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An Adult Developmental Study of the Encoding of Spatial Location

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The present study was designed to test the hypothesis that there is a differential deficit in the ability to encode contextual information with increasing age. Young, middle-aged, and elderly adults were shown target words in various quadrants of a computer screen (contexts) and were told to either (a) remember the words and their locations, (b) remember the words, or (c) tell whether the words referred to something that was alive or not. Following presentation of the words, subjects were given a recognition test for the words and were asked to identify the quadrant in which each word had been presented. If older adults have a contextual encoding deficit, then an interaction between age and instruction condition would be expected in memory for quadrants. Older adults would be expected to perform better relative to younger adults when the locations were target information (intentionally learned) than when they were contextual (not intentionally learned). Since such an interaction was not obtained, the results provide no support for the hypothesis that the elderly have an encoding deficit that is specific to contextual information.

Research has rather consistently revealed age differences in adult memory, with older adults generally performing less well than younger adults (e.g., Kausler, 1985; Perlmutter & Mitchell, 1982). It has been hypothesized that age deficits in memory may result, at least in part, from a failure of the elderly to encode information about the context in which target information is learned (e.g., Craik, 1983; Light & Singh, 1987; McIntyre & Craik, 1987; Rabinowitz, Craik, & Ackerman, 1982; Simon, 1979). The purpose of the present study was to test the hypothesis that older adults are less likely to encode contextual information than younger individuals. The dimension of contextual information selected for investigation in the present study was spatial location. The question of whether there are age differences in the encoding of spatial location is a particularly interesting one from a theoretical perspective. Those who believe there is an age-related deficit in contextual encoding would predict that older adults would encode spatial location relatively less well than younger adults when it is contextual as opposed to target information. Others (e.g., Hasher & Zacks, 1979) believe that spatial location is automatically encoded and hypothesize that age differences should not exist in the encoding of spatial location whether it be target or contextual.

The results of a number of studies of aging and automaticity are relevant to the issue of age differences in the encoding of spatial location as a contextual variable (Light & Zelinski, 1983; Park, Puglisi, & Lutz, 1982; Park, Puglisi, & Sovacool, 1983; Puglisi, Park, Smith, & Hill, 1985). The subjects in these studies were assigned to either an instructional condition in which they were told to remember only the stimulus items (e.g., objects, words or pictures) or a condition in which they were told to remember both the items and their locations. After the stimulus items were presented, the subjects were tested for their memory of both the stimulus items and their locations. The measure of memory for spatial location employed in these studies was the proportion of correctly recognized items that were also located correctly.

If older adults have a contextual encoding deficit, then

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one would expect them to exhibit a greater deficit, relative to younger adults, in memory for spatial location when told to remember only the stimulus items as opposed to the items and their locations. This type of interaction was not found in any of the relevant studies. In three of the studies (Light & Zelinski, 1983; Park, Puglisi & Sovacool, 1983; Puglisi, Park, Smith, & Hill, 1985) the interaction between instruction condition and age was not significant. In the fourth (Park, Puglisi, & Lutz, 1982), the interaction was significant but the results were in the opposite direction of what would be predicted. That is, when told to learn only the stimulus items, there were no age differences in the proportion of spatial locations correctly identified; however, when instructed to remember both the stimulus items and their locations, older adults remembered a smaller proportion of spatial locations than younger adults. Further, Light and Zelinski (1983) analyzed the total number of correct locations independent of the number of correct item recognitions. Again, no interaction between age and instruction condition was obtained. Taken together, the results of these studies provide no support for an age-related deficit in contextual encoding.

Further, none of these four studies provide support for the view that spatial location is automatically encoded. Hasher and Zacks (1979) specified that memory for automatically encoded information (a) should not be facilitated by instructions to learn the information and (b) should not vary as a function of age. In all four of the above studies, both instructional effects and age differences were obtained.

In the present study an automaticity paradigm was employed to investigate age differences in contextual encoding. However, the present study differed from the previous studies in at least three ways. First, in addition to the two instruction conditions that have typically been used, a "true incidental" condition such as that originally used by Mandler, Seegmiller, and Day (1977) was employed. In a true-incidental instructional condition, the subjects are instructed to process the stimulus items in a manner that does not require that they try to remember the items. The purpose of including such a condition is to determine whether instructions to learn the stimulus items causes subjects to encode spatial location to a greater extent than they would if not told to try to remember the items.

Second, in addition to asking the subjects to specify the locations in which the correctly recognized stimulus items had appeared, as has been done in previous research, the subjects in the present study were also asked to specify the locations of the stimulus items that were not correctly recognized. This was done to determine if memory for the location varies as a function of whether or not the stimulus items have been encoded to the extent that they can be recognized.

Third, at the end of the experimental session the subjects who were instructed to remember the stimulus items but not the locations were asked questions intended to assess the likelihood that they might have intentionally tried either to learn the locations or to use the locations to help learn the stimulus words. In earlier studies (e.g., Light & Zelinski, 1983; Park, Puglisi & Lutz, 1983; Park, Puglisi & Sovacool, 1983; Park, Puglisi, Smith & Hill, 1985) above-chance memory for location has been obtained even when subjects were not instructed to remember location. The questions were asked to determine whether above-chance memory for location would be obtained even after the subjects who intentionally tried to learn the locations were eliminated from the analysis.

Method

Subjects

The subjects were 27 men and 27 women from each of the following age groups: young adults (ages 18 to 30, $M = 23$), middle-aged adults (ages 40 to 55, $M = 47$), and elderly adults (ages 65 to 80, $M = 71$). Half of the young adults were students in an introductory psychology course, who received course credit for participating in the study. All of the other subjects were solicited through various community organizations, employment services, and local advertising; they were each paid $5.00 for their participation.

The subjects were predominately white, middle-class individuals. The average number of years of education reported by young, middle-aged, and elderly adults was 13.96, 14.24, and 14.07, respectively. There were no significant age or sex differences in education.

Design

The design was a 3 (Age) × 2 (Sex) × 3 (Instruction Condition) factorial. Nine men and nine women from each age group were randomly assigned to each of the following three instructional conditions: (a) Item-and-Location, in which subjects were instructed to remember both the words and their locations on the computer monitor; (b) Item-Only, in which subjects were instructed to remember only the words; and (c) True-Incidental, in which subjects were asked to judge whether each word shown referred to something that was alive.

Materials

An IBM 5150 PC with a color monitor was used to present the instructions and stimuli. The computer keyboard was used to record the subjects' responses. A cardboard cover with openings to expose certain keys was placed over the keyboard. One opening exposed two keys—one labelled "YES" and one labelled "NO." The other opening exposed four keys labelled "1," "2," "3," and "4."

The stimulus words were 109 nouns, four to seven letters in length. Each word was rated as having a frequency of at least 50 per million by Thorndike and

Lorge (1944) and of at least 40 per million by Kucera and Francis (1967). In addition, each word was one that had been rated for concreteness, imagery, and meaningfulness by Paivio, Yuille, and Madigan (1968). Thirteen of the words were randomly selected to serve as "buffers" (five to control for primacy and eight to control for recency effects). The remaining words were randomly assigned to two lists: 48 target words and 48 lure words. Analyses of the target and lure lists revealed no significant differences between the two lists in word length, frequency, concreteness, imagery, or meaningfulness.

Procedure

Subjects were tested individually in a location free from auditory and visual distractions. All subjects were told "You will see a number of words presented in various places on the computer screen." Subjects in the Item-and-Location condition were also told, "We want you to remember these words and where on the screen you see them. After this you will be tested on the words and their locations to see how many you remember." Subjects in the Item-Only condition were told, "We want you to remember these words. After this you will be tested on the words to see how many you remember. Subjects in the True-Incidental condition were told, "We want you to decide if each word given refers to something that is alive or is not alive. If the word refers to something alive then press the Yes key. If the word refers to something that is not alive then press the No key."

After presentation of the instructions, three sample words were presented to illustrate the manner and speed of presentation. The target words were then presented, one at a time, for four seconds each, with a 3-second interval between each word. During the interval between target presentations, the subjects in the Item-and-Location and Item-Only conditions were shown a line of twenty-four asterisks, while the subjects in the True-Incidental condition were presented with the question, "Is this alive? Yes or No," in the center of the computer monitor. All subjects received the same target words in the same randomized presentation order. Each target word appeared in one of the four quadrants on the computer monitor. The words were randomly assigned to quadrants with the restriction that an equal number of words appeared in each of the four quadrants and that the same quadrant occurred no more than twice in a row.

Following the study phase the subjects were tested for their memory of both the words and the locations in which the words were presented. They were asked to decide if each word presented had been shown before and to indicate each decision by pressing either the Yes or No button. They were instructed to guess if they were unsure of the answer. The subjects were also told that after each of the words that had been presented before they would be asked to indicate the quadrant in which the word had been shown. They were told that they would be asked to indicate their responses by using the four numbered keys on the keyboard. Again, the subjects were told to guess when uncertain of the quadrant in which a word had been presented.

The test words were then presented, one at a time, in the center of the computer monitor. The order of presentation was randomly determined, with the restriction that no more than four target or lure words occurred sequentially. All subjects received the same presentation order for these words. Underneath each word presented on the computer monitor was the question: "Was this word presented before? Yes or No." After the subjects pressed the Yes or No response key, the subjects were given feedback in the center of the screen. After each lure word the feedback was either: (a) "Correct. The last word was a new word" or (b) "Incorrect. The last word was a new word." Following presentation of each target word, the computer displayed a frame with four numbered quadrants. The feedback for the subject's response to the target word was given in the center of this frame. The subject was told either "Correct. Which quadrant was it presented in?" or "Incorrect. This word was shown before. Which quadrant do you think it was presented in?" The subjects indicated their choice of word location by pressing the one of the four keys labelled "1," "2," "3," and "4" that corresponded with the number of the quadrant in which they thought the word had appeared. No feedback was given on quadrant selection.

Results

Separate analyses were performed on each of the following dependent variables: (a) the d' scores for word recognition, (b) the total number of correctly identified target words (hits), (c) the total number of false alarms, (d) the proportion of correctly identified quadrants, and (e) the proportion of correctly recognized target words that were also correctly located. Tukey's Honestly Significant Difference test was used for all post hoc analyses; effects with $p < .05$ were considered to be significant.

Word Recognition

Separate 3 (Instruction Condition) × 3 (Age) × 2 (Sex) factorial ANOVAs were performed on d' scores, hits, and false alarms. The means and standard deviations for these scores are shown in Table 1.

The analysis of the d' scores for word recognition revealed significant main effects for Age, F (2,144) = 12.40, $p < .01$, Sex, F (1,144) = 5.10, $p < .05$, and Instruction Condition, F (2,144) = 10.56, $p < .01$. Young adults (M = 2.37) had significantly higher d' scores than either middle-aged (M = 1.64) or elderly adults (M = 1.38). Women (M = 1.99) had significantly higher d' scores than men (M = 1.40). Finally, subjects given the True-Incidental instructions (M = 2.35) had significantly higher d' scores than those given either the

TABLE 1

Average Scores for Word Recognition

	Instructional Condition					
	Item-and-Location		Item-Only		True-Incidental	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
d' Scores						
Young	1.76	1.35	2.26	1.68	3.10	1.79
Middle-age	1.37	0.49	1.56	0.75	1.98	0.64
Elderly	1.14	0.68	1.08	0.56	1.92	0.78
Hits						
Young	32.22	7.37	35.61	5.91	39.56	3.81
Middle-age	30.39	6.86	34.83	6.40	37.28	6.27
Elderly	31.72	6.16	32.33	6.08	35.61	7.60
False Alarms						
Young	8.94	8.81	6.83	5.49	3.72	3.46
Middle-age	8.94	6.92	9.89	5.88	6.94	4.57
Elderly	13.61	9.34	12.11	6.13	7.94	9.14

Item-and-Location (M = 1.42) or the Item-Only (M = 1.64) instructions.

In the analysis of hits, the only significant effect was a main effect for Instruction Condition, F (2,144) = 11.87, $p < .01$. Target recognition was better in the True-Incidental condition (M = 37.48) than in either the Item-Only (M = 34.26) or the Item-and-Location (M = 31.44) conditions.

In the analysis of false alarms, main effects for Age, F (2,144) = 6.35, $p < .01$, Sex, F (1,144) = 6.22, $p < .01$, and Instruction Condition, F (2,144) = 5.84, $p < .01$, were obtained. Post hoc analyses revealed that young adults (M = 6.50) made fewer false alarms than elderly adults (M = 11.22). The middle-aged group (M = 8.59) fell between and did not differ significantly from the other two groups. Men (M = 10.12) made more false alarms than women (M = 7.42). And subjects in the True-Incidental instructional condition made fewer false alarms (M = 6.20) than those in either the Item-Only (M = 9.61) or the Item-and-Location (M = 10.50) groups.

Quadrant Placement

Separate 3 (Instruction Condition) × 3 (Age) × 2 (Sex) factorial ANOVAs were performed on (a) the proportion of quadrants correctly identified, (b) the proportion of correctly recognized target words that were also identified as appearing in the correct quadrant, and (c) the proportion of incorrectly recognized target words that were identified as appearing in the correct quadrant. The means and standard deviations for these three variables are shown in Table 2.

In the analysis of the proportion of correctly identified quadrants, significant effects were obtained for Age, F (2,144) = 22.02, $p < .01$, Sex, F (1,144) = 7.80, $p < .01$, and Instruction Condition, F (2,144) = 4.85, $p < .01$. Young subjects (M = 0.42) correctly identified more quadrants than either middle-aged (M = 0.33), or elderly subjects (M = 0.30), and women (M = 0.37) identified more quadrants than men (M = 0.32). Finally, subjects given the Item-and-Location instructions were better able to identify quadrants (M = 0.39) than were those given the True-Incidental instructions (M = 0.33). The Item-Only instruction group (M = 0.34) fell between the other two groups, but was not significantly different from either.

In the analysis of the proportion of correctly recognized target words that were identified as appearing in the correct quadrant, significant effects were found for Age, F (2,144) = 223.30, $p < .01$; Sex, F (1,144) = 7.94, $p < .01$; and Instruction Condition, F (2,144) = 9.63, $p < .01$. Young adults (M = .48) correctly identified the quadrants for a larger proportion of the correctly recognized target words than either middle-aged (M = .36) or elderly (M = .31) adults. Women (M = .41) correctly identified a larger proportion of quadrants than men (M = .36). Subjects given the Item-and-Location instructions (M = .44) correctly identified a larger proportion of quadrants than subjects given either the Item-Only (M = .37) or the True-Incidental(M = .34) instructions.

In the analysis of the proportion of incorrectly identified target words that were identified as appearing in the correct quadrant, no significant effects were obtained.

In addition to the ANOVAs, Chi-square analyses were also used to compare the number of correct spatial

TABLE 2

Average Scores for Quadrant Identification

	Instructional Condition					
	Item-and-Location		Item-Only		True-Incidental	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Proportion of Correctly Identified Quadrants						
Young	0.49	0.17	0.39	0.12	0.38	0.11
Middle-age	0.36	0.08	0.33	0.10	0.31	0.08
Elderly	0.31	0.09	0.30	0.09	0.29	0.07
Proportion of Correct Target Words That Were Correctly Located						
Young	0.75	0.23	0.53	0.15	0.46	0.11
Middle-age	0.58	0.15	0.47	0.15	0.41	0.14
Elderly	0.47	0.14	0.46	0.19	0.40	0.12
Proportion of Incorrect Target Words That Were Correctly Located						
Young	0.30	0.15	0.21	0.15	0.23	0.17
Middle-age	0.26	0.12	0.29	0.09	0.23	0.15
Elderly	0.27	0.13	0.24	0.12	0.30	0.19

locations with the number that would be expected on the basis of chance alone. The Chi-square analyses were performed separately for each age/instruction group on the following variables: (a) the total number of correct quadrants, (b) the number of correct quadrants for the correctly recognized target words, and (c) the number of correct quadrants for incorrectly recognized target words. The results of these analyses are presented in Table 3. The analyses of both the total number of correct quadrants and the number of correct quadrants for correct target words indicated significantly above-chance performance in all three age groups in both

TABLE 3

Chi-Square Values for Tests of Above-Chance Quadrant Recall

	Instructional Condition		
Group	Item-and-Location	Item-Only	True-Incidental
Total Number of Correct Quadrants			
Young	302.16***	123.08***	104.33***
Middle-age	62.25***	53.58***	33.50**
Elderly	37.67**	31.42*	20.25
Number of Correct Quadrants for Correct Target Words			
Young	368.37***	162.04***	118.16***
Middle-age	92.57***	60.94***	37.61**
Elderly	51.02***	41.61***	14.23
Number of Correct Quadrants for Incorrect Target Words			
Young	22.64	13.36	12.75
Middle-age	14.22	7.50	13.24
Elderly	9.12	14.56	18.65

Note: The degrees of freedom for all Chi-square tests was 17. *$p < .05$; **$p < .01$; ***$p < .001$.

instruction conditions with only one exception; only the elderly adults in the True-Incidental condition failed to achieve above-chance memory for spatial location. However, above-chance spatial location was not obtained in any of the analyses of the number of correct quadrants for unrecognized target words.

Debriefing Questions

To determine whether the subjects in the Item-Only condition may have intentionally learned locations even though they were not instructed to do so, two questions were asked. First, the subjects in the Item-Only condition were asked if they had made an attempt to use the locations to try to learn the words. Eleven percent of the subjects indicated that they used location to learn words, 24 percent indicated they used location to only a limited extent, and 65 percent indicated they did not use location at all. Second, the subjects in the Item-Only condition were asked if, during the study phase, they thought that they might be asked to recall the locations of the words. Eleven percent of the subjects indicated that they thought they might be asked to recall location, six percent indicated that "at first" they thought they might be asked to recall location, and 83 percent indicated they did not think they would be asked to recall location.

In order to determine whether the above-chance levels of quadrant placement obtained when subjects were not instructed to remember location occurred *only* in subjects who reported either (a) using location to help them learn the words or (b) thinking they might be asked to recall location, the Chi-square analyses mentioned previously were performed again on the data in the Item-Only condition without any of the subjects who responded affirmatively to either of these questions. The results were identical to those obtained with the Chi-square analyses performed on the complete set of data. Above-chance performance was obtained in all three age groups in the analyses of both the total number of correct quadrants and the number of correct quadrants for the correct target words but not in the analysis of the number of correct quadrants for the incorrect words. Thus, even the subjects who do not report either trying to use location to learn the words or thinking they might be asked to recall location exhibit above-chance levels of quadrant placement.

Discussion

The purpose of the present study was to test the hypothesis that elderly adults have a greater deficit in memory for contextual information than for target information. If they do have such a differential deficit, an interaction between age and instruction condition would be expected in the analysis of both the proportion of quadrants that were correctly identified and the proportion of correctly recognized words that were also correctly located. That is, elderly adults would be expected to remember the word locations better, relative to younger adults, when instructed to remember both the words and locations than when instructed to remember only the words. As was expected on the basis of previous research, there was a decline with age in memory for both the words and their locations. However, the interaction between age and instruction condition was not significant in the analysis of either of the measures of memory for spatial location. Therefore, the results of the present study provide no support for the hypothesis of a differential deficit in contextual encoding. These results are consistent with the findings of previous studies (e.g., Light & Zelinski, 1983; Park, Puglisi, & Lutz, 1982; Park, Puglisi, & Sovacool, 1983; Puglisi, Park, Smith, & Hill, 1985). However, these earlier studies did not include a true incidental condition.

A True-Incidental condition was included in the present study to determine whether instructions to learn the stimulus items cause subjects to encode spatial location to a greater extent than they would if not instructed to remember the items. Although more quadrants were correctly identified in the Item-Only condition than in the True-Incidental condition, there was not a significant difference between the two conditions in the analyses of either the proportion of correctly recognized quadrants or the proportion of correct words that were correctly located. Thus, the results of the present study do not indicate that more spatial encoding occurs when subjects attempt to learn target information than when they do not.

It is interesting that word recognition performance was better in the True-Incidental condition than in the two intentional conditions. Although this finding seems counter-intuitive, similar results have been obtained by other investigators who used incidental tasks that require semantic processing of target words (e.g., Eagle & Leiter, 1964; Eagle & Mulliken, 1974; Rabinowitz, Ackerman, Craik & Hinchley, 1982, as cited in Craik and Byrd, 1982). However, while a number of researchers have found better performance with incidental instructions, others have found no difference in the performance of subjects given incidental and intentional instructions (e.g., Hyde & Jenkins, 1973; Walsh & Jenkins, 1973). So, it appears as if incidental tasks that require semantic processing tend to produce memory that is either equal to or, in some cases, better than that obtained with intentional learning. In those cases in which incidental instructions produce better memory than intentional instructions, it may be because subjects in the intentional condition do not process the stimuli semantically (which facilitates memory) or do not process them as extensively as subjects in the incidental condition.

The results of the present study are also relevant to the question of whether spatial location is automatically encoded. If location is automatically encoded then

instructions to learn spatial location should not have an effect on memory. Since subjects exhibited better memory for spatial location in the Item-and-Location condition than in the other two conditions, it is clear that spatial location can be, at least in part, effortfully (as opposed to automatically) encoded. These results are consistent with the results of other studies on aging and automaticity in indicating that spatial location is effortfully encoded (Light & Zelinski, 1983; Naveh-Benjamin, 1987; Park, Puglisi & Lutz, 1982; Park, Puglisi & Sovacool, 1983; Puglisi, Park, Smith & Hill, 1985). While it appears that memory for spatial location can be enhanced through effortful encoding, it also appears that some spatial encoding may occur automatically. Since Chi-square analyses indicated above-chance levels of quadrant placement in the two conditions in which the subjects were not instructed to remember location, it appears as if some memory for spatial location occurs automatically in all three age groups. (See also Light & Zelinski, 1983; Park, Puglisi & Lutz, 1982; Park, Puglisi & Sovacool, 1983; Park, Puglisi, Smith & Hill, 1985 for similar findings.) This is particularly true since above-chance levels of quadrant placement were obtained even when those subjects who reported that they either used spatial location to learn the words or thought they might be asked to recall location were eliminated from the analyses.

It is unclear how such partial automaticity might occur. Naveh-Benjamin (1987) has suggested that automatic and effortful encoding may lie on a continuum and that spatial encoding may fall somewhere between the extremes of automatic and effortful processing. He also has suggested that some of the processes involved in memory for spatial location may be automatic while other may not. Further research will be needed to clarify the extent to which spatial location is automatically encoded. However, since above-chance quadrant placement was not obtained in any of the analyses of the number of correct quadrants for incorrect target words, it is clear that the partial encoding of spatial location that occurs when words are encoded sufficiently to be recognized does not occur when the words are not encoded to that degree. This suggests that the partial encoding of spatial location that occurs when subjects are not instructed to learn location does not occur when the word is merely perceived, but rather occurs at a later stage when the word is processed to the extent that it can be recognized.

Some proponents of the view that spatial location is automatically encoded have suggested that memory for spatial location should not change as a function of age (e.g., Hasher & Zacks, 1979). The significant main effects for age obtained in the analyses of the quadrant memory variables in the present study clearly indicate that memory for spatial location declines with age. This result has been obtained in other studies of aging as well (e.g., Light & Zelinski, 1983; Park, Puglisi & Lutz, 1982; Park, Puglisi & Sovacool, 1983; Puglisi, Park, Smith & Hill, 1985). However, from a logical standpoint there is no need to postulate that automatic processes would be unaffected by age. Indeed, since automaticity may be acquired with practice (e.g., Neves & Anderson, 1981; Hasher & Zacks, 1979; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Spelke, Hirst, & Neisser, 1976), it would seem reasonable to expect changes with age. At this point, it would seem reasonable to limit the definition of automatic processes to those that occur independently of conscious intention and consume no attentional resources. Whether there are age effects in automatic processing would then simply become an empirical question rather than a theoretical assumption.

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