age) × 2 (retention interval: immediate or 15 second) × 3 (starting position: backward, middle, forward) × 2 (end location: short or long) mixed analysis of variance, with only the first factor as a between-subject variable.

Results and Discussion

The salient features of the data are presented in Table 1. Superior reproduction accuracy was revealed in the older group as reflected in the main effect of groups for absolute error (means for the older and younger groups = 4.98 cm and 6.78 cm, respectively, $F = 4.77$, 1/33 df, $p < .05$), constant error (means = 1.51 cm and 4.03 cm, respectively, $F = 4.12$, 1/33 df, $p < .05$), and variable error (means = 3.05 cm and 4.14 cm, respectively, $F = 6.26$, 1/33 df, $p < .02$). Furthermore, this superiority was not

TABLE 1

MEANS AND STANDARD DEVIATIONS (SDs) OF REPRODUCTION ERRORS FOR GROUPS, RETENTION INTERVALS, STARTING POSITIONS, AND END LOCATIONS

Movement variables	Younger group (MA 5–9 years)						Older group (MA 8–10 years)					
	AE		CE		VE		AE		CE		VE	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Retention interval												
Immediate	6.16	3.54	3.91	5.54	3.82	2.49	4.40	2.18	1.92	4.02	2.77	1.65
15-second delay	7.40	4.72	4.16	4.97	4.46	2.72	5.57	2.74	1.10	4.20	3.33	1.80
Starting position												
Backward (−10 cm)	6.63	3.86	1.96	5.97	4.63	2.84	5.15	2.50	−1.24	4.79	3.64	2.23
Middle	5.79	3.81	3.43	4.49	3.80	2.34	4.18	2.12	1.20	3.69	2.95	1.58
Forward (+10 cm)	7.92	4.62	6.72	5.31	3.91	2.65	5.64	2.75	4.56	3.85	2.58	2.16
End location												
Near[a]	7.93	4.80	6.71	4.83	4.34	2.84	5.24	2.31	2.41	3.66	2.71	1.43
Far[b]	5.63	3.46	1.56	5.73	3.92	2.38	4.73	2.66	.61	4.55	3.40	2.01

Note. AE = absolute errors in cms, CE = constant (signed) error in cms, VE = variable error in cms.
[a] Movement amplitude of 22 cm from the middle starting position.
[b] Movement amplitude of 32 cm from the middle starting position.

differential as a function of retention interval, as indicated by the null findings of the Groups × Retention Interval interaction for any of the dependent variables (no F value greater than 1.11).

The main effect of retention interval indicated greater absolute error (5.28 cm vs. 6.48 cm, $F = 16.66$, 1/33 df, $p < .001$) and variable error (3.25 cm vs. 3.89 cm, $F = 8.65$, 1/33 df, $p < .01$) for the 15-second retention interval, although constant error showed no significant differences. This increase in reproduction error over the retention interval suggests that maintenance of kinesthetic-location information over a short time period deteriorates in both groups and is in contrast with findings for nonretarded adults showing that location information is accurately retained (Keele & Ells, 1972; Laabs, 1973).

Starting position of the reproduction movement had a potent effect, as reflected in the significant main effect of starting position for absolute error, constant error, and variable error ($Fs = 94.40$, 12.32, and 7.34, respectively, 2/66 dfs, $ps < .001$). Post-hoc analysis of absolute error indicated that reproduction error from the middle starting position was significantly smaller than either the forward or backward starting positions ($p < .05$). This interesting aspect of our data suggests that subjects in both age groups used, at least to some extent, the amplitude of movement as a source of information for reproduction cue. If so, this would account for the increased reproduction error over the retention interval and is consistent with other findings with adults showing the same effect for amplitude (e.g., Laabs, 1973). With respect to variable error, post-hoc analysis showed that only the backward starting position had larger variability than either the middle or forward starting positions.

The Retention Interval × Starting Position interaction was significant for constant error ($F = 4.73$, 2/66 df, $p < .01$) but not absolute or variable error. Before interpreting this interaction, we should point out that of the 24 cells in the design, all but 5 showed positive reproduction error. This is significantly fewer ($p < .03$) than chance alone when tested by the binomial test

(Siegel, 1956) and indicates a rather consistent overshooting error. This finding has been previously reported for kinesthetic judgments (Millar, 1972) and obviously influences interpretation of constant error with respect to changed starting positions. In light of this response bias, the post-hoc analysis revealed for both retention intervals that the backward starting position significantly reduced the overshoot (i.e., biased the reproductive movements towards the backward starting position (mean at 0 seconds was 1.14; at 15 seconds, .04 while the forward starting position increased the overshooting strategy (mean at 0 seconds, 5.33; at 15 seconds, 6.25). Over the retention interval, however, this biasing effect, both forward and backward, became more pronounced.

There was a significant main effect of end location for absolute error and constant error ($Fs = 11.71$ and 52.03, respectively, 1/33 dfs, $ps < .01$) but not variable error. As indicated in Table 1, greater absolute error and a larger overshooting response were found for the short- than for the long-end location. The interaction of age with end location for constant error and variable error revealed similar findings when analyzed for simple effects ($Fs = 12.83$ and 8.26, respectively, 1/33 dfs, $ps < .01$). The younger groups showed more overshooting and increased variability at the short-end location than did the older group, while no statistical differences in constant or variable error were found at the more distant end location.

Although the subjects might have been using amplitude as a source of information, we must still contend with the finding that even under conditions where starting position remained unaltered (amplitude and location reliable), there was a decrement in reproduction error. This finding led us to a second experiment in which we attempted to increase the codability of location information by allowing subjects to preplan their movements.

EXPERIMENT 2

Since there was little evidence of maintained accuracy over a 15-second retention

interval in Experiment 1, it seemed important to introduce procedures to enhance potentially the codability of kinesthetic information. One approach is to allow subjects to define their movement (preselection) as opposed to the experimenter-defined (constrained) conditions of Experiment 1. Recent data have shown that reproduction is improved under the former conditions (e.g., Jones, 1974; Kelso & Stelmach, 1976). Although there is some disagreement as to the specific processes underlying preselected movement accuracy (see Kelso & Wallace, 1978, for a review), a dominant viewpoint is that preselection facilitates the processing of movement-produced information (Kelso, 1977; Roy & Diewert, 1975). In the case of preselection, a strategy or plan is available prior to movement that, if utilized, should have beneficial effects on the processing of kinesthetic information. In contrast, under constrained conditions no prior information is available since the end point of the movement is not known until the subjects contact the experimenter-defined stop. Thus, this experiment was designed to determine whether mildly retarded subjects could utilize preselection to remember movement more efficiently. A second aim was to examine further the retention of simple movements over time. It is not known, for example, where in the retention interval used in Experiment 1 the greatest deficits in performance occurred. Hence, a third retention-interval condition was introduced requiring subjects to reproduce movement after 7 seconds.

Method

Subjects and Apparatus

The 28 subjects were drawn from the population of subjects performing in Experiment 1 and were assigned to two groups (n = 14 in each) varying in developmental age. In each group subjects performed both preselected and constrained movements.

The apparatus was the same linear positioning device as used in Experiment 1; however, the end location in the constrained condition was determined by a moveable block that could be placed at any position along the apparatus.

Procedure and Design

The second experiment consisted of two sessions, one of which involved preselected movements and the other, constrained movements. In the preselected condition, the subjects were seated as in Experiment 1, blindfolded, and presented with the range of movement. Short movements were defined as those within the 50 cm to 60 cm mark on the slide, while long movements consisted of responses within the 60 cm to 70 cm mark. Selection of the criterion movement was voluntary (i.e., defined by the subject), with the constraint that the subject selected within the sector designated for that trial (either short or long). Each trial began with instructions to the subjects to grasp the handle and select the movement. The command "select" was given to ensure that they preset the movement prior to initiation. The subjects, on command, then moved to their selected location at a slow and constant speed. After 2 seconds at the final position of the criterion movement, the subjects removed their right hand from the handle and placed it by their sides while the experimenter returned the slide back to the starting position. As in Experiment 1, the reproductive movements were begun from three different starting positions, the order of which was randomized. Following either an immediate-, 7-second, or 15-second retention interval, the subjects were instructed to grasp the handle and replicate the movement. The end point of the reproductive movement was recorded, following which the subjects released the handle, thus terminating the trial. The subjects then rested during the 10-second intertrial interval.

In the second session (constrained), carried out 1 week later, the procedures were as above, with the exception that the experimenter placed a stop at a position matching the preselected criterion movement of the corresponding trial in Session 1, and the subjects were instructed to move to the stop. This procedure allowed for a valid comparison of reproduction errors in both conditions.

For both preselected and constrained conditions, subjects performed 12 trials

within each of the three retention intervals, whose order was counterbalanced, with approximately 30-seconds rest after each block of 12 trials. The 12 trials within each retention interval started at three different starting positions, with criterion movements terminating in either a short or long sector. Reproduction errors for each separate condition were collapsed for inspection of absolute, constant, and variable error. The data were analyzed using a 2 (groups: developmental age) × 2 (condition: preselected or constrained) × 3 (retention interval: 0, 7, or 15 seconds) × 3 (starting position: backward, middle, forward) × 2 (end location: short or long) mixed analysis of variance, with only the first factor as a between-subject variable.

Results and Discussion

The main effect of age was not significant for any of the dependent variables. There was, however, a significant main effect of conditions for absolute error ($F = 23.87$, $1/26$ df, $p < .01$), constant error ($F = 41.57$, $1/26$ df, $p < .01$), and variable error ($F = 4.39$, $1/26$ df, $p < .05$). As shown in Table 2, the preselected condition, in which subjects actively selected the terminal location of the movement, resulted in less reproduction error than did the constrained condition, a finding that did not interact with age group. Furthermore, the superiority of preselection was consistent across retention intervals, as revealed by the absence of a Conditions × Retention Interval interac-

TABLE 2

MEANS AND STANDARD DEVIATIONS (SDs) OF REPRODUCTION ERRORS FOR GROUPS, RETENTION INTERVALS, STARTING POSITIONS, AND END LOCATIONS FOR CONDITIONS

Condition/ Variables	Younger group (MA 5–9 years)						Older group (MA 8–10 years)					
	AE		CE		VE		AE		CE		VE	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Preselected condition												
Retention interval												
Immediate	3.23	1.91	.11	2.70	2.14	1.69	3.76	1.83	.93	3.13	2.25	1.81
7-second delay	4.08	2.20	.74	3.60	2.40	1.75	4.45	2.07	1.16	3.03	1.82	1.44
15-second delay	4.83	2.75	.24	4.20	2.85	2.39	5.31	2.37	1.21	3.59	2.32	1.91
Starting positions												
Backward												
(−10 cm)	4.72	2.53	−1.97	4.15	2.77	2.15	4.39	2.51	4.75	4.31	2.57	1.98
Middle	2.88	1.56	.29	2.56	2.16	1.50	3.03	1.50	.56	2.41	1.71	1.48
Forward (+10 cm)	4.54	2.78	2.39	3.79	2.42	2.17	6.10	2.26	4.48	3.04	2.09	1.70
End location												
Near[a]	4.03	2.44	1.35	3.40	2.37	1.89	5.08	2.15	1.24	3.27	2.11	1.70
Far[b]	4.07	2.13	−.88	3.60	2.55	1.99	3.94	2.03	.95	3.24	2.14	1.73
Constrained condition												
Retention interval												
Immediate	4.74	2.84	2.79	3.87	2.47	1.79	4.14	2.28	2.86	3.32	2.24	1.55
7-second delay	5.10	2.94	2.49	4.32	2.56	2.04	4.38	2.88	3.70	3.77	2.55	1.94
15-second delay	6.49	3.20	2.70	5.33	3.21	2.53	5.72	3.51	3.46	4.71	2.95	2.67
Starting positions												
Backward												
(−10 cm)	5.84	3.24	.72	5.36	3.16	2.09	4.56	2.40	.43	4.52	2.84	1.83
Middle	4.70	2.68	2.44	4.11	2.66	2.42	3.69	2.74	3.13	3.38	2.38	2.09
Forward (+10 cm)	6.15	3.08	4.83	4.05	2.43	1.85	6.00	3.53	6.46	3.91	2.54	2.25
End location												
Near[a]	4.93	3.27	4.71	4.22	2.53	1.71	5.09	2.99	4.05	3.77	2.34	1.85
Far[b]	4.55	2.72	.62	4.79	2.96	2.53	4.17	2.78	2.63	4.10	2.81	2.21

Note. AE=absolute error in cms, CE=constant (signed) error in cms, VE=variable error in cms.

[a] Movement amplitude of 22 cm from the middle starting position.

[b] Movement amplitude of 32 cm from the middle starting position.

tion for all dependent variables. It therefore appears that the faciliatory effects arising from preselecting a movement (Jones, 1974; Kelso, 1977; Kelso & Stelmach, 1976) are not restricted to nonretarded populations. If preselection enables subjects to plan the movement prior to its execution, as we have argued elsewhere, it would seem that children are perfectly capable of such operations.

As in Experiment 1, reproduction errors increased over time as indicated by the main effect of retention interval for absolute error and variable error (Fs = 6.01 and 14.09, respectively, 2/52 dfs, ps < .01), although constant error was not significant.

Post-hoc analysis utilizing Tukey's HSD test revealed that errors for the 15-second retention interval were greater than those for immediate and 7-second reproduction, which in turn were not significantly different from each other. As can be seen in Table 2, the groups did not behave differentially across retention intervals; this finding was established statistically by the null interaction effect for all dependent variables (no F value greater than 1.20, p > .05).

Effect of starting position, as in Experiment 1, was statistically significant for absolute error and constant error (Fs = 46.13 and 76.77, respectively, 2/52 dfs, ps < .01). Post-hoc analysis of absolute error showed that the middle starting position, which afforded both distance and location cues, resulted in less reproduction error than the forward and backward starting positions. Once again, systematic effects were present for constant error; backward starting positions reduced the predominant overshooting response, while forward starting positions amplified this effect.

The end-location analysis for constant and absolute error was significant (Fs = 50.93 and 9.60, respectively, 1/26 dfs, ps < .01). Greater error and more overshooting were present at the short- than long-end location. The groups variable interacted with end location for constant error (F = 16.62, 1/26 df, p < .01) and also with end location and starting position for constant error (F = 20.09, 2/56 df, p < .01). Starting position and end location had rather consis-

tent effects on both age groups. The movement of the starting position biased the reproduction movement in the changed direction, while short movements were overshot more than were long movements.

The major finding in Experiment 2 was that children in both age groups were capable of maintaining kinesthetic location information over a 7-second period. This in itself is an important result, since it suggests that retarded children can encode and maintain spatial location over a short-term interval. A third experiment was conducted to examine this interpretation further.

EXPERIMENT 3

In previous research with adults, investigators have used an interpolated task during the retention interval as a means of ascertaining whether the retention of movement information requires central processing. If reproduction is deleteriously affected by this procedure in comparison to an unfilled interval, the inference is that the movement information manipulated is subject to central processing (Keele & Ells, 1972; Laabs, 1973).

Adopting the foregoing logic, we assumed that if the maintenance of kinesthetic location information over a 7-second period requires central capacity, then the introduction of an interpolated task would block the rehearsal process and lead to elevated performance errors. Conversely, since there was little evidence of maintained performance over a longer 15-second period in either Experiment 1 or Experiment 2, the introduction of interpolated processing activity should have little or no effect in comparison to an unfilled interval. These predictions were examined in the following experiment.

Method

Subjects and Apparatus

Twenty-four subjects from the same population employed in the previous experiments were assigned to two groups (n = 12), with mean MAs of 5–9 years and 8–10 years.

The apparatus was the same linear positioning device as used in Experiments 1 and 2; however, the middle starting position (at the 33 cm mark) was the only starting position utilized.

Procedure and Design

The present experiment consisted of six trials in each of five experimental conditions. The basic procedure was closely similar to the preselected condition of Experiment 2. All criterion movements were preselected, and subjects were instructed to pick different movement end locations throughout the total defined range (from the 50 to 70 cm mark). Criterion and reproduction movements began from the same middle starting position. Following a 0-second (immediate reproduction), 7-second unfilled, 7-second filled, 15-second unfilled, or 15-second filled retention interval, the subjects were instructed to regrasp the handle and replicate the criterion movement as accurately as possible. During a filled retention interval, the subjects were required to perform a simple movement task with their right hand as quickly as possible. This activity involved taking small blocks of wood inserted on one peg and stacking them on another peg 10 cm away. Each condition consisted of six trials, with an intertrial interval of 10 seconds. The subjects had approximately 30-seconds rest between retention interval conditions when order was counterbalanced across subjects. The data were thus analyzed using a 2 (groups) × 5 (retention interval: 0-second immediate, 7-second filled and unfilled, 15-second filled and unfilled) analysis of variance for each dependent variable.

Results and Discussion

The means and SDs of the main effects of groups and retention intervals are presented in Table 3. Performance of the older group was not significantly different in terms of absolute error or constant error, although it was less variable than that of the younger group ($F = 8.17$, 1/22 df, $p < .01$). The groups were not differentiated across retention interval conditions, as revealed in the null effect of the Group × Retention Interval interaction for absolute, constant, and variable error.

The main finding of interest was the significant effect of retention interval conditions for absolute, constant, and variable errors (Fs = 26.55, 3.73, and 28.44, respectively, 4/88 dfs, ps < .01). Post-hoc analysis of absolute and variable error utilizing Tukey's HSD test indicated no significant differences between immediate reproduction and the 7-second unfilled retention interval condition, thus replicating the results of Experiment 2. As predicted, the immediate and 7-second unfilled conditions were significantly different from the 7-second filled and both 15-second retention interval conditions. Although there were no differences in the magnitude of error between the 7-second and 15-second filled conditions, errors in the 15-second unfilled condition were slightly less than those in its filled counterpart. Post-hoc analysis of the retention interval main effect for constant error revealed that only the

TABLE 3

MEANS AND STANDARD DEVIATIONS (SDs) OF REPRODUCTION ERRORS FOR GROUPS
AND RETENTION INTERVALS

Retention interval	Younger group (MA 5–9 years)						Older group (MA 8–10 years)					
	AE		CE		VE		AE		CE		VE	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Immediate	2.19	.98	−.37	1.68	2.01	.80	1.45	.55	−.26	1.16	1.30	.57
7-second unfilled	2.63	1.04	.04	1.80	2.87	1.16	2.53	1.14	−1.07	1.98	1.80	1.01
15-second unfilled	4.22	.98	−.04	2.83	4.41	1.34	3.19	1.34	.04	2.66	3.21	1.29
7-second filled	4.56	1.73	1.69	1.90	5.22	2.01	4.25	1.70	.76	3.15	4.29	1.91
15-second filled	5.29	1.89	1.71	2.82	5.56	2.26	3.97	1.65	.03	2.02	4.20	1.61

Note. AE=absolute error in cms, CE=constant (signed) error in cms, VE=variable error in cms.

7-second unfilled condition was different from both 7- and 15-second filled retention intervals. As shown in Table 3, interpolated processing activity appears to result in a marked overshooting response, a feature not indicated in immediate or unfilled conditions. Taken together, two of our findings suggest that retarded children can devote central processing capacity to maintaining kinesthetic information. First, there were no deficits in performance between immediate and 7-second reproduction conditions, an important validation of the results of Experiment 2. Second, dramatic deficits in accuracy and increased variability occurred when an interpolated task was introduced during the 7-second retention interval. Thus, the two major criteria (Laabs, 1973) for assessing whether retarded children can rehearse motor information were met.

General Discussion

The present set of experiments was the first designed to examine short-term retention of kinesthetic information in retarded children. We were concerned with whether the ability to code and retain kinesthetic information varied as a function of developmental age. There is substantial evidence that young children and mentally retarded people are deficient in their use of rehearsal processes to aid in the maintenance of information in short-term memory (Brown, 1975; Chi, 1976). Although Experiment 1 revealed clear differences in reproduction accuracy between the two age groups, there was no evidence of differential performance over the retention interval. Indeed, both age groups showed similar deficits in accuracy and variability over a 15-second retention interval.

We should note that in the first experiment, constrained movements were utilized, and, thus, no advance information of the terminal location of the movement was available. What if subjects were allowed to plan and produce their own movements? Would this enable them to organize, maintain, and attend to the relevant aspects of the movement?

In Experiment 2 we employed preselec-

tion as a variable that has been shown to enhance movement-reproduction accuracy. Both groups of retarded children were capable of preplanning movement, as evident in the superior performance of the preselected over the constrained condition at both immediate and delayed reproduction. The finding, however, that the pattern of results over the retention interval was identical in preselected and constrained conditions suggests that preselection operates primarily to facilitate the intake of movement-produced information. Thus, a context for movement-produced information is available when preselection is permitted in contrast to constrained conditions where planning is not possible. The information derived from preselection can therefore be viewed as more "meaningful" to subjects (since they have self-defined the movement) and, hence, may be subjected to a deeper level of analysis. On the other hand, input arising from constrained, exploratory movement is less efficiently processed (since the subjects do not know where the movement will terminate), and, consequently, overall memory performance is poorer. The findings from Experiment 2, then, are significant in that they demonstrate the generality of what we have termed *the preselection effect*.

A significant finding in Experiments 2 and 3 was the ability of subjects to maintain kinesthetic information over a 7-second period. The further effect of interpolated activity in Experiment 3 suggests that rehearsal processes were indeed active over that period of time. Posner (1967) and later Laabs (1973) have suggested that memory for terminal limb position involves a visual code that can be rehearsed and that interference occurs when rehearsal opportunities are blocked. The present experiments suggest that retarded children are capable of this type of representational activity for at least a short period of time and are in contrast to the sizeable literature demonstrating rehearsal deficits in verbal short-term memory (e.g., Brown, 1974; Flavell, 1970). The further finding that reproduction error increased under 15-second delay conditions and between 7-seconds and 15-seconds in Experiments 2 and 3

suggests that retarded children have difficulty in maintaining kinesthetic information over longer periods of time. While we have no direct evidence on why this may be so, attentional factors appear to be an obvious possibility (see Hermelin & O'Connor, 1975, for similar findings with autistic children).

Although we have inferred the presence of rehearsal processes from the combination of findings in Experiments 2 and 3, we should note that no direct attempts have been made to provide rehearsal strategies for subjects or to exploit the gamut of potential strategies available. Shea (1977) has shown that providing nonretarded adults with a relevant verbal label corresponding to the target position presented (in this case, the hands of a clock) is a valuable strategy for reproducing motor responses. It may prove useful to examine whether the addition of such strategies facilitates memory performance in retarded children beyond the rather limited time frame seen in the present experiments.

Finally, although we have restricted our inferences in the present experiments to retarded children, future research in this area should directly compare the performance of retarded and nonretarded children to assess the possibility of differential retention of motoric information. There is some evidence that retarded individuals show verbal memory deficits because of problems in selective scanning and organization at the input stage (Spitz, 1973). Whether preselection, for example, differentially affects the organization of movement-produced information for retarded and nonretarded children is at present unknown but warrants further study.

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