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Enhancing Free-Recall Rates of Individuals With Mental Retardation

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Generative encoding contexts promote activation of multiple retrieval routes and have been shown to enhance free-recall rates of individuals without mental retardation (Soraci et al., 1994, 1999). The present extension to individuals with mental retardation involved a comparison of two encoding conditions: (a) fade-in, initially presenting pictures out of focus then slowly fading them into focus, and (b) fade-out, presenting pictures clearly then slowly blurring them. Results indicated that free-recall rates were greater for the fade-in items for the individuals with mental retardation and CA-matched comparisons, but not for the MA-matched group. These findings demonstrate the utility of a generative encoding context that does not involve verbal instruction for individuals with and without mental retardation.

Early research on the memory performances of individuals with mental retardation was focused on identifying various types of deficiencies that affect memory performance in this population. For example, memory differences between individuals with and those without mental retardation were attributed to instructional deficiencies (e.g., Turnure, 1985), differential attention to the relevant cue (Zeaman & House, 1963, 1979), strategy production/generalization deficiencies (e.g., Belmont & Butterfield, 1971; Bray & Turner, 1986; Brown, 1974; Ellis, 1970), trace susceptibility (e.g., Boyd & Ellis, 1986), and metamemory deficits (e.g., Borkowski, 1985; Campione & Brown, 1977). This literature led to numerous studies that were focused on strategy training and other methods for lessening or overcoming the impact of the identified deficiencies (e.g., Bryant, 1965; Turner & Bray, 1985). More recently, however, greater attention has been given to identifying the memory *abilities* of individuals with mental retardation and the impact of the testing context on memory performance (Bray, Fletcher, & Turner, 1997; Bray et al., 1998). That is, individuals with mental retardation may be able to employ memory strategies but do not do so unless sufficient “situational support” is provided by the teacher/experimenter or the task design.

Various forms of situational support have been shown to be effective in enhancing the memory performances of individuals with mental retardation. Typically, these types of supports involve manipulation of the encoding context, such that organization of the to-be-remembered items is increased (e.g., Spitz, 1966) or rehearsal strategies are more likely to be utilized (Turner & Bray, 1985). Spitz (1966, 1973) showed that the poorer performances of individuals with mental retardation on recall tasks sometimes is the result of an inability or failure to organize information well during encoding. For example, Spitz (1966) demonstrated that individuals with mental retardation recall more words when word lists are presented in a clustered fashion (e.g., all animals presented simultaneously followed by clothing items, etc.) relative to a randomly ordered list of the same items. In addition, Spitz showed that recall is enhanced if the participants with mental retardation are cued to recall in clusters (e.g., "list the animals," "list the clothing items"). This clustering advantage also occurs for the recall of digits Spitz and Webreck (1972) demonstrated that individuals with mental retardation can recognize and utilize redundancy in digit strings, even when it is not explicitly cued or identified by the experimenter. However, the advantage for uninstructed clustering over recall for a series of random digits was less than that in a clustering condition in which the clustering was explicitly cued by underlining and spacing manipulations. Thus, external cues were necessary to maximize the clustering effect for individuals with mental retardation.

Cohen and Bean (1983) showed that free-recall rates of individuals with mental retardation could be increased if additional retrieval cues are incorporated into the encoding context. They found that individuals with mental retardation can remember short task descriptions (e.g., "break the toothpick") better if the tasks are demonstrated by the experimenter or performed by the participant than if they are simply read aloud. Thus, structuring the encoding context to provide additional memory cues (e.g., visual, kinesthetic) enhances immediate free recall. Similar memory advantages for "subject-performed tasks" have been shown for individuals with other neurological impairments, such as autism (Summers & Craik, 1994). These studies demonstrate that intelligence-related differences in free recall can be lessened and perhaps eliminated in some circumstances, when the encoding context is designed to provide multiple potential retrieval cues relevant to a subsequent free-recall test.

Finally, Turner and Bray (1985) showed that rehearsal deficits, often attributed to individuals with mental retardation, may result from constraints imposed by the memory tasks utilized. These authors demonstrated that individuals with mental retardation will spontaneously rehearse and demonstrate memory advantages when an unconstrained encoding task (i.e., a recall readiness task) is utilized. The recall-readiness task used by Turner and Bray allowed the participants to view the to-be-remembered objects as many times as desired and in any order desired. When these typical time constraints were eliminated, the individuals with mental retardation were able to utilize rehearsal as a memory aid. These results provide further evidence that varying the nature of the encoding context significantly impacts the performances of individuals with mental retardation.

In a series of studies, Soraci and colleagues (1994, 1999) have demonstrated that free-recall rates of individuals without mental retardation are enhanced when individuals actively choose response items as compared to passive encoding of responses. This effect is further enhanced when the *generative* encoding context includes multiple referents (i.e., potential retrieval cues) for the to-be-remembered item. For example, Soraci et al. (1999) demonstrated that free-recall rates were greater for a multiple-cue condition in which two referents were activated at acquisition (e.g., c_lf: a young cow, the lower part of the leg) than a multiple-cue acquisition condition in which only one referent was activated (e.g., c_lf: a young cow, an immature bovine). These conditions differ with respect to the number of referents for the target item that are activated during encoding, but the number of cues is constant across conditions. The activation of multiple (potential) retrieval routes (i.e., referents) during a generative encoding context, therefore, successfully increases performance on a subsequent generative memory task (i.e., free recall). These results support a multiple-cue explanation for the "generation effect" (Slamecka & Graf, 1978). The fact that these cueing advantages occurred *only* for generative encoding contexts (i.e., when the target item had to be generated by the participant) exemplifies the importance of matching cognitive processes activated during the encoding and memory tasks. Thus, the design of a *generative* encoding context may be critical for enhancing free-recall rates in individuals with mental retardation due to the generative nature of the free-recall task.

Our goal in the present study was to develop a method for presenting material to individuals with mental retardation that would (a) enhance free-recall rates without the need for extensive training and (b) could be adapted easily for computerized-learning environments. The impetus for the experiment was an early study by Auble, Franks, and Soraci (1979) on the "aha" effect and several recent studies of this phenomenon performed in our laboratory with undergraduate students. Auble et al. presented undergraduate students either with ambiguous sentences (e.g., "The notes were sour because the seam split") that were followed by a cue as to their meaning (e.g., "bagpipes") or sentences that had the cue embedded within the sentence (e.g., "The notes were sour because the bagpipes' seam split"). They found that recall for the sentences was greater in the post-cue condition than in the embedded-cue condition. Auble et al. proposed that the transition from a state of noncomprehension to a state of comprehension ("aha") was critical for the memory enhancements observed; however, the mechanism(s) underlying the effect were not specified. Two mechanisms proposed were the distinctiveness of the "aha" reaction and the integration process necessary to resolve the ambiguous sentence and the postsentence cue.

More recently, Wills, Soraci, Chechile, and Taylor (2000) assessed the generalizability of this finding to pictorial stimuli. In this study, the visual "aha" condition (i.e., connect) was a connect-the-dots condition in which the dotted figures were incomprehensible but became identifiable at some point during the drawing sequence. This condition was compared to a condition (i.e., trace) in which the participants simply had to trace an already completed connect-the-dot picture and a condition (i.e., scan) that required participants to visually scan a picture and recite the sequence of numbers of a connect-the-dot picture. Results indicated that free-recall rates were higher in the connect condition than in the two comparison conditions when there was no foreknowledge of the identity of the picture. Thus, the condition involving a transition from noncomprehension to comprehension resulted in the best recall, presumably due to the "effort toward comprehension" involved in this condition. In the pictorial study, this "effort toward comprehension" likely involved generation of candidate labels for the pictures that may have served as retrieval cues during the free-recall test phase (see Soraci et al., 1994, 1999).

Based on these findings, we designed an alternative visual presentation format more amenable to computer-based applications that we believed would induce an "aha" effect in participants with and without mental retardation. This "aha" condition involves the presentation of pictures in various states of blur, such that multiple potential verbal labels can be generated while an initially blurry picture slowly becomes recognizable in a series of programmed steps. That is, pictures initially are presented out-of-focus but slowly fade into focus across time. Thus, it is assumed that individuals will generate possible solutions early in the fading sequence (that may serve as retrieval cues), but eventually generate the correct solution at some later point during the sequential visual presentation. This process mimics the transition from noncomprehension to comprehension described by Auble et al. (1979) and Wills et al. (2000).

Our initial test of this methodology involved college students only (Soraci, Bushnell, Chechile, Wills, & Carlin, 1998). We compared two conditions: fade-in and fade-out. The fade-in condition involved presenting to-be-remembered items initially in a high state of blur and incrementally decreasing the level of blur until the item was clearly visible and identifiable. The fade-out condition presented the picture sequences in the reverse order (i.e., clear to blurry). This latter condition allows for extensive rehearsal of the label of the target object because it is known immediately and can be rehearsed during the fading-out sequence. Results for the college students tested indicated that free-recall rates were significantly higher for the fade-in items than for the fade-out items.

Though these results are consistent with our prediction that multiple potential retrieval cues are generated as items are being faded in, and the presence of these cues makes recall of the items more likely than in the comparison condition (Soraci et al., 1999), alternative explanations cannot be eliminated. For example, the two conditions differ also in that one involves a shift from a state of noncomprehension to comprehension and goal-directed problem-solving, whereas the other does not. Perhaps these additional processing differences across conditions make the fade-in items more memorable in a free-recall context than the comparison items. Thus, the "aha" condition, as defined experimentally to this point, necessarily involves several differences relative to the control conditions employed. The identification of the particular aspect(s) of the "aha" condition that leads to enhanced free recall has not been clearly delineated to this point, and it is an ongoing pursuit in our laboratory. However, it has proven to be quite difficult to isolate these processes such that a definitive conclusion can be reached.

Though we continue to pursue these theoretical issues experimentally, the present study represents an extension of this basic memory enhancement methodology to the target population of individuals with mental retardation. This type of structural manipulation of the encoding context may be especially useful for individuals with mental retardation because they often do not *spontaneously* utilize memory-enhancing encoding strategies. Typically, individuals with mental retardation require explicit instructions and/or prompts to use a specific type of strategy. The present methodology does not involve explicit verbal instructions, strategy training, or prompting of any sort. Rather, the very nature of the presentation format itself induces generation of potential labels for the to-be-identified items. In addition, we expect that the effectiveness of this manipulation is dependent upon the development of an extensive semantic network that likely is experientially based. For example, Engle and Nagle (1979) showed that use of a category cue did not facilitate free recall in young children without mental retardation until the age of 8, and children with mental retardation until age 13. They proposed that this finding reflected development of a sophisticated semantic network, and that with age "there is an increase in the number and richness of automatically elicited associations to a given stimulus" (p. 29). The inclusion of both chronological age (CA) and mental age (MA) matched groups in the present study allowed us to address this issue directly. If the effect is experientially based, then we would expect that the magnitude of the effect would be greater in the CA-matched and mentally retarded groups than in the MA-matched group.

Method

Participants

Participants were 16 individuals with moderate to mild mental retardation and equal numbers of individuals matched to those with mental retardation on CA and MA. The individuals with mental retardation were recruited from local schools in Massachusetts that serve only individuals with mental retardation. The participants in the other groups were recruited from local preschools, public schools, and Tufts University. Chronological and mental ages for the three groups of individuals are shown in Table 1.

Stimuli

The stimuli were 40 pictures of common objects (see Appendix A for a list). Twenty-eight of the 40 pictures were selected randomly for presentation during the acquisition phase, and the remaining 12 pictures were used as foils on the recognition test.

Apparatus

A Power Macintosh 4400/200 computer was utilized for stimulus presentation during the acquisition and recognition phases of the experiment. A LaCie Silverscan III scanner was used to create the computer images derived from the 40 photographs. The images then were copied into the Adobe Photoshop computer program. Color was removed from the scanned pictures, and backgrounds were cut. Each image then was blurred at two-step increments from 2 to 20 using the Gaussian Blur Filter within Adobe Photoshop. These settings were chosen so that the picture would not be identifiable for several steps in the sequence, and the individuals would generate incorrect guesses prior to correctly identifying the stimulus. Thus, 11 images of each picture (i.e., 10 blurred and the original clear image) were produced. The 11 images were presented in two orders: clear to most-blurred (fade-out) and most-blurred to clear (fade-in). An example sequence for one of the pictures is shown in Figure 1. Each image was presented for 750 msec. Thus, the entire 11-image sequence for each picture lasted 8.25 seconds.

Table 1
Descriptive Statistics by Group

	CA[a]		MA[a,b]	
Group	Mean	*SD*	Mean	*SD*
MR	197.69	34.33	96.38	33.07
MA-matched	84.19	30.12	96.19	34.44
CA-matched	205.44	29.47	—	—

[a] In months. [b] Peabody Picture Vocabulary Test-III (age equivalent).

Procedure

Participants were tested individually by the experimenter in a quiet area at their school. The participants sat in front of the computer monitor with the experimenter to their left. The experimenter controlled the start of each trial by pressing the space bar. Participants were told that they would be shown numerous images of common objects and that the pictures would be presented in either of two manners, fading in or fading out. They were instructed to name the pictures aloud and told that they were free to produce multiple responses on each trial. There was no explicit cue during a trial to generate responses, but all participants generated responses for all trials. This methodology allowed the picture sequences to continue uninterrupted and the participant to spontaneously generate possible solutions. However, these techniques did not allow us to identify the exact point in the sequence at which each participant could correctly identify the pictures. This important issue remains for future study and is discussed later. Participants' responses on each trial were recorded by the experimenter, and the final response was taken as their label for the picture. All participants also were told that they should remember what they saw, making the task an intentional-memory task. Finally, participants were told that blue dots would be presented on some trials and that they were to indicate the presence of the blue dots verbally or by rais-

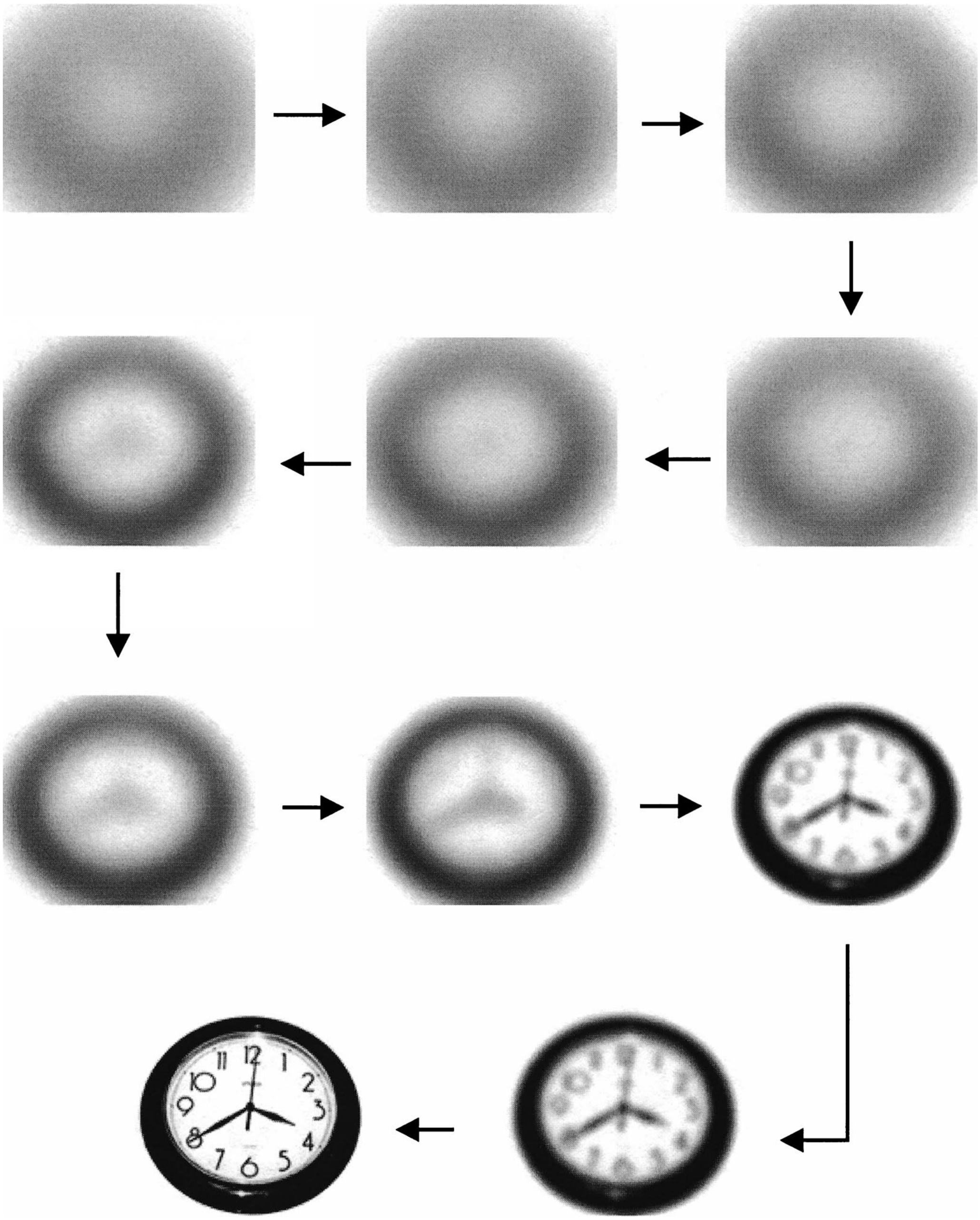

Figure 1. Example of the stages of blur utilized. Pictures were presented either from clear-to-blurred or blurred-to-clear.

ing their hand. The purpose of the blue-dot trials was to ensure that the participants were attending to all images (i.e., blurred and clear). This was especially relevant to fade-out trials in which the image was instantly recognizable, and participants may have been apt to look away once the image was identified. Blue dots appeared on every seventh trial in place of one of the blurred images. The blue-dot trials appeared on two fade-out and two fade-in trials. These four trials, however, were not included in analyses.

During the 28-trial (i.e., 12 fade-out, 12 fade-in, and 4 blue-dot trials) acquisition phase, the image sequences were presented in either of two quasi-random orders. The only limit on true randomness was that no more than two fade-in or fade-out sequences could occur consecutively. The images that were fade-in trials on List 1 were fade-out trials on List 2 and vice versa. The image sequences containing blue dots remained the same across lists. Equal numbers of participants in the three groups were assigned to each order.

Following the acquisition phase, the participants were instructed to recall verbally as many of the pictures as they could. Once they stopped producing responses, they were prompted to try to remember more of the pictures. All responses were recorded by the experimenter. Upon completion of this free-recall phase, a 30-item recognition task was given. This test comprised 18 clear images from the acquisition phase (9 fade-in and 9 fade-out) and 12 novel pictures. On each trial, participants were to indicate by responding verbally yes or no whether they had seen the picture during the acquisition phase.

Design and Analysis

A 3 (group: MR, MA-matched, CA-matched) × 2 (presentation mode: fade-in vs. fade-out) mixed design was implemented with presentation mode manipulated within-subjects. The dependent variable for the free-recall phase was the percentage of picture labels (correctly generated during the acquisition phase) recalled. List (1 vs. 2) was not included as a factor in formal analyses because no differences existed in the data as a function of this variable. Additional analyses focused on the percentage of pictures labeled during acquisition, the number of blue dots identified during acquisition, and recognition accuracy (i.e., percentage hits, percentage false alarms). All analyses were performed using the SPSS/PC+ statistical package. The measure of effect size employed was *d* (i.e., the distance between means in standard deviation [*SD*] units).

Results

Acquisition

The numbers of acquisition errors (i.e., not generating a label for a picture sequence) did not differ significantly across groups. $F(2, 45) = 1.97$, $MSE = .84$, $p = .152$. However, only the individuals with mental retardation ($M = .63$, $SD = .96$) and the MA-matched individuals ($M = .44$, $SD = 1.26$) committed errors. The individuals in the CA-matched group did not commit any acquisition errors. Thus, a qualitative difference existed across groups, but, overall, the error rates were low for all groups.

With regard to the number of blue dots recognized during acquisition, again there was not a significant difference across groups, $F(2, 45) = 2.93$, $MSE = 0.90$, $p = .06$. The mean numbers of blue dots missed by the individuals with mental retardation, the CA-matched group, and the MA-matched group were .94 ($SD = 1.48$), .13 ($SD = .34$), and .50 ($SD = .63$), respectively. Thus, there was a trend toward individuals with mental retardation missing more of the signals (23.4%) than did individuals in the CA-matched (3.1%) and MA-matched (12.5%) groups.

Free Recall

Descriptive statistics for the free-recall phase are shown in Figure 2. Results of the 3 (group) × 2 (presentation mode) analysis of variance indicated significant effects of group, $F(2, 45) = 5.98$, $p = .005$, and presentation mode, $F(1, 45) = 4.08$, $p = .049$. The Group × Presentation Mode interaction was not statistically significant. A Newman-Keuls

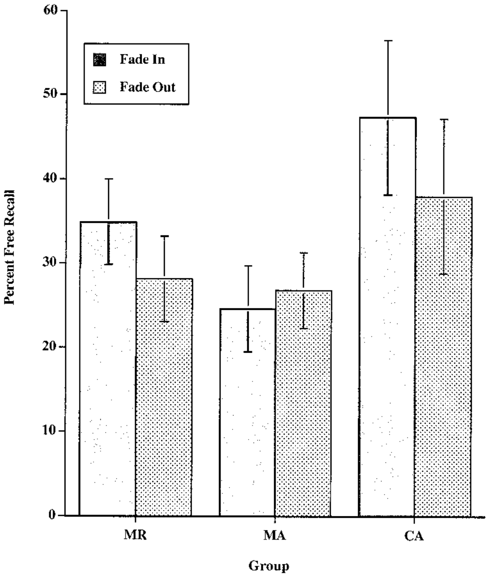

Figure 2. Mean free-recall rates by group and presentation mode. Error bars denote the 95% confidence interval limits.

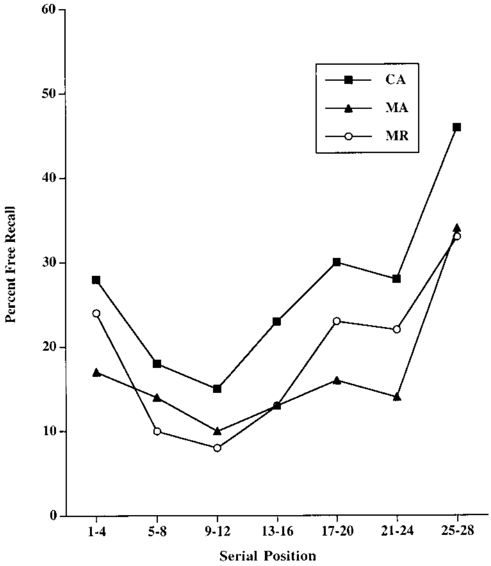

Figure 3. Free-recall rates by serial position for the three groups.

test regarding the group main effect indicated that the CA-matched group recalled significantly more items (42.71%) than did the mentally retarded (31.31%) and MA-matched (25.72%) groups, and the latter two groups did not differ significantly. The overall finding that recall was better for fade-in than for fade-out items was qualified by the fact that this effect varied across groups. Analyses indicated that there was a significant effect of presentation mode for the mentally retarded, $t(15) = 2.77, p = .014, d = .69$, and CA-matched, $t(15) = 2.18, p = .045, d = .55$, groups, but not for the MA-matched group, $t(15) = .46, p = .654, d = .11$. Thus, the memory enhancement afforded by the fade-in manipulation appears to be CA-dependent.

An assessment of primacy and recency effects in free recall was conducted by dividing the 28-item lists into seven 4-item segments. The number of items recalled in each septile by group is shown in Figure 3. It is evident that there is a strong recency effect for all three groups of individuals as well as a smaller primacy effect for each group. Because items were randomly ordered, we assessed whether the ordering of items at the end of the lists may have influenced the finding of an advantage for fade-in items over fade-out items. However, on each of the two lists, equal numbers (i.e., two) of fade-in and fade-out items were presented in the final five serial positions. The final item was not included in formal analyses because it was a blue-dot item. Thus, it is unlikely that the strong recency effect differentially affected overall recall rates for the fade-in and fade-out items.

Recognition

Recognition results are shown in Table 2. As can be seen, all three groups of individuals performed well on the recognition task; all sustained hit rates of 88.9% or greater for the fade-in and fade-out items. The relatively high false alarm rate for the group with mental retardation was due primarily to a high number of false alarms (i.e., 11) for a single individual. A composite recognition measure was calculated by subtracting the

Table 2
Recognition Results: Numbers of Hits by Item Type and Number of False Alarms for Novel Objects

	Fade-in hits[a]		Fade-out hits[a]		False alarms[b]	
Group	Mean	*SD*	Mean	*SD*	Mean	*SD*
Mentally retarded	8.75	.57	8.19	1.05	1.50	2.94
CA-matched	9.00	.00	8.20	1.01	.07	.26
MA-matched	8.19	.91	8.00	.89	.19	.40

[a] Nine possible. [b] Twelve possible.

number of false alarms (of 12 possible) from the total number of hits across fade-in and fade-out items (maximum = 18). Results for this recognition measure are shown in Figure 4. The differences across groups were not statistically significant. Thus, it appears that there were only minimal differences across groups with regard to recognition accuracy.

Discussion

Results support the hypothesis that recall rates would be better for fade-in items than for fade-out items, despite the greater opportunity for rehearsal in the fade-out condition. This result is consistent with the multiple-cue hypothesis of Soraci et al. (1999) and similar manipulations used in experiments involving participants without mental retardation (e.g., Wills et al., 2000). The enhanced recall rates are believed to result from the availability of additional retrieval cues that are generated during the fade-in sequences. That is, as the pictures are becoming more clear, participants are likely generating possible solutions prior to definitively identifying the clear picture. The additional responses produced then can serve as retrieval cues during the free-recall test.

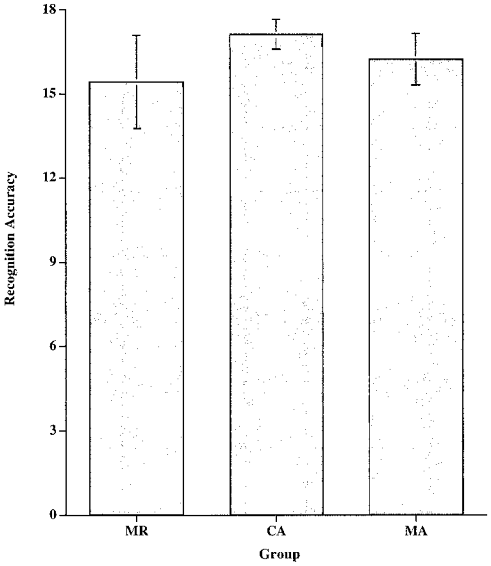

Figure 4. Mean recognition scores (hits–false alarms) for the three groups. Error bars indicate the 95% confidence interval limits.

Though this multiple-cue account is our preferred explanation for the findings (Soraci et al., 1994, 1999), alternative explanations for the phenomenon do exist. For example, it may be that the transition from a state of noncomprehension to comprehension (i.e., the "aha" effect) involves some form of alerting or heightened activation that serves to increase the memorability of the fade-in items. Recently, for example, Warren, Soraci, Chechile, and Holcomb (1999) demonstrated enhanced N400 event-related potentials to "aha" sentential solutions. Another possibility would be that resolution of the picture leads to retrospective analysis of the sequence, and this additional integration process, which is not present in the comparison condition, boosts free-recall rates. Though these possibilities were recognized by Auble et al. (1979), the specific causes of the memory advantages that accrue in these types of circumstances still have not been resolved. In fact, the three alternatives just listed may be difficult to isolate and compare experimentally.

Another important aspect of the current findings was the lack of differences across groups on the recognition test that was conducted after the free-recall phase. All three groups of individuals performed comparably, and near ceiling, on the recognition indices employed. Combined with the high rates of blue-dot identification, this shows that the individuals likely attended to the fade-in and fade-out sequences similarly. Thus, differential attention to the sequences across conditions is not a likely explanation for the findings. More important, however, the high recognition rates show that the object labels were stored sufficiently (see Chechile, 1987; Chechile & Soraci, 1999) to allow the participants to identify the previously encountered objects and differentiate them from novel objects. That is, all object labels were stored sufficiently to perform nearly errorlessly on the recognition test. Theoretically, this is important in that it indicates that storage differences across item types (fade-in vs. fade-out) likely were minimal. This is not unexpected given that items were generated by the participants, and the retention interval was relatively short.

The recall advantage demonstrated for the fade-in items likely lies in encoding and/or retrieval differences across item types. This is consistent with the theoretical basis for the design of this form of manipulation. The fade-in condition was designed to provide an enriched encoding context that induced generation of additional retrieval cues. Thus, this condition differed from the fade-out condition in that additional elements (e.g., potential labels) were activated during encoding. However, whether or not the enrichment was actually due to additional retrieval cues, the "aha" effect, or a postidentification integration process, as discussed earlier, it is clear that the enhanced encoding environment was critical for the observed recall differences.

The novelty of the present manipulation of the encoding context, or "situational support," lies in the fact that it increases free-recall rates of individuals with mental retardation without the use of verbal or physical prompts. The manipulation is instituted in a relatively passive environment, but induces internal processes (e.g., generation of potential labels) that create a stronger memory "trace," thus leading to enhanced free recall. Further, it is important that the generative nature of the encoding task is not overlooked. Use of a generative encoding task for items that are to be freely recalled (a generative task itself) instantiates the principle of transfer-appropriate processing forwarded by Morris, Bransford, and Franks (1977). This cross-task matching of processing requirements may also contribute to the memory advantages observed for the fade-in items.

An interesting, though not unexpected, finding in the present experiment was that the advantage for fade-in items over fade-out items held for the group of individuals with mental retardation and the CA-matched group only. The MA-matched group showed no such advantage. Further, despite overall higher levels of free recall, the CA-matched group and the group of individuals with mental retardation demonstrated fade-in advantages of similar magnitudes, *d*s = .55 and .66, respectively. More focused analyses of the differences between the individuals with mental retardation and the MA-matched group indicated that the groups demonstrated equivalent levels of free recall for the fade-out items, but the group with mental retardation recalled more of the fade-in items than did the MA-matched group. This indicates that the effectiveness of the fading-in manipulation was a function of CA and may reflect experiential or educational differences across groups. One explanation for this finding would be that it supports the contention of Engle and Nagle (1979) that young individuals (e.g., those less than 9 years of age) do not benefit as much from such manipulations due to a less-developed semantic network. That is, individuals below a particular age tend to have less sophisticated networks of interconnections and, thus, do not enjoy the benefits of manipulations designed to capitalize on such associations. In the present context, these individuals would not be expected to generate as many possible solutions for the pictures that fade-in, thus limiting the effectiveness of the fade-in manipulation. Alternatively, it may be that young children are less likely to spontaneously generate possible solutions or actively engage the task to the same degree as the older children, regardless of semantic memory structure. To address this issue more directly, it will be necessary to employ methods that encourage or require that participants generate labels at various points in the picture sequence. This would allow for an assessment of both the nature of the potential solutions generated and the point in the sequence at which the solution is reached (cf. Spitz & Borland, 1971). These are issues we are currently pursuing.

From an applied standpoint, this form of manipulation should be particularly amenable to computer application. For example, in computerized learning programs, the use of similar fading procedures or other manipulations that induce similar processes (e.g., puzzle construction) could easily be incorporated. This could be done to increase attention to or memorability of objects in complex visual arrays. For example, use of fading could be incorporated into matching-to-sample programs to increase accuracy of delayed matching responses and increase the length of delay at which a minimum level of performance can be maintained. Further, in story-based educational programs, such as the Jasper series of Bransford et al. (1999), fading of items could be utilized to highlight their presence because they would be the only nonstatic item in the array and increase recall of those items at a later time. This could be particularly useful in the context of the Jasper series because successful problem solution often requires memory for critical elements encountered during the programmed adventure.

In summary, the present study demonstrates enhanced free-recall rates for individuals with mental retardation when a generative encoding task (i.e., fade-in) is employed. The fade-in manipulation is novel in that it does not require physical or verbal prompting to be effective. Rather, the very nature of the presentation format induces activation of processes (e.g., cue generation, "aha" effect) that make items more memorable for a subsequent free-recall test. We believe the enhanced encoding context primarily affects retrieval probability rather than storage strength. Finally, we believe that this type of manipulation is particularly amenable to computer applications for individuals with mental retardation.

References

Auble, P. M., Franks, J. J., & Soraci, S. A., Jr. (1979). Effort toward comprehension: Elaboration or "aha!"? *Memory & Cognition, 7,* 426–434.

Belmont, J. M., & Butterfield, E. C. (1971). Learning strategies as determinants of memory deficiencies. *Cognitive Psychology, 2,* 411–420.

Borkowski, J. G. (1985). Signs of intelligence: Strategy generalization and metacognition. In S. R. Yussen (Ed.), *The growth of reflection in children* (pp. 105–144). New York: Academic Press.

Boyd, B. D., & Ellis, N. R. (1986). Levels of processing and memory in mentally retarded and nonretarded persons. *Intelligence, 10,* 1–8.

Bransford, J., & The Cognition and Technology Group at Vanderbilt. (1999). Designing environments to reveal, support, and expand our children's potentials. In S. Soraci & W. J. McIlvane (Eds.), *Perspectives on fundamental processes in intellectual functioning: Vol. 1: A survey of research approaches* (pp. 313–350). Stamford, CT: Ablex.

Bray, N. W., Fletcher, K. L., & Turner, L. A. (1997). Cognitive competencies and strategy use in individuals with mental retardation. In W. E. MacLean, Jr. (Ed.), *Ellis' handbook of mental deficiency, psychological theory and research* (3rd ed., pp. 197–217). Mahwah, NJ: Erlbaum.

Bray, N. W., Reilly, K. D., Fletcher, K. L., Huffman, L. F., Grupe, L. A., Villa, M. F., & Anumolu, V. (1998). Memory competencies and deficiencies: A conceptual framework and the potential of connectionist models. In S. A. Soraci & W. J. McIlvane (Eds.), *Perspectives on fundamental processes in intellectual functioning* (Vol. 1, pp. 3–44). Greenwich, CT: Ablex/JAI Press.

Bray, N. W., & Turner, L. A. (1986). The rehearsal deficit hypothesis. In N. R. Ellis & N. W. Bray

(Eds.), *International review of research in mental retardation* (Vol. 14, pp. 47–71). New York: Academic Press.

Brown, A. L. (1974). The role of strategic behavior in retardate memory. In N. R. Ellis (Ed.), *International review of research in mental retardation* (Vol. 7, pp. 55–101). New York: Academic Press.

Bryant, P. E. (1965). The effects of verbal labelling on recall and recognition in severely subnormal and normal children. *Journal of Mental Deficiency Research, 9,* 229–238.

Campione, J. C., & Brown, A. L. (1977). Memory and metamemory development in educable retarded children. In R. Kail & J. W. Hagen (Eds.), *Perspectives on the development of memory and cognition* (pp. 367–406). Hillsdale, NJ: Erlbaum.

Chechile, R. A. (1987). Trace susceptibility theory. *Journal of Experimental Psychology: General, 116,* 203–222.

Chechile, R. A., & Soraci, S. A. (1999). Evidence for a multiple-process account of the generation effect. *Memory, 7,* 483–508.

Cohen, R. L., & Bean, G. (1983). Memory in educable mentally retarded adults: Deficit in subject or experimenter? *Intelligence, 7,* 287–298.

Ellis, N. R. (1970). Memory processes in retardates and normals. In N. R. Ellis (Ed.), *International review of research in mental retardation* (Vol. 4, pp. 1–32). New York: Academic Press.

Engle, R. W., & Nagle, R. J. (1979). Strategy training and semantic encoding in mildly retarded children. *Intelligence, 3,* 17–30.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior, 7,* 495–531.

Slamecka, N. J., & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory, 4,* 592–604.

Soraci, S. A., Bushnell, E. W., Chechile, R. A., Wills, T. W., & Carlin, M. T. (1998, November). *Now you don't see it: An "aha" effect in picture memory.* Paper presented at the annual meeting of the Psychonomic Society, San Antonio.

Soraci, S. A., Carlin, M. T., Chechile, R. A., Franks, J. J., Wills, T. W., & Watanabe, T. (1999). Encoding variability and cueing in generative processing. *Journal of Memory & Language, 41,* 541–559.

Soraci, S. A., Jr., Franks, J. J., Bransford, J. D., Chechile, R. A., Belli, R. F., Carr, M., & Carlin, M. T. (1994). Incongruous item generation effects: A multiple-cue perspective. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 67–78.

Spitz, H. H. (1966). The role of input organization in the learning and memory of mental retardates. In N. R. Ellis (Ed.), *International review of research in mental retardation* (Vol. 2, pp. 29–54). New York: Academic Press.

Spitz, H. H. (1973). Consolidating facts into the schematized learning and memory system of educable retardates. In N. R. Ellis (Ed.), *International review of research in mental retardation* (Vol. 6, pp. 149–168). New York: Academic Press.

Spitz, H. H., & Borland, M. D. (1971). Redundancy in line drawings of familiar objects: Effects of age and intelligence. *Cognitive Psychology, 2,* 196–205.

Spitz, H. H., & Webreck, C. A. (1972). Effects of spontaneous vs. externally-cued learning on the permanent storage of a schema by retardates. *American Journal of Mental Deficiency, 77,* 163–168.

Summers, J. A., & Craik, F. I. M. (1994). The effects of subject-performed tasks on the memory performance of verbal autistic children. *Journal of Autism and Developmental Disorders, 24,* 773–783.

Turner, L. A., & Bray, N. W. (1985). Spontaneous rehearsal by mildly mentally retarded children and adolescents. *American Journal of Mental Deficiency, 90,* 57–63.

Turnure, J. E. (1985). Communication and cues in the functional cognition of the mentally retarded. In N. R. Ellis & N. W. Bray (Eds.), *International review of research in mental retardation* (Vol. 13, pp. 43–77). New York: Academic Press.

Warren, A. M., Soraci, S. A., Chechile, R. A., & Holcomb, P. J. (1999, November). *Measuring insight: "Aha" sentences and ERPs.* Poster session presented at the annual meeting of the Psychonomic Society, Los Angeles.

Wills, T. W., Soraci, S. A., Chechile, R. A., & Taylor, H. A. (2000). "Aha" effects in the generation of pictures. *Memory. & Cognition, 28,* 939–948.

Zeaman, D., & House, B. J. (1963). The role of attention in retardate discrimination learning. In N. R. Ellis (Ed.), *Handbook of mental de-*

ficiency (pp. 159–223). New York: McGraw-Hill.

Zeaman, D., & House, B. J. (1979). A review of attention theory. In N. R. Ellis (Ed.), *Handbook of mental deficiency, psychological theory and research* (pp. 63–120). Hillsdale, NJ: Erlbaum.

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Appendix A
List of 40 Pictures Utilized

bananas	dog*	key	rocking horse*
bed	fan*	kite*	scissors
brush	fire hydrant	lamp	sneakers
butterfly	flag	leaf*	stapler*
camera	flowers	mailbox	teddy bear
car	glove*	motorcycle	tennis racquet*
cat	guitar*	pineapple*	toaster
chair	hat	pumpkin	traffic light*
clock	iron	quarter	umbrella
computer	jacket*	radio	watch

*Item used as a foil on the recognition test.