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Mental Retardation and the Acquisition of Automatic Processing

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The acquisition of automatic processing in persons with and without mental retardation was examined. In Experiment 1, subjects viewed slides of objects to determine whether a pictured object belonged to a designated target category. There was an effect of search set size for both groups that decreased and eventually disappeared with practice. This result reflected the acquisition of automatic processing. Also, evidence of automaticity was observed with less practice for subjects without relative to subjects with mental retardation. In Experiment 2, subjects searched for the presence of a designated target shape in arrays containing two, three, or four shapes. Results were essentially the same. Implications of these results for the development of cognitive skills by persons with mental retardation were discussed.

The concept of automatic processing is an important part of many models of skilled performance (e.g., Ackerman, 1987; Fisk & Schneider, 1984; Logan, 1985; Neuman, 1984; Pew, 1974). Investigators have argued that as a result of general capacity limitations, it is not possible for individuals to perform the higher level activities associated with a skill until the lower level activities have been automated, thereby freeing attentional resources to perform the higher level activities (e.g., LaBerge & Samuels, 1974). To the extent that this is correct, a complete understanding of the nature of skill differences between individuals with and without mental retardation will require an examination of how these lower level activities become relatively automatic and the extent to which the acquisition of automatic processing differs for these individuals.

According to current perspectives, a process can operate automatically as a result of innate factors (e.g., Hasher & Zacks, 1979; Zacks, Hasher, & Sanft, 1982) or as a result of learning (e.g., Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). In this study we focused on learned automatic processes. A process can become automatic through learning when an individual receives extensive practice under conditions in which the stimulus–response relation is consistently mapped, that is, each stimulus is either always a target and receives a positive response or always a foil and receives a negative response (e.g., Fisk & Schneider, 1983; Schneider & Fisk, 1982, 1984). An automatic process makes few demands on central processing capacity and can, therefore, operate in parallel with other processes. Thus, automatic processing would reduce or eliminate the degree to which (a) a second task would interfere with processing (e.g., Logan, 1979) and (b) processing load would slow processing (e.g., Fisk & Schneider, 1983).

Merrill (1990) used a concurrent memory load procedure (Logan, 1979) to examine the degree to which maintaining a series of numbers in memory interfered with encoding pictures of common objects for persons with and without mental retardation. Subjects memorized a list of numbers that was either equal in length to their full digit span or equal to half their digit span while performing an encoding task. The magnitude of interference associated with memory load was greater for the subjects with relative to those without mental retardation under conditions in which subjects were required to encode pictures to their basic level (e.g., dog and table). Merrill concluded that accessing the basic level name of common objects required more of the available processing resources of the subjects with mental retardation and that this reflects a group difference in the degree to which accessing the basic level name of common objects can be performed automatically. Because labeling objects is the result of learning, this may imply differences in the manner or rate at which automatic processing is acquired by these individuals. The present study was designed to examine this issue.

EXPERIMENT 1

Experiment 1 was designed to assess whether individuals with and without mental retardation require different amounts of practice in a category detection task in order to achieve automatic processing. The general method was patterned after Fisk and Schneider (1983, Experiment 1). In one condition of their experiment, subjects memorized a list of one to four taxonomic category labels and were subsequently presented a probe consisting of two basic level concept words. They pressed one button if either of the words represented an exemplar of a memory set item and a second button if they did not. Initially, response times increased linearly with increases in set size. However, after extensive practice the effect of set size was reduced to 2 msec and was no longer significant. The lack of a set size effect, implying an ability to process in parallel, was taken as an index of the development of automatic processing.

In our modification of this procedure, we presented subjects with slides that contained either two, three, or four pictures of exemplars from eight conceptual categories. Four categories were designated as target categories and four, as nontarget categories. The subjects had to determine whether any of the objects pictured in the search set was an exemplar of one of the designated target categories. As Fisk and Schneider (1983) observed, we expected that category detection times would increase linearly as a function of set size. However, with increases in the amount of consistent practice that individuals are given on the search task, the effect of set size should decrease until subjects eventually exhibit no effect of set size at all, suggesting the acquisition of automatic processing in this experiment. A different rate of decline in slope values relating set size to category decision times as a function of amount of practice would indicate differences in the rate at which automatic processing is acquired by persons with and without mental retardation in this task.

In our version of this procedure, slope values were computed as a function of search set size and not the more commonly used memory set size because we held memory set size constant at four and varied the search set size from two to four. Pilot work indicated that a fixed memory set would make the task easier for the subjects with mental retardation. Therefore, we chose to look at response times associated with changes in search set size. The results of visual search and memory search experiments are typically functionally equivalent; there is a linear increase in search time as the number of elements in a visual set and a memory set increases (e.g., Atkinson, Holmgren, &

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Juola, 1969). In addition, age-related changes in the speed of visual and memory search processes are very similar (Kail, 1988). Therefore, we expected that changes associated with practice in our categorization task would parallel those of memory search experiments (e.g., Fisk & Schneider, 1983).

Another important issue was type of learning task. We chose category decision-making because we expected that all subjects would be familiar with the basic process and the stimuli used, and, as a result, automatic processing would develop rapidly. Indeed, under some conditions automatic detection of category relations is evident within a couple of hours (see Ackerman & Schneider, 1985). However, by choosing these highly familiar stimuli, we created a situation in which individuals with and without mental retardation differed in the degree of knowledge about our stimuli that they possessed at the start of the study (see Sperber & McCauley, 1984). Because of this, a direct comparison of the two groups using the same set of stimuli under identical conditions may not be appropriate.

We addressed this problem by establishing conditions in which the subjects with and without mental retardation would exhibit equivalent initial performance levels, measured in terms of slope values, from which we could trace the development of automatic processing. This was done in two ways. First, because all of the subjects exhibited an improvement in performance as a function of practice, there would be a time in the experiment when the performance of the subjects with mental retardation was essentially the same as performance of the subjects without mental retardation at the start of the experiment. Hence, we were able to conduct post hoc analyses of the development of automaticity in these two groups after equating performance levels through different amounts of practice; that is, we let Session 1 represent the beginning of experimental trials for the subjects without mental retardation and Session 3 as the beginning of experimental trials for the subjects with mental retardation in one set of analyses. However, it is also likely that this procedure would not equate subjects in all important ways. More specifically, the performance of the subjects without mental retardation would be the result of a lifetime of learning, and the performance of the subjects with mental retardation would be the result of a few sessions in the lab. These results of lifetime learning versus one or two hours of learning may be different. Therefore, we also employed a second method of equating subjects by varying the typicality of the category exemplars (see Rosch, 1975). One group of subjects without mental retardation received the same high typical exemplars of the categories that were presented to the subjects with mental retardation. A second group of subjects without mental retardation received less typical exemplars of the conceptual categories: the exemplars were selected so as to equate the performance, in terms of slope values, of the subjects with mental retardation with the performance of this group of subjects without mental retardation. Although neither method of equating the initial performance levels of our groups is likely to be exact, taken together the two approaches should provide some measure of confidence in the results of our study.

Method

Subjects

Participants were 24 adults without mental retardation (mean chronological age [CA] = 18.2, standard deviation [*SD*] = .4) and 12 adults with mental retardation (mean CA = 17.4, *SD* = 1.5; mean IQ = 63.2, *SD* = 6.8). The subjects without mental retardation were recruited from freshman undergraduate psychology classes at the University of Alabama and those with mental retardation, from local senior high schools. All subjects were paid for their participation.

Apparatus

A carousel slide projector equipped with a tachistoscopic lens was used to present the stimuli. A voice-operated relay was interfaced with the lens and a millisecond clock such that onset of the stimulus slide coincided with the start of the timing cycle; the subject's verbal response stopped the clock.

Materials

Photographic slides of black and white line drawings of common objects selected from eight conceptual categories (animals, clothing, toys, fruit, furniture, vehicles, musical instruments, and tools) served as stimuli. Eight objects were chosen from each category. Four of the objects were identified as highly typical exemplars of their respective categories, whereas the other four objects were identified as less typical exemplars. Typicality ratings were based on pilot data in which 40 subjects without mental retardation rated the goodness of the category-exemplar relation on a 7-point scale. Four of the categories were designated as target categories (animals, clothing, furniture, and toys), and the other categories were identified as the nontarget categories.

Each photographic slide contained either two, three, or four pictures of two, three, or four objects. The pictures were presented along a diagonal beginning in the upper left corner of the slide and extending to the lower right. Half of the slides contained only highly typical exemplars and half contained only less typical exemplars. No more than one exemplar from any given category appeared on each slide. Throughout the experiment each target exemplar appeared 36 times, 12 times per set size. Each nontarget item appeared 69 times, 23 times per set size. Target exemplars were arranged such that they appeared an equal number of times in each serial position on the target slides for each set size. In addition, an equal number of exemplars from each category appeared in each set size an equal number of times. Half of the slides included one target and half did not include a target.

Design

The variables in the experiment were group (mentally retarded, nonretarded-high typicality and nonretarded-low typicality), set size (two, three, four), trial blocks (1 through 8), and response type (match, nonmatch). Half of the subjects without mental retardation received only high typical category exemplars and half received only low typical category exemplars. The subjects with mental retardation received only the high typical exemplars. Set size, trial blocks, and response type were manipulated within subjects. The dependent variable was the amount of time subjects took to determine whether any of the exemplars presented on the slide was a member of one of the target categories.

Procedure

Subjects were tested individually in four sessions held on consecutive days. Each session lasted approximately 45 minutes. They were informed of the target categories and practiced at identifying targets from the target categories from one object displays. Because this was a study of practice effects, no other formal practice was given prior to the start of the experiment. In the experiment, subjects were shown slides picturing two, three, or four common objects and were required to determine whether any of the objects were exemplars from any one of the four designated target categories. They were to respond, as rapidly as possible without error, "yes' if one of the objects was from a target category and "no" if it were not. Subjects initiated each trial with a hand remote control device. When the subject pressed the button, a slide appeared and the timer started. The subjects' vocal response stopped the clock and removed the slide. Response times were recorded

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Subjects received 288 trials per day. Each session was divided into two equal blocks of 144 trials. Subjects received the same two blocks of trials on each day, with the presentation order of trial blocks varying across days. Subjects were permitted a break between sessions, but few subjects took advantage of the opportunity.

Results

The data from the experiment are presented in Table 1. Errors were rare (less than 4.0% overall) and did not vary significantly as a function of experimental condition. The data analysis was conducted in two phases. In the first phase, we examined category detection times using separate 3 × 8 × 3 analysis of variance for yes and no responses. All pairwise comparisons were tested at the .05 level using Tukey's HSD test. The purpose of these analyses was to determine the particular trial block at which the effect associated with target set size was no longer significant for each group. We assumed that the absence of an effect of set size would indicate the presence of parallel processing and, hence, would reflect the development of automatic detection. The variables were group (nonretarded high typicality, nonretarded low typicality, and mentally retarded), trial block (1 through 8), and set size (two, three, and four).

The analysis of "yes" response times revealed a main effect of group, $F(2, 33) = 16.25$, $p < .001$, with the subjects with mental retardation responding more slowly (1,101 msec) than did both groups of subjects without mental retardation (725 for high- and 778 for low-typicality subjects), who did not differ significantly from each other. There was also a main effect of trial block, $F(7, 231) = 55.17$, $p < .001$, with response times decreasing from Trial Block 1 to Trial Block 5 and then leveling off. In addition, there was a main effect of set size, $F(2, 66) = 131.95$, $p < .001$, with response times at Set Size 2 (823 msec) being faster than those at Set Size 3 (862 msec), which, in turn, were significantly faster than those at Set Size 4 (919 msec). There were two significant two-way interactions; Group × Set Size, $F(4, 66) = 14.44$, $p < .001$, and Trial Block

Table 1
Category Detection Times and Slope Values on Trials by Group, Trial Blocks, and Set Size

	Nonretarded														
	High typicality					Low typicality					Mentally retarded				
Response/	Set size					Set size					Set size				
Trial block	2	3	4	Slope	n^a	2	3	4	Slope	n	2	3	4	Slope	n
Yes															
1	807	868	990	92	12	885	1051	1281	198	12	1157	1358	1549	196	12
2	744	795	821	39	8	783	838	924	71	11	1030	1124	1249	110	12
3	730	748	774	22	5	745	775	865	60	6	1041	1113	1197	78	11
4	701	706	725	12	3	696	712	758	31	5	1009	1073	1142	67	10
5	696	687	716	10	2	694	714	728	17	3	1044	1104	1162	59	9
6	662	657	673	6	2	707	715	735	14	3	978	1015	1052	37	7
7	669	653	680	6	1	686	696	711	13	2	1007	1038	1070	32	6
8	623	619	615	−4	1	677	656	684	4	1	975	979	991	8	5
No															
1	896	1126	1271	188	12	1015	1241	1512	249	12	1199	1471	1673	222	12
2	816	896	985	85	12	882	1051	1229	179	12	1159	1386	1553	197	12
3	699	774	859	80	12	780	906	999	110	12	1103	1326	1445	171	12
4	705	776	849	72	12	744	829	932	94	12	1082	1261	1403	161	12
5	699	769	819	60	11	721	743	848	64	12	1092	1237	1370	139	11
6	682	728	806	62	12	710	783	857	74	12	1025	1181	1244	110	12
7	697	751	797	50	12	741	793	862	61	11	1046	1172	1247	100	11
8	694	754	809	58	12	659	718	780	61	12	1048	1141	1262	107	12

[a]Number of subjects exhibiting a significant effect of set size.

× Set Size, $F(14, 462) = 39.62$, $p < .001$. However, these effects were qualified by the significant Group × Trial Block × Set Size interaction, $F(28, 462) = 1.67$, $p < .05$.

We examined the three-way interaction further by looking at the effects of blocks and set size separately for each group. For each group, this analysis revealed a significant main effect of trial block, $Fs(7, 77) = 12.80$ for the nonretarded high-typicality group, 69.09 for the nonretarded low-typicality group, and 12.07 for the retarded group, all $ps < .001$, a significant main effect of set size, $Fs(2, 22) = 41.67$ for the nonretarded high-typicality group, 63.11 for the nonretarded low-typicality group, and 51.61 for the retarded group, $ps < .001$, and a significant Trial Block × Set Size interaction, $Fs(14, 154) = 9.98$ for the nonretarded high-typicality group, 27.46 for the nonretarded low-typicality group, and 10.70 for the retarded group, all $ps < .001$. Hence, the pattern of data was similar for the three groups. As can be seen in Table 1, the effect of set size was greatest for the first several trial blocks and smallest for the last several trial blocks. An examination of the set size effect separately for each group and block revealed that the difference among groups primarily reflected a difference in how early in the experiment the effect of set size was no longer significant. For the nonretarded high-typicality subjects, the effect of set size was significant at Blocks 1 and 2, $ps < .001$, marginally significant at Block 3, $p < .08$, and not significant at Blocks 4 through 8, all $ps > .20$. For the nonretarded low-typicality subjects, the effect of set size was significant at Block 1, $p < .001$, Block 2, $p < .001$, and Block 3, $p < .01$, marginally significant at Block 4, $p < .09$, and not significant at Blocks 5 through 8, all $ps > .20$. For the subjects with mental retardation, the effect of set size was significant at Block 1, $p < .001$, Block 2, $p < .001$, Block 3, $p < .001$, Block 4, $p < .001$, Block 5, $p < .001$, Block 6, $p < .01$, and Block 7, $p < .05$, and not significant at Block 8., $p > .20$. Thus, according to these analyses the subjects without mental retardation in both the high- and low-typicality conditions exhibited evidence of automatic detection processes after less practice than did the subjects with mental retardation.

The analysis of "no" response times also revealed significant main effects for group, $F(2, 33) = 22.24$, $p < .001$, trial block, $F(7, 231) = 71.11$, $p < .001$, and set size, $F(2, 66) = 326.71$, $p < .001$. The subjects with mental retardation responded more slowly overall (1,252 msec) than did either of the nonretarded groups (819 msec for the high- and 889 msec for the low-typicality subjects), who again did not differ from each other. There was a steady decrease in response times across trial blocks that leveled off after Block 6. In addition, response times were fastest for Set Size 2, second fastest for Set Size 3, and slowest for Set Size 4 (871, 992, and 1,097 msec, respectively). Two first-order interactions were significant: Group × Set Size, $F(4, 66) = 10.40$, $p < .001$, and Trial Block × Set Size, $F(14, 462) = 23.98$, $p < .001$. There was also a significant three-way interaction of Group × Trial Block × Set Size, $F(28, 462) = 1.78$, $p < .01$.

The three-way interaction was examined by looking at the effects of trial blocks and set size separately for each group. Each analysis revealed a significant main effect of trial block, $F(7, 77) = 47.01$ for the high-typicality subjects without mental retardation, 64.77 for the low-typicality subjects without mental retardation, and 8.08 for the subjects with mental retardation, all $ps < .001$, a significant main effect of set size, $F(2, 22) = 387.98$ for the high-typicality subjects with mental retardation, 95.06 for the low-typicality subjects without mental retardation, and 106.22 for the subjects with mental retardation, all $ps < .001$, and a significant interaction of Trial Block × Set Size $F(14, 154) = 21.00$ for the high-typicality subjects without mental retardation, 14.39 for the low-typicality subjects without mental retardation, and 4.29 for the subjects with mental retardation, all $ps < .001$. As was

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the case with "yes" trials, the effect of set size was greatest for all groups for the early trial blocks and smallest for the later trial blocks (see Table 1). However, unlike results for the "yes" trials, the set size effect was significant throughout the experiment for the "no" trials for all three groups (all simple effects significant at the .01 level). Thus, it appears that the automatic "rejection" of nontargets develops more slowly than the automatic detection of targets, if such a process develops at all. Indeed, the utility of such a process operating automatically is not obvious.

In the second phase of the data analysis, we directly compared the performance of the three groups. The data used in the analyses were the slope values of the regression lines relating response times to set size computed for each trial block for each subject. These data are also presented in Table 1. The analyses were conducted to examine the relative patterns of change in slope values for the three groups across trial blocks. The variables were group and trial blocks. "Yes" and "no" trials were again analyzed separately. For the "yes" trials, there was a significant main effect of group, $F(2, 33) = 16.28$, $p < .001$, and a significant main effect of trial block, $F(7, 231) = 55.38$, $p < .001$. However, these effects were qualified by the significant Group × Trial Block interaction, $F(14, 231) = 1.88$, $p < .05$. As can be seen in Table 1, the subjects without mental retardation who received low-typical exemplars initially exhibited slope values that were similar to those exhibited by the subjects with mental retardation, with high-typicality subjects without mental retardation exhibiting slope values that were significantly less steep than did these two groups, both $ps < .05$. However, the slope values exhibited by the low-typicality subjects without mental retardation were significantly less steep than those of the subjects with mental retardation beginning with Trial Block 2 and were no longer significantly different from those of the high-typicality subjects without mental retardation after Trial Block 3. The slope values of the subjects with mental retardation were significantly steeper than those of the two nonretarded groups until Trial Block 8. Thus, the analysis of slope values confirms the analysis of response times in suggesting differences between individuals with and without mental retardation in the amount of practice required in order for category detection processes to become automatic.

As discussed earlier, we followed two procedures to attempt to equate the initial performance levels of the subjects with and without mental retardation. One approach was to select different stimuli for the subjects with and without mental retardation after equating for task difficulty, measured in terms of slope values at the start of the experiment. As can be seen in Table 1, the slope obtained for the low-typicality subjects without mental retardation was essentially identical to that of the subjects with mental retardation at the start of the experiment. Analysis of the group data revealed that slopes were not significantly different for the two groups, $F(1, 22) < 1.0$. Nevertheless, the subjects with mental retardation required four additional blocks of trials before they exhibited evidence of automatic category detection. Another way we used to equate the category detection performance of the subjects with and without mental retardation was to allow subjects with mental retardation to practice at the start of the experiment. In essence, we allowed them to practice until they were performing at the level exhibited by the high-typicality subjects without mental retardation at the start of the experiment, and then we began the experimental analysis of the data of the subjects with mental retardation from that point of equality. As can be seen in Table 1, the slope values exhibited by the subjects with mental retardation at Trial Block 3 was slightly less steep than the slope values obtained for the high-typicality subjects without mental retardation at the start of the experiment. However, a post hoc comparison of slope values for the first six trial blocks for the high-

typicality subjects without mental retardation versus the last six trial blocks of the subjects with mental retardation still yielded a significant Group × Trial Block interaction, $F(5, 110) = 6.31, p < .001$. Despite the extensive pretraining and the slight advantage in slopes values afforded the subjects with mental retardation by this approach to equating performance, the subjects without mental retardation exhibited evidence of automatic detection with less additional practice than did the subjects with mental retardation (three vs. five additional blocks of practice, respectively; all significant $ps < .01$. Hence, we are able to tentatively conclude that differences in the rate at which automaticity develops for persons with and without retardation do not appear to be related to differences in familiarity with stimuli at the start of the experiment.

The analysis of slope values for the "no" trials also yielded results similar to the analysis of response times. There was a significant main effect of group, $F(2, 33) = 7.78, p < .01$, and trial block, $F(7, 231) = 31.34, p < .001$. However, the Group × Trial Block interaction did not quite reach significance, $F(14, 231) = 1.56, p < .10$. The major difference between the analysis of data from the "yes" and "no" trials was that the subjects with mental retardation never reached the performance level of the subjects without mental retardation on the "no" response trials. This was not unexpected because responses to nontargets never became automatic during this study. It is not clear from our data whether the automatic rejection of nontargets is ever likely to be achieved. It may be that there is an important difference in the way that target and nontarget items are processed, thereby making the acquisition of automaticity not highly probable for nontarget exemplars.

The data from the experiment were examined in one other fashion. We analyzed each subject's data individually to determine the number of subjects in each group who were exhibiting a significant effect of set size for each trial block. This analysis was done using data from individual trials as data points in a one-way analysis of variance examining the effect of set size for each subject in each trial block separately for "yes" and "no" response trials. Because there were only 24 trials per condition for each subject, tests of significance were conducted with alpha set at .10. The number of subjects exhibiting a significant effect of set size in each condition are presented in Table 1. It is apparent from these data that there were individual differences in the development of automatic detection processes within each group. Nevertheless, the trend supports the conclusion that automatic processes are acquired at a slower rate for individuals with relative to those without mental retardation.

Discussion

The results of this study support the conclusion that individuals with mental retardation require more practice in search and detection tasks than do individuals without mental retardation in order for detection to occur automatically. Regardless of the approach we used to equate initial performance levels, the subjects with mental retardation needed several blocks of additional practice relative to the subjects without mental retardation to exhibit minimal evidence of automatic processing. Even at the end of the experiment, approximately one third of the subjects with mental retardation were still exhibiting a significant effect of set size on the "yes" trials (see Table 1). However, it is not clear that either way of equating initial performance levels was adequate and that our results would generalize to other conditions. To assess the generality of the results of Experiment 1, a second experiment was designed in which the stimuli were anomalous shapes

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that were equally unfamiliar to all subjects at the start of the experiment. We also selected a simple search and detection task rather than a categorization task in order to determine whether group differences in the development of automatic processing are limited to the detection of abstract superordinate categories.

EXPERIMENT 2

Method

Subjects

Participants were 10 subjects with and 10 without mental retardation. They were selected in a manner similar to those in Experiment 1. No subjects from Experiment 1 took part. The mean IQ of the subjects with mental retardation was 64.7 (*SD* = 6.7), and their mean CA was 17.7 (*SD* = 1.6). Those without mental retardation had a mean CA of 18.5 (*SD* = .6). Again, subjects were paid for their participation.

Materials and Apparatus

Stimuli were eight anomalous black and white line drawings (see Figure 1) constructed for presentation via a Macintosh LC computer. Two of the stimuli were designated as target stimuli and the remaining six, as nontarget stimuli. Stimuli were presented diagonally across the screen in arrays of two, three, and four items as shown in Figure 2. For Set Size 2, Positions 1 and 2 were occupied by stimuli and Positions 3 and 4 were occupied by checkerboard patterns. For Set Size 3, stimuli were presented in Positions 1, 2, and 3, and Position 4 was occupied by a checkerboard pattern. A series of 288 stimulus arrays were constructed, 96 of each set size, with 48 stimulus arrays including a target stimulus at each set size. The order of the stimulus arrays was randomized for presentation.

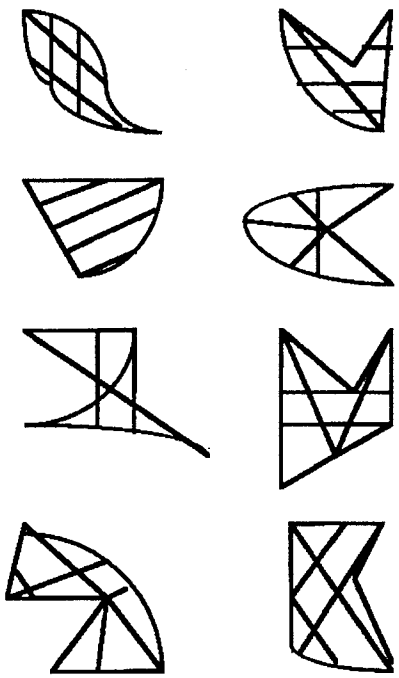

Figure 1. Anomalous shapes used as stimuli in Experiment 2.

Procedure

Each subject was tested individually on 4 different days. The duration of each session was approximately 45 minutes. Subjects received two blocks of 288 trials per day, for a total of 2,304 trials across the four sessions. Trials were presented using a Macintosh computer. Each trial consisted of the presentation of a fixation array, followed 750 msec later by the stimulus array. The fixation array consisted of a cross presented in the upper left corner of the array to designate the location of the first stimulus in the array and three dots angling diagonally to the right hand corner of the array to designate locations of other potential stimuli. The stimulus array remained in view until a response was made. Subjects responded by pressing a key with their right index finger if there was a target in the array and pressing a key with their left index finger if there was not a target in the array.

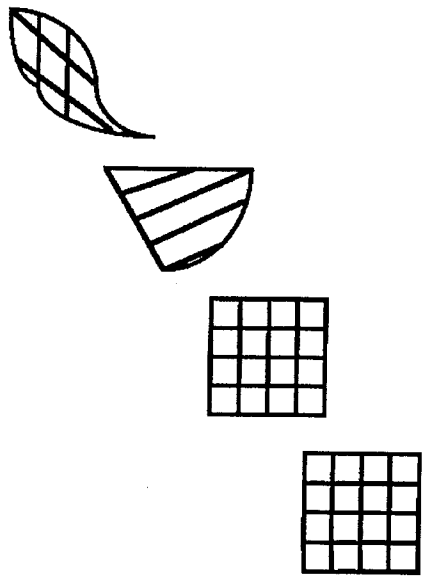

Figure 2. Example of stimulus array used in Experiment 2.

Response times were recorded to the nearest msec.

Results

The data obtained for "yes" trials in Experiment 2 are presented in Table 2. Errors were again rare (less than 3.0% across subjects) and did not vary as a function of experimental conditions. The primary analyses were patterned after Experiment 1 except that only the data from "yes" response trials were analyzed because the data from the "no" response trials did not yield information about the development of automatic processing in Experiment 1. First, we examined group differences in stimulus detection times using analysis of variance procedures to determine the trial block at which the effect of set size was no longer significant. All pairwise comparisons were tested at the .05 level of significance using Tukey's HSD. The variables were group (mentally retarded, nonretarded), trial block (1 through 8), and set size (two, three, four).

The analysis of "yes" response times revealed a significant main effect of group, $F(1, 18) = 30.96, p < .001$; the subjects with mental retardation responded more slowly than did subjects without mental retardation (845 vs. 645 msec, respectively). There was a significant main effect of trial block, $F(7, 126) = 15.98, p < .001$, with response times generally decreasing throughout the early trial blocks and leveling off at Trial Block 6. A significant main effect of set size, $F(2, 36) = 212.32, p < .001$, revealed that response times were fastest at Set Size 2, second fastest at Set Size 3, and slowest at Set Size 4 (708, 743, and 783 msec, respectively, all $ps < .05$). There were three significant two-way interactions: Group × Trial Block, $F(7, 126) = 3.93, p < .001$; Group × Set Size, $F(2, 36) = 36.48, p < .001$; and Trial Block × Set Size, $F(14, 252) = 17.91, p < .001$. These effects were qualified by the significant three-way interaction of Group × Trial Block × Set Size, $F(14, 252) = 3.60, p < .001$.

Table 2
Stimulus Detection Times and Slope Values on "Yes" Trials by Group, Trial Block, and Set Size

	Nonretarded					Mentally retarded				
	Set size					Set size				
Trial block	2	3	4	Slope	n^a	2	3	4	Slope	n
1	691	719	774	62	10	926	1044	1135	105	10
2	640	677	725	43	9	930	1013	1096	83	10
3	622	652	687	33	8	805	869	915	55	9
4	620	645	650	15	5	731	784	851	60	8
5	618	634	643	13	3	737	794	852	58	8
6	611	605	634	12	2	721	765	799	39	6
7	599	594	618	10	2	714	726	740	13	4
8	597	600	599	1	1	766	771	783	9	4

[a]Number of subjects exhibiting a significant effect of set size.

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Mentally retarded			
t size			
3	4	Slope	*n*
044	1135	105	10
013	1096	83	10
369	915	55	9
784	851	60	8
794	852	58	8
765	799	39	6
726	740	13	4
771	783	9	4

The effects of trial blocks and set size were examined for each group. The results of these two analyses were again very similar. For each group there was a main effect of trial block, $F(7, 63) = 19.06$ for the subjects without and 9.34 for the subjects with mental retardation, both $ps < .001$, a main effect of set size, $F(2, 18) = 85.73$ for the subjects without and 135.43 for the subjects with mental retardation, both $ps < .001$, and a significant Trial Block × Set Size interaction, $F(14, 126) = 7.30$, for the subjects without and 12.20 for the subjects with mental retardation, both $ps < .001$. Tests of simple effects revealed that the effect of set size was significant for the subjects without mental retardation for Trial Blocks 1, $p < .001$, 2, $p < .001$, 3, $p < .001$, and 4, $p < .05$, but not for Trial Blocks 5 through 8, all $ps > .20$. For the subjects with mental retardation, the effect of set size was significant for Trial Blocks 1, $p < .001$, 2, $p < .001$, 3, $p < .001$, 4, $p < .001$, 5, $p < .001$) 6, $p < .01$, and 7, $p < .05$, but not Trial Block 8, $p > .15$. Thus, the effect of set size was eliminated with less practice for the subjects without than for those with mental retardation.

Slope values for "yes" response trials were computed in the same way as in Experiment 1 (see Table 2) and analyzed in a Group (mentally retarded, nonretarded) × Trial Block (1 through 8) analysis of variance. This analysis revealed a main effect of group, $F(1, 18) = 46.04$, $p < .001$, a significant main effect of trial block, $F(7, 126) = 27.04$, $p < .001$, and a significant Group × Trial Block interaction, $F(7, 126) = 4.91$, $p < .001$. Tests of simple effects revealed that there was a significant difference in slope values for the two groups for Trial Blocks 1 through 6, all $ps < .01$, but the difference was not significant for Trial Blocks 7 and 8, both $ps > .20$. As in Experiment 1, the comparison of slope values in Experiment 2 paralleled the analysis of response times. Therefore, the conclusion is that for unfamiliar stimuli as well as familiar stimuli, individuals without mental retardation also acquire automatic search and detection processes at a faster rate than do individuals with mental retardation.

Finally, in looking at the number of subjects who exhibited evidence of automaticity during Experiment 2 (see Table 2), we again found that a greater number of subjects without mental retardation (9 out of 10) did not exhibit a significant effect of set size at the end of the experiment relative to the subjects with mental retardation (6 out of 10). This trend is highly consistent with other aspects of the results.

General Discussion

The results of these two experiments lead to the general conclusion that persons with mental retardation require more practice to achieve a level of processing that can be described as automatic than do persons without mental retardation. This was true for both pictures of common objects and pictures of unfamiliar shapes as well as for detection of semantic category information and detection of specific target stimuli. Regardless of the specific conditions of the two experiments, the subjects with mental retardation required approximately twice as many practice trials to exhibit evidence of automatic search and detection processes than did individuals without mental retardation. It is important to recognize that we are not certain that the subjects with mental retardation did exhibit signs of automaticity in these studies because this was only observed for the last trial block of each experiment for this group and not for every subject within the group. We would rather have demonstrated equivalent performance levels among the groups across several consecutive trial blocks. However, even if the subjects with mental retardation did not truly acquire automaticity in these experiments, this would only indicate an even bigger difference among our groups.

There are many factors that are known to influence the speed with which

automatic processing develops in search and detection tasks. For example, Schneider and his colleagues have reported that automatic processing develops faster when the stimulus–response relations are highly consistent relative to less consistent (Schneider & Fisk, 1982). In order for a response to be automatically elicited by a given stimulus, it must be the most common response to that stimulus. However, the consistent repetition of appropriate stimulus–response pairings is not sufficient to ensure the rapid development of automatic processing. Decreasing the ratio of target presentation to nontarget presentation trials while maintaining the same absolute number of target trials also seems to decrease the rate at which automatic processing is acquired (Shiffrin & Dumais, 1981). In addition, varying the similarity of target and nontarget items influences the ease with which processes become automated (Shiffrin & Schneider, 1977). It is possible to view individual differences in the rate at which automatic processing develops in terms of differences in the degree to which individuals are sensitive to these factors. For example, individuals with mental retardation may require a higher ratio of target to nontarget trials in order for automatic processing to develop with maximum efficiency. It will, therefore, be important to determine whether these general factors exert a similar influence on the performance of individuals with and without mental retardation.

One other plausible explanation for differences between persons with and without mental retardation in the rate of development of automatic processing is suggested by an earlier study. Merrill (1992) found that in some cases individuals with mental retardation may actually allocate relatively fewer processing resources to this kind of semantic decision task than do individuals without mental retardation. Whether this was due to differences in the way these subjects chose to allocate resources or differences in the amount of resources generally available was not clear. However, these possibilities are functionally equivalent in that they lead to fewer resources being devoted to the execution of the cognitive activity by subjects with mental retardation. There is at least an intuitive relation between the amount of cognitive processing resources devoted to learning and the rate at which learning occurs, and there is some empirical data to support this common sense claim (e.g., Nissen & Bullemer, 1987; Noble, Trumbo, & Fowler, 1967). Therefore, we might expect individuals who devote fewer resources to performing an activity to achieve a level of automatic processing on that activity at a slower rate than do individuals who devote more resources to the activity; however, this remains to be demonstrated.

Earlier, we alluded to the relation between automatic processing and the ability to learn and execute more complex skills. This relation is beginning to receive some important theoretical and empirical attention (see Logan, 1985). However, it is not possible to translate the results of this study into a direct discussion of how individuals with and without mental retardation should differ in the acquisition of skilled behaviors. The development of skill is likely to vary a great deal across different task domains (see Chi, Glaser, & Farr, 1988). One common theme, however, appears to be that skilled performance generally involves an increase in functional processing capacity; that is, skilled performers process more information than do unskilled performers (e.g., Logie & Baddeley, 1988; Woltz, 1988). One way that functional processing capacity can increase is through the development of automatic processing. In this research we have observed differences between individuals with and without mental retardation in the rate at which automatic processing is acquired under similar practice conditions. It is, therefore, reasonable to suggest that the rate at which more complex skills will develop will be affected by this difference. Understanding the exact nature of this relation

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Despite the nature of our argument, it is important to recognize that it is unlikely that the cognitive difficulties of individuals with mental retardation will be overcome by simply giving sufficient training on the component processes of complex activities. We are suggesting that the automatic processing of component skills may be necessary for the development of skilled behavior, but it is certainly not sufficient. In fact, automatic processing usually carries a cost as well as a benefit. When a process is executed automatically, it is no longer under the same degree of voluntary control relative to when it is not executed automatically and can sometimes interfere with the ability to perform other required activities. An early demonstration of this can be found in the work of Stroop (1935). Because the reading of words seems to operate in relatively automatic fashion, it is generally very difficult for subjects to ignore the meaning of a printed word and respond to some other aspect of the word stimulus that is inconsistent with the meaning. Hence, there is a great deal of interference associated with trying to name the color in which a word is printed when the word represents a different color name (e.g., saying "blue" to the word *red* printed in blue ink). Ellis, Woodley-Zanthos, Dulaney, and Palmer (1989) suggested that individuals with mental retardation find it much more difficult to exert control over automatic processes than do individuals without mental retardation. Therefore, an increase in the efficiency of specific activities associated with an increase in the relative automaticity of some basic operations may also decrease the relative flexibility of processing for individuals with mental retardation. Further, many accounts of intelligent behavior suggest that a higher degree of flexibility in processing is one of the more important features that differentiates the performance of individuals who differ in intellectual level (see Sternberg, 1984).

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