American Journal on Mental Retardation, 1994, Vol. 98, No. 5, 588–593

Allocation of Attention and Task Difficulty

Edward C. Merrill and Michael Peacock
The University of Alabama

Individuals with and without mental retardation did a dual task procedure designed to investigate how task difficulty influenced the allocation of attention. The primary task required semantic category decisions. Subjects sorted cards according to whether the object pictured on the card belonged to a target category. The easy decision task used basic level categories (horse and hammer). The difficult decision task used superordinate categories (animals and tools). While making decisions, subjects were required to signal detection of auditory probes. Response times to the probes were used to index attention to the primary task. Subjects without mental retardation allocated more attention to the difficult task. Those with mental retardation gave similar attention to the easy and difficult tasks. Possible explanations for their failure to allocate attention in accordance with task difficulty were discussed.

Research shows that individuals with mental retardation are slower information processors than are those without mental retardation who are matched for chronological age (CA) (see Baumeister & Kellas, 1968; Jensen, 1982; Merrill, 1990; Sperber & McCauley, 1984). A portion of their slowness may be due to differences in the allocation of attention (Merrill, 1990, 1992). Merrill's (1992) subjects participated in a modified Posner encoding function task (Posner, 1978) while retaining a short list of digits in working memory. The encoding function task is a stimulus-matching task in which the two stimuli are presented successively. By varying the time between the onset of the first and second stimulus, it is possible to measure stimulus encoding time and decision-making time separately (see Merrill et al., 1987; Posner, 1986). Merrill (1992) had subjects make physical and name identity matches to stimuli. While performing the matching task, subjects remembered a list of digits corresponding to a full memory load or to half that number. The allocation of attention was measured in terms of how much the memory task slowed encoding and decision-making. Subjects allocating more attention to encoding and decision-making would be slowed more by the full relative to the half memory load than would individuals who allocate less attention.

Merrill's (1992) results indicated that encoding and decision-making times for the subjects without mental retardation were slowed more than those of the subjects with mental retardation. This was interpreted as indicating that the former subjects were allocating more attention to encoding and decision-making processes. In fact, differences in matching times between individuals with and without mental

retardation were reduced by about two thirds in the full relative to half memory load condition.

Research has also shown that response time differences between people with and without mental retardation are greater when subjects perform more difficult tasks (e.g., Davies, Sperber, & McCauley, 1981; Merrill, 1985; Merrill et al., 1987; Mulhern & Baumeister, 1971; Sperber, Davies, Merrill, & McCauley, 1982). Merrill (1990) suggested that this finding is consistent with the possibility that individuals with mental retardation allocate less attention to information processing than do individuals without mental retardation. In the research reported here, we used a dual-task procedure to examine whether the larger performance differences in processing speed between individuals with and without mental retardation that are seen for high relative to low difficulty tasks are due to differences in the allocation of attention.

We chose category decision-making as our primary task because it met two criteria: there were two obvious levels of task difficulty, and people with and without mental retardation exhibit group differences related to task difficulty. First, when individuals make decisions about the category membership of objects, they are typically slower at superordinate classification (e.g., it is furniture) than at basic level classification (e.g., it is a table) (see Rosch, 1975). Second, the response time difference between making decisions about basic level category membership is greater for individuals with than for those without mental retardation (Davies et al., 1981; Sperber et al., 1982).

In the experiment, subjects sorted cards of pictured objects on the basis of semantic category. For half of the experiment, classification was based on the basic level identity of the objects, and for half it was based on the superordinated identity of the objects. We expected that participants would classify more pictures in basic level classification than in superordinate classification and that subjects with mental retardation would exhibit a greater difference in response times between basic level and superordinate condition (Davies et al., 1981; Sperber et al., 1982). While performing the classification task, subjects performed an auditory detection task. Auditory signals were presented at random intervals during card sorting. Subjects had to press a foot pedal as rapidly as possible when a signal was heard without disrupting their card sorting.

Time to respond to the auditory probe served as the dependent measure. Based on the logic of the dual task method (Duncan, 1980; Kerr, 1973; Posner, 1986), we expected that response times to auditory probes would be slower if attention was required to perform the classification task. If superordinate classification uses more attention than does basic level classification, then response times to auditory probes should be slower for superordinate classification than for basic level classification. If the larger performance difference between individuals with and without mental retardation for superordinate versus basic level classification is due, in part, to the failure to allocate more attention to superordinate classification, then we expect a smaller difference between probe response times in the superordinate relative to basic level classification conditions for subjects with than without mental retardation.

Method

Subjects

Subjects were 24 persons with and 24 without mental retardation. The former were recruited from the community and paid $2.50 for their participation (mean CA = 17.2 years, standard deviation [*SD*] = 1.67; mean IQ = 62.3, *SD* = 6.78). The subjects without mental retardation were recruited from freshman psychology courses and received course credit for participation (mean CA = 18.2, *SD* = .4).

Materials

Stimuli for the classification task were pictures of common objects printed in the center of white 5 × 8 cards, one picture per card. Pictures were of four objects chosen from each of four superordinate categories: kitchen utensils (plates, pot, mixer, and coffee maker), vehicles (car, bus, truck, and van), animals (dog, horse, hippopotamus, and alligator), and tools (screwdriver, hammer, drill, and shovel). There were 15 copies of each picture, for a total of 240. Animals and tools were the target categories. The pictures were randomized with the restriction that for every subset of 40 cards, 20 pictures were from target and 20 were from nontarget categories. A set of 240 cards was also used in the basic level condition. This set included 15 copies of each kitchen utensil and vehicle and 60 copies of hammer and horse. Hammer and horse were targets in the basic level classification task.

Stimuli for the auditory probe task consisted of three 2-minute tapes of auditory beeps randomly presented at the average rate of one beep per 5 seconds. The interval between beeps ranged from 1 to 15 seconds.

Design and Procedure

The variables in the experiment were group (mentally retarded, nonretarded) and decision type (basic level, superordinate). Decision type was manipulated within subjects, with the order of presentation for this variable counterbalanced for subjects within each group. Two dependent variables were used: number of cards sorted in the classification task and auditory probe response times in the probe detection task.

Subjects were seated at a desk in a small room. They were instructed to rest their feet on a slightly raised platform below the desk. On the platform were two buttons. The button on the right was the "resting button." Subjects were to keep their right foot on this button until they heard a beep. Then they were to use their right foot to press the button on the left as rapidly as possible and then return their foot to the button on the right. To ensure that subjects were complying with instructions, pressing the button on the right caused a light to come on in view of the experimenter and the subject. The left button was wired to a millisecond clock. Onset of the auditory signal started the clock, and the subjects' foot press stopped the clock. For the primary task, subjects were given the set of cards corresponding to the decision-type condition that they were assigned to perform first. They were instructed to sort the cards into two piles as rapidly as possible without error. One pile was to include the horses and hammers (or animals and tools) and the other pile was to include everything else.

At the start of the experimental session, baseline performance was established for the auditory probe task, basic level decision task, and superordinate decision task. Baseline for the auditory probe task was established by having subjects perform the detection task alone for 2 minutes. Cumulative response time to detecting the probes was recorded to the nearest msec. Baseline for each decision task was established by having subjects sort the first 40 cards of each decision type. The times required to sort each set of 40 cards were recorded to the nearest 1/10th second. After baselines were established, subjects were given a brief opportunity to coordinate the two tasks using cards that were not used in the experiment. They were instructed to sort the cards as rapidly as possible and to respond to the auditory probe as rapidly as possible without disrupting performance on the card-sorting task. After this brief warm-up, subjects performed the auditory probe task with each of the decision tasks for 2 minutes. Cumulative response times to the auditory probes were recorded to the nearest msec for each decision type condition. Number of cards sorted in 2 minutes were counted and recorded for each decision task.

they were to use their
ıe button on the left as
and then return their
›n the right. To ensure
omplying with instruc-
button on the right
›me on in view of the
the subject. The left
o a millisecond clock.
ory signal started the
:cts' foot press stopped
primary task, subjects
›f cards corresponding
›e condition that they
:rform first. They were
: cards into two piles as
vithout error. One pile
orses and hammers (or
and the other pile was
ıg else.
the experimental ses-
·mance was established
robe task, basic level
ıuperordinate decision
ıe auditory probe task
· having subjects per-
task alone for 2 min-
ponse time to detecting
:orded to the nearest
:ach decision task was
ıg subjects sort the first
:cision type. The times
:h set of 40 cards were
earest 1/10th second.
e established, subjects
opportunity to coordi-
using cards that were
:periment. They were
he cards as rapidly as
ıpond to the auditory
: possible without dis-
:e on the card-sorting
ıef warm-up, subjects
itory probe task with
n tasks for 2 minutes.
e times to the auditory
ed to the nearest msec
'pe condition. Number
minutes were counted
ıch decision task.

Results

Number of cards sorted was converted to average decision time per card. Means for each condition are presented in Table 1. Errors on the primary task were low (9 versus 3 errors for the subjects with and without mental retardation). Cumulative response times obtained on the probe detection task are reported in Table 2. There were no errors associated with probe detection. Data from the primary and secondary tasks were analyzed separately.

Table 1
Mean Card Sort Times (in msec) by Group, Time, and Decision Type

Group/Time	Basic level	Superordinate
Mentally retarded		
Baseline	880	1000
Experiment	967	1080
Nonretarded		
Baseline	769	849
Experiment	804	879

Table 2
Mean Probe Detection Time (in Seconds) by Group and Primary Task Requirements

Group	None	Primary task basic level	Superordinate
Mentally retarded	8.185	9.257	9.323
Nonretarded	5.763	6.983	7.794

Primary Task. Mean decision times per card were analyzed using a 2 (group) × 2 (time: baseline, experiment) × 2 (decision type) mixed analysis of variance, with time and decision type treated as within subjects variables. The analysis revealed a significant main effect of group, $F(1, 46) = 27.884$, $p < .001$, with the subjects who had mental retardation responding more slowly than did the subjects without mental retardation (982 and 826 msec, respectively), a significant effect of time, $F(1, 46) = 10.609$, $p < .01$, with baseline trials being faster than experimental trials (874 and 933 msec, respectively), and a significant effect of decision type, $F(1, 46) = 120.747$, $p < .001$, with basic level decisions taking less time than superordinate decisions (856 msec and 952 msec, respectively). There was also a Group × Decision Type interaction, $F(1, 46) = 4.976$, $p < .05$, with subjects who had mental retardation exhibiting a greater difference between basic level and superordinate decision times than did the subjects without mental retardation (116 and 77 msec, respectively). This finding is consistent with previous research (e.g., Davies et al., 1981; Sperber et al., 1972). The main effect of time indicates that subjects were not able to maintain primary task performance at maximum levels when performing the secondary task. However, no interaction with time was significant. Hence, the presence of the secondary task did not differentially influence the performance of the subjects with and without mental retardation. Therefore, it is appropriate to use secondary task data to assess group differences in the allocation of attention.

Secondary Task. Cumulative response times in the detection task were analyzed in a 2 (group) × 3 (primary task: no, basic level, and superordinate) mixed analysis of variance, with primary task treated as a within subjects variable. There was a significant main effect of group, $F(1, 46) = 6.815$, $p < .01$, with the subjects who had mental retardation responding more slowly to the probes than did those without mental retardation (8.922 vs. 6.847 seconds, respectively). There was a significant main effect of primary task, $F(2, 92) = 49.344$, $p < .001$, with probe detection times being faster with no primary task (6.974 seconds) than either the basic level (8.120 seconds) or the superordinate decision task (8.559 seconds). However, both effects were qualified by the significant interaction of Group × Primary Task, $F(2, 92) = 4.223$, $p < .05$.

The interaction was examined by analyzing the effect of Primary Task separately for each group. For the subjects with mental retardation, there was a significant effect of primary task on probe detection times, $F(2, 69) = 4.993$, $p < .05$; detection times in the no primary task condition (8.185 seconds) were significantly faster than in either the basic level or super-

ordinate conditions (9.257 and 9.323 seconds, respectively, $ps < .05$ using Tukey HSD). The latter two conditions did not differ from each other. For the subjects without mental retardation, there was also a significant effect of primary task, $F(2, 69) = 19.914$, $p < .001$. As with the subjects who had mental retardation, the detection times of the subjects without mental retardation in the no primary task condition (5.763 seconds) were faster than in either the basic level (6.983 seconds, $p < .05$) or superordinate conditions (7.795 seconds, $p < .05$). In addition, there was a significant difference between the basic level and superordinate conditions for the subjects without mental retardation, $p < .05$. Thus, these subjects exhibited greater probe interference when performing the superordinate decision task relative to the basic level decision task, whereas the subjects with mental retardation exhibited the same degree of probe interference when performing the basic level and superordinate decision tasks.

Discussion

The results of this research are consistent with the possibility that differences between individuals with and without mental retardation in the speed with which superordinate level relative to basic level decisions can be made are mediated, in part, by the allocation of attention. The subjects without mental retardation allocated more attention to superordinate decision- making than they did to basic level decision-making, and the difference in speed between conditions was relatively small. The subjects with mental retardation allocated the same degree of attention to superordinate and basic level decision-making and the difference in speed between conditions was relatively large. Apparently, some of the deficiencies in processing speed observed for individuals with mental retardation that are related to task difficulty may be due to the inefficient allocation of attention (e.g., Merrill, 1990, 1992; Sperber & McCauley, 1984). However, the generality of this result may depend on how task difficulty is manipulated.

These data may also shed some light on operation of the attention allocation system of people with mental retardation. Capacity models of attention generally assume that some of an individual's processing attention can be flexibly allocated as needed (e.g., Kahneman, 1973; Keele, 1973; Norman & Bobrow, 1975; Wickens, 1984). The subjects with mental retardation did not allocate attention as needed in this experiment. There are several alternative explanations for this finding. A metacognitive analysis may be that the subjects with mental retardation did not judge that a change in allocation policy was needed because they did not perceive a change in task difficulty. A motivational explanation may be that they allocated resources as desired and simply did not wish to put more effort into or allocate more attention to the more difficult task. A limited capacity explanation may suggest that the subjects with mental retardation had allocated all of their attention to the easy task and did not have any additional attention to give to the more difficult task. It will be important to try and determine which alternative best characterizes the attentional allocation processes of individuals with mental retardation.

References

Baumeister, A. A., & Kellas, G. (1968). Reaction time and mental retardation. In N. R. Ellis (Ed.), *International review of research in mental retardation* (Vol. 3, pp. 162–193). New York: Academic Press.

Davies, D., Sperber, R. D., & McCauley, C. (1981). Intelligence-related differences in semantic processing speed. *Journal of Experimental Child Psychology, 31,* 387–402.

Duncan, J. (1980). The demonstration of capacity limitation. *Cognitive Psychology, 12,* 75–96.

Jensen, A. R. (1982). The chronometry of intelligence. In R. J. Sternberg (Ed.), *Ad-*

lcCauley, 1984). How-
ty of this result may
sk difficulty is manipu-

ıy also shed some light
ıe attention allocation
ith mental retardation.
attention generally as-
ın individual's process-
ıe flexibly allocated as
man, 1973; Keele, 1973;
, 1975; Wickens, 1984).
mental retardation did
on as needed in this
are several alternative
his finding. A meta-
ıay be that the subjects
tion did not judge that
ion policy was needed
ɔt perceive a change in
ɔtivational explanation
allocated resources as
did not wish to put
allocate more attention
task. A limited capacity
ggest that the subjects
ion had allocated all of
e easy task and did not
attention to give to the
It will be important to
which alternative best
attentional allocation
luals with mental retar-

Kellas, G. (1968). Reac-
tal retardation. In N. R.
tional review of research
on (Vol. 3, pp. 162–193).
ıic Press.

R. D., & McCauley, C.
e-related differences in
g speed. *Journal of Ex-*
sychology, 31, 387–402.

The demonstration of
Cognitive Psychology, 12,

2). The chronometry of
J. Sternberg (Ed.), *Ad-*

vances in the psychology of human intelligence (Vol. 1, pp. 255–310). Hillsdale, NJ: Erlbaum.

Kahneman, D. (1973). *Attention and effort.* Englewood Cliffs, NJ: Prentice-Hall.

Keele, S. W. (1973). *Attention and human performance.* Pacific Palisades, CA: Goodyear.

Kerr, B. (1973). Processing demands during mental operations. *Memory & Cognition, 1,* 401–412.

Merrill, E. C. (1985). Differences in semantic processing speed of mentally retarded and nonretarded persons: Comparison of short- and long-term memory processing. *American Journal of Mental Deficiency, 90,* 71–80.

Merrill, E. C. (1990). Resource allocation and mental retardation. In N. W. Bray (Ed.), *International review of research in mental retardation* (Vol. 16, pp. 51–88). Hillsdale, NJ: Erlbaum.

Merrill, E. C. (1992). Attentional resource demands of stimulus encoding for persons with and without mental retardation. *American Journal on Mental Retardation, 97,* 87–98.

Merrill, E. C., & McCauley, C. (1988). Phasic alertness and differences in encoding speed. *American Journal on Mental Retardation, 93,* 245–249.

Merrill, E. C., Sperber, R. D., McCauley, C., Littlefield, J., Rider, E. A., & Shapiro, D. (1987). Picture encoding speed and mental retardation. *Intelligence, 11,* 169–191.

Mulhern, T., & Baumeister, A. A. (1971). Effects of stimulus-response compatibility and complexity upon reaction times of normals and retardates. *Journal of Comparative and Physiological Psychology, 75,* 459–463.

Norman, D., & Bobrow, D. (1975). On data limited and resource limited processing. *Cognitive Psychology, 7,* 44–60.

Posner, M. I. (1978). *Chronometric explorations of mind.* Hillsdale, NJ: Erlbaum.

Posner, M. I. (1986). *Chronometric explorations of mind* (2nd ed.). Hillsdale, NJ: Erlbaum.

Rosch, E. (1975). Cognitive representations of semantic categories. *Journal of Experimental Psychology: General, 104,* 192–234.

Sperber, R. D., Davies, D., Merrill, E. C., & McCauley, C. (1982). Crosscategory differences in the processing of subordinate-superordinate relationships. *Child Development, 53,* 1249–1253.

Sperber, R. D., & McCauley, C. (1984). Semantic processing efficiency in the mentally retarded. In P. Brooks, R. Sperber, & C. McCauley (Eds.), *Learning and cognition in the mentally retarded* (pp. 141–163). Hillsdale, NJ: Erlbaum.

Wickens, C. D. (1984). Processing resources in attention. In R. Parasuraman & D. R. Davies (Eds.), *Varieties of attention* (pp. 63–102). New York: Academic Press.

Received 12/17/91; first decision 7/21/92; accepted 9/9/92.

This research was supported by National Institute of Child Health and Human Development Grant No. HD23325 awarded to the first author. Requests for reprints should be sent to Edward C. Merrill, Department of Psychology, PO Box 870348, University of Alabama,