

THE UNIVERSITY OF CALGARY

AN INVESTIGATION OF THE TEMPORAL CHARACTERISTICS AND
LOCATION OF ICONIC MEMORY IN MILDLY RETARDED AND
NONRETARDED INDIVIDUALS

by

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A THESIS

SUBMITTED TO THE FACULTY OF
GRADUATE STUDIES IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

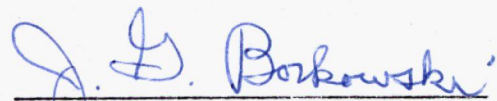
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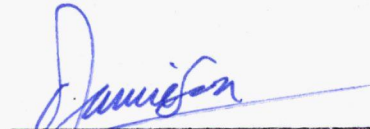
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THE UNIVERSITY OF CALGARY
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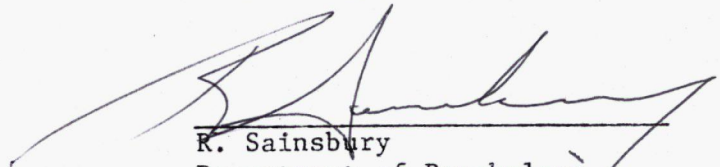
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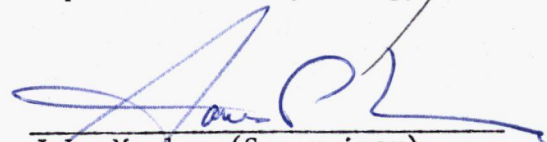
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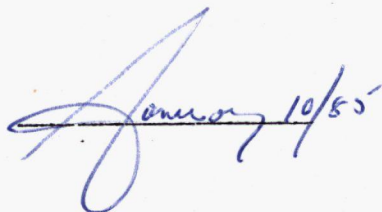


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ABSTRACT

Iconic memory was investigated in mildly retarded, equal-CA, and equal-MA matched nonretarded subjects employing a dichoptic/monoptic masking paradigm with verbal and nonverbal stimuli. In addition, stimulus type was varied in a dichotic listening task to highlight any potential differences in the information processing of retarded and nonretarded subjects. Results indicated that mildly retarded and nonretarded individuals differed qualitatively only in those situations in which control processes were most important. The significantly longer critical target duration intervals required by the mildly retarded subjects relative to the equal-CA and equal-MA groups suggested the inefficient operation of feature extraction (encoding) combined with response uncertainty. With verbal stimuli, the mildly retarded subjects demonstrated significantly inferior performance relative to that of equal-MA and equal-CA groups. It was suggested that the mildly retarded subjects were not able to durably encode the stimuli features. Furthermore, the lack of a Group X SOA interaction effect when nonverbal stimuli were employed supported the conclusion that stimulus type may be a significant contributor to the poor performance of the mildly retarded individuals. The increase in response accuracy across time with all 3 groups demonstrated when

the monoptic backward visual masking paradigm was employed was consistent with the literature suggesting that the duration of iconic storage is approximately 250 ms under normal viewing conditions. The current masking data suggested that retinal processes are preeminent over central processes in all 3 groups in explaining the primary processing locale for iconic memory. The dichotic listening task performance revealed that mildly retarded individuals are less efficient in the processing of verbal stimuli and further highlighted the need to consider the influence of stimulus type when investigating processing differences between retarded and nonretarded groups.

ACKNOWLEDGEMENTS

This dissertation took a very long time to complete; it was largely due to the unending and selfless patience, understanding and guidance (sometimes quite direct) offered by primarily two people, that I ended up finishing this document: first, I can't begin to express my gratitude and appreciation to Catherine for supporting and encouraging me during every step of this painful process. Second, I thank Larry Mosley for largely maintaining his sense of humor and always providing me with needed structure, knowledge, friendship and the occasional kick in the pants.

I would also like to express my appreciation to John Borkowski, Don Jamieson, David Romney and Bob Sainsbury, individually and as a group, for their particular assistance and support.

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CHAPTER I

INTRODUCTION

Mental retardation -- what is it?

Mental retardation refers to significantly subaverage general intellectual functioning existing concurrently with deficits in adaptive behavior, and manifested during the developmental period. These criteria include a heterogeneous group, behaviorally and biologically. Intelligence ranges down to that of vegetative organisms, some capable of little adaptive behavior. The damage to the central nervous system may have resulted from physical trauma, disease, genetic damage, and extreme environmental conditions.

The two-group approach to mental retardation (Zigler, 1966) calls attention to the fact that those mentally retarded individuals who have known physiological defects represent a distribution of intelligence with a mean which is considerably lower than that of familial retarded individuals. Such people, for the most part, fall outside the range of normal intelligence as determined by the polygenic model for the heritability of intelligence, i.e., below an IQ of 50, although there are certain exceptions. The polygenic model of intelligence holds that the genetic foundation of intelligence is not viewed as dependent upon a single gene. Rather, intelligence is viewed as the result

of a number of discrete genetic units acting additively (as in height, weight, etc.), which produce a continuous distribution. A second curve, that representing the so-called organic retarded individuals (IQ range = 0-70, $M = 35$), represents those individuals whose intellectual functioning reflects factors other than the normal polygenic expression, i.e., those retarded individuals for whom there is a suggestion of or identifiable cause for the retardation (e.g., Down's Syndrome, hemorrhage, eclampsia, etc.).

Thus, the empirical distribution of intelligence may best be represented by two curves, one for those with organic deficits and the other for the familial retarded individuals. The Developmental Lag Theory suggests that the cognitive development of the familial mentally retarded is characterized by a slower progression through the same sequence of cognitive stages as the nonretarded and asymptotes at a lower level of cognitive development. Thus, the difference between the nonretarded and retarded is analogous to the difference between the very superior and normal. The developmental lag position generates the hypothesis that there are very minimal differences in cognitive functioning between familial retarded individuals and nonretarded individuals, matched on general level of cognitive development, typically measured by mental age (MA), (Clarke & Clarke, 1974). The two-group approach attempts to

eliminate some of the heterogeneity in retardation by eliminating the organic retarded individuals from consideration. Granted, that the population that remains is still heterogeneous on some factors such as environmental influence, socioeconomic status, etc., but nonetheless this population has an underlying commonality, that being impaired intellectual functioning along with deficits in adaptive behaviour during the developmental period. The educable mentally retarded individuals are different only in that they have not been labelled organic (Weisz & Yates, 1981). Retarded persons are less efficient in abstract and conceptual behaviours. On memory, learning, perceptual motor, and attention-demanding tasks they perform more poorly than nonretarded persons (Ellis, 1977).

As mentioned above, retarded individuals have difficulty in tasks demanding attention. If they do not pay attention, then the quality of information entering the memory system could be quite poor, and this may be reflected in performance deficits in other tasks.

Attention in mental retardation

Selective attention can be described as consisting of the parallel operations of two components, namely, an orienting or arousal component, which prepares the organism to ensure optimal reception of the sensory input, and an internal cue selection component, which involves relating

the present input to past or stored information (Berlyne, 1960; Jeffrey, 1968; Sokolov, 1960). The orientation response (OR) is a response such as pupil dilatation, turning or orienting of the head, heart rate acceleration or deceleration, etc. which is interpreted to indicate the organism's alerting to stimulation and readiness to respond (Reese & Lipsitt, 1970). Jennings, Averill, Opton and Lazarus (1971) have suggested that heart rate deceleration reflects a component of the attention process. This has been studied with adult subjects, but developmental studies are consistent with the adult data. In a series of studies Lewis and his colleagues (Lewis, 1971; Lewis, Kagan, Campbell & Kalafat, 1966; Lewis & Spaulding, 1967; Lewis & Wilson, 1970; Lewis, Wilson & Baumel, 1971) have indicated that fixation on or attention to stimuli as indicated by reaction to stimulus onset, are accompanied by a monophasic heart rate deceleration. Lewis (1971) suggests that the onset OR (i.e., OR to onset and offset of auditory signals) is associated with information processing and is under cognitive control, while offset OR's are simply those related to energy change and have little to do with any cognitive function. Evidence for this comes from his habituation data. Lewis (1971) hypothesizes that the failure to habituate is associated with inefficient processing related to such factors as CNS dysfunction, state of arousal and immature functioning.

Furthermore, habituation has a developmental component in that as an individual becomes older, habituation is more evident, that is, as the individual becomes older he shows faster rates of habituation to stimuli, as compared to younger subjects who show slower rates of habituation to stimuli. Stimulus events--the onset of some signals--contain maximum information at their beginning because they have both meaning, which undergoes habituation (is assimilated) during its duration, and energy change. Mildly retarded subjects are like children, in that their deceleration is at a significantly slower rate than in adults, that is, they habituate more slowly (Heal & Johnson, 1970). Thus, if retarded subjects do indeed show a lesser magnitude of heart rate deceleration at stimulus onset than nonretarded subjects, and/or if their habituation is impaired, two points are suggested: (a) Initial attentional levels are deficient and they may be unable to maintain a level of attention required to process information; (b) Less information is assimilated and they are operating at an immature level. As a partial test for these points, Krupski (1975), using noninstitutionalized retarded subjects (IQ range: 55-82) and undergraduate college students in a fixed reaction time paradigm (fixed preparatory interval - PI; subject is to respond to offset of a signal that is on during the PI), did illustrate that the retarded subjects differed from the nonretarded subjects in the degree of

heart rate (HR) deceleration during the reaction signal. At this point, nonretarded individuals exhibited significantly larger magnitude HR deceleration than did retarded individuals. There were no group differences in magnitude of HR responses to the onset of a warning signal or in HR responses during the middle of a preparatory interval. Thus, it appears that the retarded subjects were unable to maintain their attention for the optimal time required for efficient responding even though initially there were no significant attentional differences. Krupski (1975) says that the retarded subjects were deficient in their "covert timing." If attention is deficient, then information storage is reduced; this is reflected in poorer STM functioning of retarded individuals. Krupski's data seem to suggest, therefore, that retarded individuals may have sufficient attentional ability initially, but as time passes, their ability to perpetuate the alertness may decline, resulting in more errors of perception of environmental information.

A series of studies by Luria (1963) provided evidence for a weak OR in oligophrenic children with organic abnormalities. A novel weak stimulus that always evoked an OR in nonretarded children frequently did not do so in retarded children of the same chronological age (CA). If evoked, this OR habituated at a rapid rate (one or two stimulus presentations for the retarded versus 10 or 12 for the

nonretarded). The infrequent occurrence and the rapid extinction were interpreted as evidence for a weak OR in the retarded children with organic impairments. Luria (1963) suggested another characteristic of the oligophrenic person which is possibly related to a weak OR is hyperdistractibility. As noted earlier, one characteristic of the OR is its ability to filter irrelevant stimuli. Presumably a weak OR would be correlated with a weak filter. Luria reported on a retarded child, apparently an N of one, who was to push a button in response to a light signal. The finger blood volume recorded showed no response to the light but a significant response to an irrelevant noise outside the window.

As reviewed by Heal and Johnson (1970), however, American attempts to replicate Luria's findings of a weak OR in retarded subjects have been inconsistent. Nonetheless, Vogel (1961) found that within a trial the responses of the retarded group (IQ = 50 to 70) recovered the baseline of a GSR faster than responses of the other groups. If this response duration is taken as an index of the strength of the OR, then it might be concluded that the retarded subject's OR was weaker.

Clausen and Karrer (1968) compared the divergent head-finger blood volume response, GSR and systolic blood pressure response of nonretarded individuals, organic and nonorganic retarded individuals. In the first session,

the nonretarded subjects made more ORs than the nonorganic retarded subjects who made more ORs than the organic retarded subjects. In the second sessions, however, the responding of the nonretarded subject decreased, while that of the retarded subjects increased to the point that the group differences were eliminated. However, the GSR data indicated a slight increase from session 1 to session 2 in the nonretarded subjects and a definite decrease in the retarded subjects. The groups did not differ in habituation or in response to the change from tone to light.

Baumeister, Spain and Ellis (1963) comparing alpha block durations in nonretarded and institutionalized retarded subjects (mean IQ = 54.2) found that nonretarded subjects displayed a significantly longer block than the retarded subjects, indicating a weak OR in the retarded subjects. There was also evidence that the nonretarded subjects habituated to the stimulus over trials while the retarded subjects did not. All of these results were interpreted as evidence for a weak OR in the retarded subject. Regarding Luria's (1963) findings of faster habituation in oligophrenic subjects, Baumeister et al. (1963) and Tizard (1968), who investigated GSR and EEG changes, found that mildly retarded subjects habituated more slowly than the nonretarded, if at all.

As suggested by Heal and Johnson (1970), the findings of slower rather than faster habituation in retarded subjects may be due to less information input per stimulus presentation, necessitating more trials. If the magnitude of the OR is, in fact, correlated with the amount of information processed, then evidence consistent with this hypothesis comes from the studies previously cited which showed weaker ORs in the mildly retarded subjects. If material is not processed efficiently, or less information is available, then the capacity deficit suggested to occur in retarded subjects (Pennington & Luszcz, 1975) would be a logical result. Finally, the mildly retarded subject appears more likely to make an OR to stimuli that are extraneous to the task at hand, resulting in disrupted performance.

The evidence has also indicated that while the mildly retarded subject's OR to a given stimulus is weak, it is very likely to occur. The implication is that the smaller magnitude and slower habituation rate are both linked to the same deficiency. The OR in the nonretarded individual is seen to be sufficiently strong to filter extraneous stimuli. The OR in the retarded individual, on the other hand, appears to be too weak to act as such a filter and extraneous stimuli evoke their own ORs. Brown (1974) agrees with the above views by indicating that retarded individuals are unable to select the relevant aspects of the stimulation for attention. Elliot and

Johnson (1971) and Belmont and Ellis (1968), however, found no distractibility manifested by retarded subjects. Furthermore, Elliott and Johnson (1971) found no habituation or OR differences at all between mildly retarded and nonretarded individuals. On the other hand, Heal (1967) and Bryant (1967) did find distractibility among mildly retarded subjects when the novel cues were embedded in the task. These contrasting results are interpreted as perhaps indicating that the mildly retarded individual responds to global cue compounds, which he is unable to recognize when some of their component parts are changed. Moreover, Elliott and Johnson (1971) suggest that their results may be due to stimulus strength. That is, a strong stimulus is more likely to evoke an OR from mildly retarded subjects than is a mild one. Their stimuli were quite intense (40 dB intensity tone). Perhaps the stimuli were so strong that they masked the nonretarded-retarded differences found with weaker stimuli. If they had used the weakest stimuli known to elicit an OR in nonretarded individuals with their retarded subjects, perhaps then the differentiation would have become evident.

Mosley and his colleagues (Mosley, 1975; Mosley & Bakal, 1976; Mosley, Bakal & Pilek, 1974) conducted research involving the extinction of a classically conditioned eyelid response. They indicated that mildly retarded individuals oriented to the change in stimulus condition

(elimination of the unconditioned stimulus), but failed to take advantage of this information. That is, they exhibited prolonged responding during the extinction phase of the procedure relative to nonretarded individuals because they failed to attend to the stimulus change. Furthermore, Mosley (1980) had mildly retarded, equal-MA, and equal-CA individuals view tachistoscopic presentations of single element displays of letters (familiar stimuli) and Chinese characters (unfamiliar stimuli) under a backward masking paradigm. Stimulus onset asynchrony and stimulus familiarity were varied to examine the process of selective attention. The data revealed that the internal-cue selection component of selective attention for mildly retarded subjects is comparable to that of the nonretarded subjects when familiar stimuli are used. Alternately, when unfamiliar stimuli are employed, the equal-MA and the mildly retarded subjects are significantly less efficient relative to the equal-CA subjects. This inefficiency is attributed to the failure of the low-MA groups to apply a durable code to the products of the orienting component of selective attention.

Another aspect of the arousal component should also be considered--reaction time (RT). The swiftness with which an organism perceives and responds to its environment frequently is taken as an index of adaptability. Individuals who can process information rapidly and respond

appropriately have a distinct advantage over slower individuals.

Dingman and Silverstein (1964) argued that the slower performance of mildly retarded subjects on perceptual-motor tasks may be due almost entirely to factors associated with motor disability. Yet, as Nettelbeck and Brewer (1976) have argued, the tasks used to examine response mechanisms in Dingman and Silverstein's (1964) and other's studies appeared to involve components of both stimulus discrimination and stimulus-response (SR) translation, i.e., central decision processes antecedent to action.

Baumeister and Kellas (1968) in their review illustrate that there are behavioral deficiencies in RT when nonretarded individuals and mildly and organically retarded individuals have been compared, although these differences tend to be more situation and condition specific.

Tentative conclusions, based on data available, do indicate, however, that mildly retarded individuals suffer a prestimulus arousal deficiency or attentional lag. Although there are some marked individual differences, as a group they appear to function under an impoverished preparatory set, both with respect to initial levels and in maintaining the set over lengthy warning intervals. This latter point is somewhat akin to the previously mentioned inability to maintain a cognitive set in that it seems that the "necessary states" cannot be prolonged

for the optimal time periods required for efficient processing of information. This position is also supported by Krupski (1975). She found consistently inferior performance in an RT task with mildly retarded individuals compared to nonretarded individuals. In addition, she noted that retarded individuals were unable to maintain their initial attentional levels because of inaccurate covert timing of preparatory intervals. Nettelbeck and Brewer (1976) and Brewer and Nettelbeck (1977) using an SR ensemble that consisted of eight lights and eight response keys, reported RT data that were consistent with the suggestion that mildly retarded subjects may be slower to accumulate information relevant to the discrimination of both the stimulus and its associated response. Nettelbeck and Brewer (1976) also reported that increasing the complexity of a spatial SR translation resulted in disproportionately longer RTs for retarded subjects (mean IQ = 68). Finally, Brewer (1978) demonstrated that retarded subjects' (mean IQ = 67) RTs were reduced markedly, becoming not much longer than those of nonretarded subjects, when the degree of processing required for stimulus discrimination and SR translation was minimized by stimulating the responding finger directly via a vibrating key.

In Sternberg-type memory scanning paradigms, RT increases linearly with an increase in set size up to an optimum point, at which there is a plateau. This is assumed to represent a serial-exhaustive search of

memory, and that the search is dependent on the efficient internal cue selection component of attention.

Dugas and Kellas (1974) compared a group of mildly retarded adolescents with a group of MA-matched non-retarded children on a memory-scanning task with digits as stimuli. The retarded subjects displayed a scan rate that was twice as slow as that of the nonretarded children. However, the linear relationship between RT and positive set size in the retarded subjects suggested a serial scan of memory. Furthermore, the serial position of the target item did not affect RT, suggesting that the scan was also exhaustive. Although the memory-scanning rate was slower in the retarded, a qualitative difference did not appear to be present.

A study by Silverman (1974) calls into question the notion of a memory scanning deficit. He used nonalpha-numeric, letterlike, geometric forms as stimuli. They are presumably meaningless to both retarded and non-retarded subjects. Although the three nonretarded groups (second, fifth and eighth graders) displayed decreasing stimulus encoding and response selection time (as measured by the constant "A" in the equation $RT = A + B[M]$) with age, the slope of the RT/set-size functions were nearly equal. The mildly retarded group (mean CA = 18.52 yrs.) performed in a manner similar to the eighth graders in both slope and intercept. In addition, all groups

displayed the additivity of set size and response type that is predicted by a serial-exhaustive model.

Silverman (1974) concluded that the mildly retarded subjects' memory comparison is similar qualitatively to that of the nonretarded, although at a much slower rate when alphanumeric (digits and/or numbers) stimuli are used. He invoked the concept of "familiarity" to explain these performance differences, i.e., since mildly retarded people have presumably had less experience with letters and/or digits, their performance relative to the nonretarded is biased. However, Maisto and Jerome (1977) have criticized Silverman's (1974) study on procedural grounds. Specifically, in Silverman's (1974) design, the positive-set stimuli were in constant view of the subjects during all probe-stimulus presentations. In fact, the positive-set stimuli were made available in the form of an array located 17.78 cm to the left of the probe-stimulus position. Possibly, Silverman's (1974) data reflect a visual-scanning process rather than a memory-scanning process. Therefore, the conclusions drawn from Silverman's (1974) data should be treated cautiously.

Nettelbeck and Lally (1976) and Lally and Nettelbeck (1977) using a limited exposure stimulus discrimination task have highlighted slower perceptual processes in the mildly retarded. Choice RT studies (Brewer, 1978; Brewer & Nettelbeck, 1977; Nettelbeck & Brewer, 1976) have

emphasized slower processing associated with the discrimination of the stimulus and the translation from stimulus into the appropriate response.

In summary, it appears that while the findings reported here are not unequivocal, it does appear that the OR in mildly retarded individuals is weaker than in nonretarded individuals and more likely to occur in the presence of extraneous stimuli resulting in increased distractability.

Taken together, the RT data suggest the possibility that the nature and magnitude of any impairment shown by mildly retarded subjects is a consequence of a central executive function, such as attention, that controls both perceptual and response organization.

Short-term memory deficits

A deficiency in rehearsal has been a consistent finding with mildly retarded subjects. Since rehearsal is thought to be an integral portion of STS, it has been concluded that retarded subjects have a deficit in STS.

Failure to spontaneously rehearse in retarded individuals has been demonstrated using the serial position paradigm (Ellis, 1970) and pause patterns (Belmont & Butterfield, 1969, 1971). The typical serial position curve, characteristic of mildly retarded children, lacks the

elevated primacy position found with rehearsing adults. Accuracy on the first few serial positions is approximately equal to that for items in the middle of the list for mildly retarded children. Adults, however, commit fewer errors in the initial serial positions, a consistent pattern of accuracy which is referred to as the primacy effect.

The presence of primacy effect has been attributed to rehearsal of the first few items (Atkinson & Shiffrin, 1968) so that the conspicuous absence of primacy in the retarded performance curves have been used as evidence for rehearsal deficiency. A second source comes from Belmont and Butterfield (1969, 1971). They measured the interitem pause time in a self-paced task. They found that the pause pattern of normal CA comparison subjects reflected the active acquisition strategy adopted. Mildly retarded subjects, on the other hand, used constant pause times, indicating that they did not systematically organize their study time as a function of an item's position in the list. However, forcing mildly retarded subjects to mimic adult pause pattern improved performance particularly in the primacy portion of the curve. Other studies (Ashcraft, McCauley & Kellas, 1973; Butterfield, Wambold & Belmont, 1973; Kellas, Ashcraft & Johnson, 1973), have manipulated rehearsal and demonstrated that when persons of low intelligence are trained to rehearse actively while learning a list, considerable improvement occurs both in levels

of correct responding and in the time required to retrieve information from memory. Typically, such data lead to the conclusion that mildly retarded individuals suffer a deficit only in secondary memory (SM), implying that their primary memory system is relatively intact.

In contrast to the emphasis on SM the data of the Dugas and Kellas (1974) study have some bearing on these notions in that they provide evidence that the PM (passive or primary memory) system of mildly retarded individuals is not deficit free. The use of subspan lists and an immediate recognition test attempted to insure that only PM systems were being tapped. Mildly retarded subjects in this study were clearly at a distinct disadvantage, relative to nonretarded subjects, in retrieving information from PM.

Ellis (1978) reports a study in which he compared the total recall of equal CA normal and mildly retarded subjects for a 12-letter matrix with exposure durations of 1, 2, and 3 sec. over retention intervals of 0, 3, 6, and 9 sec. There were pronounced differences between the groups. Indeed all main effects, but none of the interactions, were significant. Therefore, Ellis (1978) demonstrated quantitative but not process differences with the mildly retarded group. The differences between mildly retarded and normal subjects predates the zero retention interval and supports Dugas and Kellas' (1974)

suggestion that performance levels of the mildly retarded differ initially, that is, immediately after exposure to the task.

Brown (1974) and Borkowski and Wanschura (1974) have also supported that STS deficits in the mildly and moderately retarded (IQ = 40-70) are due to differences in strategies to learn/remember. Brown (1974) conducted a series of studies using a "keeping track" memory task in which subjects memorize a number of variables, each with several "states". For example, the variables might be foods with four states: bread, pie, milk, cheese; animals with two states: dogs and birds, etc. On each trial the subject is shown one state of each of four variables. Subjects must "time tag" states of variables so that in response to test probes they can recall the last state of a variable. Within this paradigm Brown (1974) shows that the mildly retarded are inefficient as a result of lack of rehearsal. Not only did untrained mildly retarded individuals do poorly, but those trained to rehearse performed very well, and normal subjects prevented from rehearsing and thus orienting to the appropriate proportions of the stimuli performed poorly. Borkowski and Wanschura (1974) studying the use of mediators in paired-associate learning reinforced Brown's (1974) findings. They discovered that when instructed to do so, moderately and mildly retarded subjects could use

mediators and their performance did not differ from non-retarded subjects. However, these retarded subjects are unable to generate these mediators independently even if all relevant information is available to them. Furthermore, long-term learning or transfer did not occur. Mildly and moderately retarded subjects had to be consistently reintroduced to the necessary strategies.

Brown (1974) followed these studies with a series of continuous recognition memory tests in order to demonstrate that mildly retarded subjects will not show a deficiency on a "passive" memory task.

In these tasks, mildly retarded subjects viewed a continuous series of pictures with subjects responding "old" or "new" to each. Lags, defined by the number of intervening items, ranged from 0-50. Performance levels were quite high on these tasks. However, she did not compare her mildly retarded subjects' performance with that of normal subjects.

With this in mind Ellis, McCartney, Ferretti and Cavalier (1977) compared normal and mildly retarded subjects directly on a continuous recognition memory task. The subjects were 20 college students and 20 retarded individuals. The latter averaged 30 years of age with a mean I.Q. of 54.8. The stimuli were randomly selected pictures from popular magazines photographed and mounted on 35 mm

slides. Following a practice session subjects saw a 480-picture series including 222 which occurred twice, and 36 filler items that occurred only once. The task was subject-paced and they indicated "old" or "new" by pressing keys. The pictures were arranged so that the second presentation followed 0, 5, 10, 25, 50, 75, 150, or 250 intervening pictures, i.e., lags. There were 27 tests for each subject at each lag. Data for the initial 30 pictures in the series were eliminated in order to exclude primacy effects.

Again, they found evidence for normal-retarded differences at zero lag which is reminiscent of results presented earlier in this paper. The curves obtained differed only on intercept and not form. An analysis of variance showed main effects for group difference and for the lag effect, but no significant interactions supporting the conclusion that the curves were similar in shape. Ellis et al. (1977) went on to suggest that the failure to observe interactions might imply no memory difference, although performance differences were observed.

In summary, the mildly retarded subjects show an inability to spontaneously rehearse and generate effective strategies. This strategic shortfall seems to be characteristic since studies assessing lag show group performance differences after zero lag. Furthermore, differences seem

to exist in PM.

From a broad perspective, the poor STM performance may result from the interaction of several processes, one of which is attention. Perceptual processes cannot be divorced from attention and memory. The storage and retrieval of an item are directly related to the amount of perceptual processing of that item. Craik (1973) considers the memory trace to be one product of physical feature analysis at a particular level or depth of perceptual processing, these levels existing on a continuum from the transient products of physical feature analysis to the longer lasting results of more complex semantic processing. Within this framework, STM rehearsal is viewed as an attempt to maintain and prolong perceptual experience by deliberately recycling information at one level of analysis. Rehearsal strategies in STM involve operations which are logically preceded by attention to relevant stimuli, perceptual encoding and readout from sensory storage (Neisser, 1967; Sperling, 1960).

Iconic memory

When stimuli consisting of a number of items (6 to 18 or more) are shown briefly to an observer - for 500 msec or less - only a limited number of the items can be correctly reported. This number defines the so-called "span of immediate memory" (otherwise known as short-term

memory-STM) which is illustrated by whole-report. It has been demonstrated that this average number of correct letters contained in a subject's whole-report is approximately 4.5 items per stimulus exposure, with a range of 4 to 8 items, and is independent of the number and spatial arrangement of the letters (Sperling, 1960), within limits. The fact that observers commonly assert that they can see more than they can report suggests that read-out sets a limit on the amount of information that can be reported from this form of memory. It is as though the sensory impression of a stimulus persisted for a brief time after the stimulus was gone and then faded out, leaving a memory residue different from that initially present (Keele, 1973). Sperling (1960) has shown that at the time of stimulus exposure and for a few tenths of a second thereafter, observers have two or three times as much information available as they can later report. The availability of this information declines rapidly, and within 250 ms after exposure the available information no longer exceeds STM memory span. He further indicates that the span of immediate-memory is constant over a wide range of stimuli and exposure durations. This consistency has also been reported more recently by Turvey and Kravetz (1970), Doost and Turvey (1971), and Eriksen and Colegate (1971). Thus, the stimulus information has been suggested to be stored as a persisting visual

image of the objective stimulus. As this image fades, its legibility (information content) decreases and consequently the accuracy of reports based upon it decreases. Furthermore, the available information is sensitive to interference by non-informational visual stimuli which follow stimulus exposure. The durability of relevant visual information is dependent upon subsequent visual inputs of a noninformational nature (Keele, 1973; Sperling, 1960; Turvey, 1973). Three other lines of evidence have been used to supplement this viewpoint. First, if the lighting is brighter during exposure of items (Keele & Chase, 1967), or if it is dark before and after exposure (Averbach & Sperling, 1961), the storage persists longer, sometimes as long as five seconds. Second, when reporting is slightly delayed, many of the errors are visual confusions (Keele & Chase, 1967). It is as though the image of the items had faded, making visual confusions more likely. Finally, Eriksen and Collins (1968) presented two successive patterns of dots. The dots in each presentation were scattered and uninterpretable, but when the two patterns were superimposed, they formed three letters. The letters could be accurately identified even when 100 ms separated two exposures, implying that the first exposure was preserved in a visual memory. This evidence plus that indicating performance superiority in partial report relative to whole report (Doost & Turvey, 1971;

Eriksen & Colegate, 1971; Sperling, 1960; Turvey & Kravetz, 1970); research indicating that a backward visual mask reduces performance when presented at delays shorter than the asymptotic cue delay, but not when presented at a much longer delay, 1000 ms (Lowe, 1975; Turvey, 1973); and the demonstration that partial-report superiority declines to zero as the cue delay increases from zero to approximately 250 ms (Averbach & Coriell, 1961; Averbach & Sperling, 1961; Sperling, 1960) have been used to suggest that visual information is held in a brief sensory visual store in an unprocessed state which is both comprehensive and amenable to subsequent access.

This brief sensory store has been subsequently termed "iconic memory" by Neisser (1967). The characteristics of iconic memory have been isolated via the delayed partial-report technique of Averbach and Coriell (1961) and Sperling (1960). Essentially this procedure involves presenting simultaneously an overload of items, usually letters or digits, under a brief tachistoscopic exposure which is followed by an indicator designating which element or subset of elements the subject is to report. If the indicator is presented soon enough after the stimulus, the subject can report proportionately more with the partial-report than if asked for a report of the whole stimulus. This superiority permits the inference of a large capacity store; the sharp decline in partial-report

superiority with indicator delay permits the inference of rapid decay. Estimates of decay times of iconic storage vary from 250 ms to several seconds after the end of the stimulus, depending on energy characteristics (Averbach & Coriell, 1961; Averbach & Sperling, 1961; Coltheart, 1975; Keele & Chase, 1967).

Sperling's (1960; 1967) results have shown that the form of memory investigated at short cue delays contains many items while the form of memory investigated at long cue delays contains relatively few. He indicated that two qualitatively and quantitatively distinct memory modes are involved in the report of brief visual displays. The first is iconic storage characterized by high capacity and rapid decay. Since a subject's responses do not begin until some time after the point at which iconic memory has decayed, these responses must be based upon a second memory function. This has been termed short-term memory (STM). In the present context, its most significant properties are: 1) that its decay time, relative to the time required for the subject to report as many items as he can, is negligible, and 2) that STM is capacity-limited, with the upper limit resting at 7 ± 2 bits of information (Miller, 1956).

Thus, most or all of the items in a display are stored in iconic memory; but only a subset of these items (about 4 or 5) can be transferred to STM and hence

reported. The existence of partial-report superiority demonstrates that subjects can choose which of the items in iconic memory are to be transferred. At very short cue delays, where partial-report performance is superior, all, or nearly all, of the items of a cued subset are transferred to STM. As cue delay increases, there is an increasing probability that a cued item will have decayed from iconic memory before it can be identified as a cued item and hence can be transferred to STM. When the delay between display offset and the point at which the cue information is available exceeds the lifetime of iconic memory, selective transfer into STM of items will no longer be possible.

This raises a question regarding what the subject is doing during the interval between display offset and cue onset. The usual finding is that partial-report performance at cue delays exceeding the lifetime of the icon is equal to whole-report performance. This suggests that a common strategy for the subject is to begin transfer into STM as soon as he can, even though he does not yet know which are to be the cued items. This nonselective transfer of items continues until information as to which are the cued items becomes available. Then the transfer process switches to a selective one encompassing only these cued items (Averbach & Coriell, 1961; Coltheart, 1980).

Sperling (1960) noted that at long cue delays, subjects employed nonselective transfer; at short delays, they avoided this, waiting for the cue before performing the transfer. For example, one of his subjects, in an experiment where cue delay was blocked and thus predictable, waited for the cue and used selective transfer at cue delays up to and including 150 ms, but used nonselective transfer at cue delays of 300 and 500 ms. Since at short delays, where selective transfer is likely to occur, subjects eschew nonselective transfer, this implies that they consider that some benefit accrues from not carrying out nonselective transfer. This benefit might be avoiding overcrowding of STM, or it might be avoiding overtaxing of the transfer mechanism. Further work is needed to clarify the nature of the benefit.

Since it is possible to selectively transfer items from iconic memory according to spatial locations they occupied in the display, information about an item's spatial location must be represented in iconic memory. Similarly, it is possible to discover which forms of information exist in iconic memory by determining which forms of display cueing produce a partial-report superiority. Strictly speaking, various cue delays ought always to be used, so as to demonstrate that the partial report superiority declines as cue delay increases. If this is not done, it is less easy to dismiss alternative

explanations of partial-report superiority, such as "output interference" (Coltheart, 1975; Holding, 1975).

Coltheart (1980), Dick (1974) and Turvey (1973) in their reviews have suggested that iconic memory is literal or precategory, a proposition supported, in part, by the kinds of selection criteria which yield efficient performance in the delayed partial report task. Furthermore, generally superior partial report can be demonstrated when the selection criteria are brightness (von Wright, 1968), size, colour (Clark, 1969; Coltheart, Lea, & Thompson, 1974; Dick, 1969; von Wright, 1968), shape (Turvey & Kravetz, 1970), location (Keele & Chase, 1967), or flicker (Russell, 1977). Partial-report performance, however, is notably poorer when the letter-digit distinction is the basis for selection (Sperling, 1960; von Wright, 1968), or whether a letter's name does or does not contain the phoneme "ee" (Coltheart, Lea, & Thompson, 1974). This demonstrates that we can select or ignore items in iconic memory on the basis of their general physical characteristics and not on the basis of their derived properties. All this indicates the precategory nature of iconic memory. In theory, the content of iconic memory could be either a description of a visual object or objects suitable for the subsequent operations of pattern recognition, or a conglomerate of "crude," context-independent features which requires some

further operations before it can be classified properly. However, this latter view seems unlikely since, generally, subjects' descriptions imply that they see far more items than they can report (Sperling, 1960), and indeed they may know how many items were presented, as well as the particular letters which have been cued (Sperling, 1967). In other words, the particular aspect of visual information processing focused upon using the partial-report technique, illustrates that something is known about the gross form of the input and it is the persistence of this knowledge which has been called iconic memory. The final state has not yet been achieved at this point in the flow of visual information. For example, what is stored for an input to a certain region of the visual field is the decision that the input in this region has this size, this brightness, this colour, this general shape, etc., but whether the letter was the letter "H" or something else is not yet known.

Research investigating other parameters within the context of the Sperling (1960) and/or Averbach and Coriell (1961) paradigms include the effects (none) of repetition of display items (Merluzzi & Johnson, 1974; Turvey, 1967), the effects (very little to none) of approximation to English of the letters in the display (Mewhort, 1967), the effects (debated) of target luminance (Sakitt, 1976; Sharf & Lefton, 1970), the sensitivity (very marked) of

short-term visual storage (STVS) to stimulus background levels (Sperling, 1963), the workability (variable) of the fading icon (Jacewitz & Lehmann, 1972; Spencer, 1969; Sperling, 1963), the role (debated) of the rod photo-receptors (Adelson, 1978, 1979; Sakitt, 1976), and the effects (slight) of visual field presentation (Marzi, Distefano, Tassinari, & Crea, 1979).

Coltheart (1980) has recently reviewed much of the work to date concerning iconic memory and has made a case for distinguishing between iconic memory and visual persistence through a critique of various experimental techniques. Visual persistence is taken to include:

- (1) neural persistence, i.e., that some or all of the neural components of the visual system which respond when a visual stimulus is present continue their activity for some time after the effect of a stimulus; and
- (2) phenomenological visual persistence, i.e., a visual stimulus continues to be phenomenally "visible" for some time after its physical offset. Iconic memory (informational persistence) is taken to refer to the visual information present that continues to be accessible for some time after stimulus offset. He has suggested that many of the empirical techniques employed to assess the characteristics of iconic memory (e.g., judgment of synchrony, phenomenal continuity, onset-offset reaction time technique, flicker, temporal integration of form

parts, stereoscopic persistence, moving slit technique) are in fact elucidating the parameters involved in neural or phenomenological persistence, since they depend upon subjects' experiences of visual sensation after stimulus offset, as opposed to processing of visual information after the visual stimulus has been terminated. Coltheart (1980) has proposed, however, that the following may be sufficient for the demonstration of iconic memory:

A visual display consisting of a number of items is presented. At or after display offset, the subject is given a cue which defines a subset of the display items. The subject's task is to report as many of the items in this subset as he can. If his performance declines as the interval between display and cue increases, down to some asymptotic level, and remains at that level for longer cue delays, then the display was represented in iconic memory and the cue used to sample selectively the content of iconic memory The display luminence must have been too low to generate an after-image [and] if full report diminishes as report delay increases, then a diminution of partial report may not indicate the existence of iconic memory (Coltheart, 1980, p. 221).

This implies that the characteristics of iconic memory as demonstrated by the partial-report technique are likely to be more valid than those obtained by the other experimental techniques. Coltheart has indicated that iconic memory is not visual persistence, or an afterimage, or neural persistence at any stage of the visual system from retina to cortex. However, he has said very little about what it is beyond suggesting that based on Allport

(1977), Dick (1969), DiLollo (1978), Townsend (1973) and van der Heijden (1978) it may include the following: The identity of an item is stored rapidly and in a stable form early in the lifetime of a display, while the physical attributes of the item are registered with more difficulty and in an unstable decaying form. Each item is tagged with information about the physical characteristics of the word. This physical information decays rapidly unless "lexically stabilized" by a "lexical monitor" of limited capacity. This is accomplished, theoretically, by transforming the information into some more durable form. Lexical excitation itself also decays, though more slowly and so also may require lexical stabilization. Backward masking can interfere with lexical stabilization by claiming the attention of the lexical monitor; this is how "perception without awareness" occurs. This is the postlexical or postcategorical view of iconic memory. The above conceptualization is admittedly speculative and future work must be done to explore these issues. However, Coltheart's (1980) point is that it is necessary to differentiate between neural persistences at different levels of the visual system and how these are related to visible persistence on the one hand and to iconic memory on the other.

Long (1980) has also examined the iconic memory literature in much the same fashion as Coltheart (1980),

i.e., a separate description and critique of each of five general classes of procedures: (a) Sperling's (1960) original partial-report procedure and various modifications of this post-stimulus sampling approach by later researchers (Averbach & Coriell, 1961; Keele & Chase, 1967); (b) the persistence-of-form procedure, by which a stimulus is flashed repeatedly at various rates until the observer perceives it to be phenomenally continuous (e.g., Haber & Standing, 1969; Meyer & Maguire, 1977); (c) the duration-of-stimulus procedure, in which a brief probe stimulus is adjusted to coincide with the phenomenal offset of a stimulus (e.g., Efron, 1970); (d) the duration-of-masking-effect procedure, in which the interval following stimulus offset during which a mask can influence performance is assumed to reflect the extent of iconic persistence (e.g., Erwin, 1976; Kahneman, 1968); (e) the successive-field procedure, in which successive stimuli that must in some way be combined or compared are separated by a variable inter-stimulus interval (ISI) to determine the temporal limits for successful performance (e.g., Eriksen & Collins, 1967).

Long (1980) noted, based on his critiques and re-examination, that while, occasionally, contradictory results were obtained by different researchers using the same general paradigm, more frequently inconsistent results were a consequence of the use of nonequivalent

measures with which to assess iconic memory. The aforementioned nonequivalence refers to the extent to which interpretation of experimental results is based on alternate visual processes as opposed to the ones under study. For example, in persistence-of-form procedures:

(a) The perceived flicker or fusion of intermittent stimuli is only minimally related to visual persistence effects, i.e., DeLange (1958), Lewinson (1968), and Kelly (1961, 1972) have demonstrated the differential sensitivity of the visual system to different rates of flicker. It is not known how simple visual persistence effects could account for the so-called temporal modulation transfer function (cf. Cornsweet, 1971; Kaufman, 1974); (b) there are a number of empirical similarities between flicker research and persistence-of-form studies. Moreover, these similarities are frequently at odds with findings in the iconic literature obtained with alternate procedures. For example, according to the Ferry-Porter law (see Landis, 1954) formulated around the turn of the century, as the luminance of the flickering stimulus is increased, the rate at which the stimulus must be flickered for subjective fusion (CFF) increases correspondingly (Wilson & Kohfeld, 1973). Comparably, Haber and Standing (1969) and Haber (1970) reported that observers typically select faster presentation rates on a Persistence-of-Form task for higher luminance targets to maintain a judgment of

continuity. They interpreted this result as reflecting briefer persistence effects or storage time for more intense stimuli. But this is the finding which others (e.g., Brown, 1965; Sakitt, 1976) have used to argue that the flicker-fusion phenomena cannot reflect simple persistence effects, since persistence is known to increase with increasing stimulus luminance. The point to be made is that the persistence-of-form tasks frequently used in the investigation of iconic memory share many features with the older flicker literature and, hence, may also be only peripherally relevant to the study of iconic memory. Thus, the results obtained with persistence-of-form techniques, which are consistently at odds with much of the iconic memory literature, need no longer be integrated with those obtained with other iconic procedures.

Based on similar kinds of arguments around the other experimental paradigms used to investigate iconic memory, Long (1980) has argued that it should be possible to eliminate or de-emphasize the results from those studies using the more questionable procedures and perhaps obtain a clearer picture of iconic memory and its relationship to stimulus variables. In this vein, Long (1980) has examined the persistence literature emphasizing the important variables of target luminance and target duration. He has concluded that the specific prediction from the retinal interpretation of iconic memory (cf. Sakitt,

1976) has received the greatest support. As either stimulus luminance or duration is increased, iconic memory duration increases. This conclusion is directly contrary to that of Coltheart (1980) who, as mentioned earlier, wishes to distinguish visual persistence from iconic memory. A critical argument in Coltheart's (1980) proposal is that visual persistence exhibits an inverse relationship both with target luminance and with target duration, whereas iconic memory (informational persistence) is independent of these variables. However, several studies, many since the submission of the Coltheart (1980) article, do not support this claim nor his proposal (Long, 1979; Long & Sakitt, 1980a, 1980b; Sakitt & Long, 1979a, 1979b). Moreover, Long (1980) has suggested that the parsimony of equating visual persistence and iconic memory, which has traditionally been the case (e.g., Neisser, 1967), need not then be abandoned.

Relevant to the assertion of the superior applicability of the retinal basis of iconic memory is the controversy concerning the physical locus of the icon in the visual system. The dominant view in the past has been that the icon represents a central but relatively early stage in the visual system. This view has resulted, on the one hand, from the aforementioned precategorical or unprocessed nature of the persisting image as reflected in the relative success and failure of various cue types

(e.g., row position vs. letter-digit distinction) on a partial-report task (e.g., von Wright, 1972). On the other hand, the susceptibility of the fading icon in one eye to masking by a stimulus presented to other eye (dichoptic masking) has been used as critical evidence for the post-retinal locus of persistence (e.g., Dick, 1974). In this view, iconic memory is sometimes conceptualized as a post-retinal buffer that extends the perceived durations of brief stimuli to allow the later stages greater processing time (Atkinson & Shiffrin, 1968; Keele, 1973).

On the other side of this controversy is the position which advocates that the icon represents a retinal and even photoreceptor persistence effect (Sakitt, 1976; Sakitt & Long, 1978, 1979a, 1979b, 1979c). For example, Sakitt (1976) in one experiment with a rod monochromat presented white target letters superimposed briefly on an intensely illuminated white background such that no matter how bright the target letters they could not be seen. However, when the rod monochromat closed her eyes shortly after the target exposure, she experienced a visible and persisting record of the letters.

In Sakitt's interpretation the background field saturates the rods so that any increments in intensity, such as would result from the target exposure, are indistinguishable. But since the letters are eventually

distinguishable, the source of their persistence must be localized prior to the first stage of the visual system that saturates. The weight of evidence suggests that the first stage that saturates is most likely the rod photocurrent, and the source of the visible icon is adjudged, therefore, to be in the photoreceptors. When the rod monochromat closes her eyes, the rods start to recover and the photocurrents dip below their saturation level. With the advent of this state, those photoreceptor locations that were more strongly stimulated, that is, those coincident with the letter display, induce a larger neural signal than the surrounding photoreceptor locations that were stimulated only by the background field. It is this "larger neural signal" that is said to give rise to the visible icon subsequent to the closing of the eyes. These persistence effects are analogues to, but distinct from, the classical after-image. This position tends to argue against the "memory" aspect of so-called iconic memory on the same grounds that after-images are not true memory effects. Rather, iconic memory is treated as a passive decay process of simple visual persistence resulting from sluggish retinal recovery after stimulation.

However, Banks and Barber (1977), using coloured stimuli, showed that the decay functions obtained paralleled those obtained with black-on-white stimuli. They concluded that iconic memory carries colour information and is

therefore not simply a rod phenomenon. Their experiments in no way force the conclusion that iconic memory is a central stage but they do tend to negate the argument that it is only carried by the rods and therefore must be wholly peripheral (in the photoreceptors), i.e., they showed a type of stroop colour-word interference in which the subject's ability to read out symbolic information was disturbed for the entire duration of iconic memory by irrelevant and iconically stored colour information. Since it seems that the visual system must be able to integrate both colour (cone) and rod information, it seems unlikely that this is occurring at the level of the photoreceptor. In addition, the results of Triesman, Russel and Green (1975) strongly suggest that iconic storage of both shape and movement is at a feature-detector level. Their demonstration of iconic memory for movement, in particular, implicates structures central to the photoreceptors, since there seems to be no way that the photoreceptors could preserve a dynamic pattern.

Furthermore, Banks and Barber (1977) show that colour information persists throughout iconic memory. It therefore seems unlikely that iconic memory under normal conditions of light adaptation has a short cone component, and a long rod component, as Sakitt (1976) and Sakitt and Long (1979c) have suggested, since the decay curves obtained for both the coloured and black stimuli converged

at long ISI's (400-1000 ms) and were not significantly different at these points. Furthermore, Banks and Barber (1977) indicated that the most striking piece of evidence against the rods as the primary carriers of iconic information is the retinal acuity gradient in iconic memory. Scotopic vision has a central region of blindness from $.5^\circ$ to 1° in diameter, centered on the usual fixation point, and a nonmonotonic central-peripheral acuity gradient, with maximum acuity about 4° to 6° from the center of fixation. Iconic memory, on the other hand, typically has an acuity function that is similar to a cone acuity function, with highest acuity in the foveal area and a monotonic and quite steep central-peripheral decline in acuity. Averbach and Coriell (1961), for example, presented strings of letters across the visual field, including foveal and nonfoveal regions, and their partial-report data showed greatest accuracy for elements cued in the foveal area. In fact, if a single photoreceptor system were to be held responsible for iconic memory (with bright stimuli), the acuity gradients indicate that cones are a more likely guess than the rods. As was mentioned earlier, Banks and Barber (1977) do not directly address the central-peripheral question of iconic memory locus. They only show that the argument that iconic memory is exclusively a rod function and therefore must be peripheral is not

necessarily valid.

Sakitt and Long (1979c) have responded to these criticisms by suggesting that while Banks and Barber (1977) used a partial-report paradigm, their study used the successive-field technique. As such, the partial-report superiority may have been due to visual and nonvisual factors since even a large partial-report superiority can be induced by nonvisual factors (cf. Holding, 1973, 1975; Long, 1980). However, the difficulty with this criticism is that Sakitt and Long (1979c) did not specify the nature of and to what degree these "nonvisual factors" contributed to the empirical differences between their own and Banks and Barber's (1977) experimental results, and furthermore, did not state whether these nonvisual factors were critical in explaining the differences. Moreover, Sakitt and Long (1979c) failed to mention that many of the nonvisual factors, thought by some authors (e.g., Holding, 1973, 1975) to account for partial-report superiority, have been strongly argued against (cf. Coltheart, 1975, 1980; Coltheart, Lea & Thompson, 1974). For example, Holding (1975) has maintained that the superiority of the partial-report condition over the whole-report condition is due to the fewer number of responses necessary in the former condition. This in turn reduces the amount of interference on each trial from items already reported to those to be

reported. However, other reviewers (e.g., Coltheart, 1975; Dick, 1974) have shown this argument to have a number of weaknesses: (1) if the partial-report superiority is due to output interference, why would the delay of the cue have any effect on the degree of superiority? Since the interference is response dependent, time of response should be relatively unimportant, but this is definitely not the case; (2) Why does the type of stimulus attribute by which the observer is to retrieve items from the array have any effect? Retrieval by location or category should reflect equal interference effects, but, in effect, retrieval by the latter dimension reveals no partial-report superiority; (3) the partial-report procedure used by Averbach and Coriell (1961) requires retrieval of a single cued item and does not compare whole and partial-report conditions. How would the criticism of output interference apply to such a procedure? And finally, the successive-field procedure used by Sakitt and Long (1979c) itself has methodological difficulties, as elucidated by Long (1980) (e.g., processing other cues beyond those specifically presented by the procedure; contradictory effects of stimulus energy in different forms of the task; practice effects), and thus may also be sampling other processes than those involved in iconic memory.

It should also be noted that for foveal presentations, iconic memory could not possibly be mediated primarily by the rods since there are few rods in the fovea (Milner, 1970; Hitchcock & Forrester, 1971; Mote & Keesey, 1973). Additionally, with adapting fields which are sufficiently bright (i.e., providing retinal illumination of approximately 3 log trolands) the rods become saturated and so cannot mediate iconic memory. Yet studies which have had adapting fields of such brightness (e.g., Adelson & Jonides, 1980; Averbach & Coriell, 1961) and studies which have presented stimuli foveally (e.g., Hornstein & Mosley, 1979) still report robust partial-report performance and hence demonstrate the existence of iconic memory.

If the eye is dark adapted, if stimuli are sufficiently bright, and if the letters are sufficiently large, the conditions for rod mediation may be met (Sakitt, 1976; Keele & Chase, 1967). But variations from these conditions may destroy the usefulness of rod afterimages.

In conclusion, it seems unlikely that the rods entirely mediate iconic memory. Furthermore, recent results obtained by Adelson and Jonides (1980) tend to argue against any form of receptor afterimage as the basis of iconic memory. They found, in their first experiment, that as soon as display letters become fully legible, they produced a full-fledged partial-report performance, and

increases in stimulus intensity had virtually no effect on the duration of this performance. In their second experiment, they found the icon to be insensitive to adaptation level and contrast, two variables that have large effects on receptor responses. They concluded that one would have to set one's sights beyond the receptors (and probably beyond the retina as a whole). Their experiments placed no limit on how central the icon may be but did limit how peripheral it may be.

Most recently, however, Long and Beaton (1982) have answered Adelson and Jonides' (1980) criticism by pointing out that Adelson and Jonides' illumination levels (high) size of letters (small) and area of presentation (foveal) are at variance with the majority of iconic memory investigations and as such, their results are not readily generalizable. Furthermore, Long and Beaton (1982) suggest (as Adelson & Jonides have already pointed out) that with larger letters and lower target and background luminance levels, there seems to be a considerable contribution made by the rods to the iconic memory phenomenon. This in no way invalidates Adelson and Jonides' observations, but it does suggest that there is a significant peripheral component to iconic storage, given the variable influence of target parameters.

So, how can one integrate such varying results into a salient model of iconic storage? Breitmeyer and Ganz (1976)

distinguished between two subclasses of iconic memory:

(1) central, contour-specific iconic store (ISc), which corresponds to that neural level at which figural information, in particular, contour orientation and size of a stimulus, is processed in a retinotopic fashion; and
 (2) peripheral iconic store (ISp) which is a more peripheral, preconscious sensory process. They have also proposed a neurophysiological model of visual masking that assumes (a) that a brief stimulus elicits a short latency transient response that persists for a relatively short duration; (b) that a brief stimulus also elicits a long latency, longer duration sustained response with the latency as well as the duration of persistence increasing as the spatial frequency of the stimulus increases; and
 (c) that transient activity can inhibit sustained activity, particularly when the target-mask onset asynchrony (SOA) is at a value such that the inhibition produced by transient activity of the spatially flanking mask is optimally superimposed in time on the excitatory sustained activity of the target. What is shown additionally is a reciprocal inhibition of transient activity of the mask by the sustained activity of the target (cf. Breitmeyer, 1980).

If one integrates Adelson and Jonides' (1980), Coltheart's (1980), Long's (1980), and Long and Beaton's (1982) approaches within the Breitmeyer and Ganz (1976)

framework one can conceptualize iconic memory as a dual stage process in which purely sensory (i.e., receptor) input enters the ISp and becomes sustained channel activity. Changes in foveal fixations (i.e., saccades) activate short latency transient channels that inhibit the sustained activity that would persist from a preceding fixation interval and an aftercoming target would initiate sustained activity that inhibited the transient activity of the saccade. The result, which would consist of a series of clear, unmasked, and temporally segregated frames of sustained activity, each one of which represents the pattern information contained in a single fixation interval, would then be passed on to ISc. Successive saccades would terminate information in ISp, but would leave unaltered the information transferred to ISc, thus lending a dynamic versus static flavour to information processing (Breitmeyer, 1980). Much of the same kind of approach has been advocated recently by DiLollo, Arnett, and Kruk (1982). They postulate that iconic storage represents sensory coding activity at an early stage of visual information processing, and its duration depends on the original stimulus being represented within the visual system by a given neural code which preserves brightness, texture, colour and contour information. Visual persistence stops when the neural code is changed (as in

saccades or when processing continues to the next stage), but information is preserved within the system. Thus, in the central decision process, iconic storage can be perceived as the first step in a sequence of operations which includes selection and categorization, penultimately short-term, and ultimately permanent storage.

In mildly retarded subjects investigations of the nature of short-term memory have indicated deficits in the mechanisms necessary for the acquisition, storage and retrieval of information (Brown, 1974; Dugas & Kellas, 1974; Kellas, Ashcraft & Johnson, 1973; Mosley, 1980; Olson, 1971). But it has been noted that many of these studies did not employ techniques sensitive enough to draw concrete conclusions about the nature of iconic storage in the retarded individuals compared to nonretarded individuals. Using verbal stimuli presented tachistoscopically, partial-report and whole-report results indicated that the mildly retarded individuals were not able to handle the stimulus input efficiently and their responding, both in terms of their overall percent correct recall and their relatively high percentage of non-specific errors of commission, was consistent with situations in which stimulus overload occurs.

A number of studies have been conducted to evaluate this initial processing stage in retarded individuals and

its possible influence on later stages of information processing. The relevant findings are presented in the following section.

Iconic Memory and Retardation

The relationship between iconic memory and intelligence has received recent experimental attention. Most of these studies (e.g., Friedrich, Libkuman, Craig & Winn, 1977; Libkuman & Friedrich, 1972; Mosley, 1978, 1980; Pennington & Luszcz, 1975; Saccuzzo, Kerr, Marcus & Brown, 1979; Spitz, 1973) have supported the view that iconic storage of retarded individuals is deficient. For example, Spitz (1973) has suggested that the mildly retarded individual has a longer lasting icon which interferes with the rapid input of information. However, Pennington and Luszcz (1975) report findings which are inconsistent with a specific iconic deficit conceptualization of retardation. Using a group of mildly retarded adults and a nonretarded equal-CA comparison group, they first established, that under tachistoscopic viewing conditions, the whole-report performance of the retarded subjects was significantly worse than that of the nonretarded subjects. This is not surprising given the well-documented poorer immediate memory span of the mildly retarded (Belmont & Butterfield, 1969; Ellis, 1970; Spitz, 1973). In another experiment, Pennington and Luszcz found that below 250

ms, exposure duration had no effect on the whole-report performance of either group, a result in line with Sperling's findings. In addition, Pennington and Luszcz (1975) investigated the temporal properties of iconic storage by using the delay of partial-report cue paradigm. They found that, although the performance of nonretarded subjects was superior at all delay intervals, there was no interaction between delay and intelligence. This result indicates that the rate of information loss from iconic storage is the same for both mildly mentally retarded and nonretarded subjects. Another result that indicated a similarity in the functioning of iconic storage was the finding that the two groups of subjects displayed similar serial position curves over the seven-letter array.

Taken as a whole, the results of Pennington and Luszcz (1975) argue against the notion that the iconic storage system of the mildly retarded is functionally or qualitatively different from that of nonretarded individuals. In view of the fact that intelligence did not interact with any of the experimental variables, this precludes any conclusions confirming the existence of a specific processing deficit. Pennington and Luszcz (1975) preferred to describe the retarded individual as an information processor whose sensory storage analyses are

essentially similar to those of nonretarded persons, but at a lower level, i.e., performance differs quantitatively, but not qualitatively.

Libkuman and Friedrich (1972) employed the partial-report procedure and varied the stimulus duration of a six-digit array by the method of limits to obtain a threshold measure of recognition. The recognition threshold for a single immediately cued digit was higher for mildly retarded adolescents than for an equal-CA sample of non-retarded adolescents. Based on this data, Libkuman and Friedrich (1972) concluded that the iconic memory processing of retarded subjects is inefficient. However, since the delay of the partial-report cue was not varied, the experiment does not include the necessary partial-report delay X intelligence interaction. In its absence, one is left simply with inferior performance of mentally retarded subjects on a single task, rather than a statement about a specific deficit. More recently, Friedrich et al. (1977) again used the method of limits to obtain read-out times for a sample of mildly retarded and CA-matched nonretarded subjects. Stimulus arrays of two, four or six digits were presented for a variable duration, followed immediately by a post-stimulus cue which indicated a single digit to be reported. Results indicated that for all groups read-out time increased as the number of digits increased and read-out time was longer for the retarded

subjects. They concluded that the mildly retarded individual demonstrates a deficit in iconic memory in that he/she cannot process as much information as his/her normal peers. However, again there was no significant interaction between partial-report delay and intelligence, and between number of digits and intelligence. Once more, this indicates a performance inferiority, but not a specific processing deficit.

Saccuzzo, Kerr, Marcus and Brown (1979) determined the minimum stimulus duration (critical exposure interval) for criterion accuracy and the minimum interval between the presentation of test stimuli (capital T's and A's) and the presentation of a masking stimulus (paratype capital W's placed side-by-side) for criterion accuracy for mildly and moderately retarded adults and normal controls of the same mental and chronological age. Results indicated that both retarded groups required longer stimulus durations as well as longer intervals between the test and masking stimuli for criterion performance than did both the mental age and chronological age control groups. However, unlike the Spitz and Thor (1968) and Welsandt and Meyer (1974) studies, in which the inter-stimulus interval (ISI) between target and mask was an independent variable, ISI was employed as a dependent variable by Saccuzzo et al. (1979). Thus a critical ISI X Group interaction was precluded. What was

demonstrated were single task differences between retarded and nonretarded subjects, and these task differences are open to multiple interpretations independent of any specific iconic deficits (see Stanovich & Purcell, 1981a, b).

What seems to have been demonstrated by the above studies is that mildly mentally retarded individuals display performance inferior to that of nonretarded subjects on a variety of tasks. However, the observation of a generalized performance difference as reflected by a significant main effect sheds little light on the specific information processing operation which is the source of the deficit. A performance deficit as reflected by a significant main effect could be due to a variety of nonspecific factors such as attentiveness, stereotypic response patterns, inconsistent strategy selection, failure to inhibit incorrect verbal responses, and failure to maintain optimum performance levels (Ryan & Jones, 1975; Stanovich, 1978; Stanovich & Purcell, 1981a), which are control processes of the system, as opposed to being structural features. That is, multistore models of memory (e.g., Atkinson & Shiffrin, 1968; Mosley, 1980) view the processing of information as occurring in discrete stages involving the utilization of specific structures or stores where information is held prior to or concurrently with its being transformed and/or otherwise operated upon.

The structural or permanent features of these models include the sensory registers (auditory, haptic, visual, etc.), short-term memory and long-term memory. Control processes, in these models, refer to processes that are not permanent features of memory but are transient phenomena under the subject's control (e.g., coding, rehearsal, attention, etc.).

Due to the difficulty of isolating a specific processing difference on the basis of a generalized performance difference researchers in the experimental psychology of mental retardation have established that the attribution of a specific processing deficit is only theoretically justified by evidence of a Group X Experimental Factor interaction, when the factor in question is known to influence the particular processing operation to which the deficit is attributed (Baumeister, 1967; Milgram, 1973; Stanovich, 1977, 1978). Included in this interaction is the requirement that at some level or levels of the experimental factor, there must have been some comparability between the groups. No such interactions have been demonstrated by the studies cited above.

A few studies have used visual masking to assess group differences in iconic storage between retarded and nonretarded samples. One of the earliest such backward masking studies was carried out by Spitz and Thor (1968), who tested educable retarded individuals (mean IQ = 63.85),

and subjects matched on MA and CA. The target stimuli were the capital letters D or O, and the masking stimulus was a square enclosing several diagonal lines. The ISI between target and mask was varied. The results, in terms of percentage correct as a function of ISI, showed that the educable retarded and MA-matched subjects performed at essentially identical levels, but both significantly below that of the CA-matched individuals. However, the data displayed no IQ X ISI interaction, and are thus consistent with the notion that there is no difference in the iconic processing of mildly retarded and nonretarded individuals.

Galbraith and Gliddon (1972) compared mildly retarded and nonretarded CA-matched subjects on two masking tasks. The target stimulus was an electronic stroboscopic flash (.024 ft-c) which consisted of a rocket-ship form that was presented in either the vertical upward or downward position. The mask was an intense (20 ft-c) flash that was either homogeneous or checker-patterned. The ISI's used were not reported, but curves were presented showing increased detection of the form orientation as a function of ISI's from 10 to 80 ms. The nonretarded subjects were better than the retarded under both masking conditions with the differences greater with the patterned mask. These results were interpreted in light of then-published reports that masking by flash (homogeneous) occurs peripherally, while masking with a pattern mask occurs

centrally. Hence the aforementioned interaction implied primarily central perceptual deficits. However, with such a brief target stimulus (3 ms) and much more intense masking stimulus (.024 vs 20 ft-c), it is not at all certain that the two masking conditions produced peripheral and central masking. In addition, recent reconceptualizations of visual masking (e.g., Felsten & Wasserman, 1980) suggest that both peripheral and central masking can be mediated by integrative mechanisms. Furthermore, there was no IQ X ISI interaction. Thus their conclusion of a central perceptual deficit is tenuous.

Welsandt and Meyer (1974) tested forward and backward masking performance of mildly retarded (mean IQ = 62) and nonretarded subjects matched on CA and MA. The target stimulus was one of four possible letters followed or preceded after a variable ISI by a pattern masking stimulus. The subject was to identify the target letter. Results indicated that initial levels of accuracy were equal for their mildly retarded, equal-CA and equal-MA groups, and increased with increasing ISI. However, at the 75 ms ISI the CA-matched subjects showed superior performance compared to the other two groups which did not differ. From that point on the mildly retarded group was less accurate than the equal-MA group which was less accurate relative to the equal-CA group. In essence, they did obtain an IQ X ISI interaction, indicating a

slower rate of perceptual processing by mildly retarded subjects. However, current theories of visual masking (e.g., Breitmeyer & Ganz, 1976; Felsten & Wasserman, 1980) have indicated that masks may function by altering the clarity or nature of the target, rather than by terminating the processing, i.e., the processing of a degraded target continues. As such, it has been suggested that masking procedures cannot justifiably be used to measure processing time in the visual system (e.g., Long, 1980). Therefore, rather than assessing rate of perceptual processing, the IQ X ISI interaction demonstrated by Welsandt and Meyer (1974) may reflect the reduced ability of mildly retarded and equal-MA subjects to separate the salient pieces of the target from the altered or unclear target-mask montage. This may suggest more strategic differences rather than a deficit in basic sensory processes. That is, nonretarded subjects may be able to separate potentially salient features of the stimulus event to serve as cues and have this reflected by higher percent correct recall.

In summary, the masking studies cited here seem to have also failed to demonstrate a specific iconic memory deficit in mildly retarded subjects. The Welsandt and Meyer (1974) study did demonstrate an IQ X ISI interaction, but as noted this may be due to strategic differences as opposed to a specific structural deficit in the functioning

of iconic memory.

As indicated, the aforementioned failures to isolate the specific information processing deficits suggest that a more fruitful approach might be to investigate the contribution of factors such as attentiveness, stereotypic response patterns, inconsistent strategy selection, failure to inhibit incorrect verbal responses, and failure to maintain optimum performance levels to the inferior perceptual processing of the mildly retarded. One such area involves differential familiarity with the stimulus materials. Silverman (1974) has most clearly argued that the performance of retarded individuals is systematically underestimated when alphanumeric stimuli are employed, because nonretarded individuals typically have had more experience with such materials. Thus, it would seem that since most of the studies of information processing in retarded subjects have employed alphanumeric stimuli, one needs to be cautious in attributing a specific processing deficit using such stimuli. A more cautious approach would be to infer a specific deficit only when studies employing stimuli of equal familiarity to all subject groups display the same intelligence X experimental factor interactions as do studies using alphanumeric stimuli.

Two recent studies by Hornstein and Mosley (1979) and Mosley (1980) have investigated iconic memory functioning, the role of strategic differences and attentional factors, and the effects of differential familiarity. Hornstein

and Mosley (1979) used mildly retarded, CA- and MA-matched subjects in a visually cued partial-report procedure and a backward visual masking procedure. Subjects viewed stimulus arrays consisting of six Chinese characters arranged in a circular pattern for 100 ms. At variable stimulus-onset asynchronies, a teardrop indicator or an annulus (masking stimulus, as well as an indicator) was presented for 100 ms. Immediately upon cue offset, the subject was required to recognize the cued stimulus from a card containing single characters. Retarded subjects' performance was comparable to that of MA- and CA-matched subjects. There was no significant Group X SOA interaction. The only significant interaction (Group X Response Type) in conjunction with a signal-detection analysis suggested differences in the response criteria adopted by the retarded and nonretarded subjects as opposed to basic sensory differences in the processing of unfamiliar stimuli. The authors concluded that

The differences reported earlier between retarded and nonretarded individuals employing familiar stimuli may be attributable to processes other than iconic memory. The present data suggest that the expectations and response criteria adopted by retarded and nonretarded subjects are different. In the case of familiar stimuli, such differences would lead to differences in the strategies employed that, in turn, would influence performance outcomes. (p. 47).

However, the authors did not include a condition where performance with alphanumeric stimuli was compared to performance with nonalphanumeric stimuli. In this way, their conclusions are limited.

Mosley (1980) employed mildly retarded, equal-MA, and equal-CA individuals in viewing tachistoscopic (20 ms) presentations of single element displays (single letter or a single Chinese character). At variable SOA's a mask was then presented. By varying SOA's and employing an approximate critical target duration (the minimum duration of a target that permits evasion of masking at an inter-stimulus interval equal to 0 ms), Mosley (1980) controlled the amount of time during which the subject was exposed to the stimulus. He also varied familiarity by employing familiar (letters) and novel (Chinese characters) stimuli. Results were interpreted based on a proposed model which suggests that recall in the current task requires orientation to the visual input, transfer of the input into short-term memory (STM) and a concurrent search-and-match analysis of previously stored input. Recognition, in the current task, requires orientation to a feature or characteristic of the novel stimulus and encoding this information in a way designed to aid in keeping it active in STM since a search-and-match analysis for the character "per se" was difficult. The data revealed that, under minimal load conditions, the

mildly retarded subjects were able to conduct the search-and-match procedure with familiar stimuli, albeit at a lower level. However, when novel stimuli were employed, the retarded subjects were unable to hold onto the potentially salient features of the stimulus. Mosley (1980) concluded that mildly retarded subjects are likely unable to durably encode the salient features of unfamiliar, novel stimuli and may thus demonstrate a deficit in the orienting component of selective attention.

Taken together, these studies suggest that rather than the mildly retarded showing any specific sensory deficits in terms of the functioning of iconic storage, it may be that factors such as stimulus familiarity, attention, and strategic differences underly most of the previously demonstrated retarded-nonretarded performance differences.

As summarized earlier, the current state of knowledge concerning iconic memory, although equivocal, views it as a storage process whose function is to preserve brightness, texture, colour and contour information received from the receptors as the eye makes successive saccades. It is a primary step in a sequence of operations which includes the development of visual and auditory-semantic codes for transfer of information to the short-term store, and ultimately the transfer of this coded information to permanent storage.

Attempts to evaluate the functioning of this primary step in the information processing of the mildly retarded have tended to demonstrate only a generalized performance difference between them and chronological age-matched subjects. The failure to find significant Retardation X Experimental factor interactions has suggested that mildly retarded subjects may perform poorly because of factors such as stimulus familiarity, attention, and strategic differences, rather than because of any specific sensory deficits.

The present study will examine iconic memory employing familiar (two-letter words) and unfamiliar (geometric shapes) stimuli in contrast to much of the traditional work in which digits and/or letters were used. A backward visual masking paradigm will be used in which the stimulus and mask are presented dichoptically (to different eyes) and monoptically (to same eye) in order to examine iconic memory from the peripheral (retinotopic) and central processing perspectives. The masking paradigm can also be used to assess the ability of subjects to extract relevant features as cues for recognition and recall. It has been illustrated by Averbach and Coriell (1961), Dick (1974), Haber and Standing (1968, 1970), Kahneman (1968), Neisser (1967), and Turvey (1973) that the backward visual masking phenomenon documents the

existence of iconic memory.

Visual Masking

Visual masking occurs when one visual stimulus interferes with the perception of another visual stimulus. The quantitative and qualitative characteristics of this perceptual interference are determined by the figural, spatial, temporal, and intensive characteristics of the interacting stimuli. The interactions produced by manipulating these stimulus characteristics have been quantitatively defined as the amount by which the threshold for perception of one visual stimulus is raised by the presence of another visual stimulus (Felsten & Wasserman, 1980; Sperling, 1965; Weisstein, 1968).

The "masking stimulus" (MS) is that stimulus that interferes with (and raises the threshold for) the perception of the "test" or "target stimulus" (TS). Kahneman (1968) has reported a number of different masking paradigms that continue to be utilized in current research: (1) In "masking by light," the MS consists of a flash of homogeneous illumination over an area that completely contains the contours of the TS, i.e., the MS and TS fall on the same retinal area; (2) The "masking by pattern" paradigm includes several situations in which the MS is not a homogeneous flash of light but is instead a pattern that may or may not form a recognizable figure.

A completely random array of white and dark areas is called "masking by visual noise"; (3) When the MS is homogeneous but is presented to an adjacent or nonoverlapping area, the paradigm is called "metacon-
trast masking". The TS also varies and may be a recognizable form, such as a geometric figure or a text character, or it may simply be a homogeneous flash of light.

The temporal relationship between the MS and the TS has been extensively studied and plays a major role in masking. When the MS precedes the TS, the effect is called "forward masking" (sometimes "proactive").

"Backward masking" (sometimes "retroactive") occurs when the TS precedes the MS. The time between the offset of the first stimulus and the onset of the second stimulus is called the "interstimulus interval" (ISI). But the second stimulus may be presented before or after the offset of the first stimulus, and hence the sign of the ISI would differ in these two cases, even though the order of stimulus presentation would be the same. Therefore, another descriptor of the temporal relationship between the stimuli is more often used, namely, the "stimulus onset asynchrony" (SOA), which is a signed measure of the interval between the onsets of the two stimuli. Whenever the presentation of the TS follows that of the MS (forward masking), the SOA is defined as positive, and vice versa. ISI is generally used only in those situations

in which the two stimuli do not overlap. The duration of the TS is usually short, ranging from several milliseconds to several tenths of a second; MSs can range from several milliseconds up to several minutes.

Dichoptic masking is a special case of backward masking. In the usual dichoptic masking experiment, the target is presented to one eye, and the mask is presented, following a variable ISI or SOA, to the other eye. Perceptual performance (e.g., probability of detection or percentage of letters correctly reported) is then compared under the same temporal conditions with that obtained when both parts of the stimulus array, target and mask, are presented to the same eye (monocular viewing) or to both eyes simultaneously (binocular viewing). If there is very little difference between the dichoptic and monocular (or binocular) masking conditions, post-retinal processes are usually inferred to underlie the masking effect. Hence the masking of letters with complex patterns has been hypothesized to involve more cortical processes, because of the general comparability of monocular and dichoptic demonstrations (cf. Breitmeyer & Ganz, 1976). On the other hand, if it is not possible to mask a target presented to one eye with a mask presented to the other eye, more retinal processes are inferred to dominate in any masking effects with the same stimuli obtainable under normal viewing conditions. Thus,

homogeneous field masking by a bright, blank field has been relegated to retinal factors (cf. Breitmeyer & Ganz, 1976; Felsten & Wasserman, 1980). Even though a certain visual phenomenon is retinal does not mean that central stages are unnecessary. Rather, the dichoptic viewing procedure has been employed to determine whether the central processing of separate retinal signals from the half stimuli presented to different eyes is sufficient, or whether peripheral structures must process certain aspects of the stimulus event in combination prior to the involvement of the higher centers.

For both forward and backward masking, two types of effects have been commonly demonstrated: (1) when masking magnitude decreases monotonically as the absolute SOA value increases, a "Type A" masking effect is said to prevail; (2) when the masking magnitude varies in a nonmonotonic, U-shaped fashion, a "Type B" masking effect is said to prevail (Breitmeyer & Ganz, 1976; Kahneman, 1968).

The masking paradigm involves a recognition and/or recall task in which the TS is presented for a duration normally sufficient to produce accurate identification. However when the MS is presented shortly before or after TS offset, interference occurs in recognition/recall which has traditionally been explained primarily by two theoretical constructs. These two processes, termed "summation"

and "erasure" by Averbach and Coriell (1961), have more recently been termed "integration" and "interrruption," respectively (Kahneman, 1968).

Interruption. The principal argument behind this proposition is that if a pattern mask follows a TS after some delay, iconic processing is assumed to have occurred during that delay but is terminated or interfered with by the mask. Felsten and Wasserman (1980) have provided an analogy of information processing in digital computers that have two important characteristics: (a) complex analyses are carried out by means of a series of elementary operations, each of which takes a fixed amount of time. Therefore, the more complicated the analysis, the more total time is needed; (b) only one operation can be performed by the central processor at a time. These two constraints would limit the amount of information produced from one analysis if an interrupt signal were to arrive before the analysis was completed. The interruption hypothesis localizes the effect of backward masking by pattern subsequent to iconic storage. It is assumed that a clear icon is established and that an "aftercoming" pattern interferes with the translation into categorical form. The time needed to effect that translation is cut short by the after-coming stimulus. Within the backward masking paradigm, five classes of evidence have been used to support interruption theory: (1) the U-shaped backward

masking function (Averbach & Coriell, 1961; Coltheart, 1975; Turvey, 1973). The fact that under certain conditions strongest masking is obtained not at $SOA = 0$, but several tens of milliseconds later, has been interpreted as crucial evidence that the mask must be delayed so as to synchronize with the initiation of the transfer from iconic storage to short-term memory; (2) the SOA law. Turvey (1973) has shown that for a fairly large range of target energies, obtained by varying target duration, the effects of a subsequent mask can be just evaded by a target only if a fixed amount of time (called the critical SOA) is allowed to elapse from target to mask onsets. That is to say, for a range of energy values, $critical\ SOA = target\ duration + ISI = constant$. This is interpreted to mean that a constant central processing time is required before transfer to a post-iconic stage can occur.

Spencer and Shuntich (1970) varied processing load and reported that integration seemed to occur up to 150 ms, with interruption occurring at longer SOAs. This suggestion was based on the finding that backward masking of multielement target displays was energy dependent at SOAs below 150 ms, but was independent of MS energy at SOAs greater than 150 ms. Scheerer (1973) also indicated that the critical SOA which defines the central component of interference in backward masking is

of the order of 100 to 150 ms. That is, at SOAs of greater than or equal to 100 ms, the central effects of "interruption" take precedence; (3) icon clarity (Haber & Standing, 1969b; Liss, 1968). While subjects report seeing a clear TS, they nevertheless cannot identify it. For example, Haber and Standing (1969b) had subjects make clarity and recognition judgments of letters, either under conditions of short duration of exposure (no mask) or under conditions in which a mask followed a letter. They found that at a particular level of reported clarity, perceptual recognition was significantly lowered in the mask condition. This supported interruption theory because it was suggested that iconic representations were equally clear in the mask and no-mask conditions, but that processing time was cut short as a result of backward masking; (4) direct estimates of icon duration (Haber & Standing, 1970; Sperling, 1967). The procedure originated by Sperling (1967) involves the following: In a target-then-mask paradigm, subjects are asked to synchronize the onset of two tones to the perceived onset, and, at a later time, to the perceived termination of the target icon (Haber & Standing, 1970). The asynchrony between the two tone onsets presumably provides an estimate of icon duration. These estimates were interpreted to be consistent with the view that a clear icon is established and then terminated by the mask;

(5) Turvey (1973) has investigated the masking effects due to pattern masks (PM) and random noise masks (RNM). He found that a dichoptically presented PM in one eye could mask an earlier test figure in the other eye. However, if the PM were followed 5 ms later by a RNM to the same eye, the target figure was not masked. Presentation of the RNM to the eye that received the target did not lead to a similar "unmasking," nor did the RNM have an effect on the perception of the target when delivered without the PM at the ISI used. Turvey concluded that the dichoptically presented PM acted according to an interruptive mechanism without a degradation of the TS representation. This was based on the finding that the TS could be unmasked by subsequent interference with the PM. Had the PM been integrated with the TS, the subsequent RNM could not selectively interact with the PM to prevent its masking effect. Furthermore, Turvey (1973) found that under dichoptic conditions, a RNM or a flash of homogeneous light was ineffective, whereas a PM was effective. Turvey suggested that his data indicated two mechanisms subserved RNM and PM masking; the effects of RNMs and homogeneous light masks were given a peripheral locus, whereas those of PMs were given a central locus.

Integration. This hypothesis stresses the effect that a visual pattern has on the sensory character of the target stimulus representation, rather than on the

extraction of information from the target representation.. The idea is that two stimuli which follow one another in rapid succession are effectively simultaneous within a single "frame" of psychological time, analogous to a double exposure of a photographic plate. Responses evoked by the two stimuli interact within some common neural element somewhere in the visual system.

Kinsbourne and Warrington (1962a, 1962b) investigated backward and forward masking by random patterns and found that in both cases the relation between the TS duration and the critical interval (i.e., the time between TS offset and MS onset that just permitted the target to evade masking) could be described by the expression, stimulus duration x critical interval = constant.

Turvey (1973) investigated this further and found that the total energy of the TS determined the degree of masking, not its intensity or duration alone. The fact that energy summation exists was taken as support for the notion that temporal integration of the two stimuli occurs. Turvey offered an equation that described integrative masking by a multiplicative rule: target energy x critical ISI = constant, where the critical ISI is the time between TS offset and MS onset that yields a criterion level of masking, when the parameters of the MS are held constant. The equation suggests that the dynamic integration period for backward masking is energy dependent.

Eriksen and Lappin (1964) offered an integrative model of masking to account for form recognition under conditions of backward, forward, and concurrent masking by light. Their results indicated that masking was maximal when the TS and MS were presented concurrently and decreased toward control levels when the ISI increased. Control levels were reached with ISIs of approximately 100 ms for both forward and backward masking. Eriksen and Lappin (1964) attributed their findings to an integrative luminance summation that reduced the contrast of the target background display. Further support for this position was presented by Eriksen (1966) when he tested a number of predictions based on this luminance-summation model and concluded that it could account for certain backward and forward masking effects.

Eriksen and Rohrbaugh (1970) reported an experiment in which backward pattern masking was used with multi-element target displays. They found that the masking of a letter in a randomly chosen position of the display increased to a maximum level (at an ISI that depended on the energy of the MS) and then decreased. They attributed this finding to integrative mechanisms in which the trace (or icon) of the TS faded with increasing ISI and thus became more sensitive to masking.

Coltheart and Arthur (1972) tested the effectiveness of two visual noise masks on masking of target letters.

Both masks were checkerboard patterns with half of the squares blackened, but one had a normal checkerboard arrangement of blackened squares, whereas the other had a random arrangement of blackened squares. The regularly arranged masking field was less effective in interfering with the identification of target letters. The authors suggested that their results were consistent with an integration theory but not an interruption theory, which would predict equal masking regardless of the pattern as long as processing was stopped.

Henderson (1973) criticized Coltheart and Arthur's (1972) support for an integration model on several grounds, including a failure to account for apparent contrast of the MS and a failure to take account of Henderson's interpretation of pattern masking, which suggested that interruption occurs through a competition of feature analyzers when the TS and MS are composed of similar graphic features.

Coltheart (1973) responded that an integration theory predicts different masking effects based on apparent contrast and that any competition for feature analyzers would suggest the existence of representations of both the TS and MS, which is not consistent with an interruption theory, but is consistent with an integrative mechanism.

The most definitive psychophysical support for an integration theory of visual masking was reported by Schultz and Eriksen (1977). They presented subjects with one of four incomplete target numerals composed of dots. The TSs were presented either alone or followed at various SOAs by one of three different types of MS's, also composed of dots: (a) Enhancement masks were designed so that the composite pattern of TS and MS made the target more identifiable, (b) noise masks were randomly arranged so that a complete image of the TS and MS would make the target more difficult to identify, and (c) confusion masks were designed so that the composite image of each TS with its appropriate MS would make the targets more easily confused with each other. Predictions based on both interruption and integration theories of visual masking were considered.

Interruption theories, according to Schultz and Eriksen (1977, p. 92) would predict (a) "impaired target identification under not only the noise condition, but also the enhancement and confusion conditions," and, (b) "much more extensive masking under a backward than under a forward masking paradigm."

Integration theories would predict (a) "little difference between backward and forward masking," (b) that "target identification should be better at short ISIs under the enhancement condition than under the other

conditions"; (c) with increasing ISI, that target identification in the enhancement condition "should decrease . . . to the no-mask condition"; (d) that target identification under the noise condition should be poorer than under the no-mask condition, but that performance "should increase to the no-mask condition as ISI increases"; and (d) "performance in the confusion condition should be worst of all."

Schultz and Eriksen's (1977) results confirmed all the predictions based on integration theory and none of those based on interruption theory. They concluded that integration occurs either through "energy summation when the successive stimulations fall within the critical duration or summation interval" (p. 94) or through "superimposition on the sensory register of the new stimulation (mask) on the decaying trace or icon of the previous stimulus (target)" (p. 94).

Although no particular neural locus for integrative masking is logically required by the results of the foregoing experiments, most investigators have assumed that integrative effects occur in the peripheral visual system because of the results of experiments which show that integrative effects appear to be limited to cases in which the two stimuli fall on the same area of the retina and not when the two stimuli are presented to different eyes (e.g., Kietzman, Boyle, & Lindsley, 1971; Turvey,

1973).

In summary, the aforementioned findings have suggested that the following points can be made:

- (1) Integrative masking is thought to occur peripherally and is dependent on stimulus energy that roughly obeys a multiplicative rule.
- (2) Interruptive masking which is thought to be primarily a central effect and not influenced by stimulus energy, depends on SOA or time, according to an additive rule.
- (3) Masking by homogeneous light and random noise is integrative, whereas masking by pattern has integrative as well as interruptive components. The ascendancy of the particular component depends on SOA. At SOAs that cause integrative mechanisms to predominate, masking is dependent on stimulus energy and obeys the multiplicative rule. When interruption dominates, the additive rule holds.
- (4) Interruptive masking has been implicated by exclusion, i.e., interruption is frequently posited because simple energy integration is apparently absent;
- (5) A major variable has been whether the two stimuli share the same receptors. However, the influence of this variable frequently has not been investigated.

The studies cited above and others like them have tended to make conclusions around the interruption-integration and peripheral-central issues based largely on the manipulation of stimulus, mask, and temporal

variables. However, these psychophysical investigations alone are unlikely to characterize fully and reliably the mechanisms and loci involved in visual masking, since they fail to take into consideration the time dependence, energy dependence, response characteristics and functional architecture of the visual system.

There exists a literature which has investigated masking from the psychophysiological perspective at the levels of the cortex, lateral geniculate nucleus, optic nerve and the photoreceptor (e.g., Bridgeman, 1975; Felsten & Wasserman, 1978, 1979a, 1979b, 1981; Ratliff, Hartline & Miller, 1963; Schiller, 1968), as well as attempting to explain specific masking phenomena (e.g., metacontrast - Weisstein, 1968, 1972; Weisstein, Ozog & Szoc, 1975). These studies have generally concluded that the major mechanism that mediates the response interaction in any masking situation in which stimuli share receptors is response integration in the photoreceptor, even though central structures contribute. This integration results in a degraded and shortened primary neural signal and consequently reduces the information available for subsequent processing. For example, Felsten and Wasserman (1979b) presented single *Limulus* photoreceptors with stimuli equivalent to Landolt Cs, and recorded the receptor responses with intracellular microelectrodes. They took the incremental response to the

TS as the portion of the response to that stimulus that had survived masking and hence was available for subsequent neural processing and information extraction. Incremental responses were obtained by subtracting the response to the MS from the response to the combined presentation of TS and MS.

Analyzing the integral of the incremental responses as a function of TS duration produced results consistent with Kahneman's (1966) psychophysical findings i.e., time-intensity reciprocity or energy dependence dominated when the TS was presented in the middle of the MS, but supersummation or time dependence dominated when the TS was presented either before or after the presentation of the MS. The neural interaction that determined the incremental response to the TS was response integration in the photoreceptor. This finding adds support to integration theories because it showed that time-dependent departures from time-intensity reciprocity in visual masking could have their origin in the receptor that most investigators would consider as a site of neural integration rather than interruption.

Breitmeyer and Ganz (1976) and Breitmeyer (1980) have proposed a neurophysiological model of visual masking that explains many of the psychophysical results that have been obtained so far. It is an integrative model in that the masking effects are viewed as a consequence

of interactions between and within visual channels which result from summation of excitation within channels and/or inhibition within or between channels. The main features of the model have been gleaned from known neurophysiological and psychophysical properties of the visual system's spatiotemporal responses and are as follows: (a) a brief stimulus elicits a short latency transient response that persists for a relatively brief duration, and which is involved in signalling the spatial location or change in spatial location (motion) of a stimulus; (b) a brief stimulus also elicits a long latency, longer duration sustained response with the latency as well as duration of persistence increasing as the spatial frequency of the stimulus increases, and which is involved in the processing of structural or figural information; (c) transient activity can inhibit sustained activity, especially when time parameters (SOA) allow transient activity of mask to be superimposed in time on sustained activity of target. Deviance from optimal superimposition results in less than optimal masking; (d) there is also reciprocal inhibition of transient activity of the mask by sustained activity of the target.

So, for example, the U-shaped backward masking function and Turvey's (1973) additive rule for interruptive masking can be explained in terms of the difference between response latency in sustained channels activated

by the target. Strongest masking occurs at SOAs where the transient channels activated by the mask synchronize their inhibitory effects with the excitatory activity of the sustained channels activated by the target. Thus U-shaped backward masking functions are generated by the integration of excitatory processes activated by the target and inhibitory processes activated by the mask, and not through any interruption of processing.

With regard to direct estimates of icon duration, Breitmeyer and Ganz (1976) suggest that it is likely that subjects make duration judgments on the basis of the interval between the onsets of transient channels activated first by the target stimulus and second by the mask stimulus. This is plausible, since in order to make a high-resolution temporal judgment such as is required in this task, a subject would need to use channels characterized by high temporal resolution. Breitmeyer and Ganz (1976) have cited psychophysical and neurophysiological evidence that indicates that only transient channels are capable of high temporal resolution. Therefore, icon-duration estimates so acquired are most probably indicative of the activity of transient channels than of sustained channels which are necessary for letter recognition (sensitive to spatial frequency) and are poor at temporal resolution. This suggests, further, that icon duration estimation cannot be reasonably accomplished using

visual masking experiments.

Most recently, Felsten and Wasserman (1980) have reviewed psychobiological evidence which indicates that, rather than distinguishing between two types of masking, the additive and multiplicative rules mentioned earlier describe two conditions of integrative masking. The multiplicative rule is appropriate at short SOAs at which the early portions of the responses to the TS and MS have a chance to interact. The additive rule is appropriate at longer SOAs at which the initial portion of the response to the MS interacts with the later portion of the response to the TS. Both types of interaction result in a reduced TS representation and therefore produce visual masking, but the interaction characterized by the multiplicative rule yields a reduction both in the amplitude of the early part and in the duration of the entire incremental receptor response to the TS which is strongly energy-dependent. The interaction characterized by the additive rule does not affect the early part of the receptor response to the TS but yields a reduction in the duration of the incremental response to the TS that is time-dependent.

Furthermore, Felsten and Wasserman (1980) have reviewed evidence which suggests that at the receptor level, the signal (i.e., electrochemical response itself) and not its processing is truncated or interfered with by

the mask.

In conclusion, it seems that masking is primarily mediated by integrative mechanisms, and that when stimuli share the same receptors, masking is mainly peripheral, characterized by receptor dynamics. This does not exclude all interruptive mechanisms as explanatory constructs for visual masking since it has not yet been clearly demonstrated what occurs when stimuli do not share the same receptors (i.e., dichoptic presentations). However, the data do suggest that backward masking does not limit processing time but rather limits the duration of an undegraded sensory signal itself. This implies that the visual masking paradigm allows the delivery of a pulse of information to the central nervous system with control on the duration of that pulse.

Thus, the masking paradigm, and specifically the dichoptic masking paradigm in concert with the manipulation of SOA, provides a means for investigating the nature of iconic memory in retarded and nonretarded subjects.

It has already been mentioned that contrary to previous research, Hornstein and Mosley (1979) found no difference in the iconic memory performance between retarded, equal-MA and equal-CA matched subjects. The stimuli used in this study were nonverbal, and hence, there was no potential verbal advantage to be enjoyed by the nonretarded subjects. An examination of the potential

verbal advantage enjoyed by the nonretarded relative to the retarded subjects will be undertaken by assessing functional cerebral asymmetry.

Auditory Asymmetries

Dax (1865) delivered a paper to the French Medical Society in 1836 that linked right hemiplegia and loss of speech to lesions of the left hemisphere. However, it was not until the work of Broca (1861, 1865), which demonstrated that damage to the third frontal gyrus of the left cerebral hemisphere resulted in a motor speech disturbance (Broca's aphasia) but did not affect the comprehension of spoken language, whereas homologous damage to the right hemisphere did not produce corresponding clinical symptoms, that it became clear that the two cerebral hemispheres may not be functionally equivalent.

Approximately 15 years later, Carl Wernicke described another language disorder (cited in Geschwind, 1972). Clinical symptoms included both quick articulate speech that was devoid of meaningful content and severe loss of understanding of spoken verbal material. Post-mortem examination of the brains of these patients revealed lesions located between Heschl's gyrus and the angular gyrus in an area adjacent to the cortical auditory region. This area, now known as Wernicke's area, was located in the left hemisphere for most patients; damage to the

equivalent area in the right hemisphere did not cause equivalent behavioural deficits.

Wernicke proposed a model of how this area interacted with Broca's area to provide normal speech capabilities. The key points of the model are as follows:

a) When a word is heard, it is conveyed to the auditory cortex, then relayed to Wernicke's area, where comprehension occurs. If the word is to be spoken, it is further conveyed to Broca's area via the arcuate fasciculus, a large band of fibres that connect the two areas. In Broca's area the spoken form of the word is accessed and passed on to the motor area that controls the muscles of speech.

b) When a word is read, output from the visual cortex is relayed to the angular gyrus and further to Wernicke's area. In Wernicke's area the auditory form of the word is accessed and processing continues as described above. In terms of clinical value, this model has been valuable in predicting which areas of the brain are involved in specific language disorders (Geschwind, 1972).

One of the most important findings in these early studies was that only one side of an individual's brain seems to be involved in language processing. For the vast majority of patients studied, damage to the left hemisphere resulted in the language disorders described, whereas patients with equivalent damage to the right

hemisphere did not develop language deficits. For a small percentage of the population, the opposite condition exists; that is, language abnormalities develop only when there is damage to the right hemisphere.

Furthermore, Dax (1865) formulated the first hypothesis concerning the relationship between manifested handedness and language lateralization. Along with Broca (1865), he postulated that right-handed (RHs) individuals have their language functions localized in the left hemisphere and all non-righthanded (NRHs) individuals have their linguistic skills present within the right hemisphere (Penfield & Roberts, 1959). This simplified conceptualization was soon challenged by the apparently inexplicable cases of crossed aphasia that began to fill the clinical literature. A patient is deemed crossed aphasic when damage sustained by the hemisphere ipsilateral to the preferred hand results in aphasia. In other words, a crossed aphasic is either a RH who becomes aphasic following damage to his right hemisphere or a NRH who becomes aphasic following damage to his left hemisphere (Searleman, 1977).

The incidence of crossed aphasia in RHs was found to be very low, implying that for RHs, Dax and Broca had, for the most part, accurately described the relationship between handedness and language lateralization. However, mounting clinical evidence indicated that for NRHs,

crossed aphasia was the rule and not the exception (Hecaen & Sauguet, 1971). These results forced researchers to abandon the simplistic hypothesis laid down by Dax and Broca that the direction and degree of language lateralization in NRHs was simply the reverse of that found in RHs.

Today, based largely on extensive examination of clinical populations, in particular, patients who have become aphasic due to unilateral brain damage, it is estimated that 90% - 99% of all RHs have their language functions predominantly subserved by the left hemisphere (Levy, 1974; Penfield & Roberts, 1959; Pratt & Warrington, 1972; Wada & Rasmussen, 1960; Zangwill, 1960). Similarly, it is estimated that 50% - 70% of NRHs also have their language functions localized primarily within the left hemisphere (Goodglass & Quadfasel, 1954; Hecaen & Sauguet, 1971; Piercy, 1964; Roberts, 1969; Russel & Espir, 1961; Wada & Rasmussen, 1960; Warrington & Pratt, 1973; Zangwill, 1967).

These findings imply that the left hemisphere controls the language abilities of most RHs, whereas a significant proportion of NRHs have their language abilities controlled by the right hemisphere. In addition to the higher incidence of right hemisphere language lateralization among NRHs, several researchers have suggested that linguistic abilities may be bilaterally represented in the brains of

many NRHs, that is, that both hemispheres are capable of complex linguistic functioning (Beaumont, 1974; Bryden, 1964; Dimond & Beaumont, 1974; Goodglass & Quadfasel, 1954; Hecaen & Sauguet, 1971; Kimura, 1967; Levy, 1974; Zangwill, 1967; Zurif & Bryden, 1969). Additionally, it has been suggested that familial sinistrality (i.e., family history of left handedness) has an influence on the degree and direction of language lateralization. Some investigators believe that familial sinistrality is associated with less dependence on the left hemisphere for language functioning (Arnett, 1973; Bryden, 1970; Hecaen & Sauguet, 1971; Hines & Satz, 1971; McKeever, Van Deventer & Suberi, 1973; Zurif & Bryden, 1969). Other investigators, however, have viewed familial sinistrality as a hallmark of left hemisphere dominance for language (Newcombe & Ratcliff, 1973). To further complicate matters, Arnett (1973) has found that the relationship of familial sinistrality to the severity of physical and intellectual handicaps of hemiplegic children varies as a function of both sex and side of hemiplegia. In addition, though several studies conducted with normal subjects have reported smaller sensory field differences in subjects with a history of familial sinistrality, even for RHs, thereby suggesting a less lateralized language makeup (Hines & Satz, 1971; McKeever, Van Deventer, & Suberi, 1973; Piazza, 1980; Zurif & Bryden, 1969), other studies

have not found familial sinistrality to be a relevant factor at all (Bryden, 1973; Warrington & Pratt, 1973).

In summary, studies of handedness have shown that the left hemisphere controls language functioning, in particular, speech production, in most RHs and in about two thirds of all NRHs. In addition, to the 30% who exhibit right hemisphere language lateralization, it has been observed that a significant proportion of NRHs have linguistic skills present in both hemispheres. The findings from both dichotic listening tasks and tachistoscopic studies have tended to confirm the above (e.g., Hines, 1978, Kimura, 1966, 1967; Kinsbourne, 1974, Klein, Moscovitch & Vigna, 1976; Levy, 1974).

The central auditory system in both humans and animals is physically a bilaterally projecting system. Kimura (1961, 1967) has proposed that the functional asymmetry of the hemispheres (left-verbal; right-nonverbal) results from differences in the neural pathways over which information travels between the ears and the language centres of the left hemisphere. Specifically, she suggested that the ipsilateral ear-to-cortex pathways are occluded to some extent under conditions of dichotic presentation, resulting in an advantage for information traveling over the contralateral route connecting the right ear and the left hemisphere. Much of the information that does reach the ipsilateral cortex is thought to

derive from input that has travelled along the contralateral pathway and has been redirected back to the side of original stimulation (Craig, 1979).

Support for this structural model of the ear advantage effect has been adduced from electrophysiological studies with both humans and animals that demonstrate greater activity in the contralateral than the ipsilateral hemisphere following monaural auditory stimulation (Hall & Goldstein, 1968; Pfalz, 1962; Rosenzweig, 1951; Tanguay, Taub, Doubleday & Clarkson, 1977). However, the data provided in some of these reports reveal a certain amount of variability in the extent of this functional superiority. For example, Rosenzweig's (1951) gross recordings at the auditory cortex of anaesthetized cats have been used as evidence for contralateral pathway superiority. Indeed, Rosenzweig demonstrated that the contralateral ear projects to a larger population of cortical cells than does the ipsilateral ear and that these areas are largely overlapping. However, his data also revealed that the degree of superiority was variable i.e., not all recordings yielded significant contralateral advantages, nor was the extent of contralateral advantage the same in each hemisphere (Sidtis, 1981). Variability in the degree of contralateral ear superiority can also be found in human auditory evoked responses. Majkowski, et al. (1971) have shown that the latency of the N1 wave is smaller in

response to contralateral stimulation than to ipsilateral stimulation. Following right ear presentation, 77% of their subjects showed a contralateral advantage while the remaining 23% demonstrated no difference in latency between contralateral and ipsilateral response. For the subjects who did show an advantage, its magnitude ranged from 4.5% to 18.0% of the mean latency. In this group of subjects, the functional superiority of the crossed auditory pathway can be estimated to range from 0 - 18%. This variability may be due to differences in the relative distribution of contralateral and ipsilateral auditory fibers, to differences in the degree to which the projection areas of each overlap, or to both of these factors (Sidtis, 1981).

The degree of competition between ipsilateral and contralateral information is dependent then, on at least two interacting factors, one physiological, the other acoustic. Because the auditory system is tonotopically organized, the frequency separation between ipsilateral and contralateral stimuli as well as the physiological differences between the pathways along which they are conveyed determines the extent of their functional competition. For example, Sidtis (1981) has shown that relatively small acoustic differences can have a significant effect on the magnitude of left-right asymmetry. He has further suggested that without an estimate of the

contribution of the competition to an individual's perceptual asymmetry, the *magnitude* of that individual's laterality effect is largely uninterpretable within the normal range of performance. He has concluded that ". . . dichotic tests . . . appear to be most readily evaluated across groups of subjects and in situations where direction rather than degree of asymmetry is of interest" (p. 110).

In contrast to the aforementioned structural model of dichotic listening performance, Kinsbourne (1970, 1973, 1974) has developed a model that is attentional in nature. Basic to this model is the premise that each hemisphere is primarily attentive to the contralateral half of perceptual space and that the division of attention between left and right is modulated by a mutually inhibitory feedback system involving fibers of the corpus callosum. Kinsbourne (1975) proposed that the right ear advantage usually observed in dichotic listening experiments actually result from the preferential attention the language hemisphere (usually the left) allocates to speech stimuli in the contralateral perceptual field.

Evidence favouring the attentional theory is available from experiments which show that the context in which a listener hears competing speech stimuli affects the magnitude of the performance asymmetry. A study by Morais and Landera (1977), for example, showed that the right

ear advantage for dichotically presented consonant vowel (CV) syllables decreased when the subject was required to hold in memory a short musical passage presented immediately before each syllable pair. The result is explained by the attentional model by postulating that the musical passage primarily activates the right hemisphere. The activation is assumed to produce an attentional bias for the left perceptual field, partially offsetting the right field bias created by the linguistic nature of the subsequently presented speech stimuli.

The attentional theory holds that the main function of the corpus callosum is the maintenance of a roughly balanced division of attention across the two halves of auditory space. For this theory, the exaggerated right ear advantage found in commissurotomy patients (e.g., Milner, Taylor, & Sperry, 1968; Springer & Gazzaniga, 1975) is the result of breakdown in this callosally mediated balance. Sectioning the cerebral commissures deprives the right hemisphere of its inhibitory control over the left hemisphere, which then becomes preoccupied with linguistic stimuli from the right perceptual field.

Thus, although each model is supported by experimental evidence from a number of paradigms, they cannot be distinguished in terms of their predictions for the dichotic listening experiment. Each predicts both the

mild right ear advantage observed in normal right-handed subjects and the extreme ear asymmetry observed in commissurotomy patients.

One relatively simple experimental test of the two different models was made by Tweedy, Rinn and Springer (1980) by taking advantage of different predictions the models make about the relative magnitudes of the performance asymmetry which results from the loudspeaker presentation compared with that which is obtained using earphones. The attentional model claims that the perceived location of the sound's source is the principle determinant of its identification likelihood. This implies that a similar right-side advantage should be observed regardless of whether stimuli are presented through loudspeakers or headphones. The structural model, on the other hand, predicts that the performance asymmetry obtained with loudspeakers should be smaller than that obtained with headphones to the extent that left-side stimuli are audible in the right ear.

Tweedy et al. (1980) used commissurotomized and neurologically normal right-handed subjects and presented them with dichotic CV syllables. They reported results which tended to support the structural model, i.e., performance was more asymmetric in the headphone condition than in the speaker condition. However, they also reported a significant asymmetry in the loudspeaker

condition and suggested that both models could account for the asymmetry. They conclude that, "Characterizing the auditory laterality effect as either an ear-of-entry or a spatial-position phenomenon exclusively appears overly simplistic in either case. In addition, the ear-of-entry characterization needn't require a purely structural interpretation, nor does the spatial position characterization necessarily imply an exclusively attentional characterization" (p. 337).

In summary, then, regardless of the particular model adopted, it seems that the contralateral pathways are preeminent over the ipsilateral pathways such that the right ear primarily connects with the left hemisphere and the left ear accesses the right hemisphere.

The behavioural studies of the role of cerebral dominance in auditory perception are almost exclusively dichotic-listening experiments. Dichotic listening is a technique in which different inputs are simultaneously delivered to the right and left ears. This technique represented a noninvasive procedure for assessing speech lateralization. Other than the use of tachistoscopic methods, there have been two other techniques for assessing language representation. One has relied on observing whether or not an individual developed aphasia after unilateral lesion of the right or left hemisphere. By this criterion, the incidence of left-brain dominance for language approaches 99% for right-handers (e.g.,

Zangwill, 1962). The second technique was developed by Wada and Rasmussen (1960) and came to be known as the Wada-test. It involves the injection of sodium amylobarbitone into one of the carotid arteries. This barbiturate produces a transitory loss of function in the ipsilateral hemisphere that is marked by a total contralateral hemiplegia including the cessation of speech. Due to its inherent risks, the Wada test is administered only to patients undergoing brain surgery where fore-knowledge of hemispheric speech lateralization is of utmost importance. Utilizing this technique Milner, Branch and Rasmussen (1964) found that 17 of 117 non-right-handed individuals displayed aphasic symptoms following both left-and-right-sided injections. In contrast only 1 out of 95 right-handed subjects produced similar aphasic results. However, Levy (1974) has cautioned that subjects that undergo the Wada test are predominantly made up of patients suffering from epilepsy or other early brain damage and consequently generalizations made from this group must be regarded cautiously.

Kimura's (1961, 1967) studies were the seminal investigative reports elaborating cerebral dominance effects in audition by way of the dichotic listening technique. As mentioned earlier, she showed that the contralateral auditory pathways are more effective than the ipsilateral pathways, and that the dominant hemisphere

is more important than the nondominant hemisphere in the perception of speech. Furthermore, she proposed that the cerebral dominance effect is the result of competition between simultaneous inputs to opposite cerebral hemispheres. Superior responses to the stimuli presented to the dominant hemisphere result from the conflict between the disparate perceptions of the two hemispheres.

One objection to Kimura's (1967) hypothesis focused on the role of memory. Laterality might be due to asymmetries in recall rather than to asymmetries in perception. The objective, then, was to separate the perceptual from the storage or response phases of the dichotic listening method.

Bryden (1967) studied this issue by suggesting that the material from the ear that was reported first would be identified more accurately than material from the other ear. This would occur because time elapsed decreases the accuracy of memory for the second channel. Therefore, a tendency to consistently report material from a preferred ear would account for the laterality effect, even if initial perception of material to both ears were equal. He examined the difference between free recall, in which the subject was allowed to report material from either ear at will, and ordered recall, in which the subject was required to report all material from one or the other ear first.

He found a high correlation between right-ear advantage in free recall and right-ear dominance in ordered recall. His data indicated that verbal material presented to the right ear was more accurately identified than verbal material presented to the left ear (using right-handed subjects). When the two ears were compared as channels of immediate recall, the right ear was superior to the left. Also, the right ear was better as a storage channel than the left. In addition, there was a general tendency to report the right ear first. He concluded that the data supported the notion that right-ear superiority is due to a perceptual difference rather than to an order effect. This conclusion supports Kimura's (1967) hypothesis that the cerebral dominance effect is a result of competition between simultaneous inputs to the two cerebral hemispheres.

The second objection to Kimura's (1967) hypothesis concerned the role of attention. Bryden (1969) tested an hypothesis that the laterality effect obtained by Kimura was due to a division of attention rather than to competition of simultaneously arriving stimuli. In the first experiment, subjects listened to monaural stimuli but had no prior knowledge of which ear would receive the next stimulus (monaural presentation with division of attention). Responses in these conditions showed no laterality whatsoever.

Bryden (1969) also tested two other conditions. In the first, subjects were told to which ear to attend; therefore, they ostensibly were attending to only one channel while receiving competing stimulation through both ears. In the second, subjects were not told to which ear they should attend; this condition offered both stimulus competition and division of attention. In both conditions a significant laterality effect was obtained. Thus, regardless of instructions or deliberate direction of attention lateralization of response occurred. Bryden (1969) concluded that these results supported Kimura's (1967) hypothesis that laterality effects obtained in dichotic listening experiments are due to signal competition rather than to attention factors.

Pathological subjects have also been used in the study of cerebral asymmetries with the dichotic listening paradigm. For example, Milner, Taylor and Sperry (1968) found that right-handed commissurotomed patients could not report verbal input to the left ear if a different verbal input was simultaneously delivered to the right ear. However, all known auditory pathways remained intact and the subjects could report with total accuracy monaural input to either ear.

The results of this study were duplicated by Sparks and Geschwind (1968) and led them to propose another model for dichotic auditory asymmetries, which incorporated

Kimura's (1967) model but suggested in addition a colossal auditory pathway between the two cerebral hemispheres. This model could account for the cerebral dominance effect evident in normal subjects and the left-ear suppression by right-handed commissurotomed patients. The main points were as follows:

- 1) In dichotic listening contralateral ear input virtually suppresses ipsilateral input.
- 2) There is competition for report by the left-hemisphere speech system between information arriving directly from the right ear via the contralateral pathway and information from the left ear.
- 3) Since information from the left ear has also travelled along a contralateral pathway to the right hemisphere, it must in addition be projected to the left hemisphere for report. This projection probably involves a callosal pathway.

In a further study, Sparks, Goodglass, and Nickel (1970) used this model to explain data gathered from left-brain-injured aphasic patients and right-brain-injured nonaphasic patients. The right-brain-damaged group could not report the signals received by the left ear after listening to dichotic verbal stimuli. However, the left-brain-damaged group was divided between those who experienced inhibition of right-ear input and those who experienced inhibition of the left-ear input. One

possible explanation for these results was that competition between signals received by both ears occurs exclusively in the left hemisphere. Therefore, they revised the earlier model to state that only damage to the left hemisphere can affect information from either the contralateral or ipsilateral ear.

However, there are also incidences in the commissurotomy literature that have demonstrated that some left ear inputs are processed by the right hemisphere. For example, it has been reported that commissurotomed patients who couldn't report the left ear input during dichotic presentation of consonant-vowel pairs were often able to process the left ear stimuli when pairs of animal names such as "doggy/horsey" were substituted instead (Gazzaniga, Risse, Springer, Clark, & Wilson, 1975; Springer and Gazzaniga, 1975). To account for these inconsistent findings, Gazzaniga and his colleagues have suggested that the type of stimulus used (e.g., consonant - vowel syllables versus familiar words) may be the determining factor in whether or not the right hemisphere will be able to process the left ear input.

It must be kept in mind, however, that commissurotomed subjects in particular may be prone to bilateral language representation due to early cerebral damage from epileptic seizures. If there is a higher incidence of bilateral language representation in these subjects,

it could account for the relatively high degree of right hemisphere linguistic skills often observed to be present in this population (Searleman, 1977).

Nonetheless, since the early studies mentioned previously there have been numerous studies which have indicated that the left hemisphere is the one primarily responsible for the processing of most linguistic features of speech (e.g., Dimond & Beaumont, 1974; Levy, 1974; Segalowitz & Gruber, 1977).

Right hemisphere function has also been investigated in audition spurred on by the studies of cerebral asymmetries in vision. These studies showed that damage to the nondominant hemisphere produced impairment on many visual, nonverbal tasks and also showed that stimuli such as faces, complex designs, and other visuospatial stimuli were more efficiently processed by the right hemisphere (e.g., Fontenot, 1973; Gazzaniga, 1970; Haun, 1978; Hines, 1978).

Milner (1962) examined the effects of temporal lobectomy on nonverbal auditory discriminations. Her subjects were left dominant for speech; in addition, each subject had a lesion in either the right or left temporal lobe. These subjects responded to the Seashore Measures of Musical Talents, which included tests for pitch, loudness, rhythm, time, timbre and tonal memory. Her data showed that the group with right temporal lesions made

more errors than the group with left temporal lesions. The difference between the two groups was strongest for tonal memory and timbre. This research indicated that the right hemisphere is strongly involved in processing certain types of musical sounds in left-dominant subjects.

Later, Kimura (1964) verified these results with normal subjects. She presented melodic patterns dichotically. Left ear melodies were reported correctly significantly more often than right-ear melodies. Kimura (1964) concluded on the basis of these data and Milner's (1962) studies that the difference in function between major and minor hemispheres is along a verbal-nonverbal dimension. She also noted that this asymmetry is obtained only in dichotic listening conditions.

Curry (1967) investigated the effect of the meaningfulness of stimuli. He used a three-condition task with words (meaningful verbal), nonsense syllables (nonmeaningful verbal) and environmental sounds (nonverbal). His subjects were instructed to identify both stimuli in a free-recall paradigm. They obtained higher scores for right-ear words and nonsense syllables but higher left-ear scores with the nonverbal stimuli. This study showed that meaningfulness is not critical for the functional division obtained and supports Kimura's model.

Shortly after this time, research began to appear which indicated that the situation is not a simple

dichotomy of function. Studdert-Kennedy and Shankweiler (1970) presented data which suggest that consonants are processed by the left hemisphere, whereas vowel sounds are processed by both hemispheres. The stimuli were spoken consonant-vowel-consonant syllables presented in dichotic pairs. For any pair of stimuli, only the initial consonants, the final consonants, or the vowels differed. Subjects were tested separately for each of the three types of stimuli. They were told to report both initial consonants in the dichotic pair, both final consonants, or both vowels. Significant right-ear advantages were obtained for the initial and final consonants. Data showed mixed ear superiority for vowel sounds, which suggests that both hemispheres are involved in speech analysis.

More recently Searleman (1977) extensively reviewed the evidence supporting right hemisphere linguistic skills in both normal and clinical populations. He noted the need to distinguish between speech production and speech perception since it appears that the ability to produce speech is usually more lateralized than is the ability to comprehend speech. He cites, as an example, the work of Sussman and his colleagues (Sussman, 1971; Sussman & MacNeilage, 1975; Sussman, MacNeilage, & Lumby, 1974) with a dichotic listening technique, called pursuit auditory tracking, which provides ostensibly the first

accurate index of hemispheric specialization for speech production in normals. Briefly, the test requires the subject to monitor a tone presented to one ear, which varies randomly in both frequency and intensity. The subject tries to match the varying tone with a second tone presented to the other ear, by regulating the continuous movement of a part of his body.

Typically, when a speech articulator such as the tongue or jaw is used to track the fluctuations of the first tone, the subject does best when the second tone is presented to the right ear (Sussman, 1971). As added support for Sussman's conclusion that this right ear advantage is due to the left hemisphere's greater functional control of the motor pathways involved in speech production, a control group showed that no ear advantage occurred when the second tone was regulated by a nonspeech articulator, hand movements. These findings are even more important when one considers that the motor pathways involved in speech production are bilaterally represented (Gazzaniga, 1970; Penfield & Roberts, 1959). This implies that the left hemisphere's superiority in pursuit auditory tracking is reflective of a functional and not a structural advantage. In addition, this technique further emphasizes the need to separate speech production from speech comprehension when investigating language lateralization.

Searleman (1977) further cites evidence that other linguistic features of speech, such as intonation contours and pitch processing, are not only processed bilaterally but are often handled better by the right hemisphere (Curry, 1968; Schuloff & Goodglass, 1969; Zurif, 1974; Zurif & Mendelsohn, 1972). Furthermore, evidence from studies with commissurotomed subjects have demonstrated that the right hemisphere, unaided by crosstalk with the left, using the left hand, can retrieve objects upon hearing verbal descriptions of their uses or characteristics (e.g., Gazzaniga, 1970; Searleman, 1977).

So, it appears that the right hemisphere possesses a far greater capability to comprehend speech and language than was previously thought.

Studies that investigated the processing of nonverbal dichotic stimuli also report a complex division of function, as noted earlier by Searleman (1977). These studies suggest that different acoustical attributes of nonverbal stimuli are differentially processed by the cerebral hemispheres. Spellacy (1970) found a significant left-ear advantage for dichotic melodies but found no significant difference between ears for timbre, temporal or frequency patterns. Stimuli used for the melodies test were unfamiliar violin solo melodies. Frequency patterns were composed of four 500 msec consecutive tones. Each tone was of a different frequency and all tones were between 440 Hz and 880 Hz.

Temporal stimuli were tone pulses arranged in Morse code patterns. Timbre stimuli consisted of single notes played on a pipe organ using varying combinations of pipes. After listening to the dichotic test stimuli, subjects listened to binaural identification stimuli and then reported whether the identification stimulus matched either of the test stimuli.

Sidtis (1980) investigated the nature of functioning underlying the right hemisphere superiority in processing some types of auditory stimuli by investigating the relationship between the degree of functional asymmetry observed during dichotic testing and the harmonic information conveyed in the test stimuli. Ninety-six right-handed subjects received one of four dichotic pitch recognition tests. The tests differed from one another in the number of constituent overtones present in the tonal stimuli. As stimuli increased in complexity from pure tones to square waves, the overall accuracy of pitch discriminations increased and a right hemisphere advantage emerged for both accuracy and latency of response. These results indicate that right hemisphere auditory function is specialized for the analysis of steady state harmonic information rather than for music perception per se.

Craig (1979) has further emphasized the need to separate the acoustic properties of nonverbal stimuli. In his review, he presents evidence supporting the need

to partial out elementary information before any definitive statement about how they interact in complex stimuli can be made.

This review has served to illustrate that the verbal-nonverbal dichotomy is in some ways oversimplified. These categories have been thought of as the essence of the input to the brain. However, the one omission that becomes apparent is that the inputs to the brain have not been examined in terms of units that are of relevance in cerebral processing. Language, on the one hand, is the result of complex behaviour that requires the integration of many functions at different levels in the nervous system in order for it to be perceived as well as produced. It has been mentioned already that linguistic features such as consonants and vowels, and pitch processing may involve both hemispheres. On the other hand, musical tone recognition must be in some ways reduced to components such as timbre, pitch and harmonic composition, because these components may involve differential hemispheric processing. Thus, when we speak of processing asymmetries, we must be specific as to what is being processed asymmetrically.

The distribution of speech lateralization is less clear with children than with adults. One of the two major theories holds that language is completely lateralized to one hemisphere or the other by age 5 (Krashen, 1972,

1973; Krashen & Harshman, 1972), whereas the other theory maintains that language functions are not fully lateralized until puberty (Basser, 1962; Lenneberg, 1967; Zangwill, 1960).

Unfortunately, because the literature contains so few reports of patients who have had left hemispherectomies between age 5 and puberty, it is difficult to test the two theories directly. To complicate matters, in the few reported cases, the time of onset of the disease was rarely adequately determined (Searleman, 1977). An accurate assessment of the time of onset is vital, since both theories predict that the right hemisphere will take over if the left malfunctions early in life. If the left hemisphere did malfunction early in life, then it becomes meaningless to place any significance on the age at which the hemispherectomy was performed, since the transfer of linguistic abilities has probably already taken place.

With this in mind, Krashen (1972) reviewed case histories of the hemispherectomy literature and found that language skills were recovered only if the onset of the malfunction was before age 5.

Citing evidence from studies examining the effects of right-and-left-sided unilateral brain damage in producing aphasia in children, Krashen (1972) noted that the same percentage of children above age 5 became aphasic

due to right hemisphere injuries as did adults, indicating that children above age 5 are no more dependent upon the right hemisphere for language functioning than are adults.

Krashen (1972) also reinterpreted data from several dichotic studies that had yielded decreasing right ear advantages throughout childhood and concluded that the magnitude of the right ear advantage for verbal material remains fixed following its appearance at age 5. Since the right ear advantage is considered indicative of left hemisphere specialization for speech perception, Krashen's findings gave further support to the lateralization-by-5 hypothesis.

However, since Krashen's (1972, 1973) reappraisal, several dichotic listening studies have appeared which provide evidence that language is not completely lateralized by age 5. These studies have shown that the typical right ear advantage continues to increase in magnitude throughout childhood (Bryden, 1973; Bryden & Allard, 1978; Satz, Bakker, Teunissen, Goebel, & Van der Vlugt, 1975). For instance, although Satz et al. (1975) did find a trend for a right ear advantage by age 5, a significant difference between ears was not found until age 9, and the magnitude of the right ear advantage continued to increase until age 11. After critically reviewing the developmental dichotic literature, which purportedly provided support for the lateralization-by-5 hypothesis, Satz et al.

rekindled the lateralization-by-puberty hypothesis by demonstrating "that the ear asymmetry, regardless of its age of onset, does undergo major changes after 5 years of age" (p. 184).

More recently, Segalowitz and Chapman (1980) investigated hemispheric brain asymmetry for speech reception in premature (short gestation) infants (mean gestational age = 36 weeks). Segalowitz and Chapman (1980) noted that premature infants expend much energy in limb tremors presumably due to insufficient maturation of neuromuscular inhibitory patterns, either at a cortical or subcortical level. They also discovered that auditory input can reduce such tremors and in fact auditory input produces an asymmetric response (Chapman, 1978).

Segalowitz and Chapman (1980) made two tapes, one of the mother reading a monolog of nursery rhymes, and the other of music and presented the taped speech or music to the infants. The results indicated that the right arm showed a greater reduction in movement in the group hearing the speech tape than the group hearing the music or no patterned stimuli. This suggested that the speech input is differentially affecting the two sides of the brain, while the music does not. Since reduction of movement tremors indicates an increase in control, the speech must be inducing greater control in the left hemisphere.

They conclude that language skills are not needed for cerebral specialization for speech. Some aspect(s) of the speech signal that differentiates it from music or ambient noise is detectable by the infant. They further conclude that brain specialization for language functions doesn't necessarily appear over time; rather, specialization for some functions (e.g., speech reception) must be present at birth.

In summary, the question of language asymmetry in children is not yet answered. Some negative findings may be a result of procedural inadequacies such as ceiling effects (Satz, et al., 1975), too many stimulus items and inter-trial intervals which were too short (Hiscock & Kinsbourne, 1977). Some specialization may be present at birth while other functions may require maturation time. More research is necessary to resolve these questions.

The Present Study

Iconic memory has been conceptualized in multistore memory models as the initial memory stage, and the stage at which information first enters the system. As such, it is dependent upon attention to incoming stimuli. If an individual does not attend to his/her environment this can have the consequence of poor memory performance. Furthermore, the quality and quantity of information in iconic memory will bear directly on what is entered into

the short-term memory; therefore, the short-term memory performance deficits reported for retarded individuals may be attributable to iconic memory inadequacies.

It has already been illustrated that differences in iconic memory performance accuracy occur when mildly retarded and nonretarded subjects are compared. However, these earlier studies generally utilized familiar stimuli, i.e., letters and/or digits. When unfamiliar, non-verbal stimuli have been used (cf. Hornstein & Mosley, 1979), group differences in performance accuracy were not obtained. Furthermore, it has been argued that most of the earlier studies have failed to demonstrate the Group X Experimental Factor interaction which is necessary for the attribution of a specific processing deficit.

In the present study the use of a backward visual masking paradigm which varies SOAs should provide information regarding the point in time at which potential iconic memory differences between mildly retarded and nonretarded individuals become manifest. Such an interaction, if obtained, would highlight the temporal foundation for the iconic memory processing differences. The visual backward masking paradigm limits the duration of an undegraded stimulus input and thus allows control over the exposure duration for such input.

In addition to the investigation of the temporal features of iconic memory, a great deal of research has been directed to the assessment of the locus of iconic memory. The focal issue highlighted by this research involves the peripheral versus central controversy. In an attempt to isolate the "locus" of iconic memory, the present study will employ a dichoptic/monoptic masking procedure. The dichoptic/monoptic masking procedure will assist in determining whether the central processing of separate retinal signals from the stimuli presented to different eyes is sufficient, or whether peripheral structures must process certain aspects of the stimulus event in combination prior to the involvement of higher cortical centers.

The investigation of the influence of stimulus familiarity has produced equivocal results. Studies employing familiar/verbal stimuli have yielded data suggesting that nonretarded individuals are more efficient in the processing of these stimuli when compared to mildly retarded individuals. However, studies employing unfamiliar/nonverbal stimuli do not typically report such findings. In the present study, both verbal/familiar (two-letter words such as to, of, etc.) and nonverbal/unfamiliar stimuli (polygons) will be used.

The examination of the influence of stimulus familiarity raises a further question as to the potential

verbal advantage enjoyed by nonretarded compared to mildly retarded individuals. This question will be addressed by examining the functional cerebral asymmetry demonstrated by mildly retarded and nonretarded individuals through the use of a dichotic listening paradigm. Although the auditory system is not completely crossed as is the visual system (i.e., both hemispheres receive projections from each ear), it has been demonstrated that the connections from the contralateral ear do appear to have preferred access to the opposite hemisphere. As such in right-handed individuals verbal stimuli presented to the right ear are more efficiently processed by the left hemisphere, in 90-99% of all cases, while non-verbal stimuli (e.g., tones, music) are more efficiently processed by the right hemisphere in a large majority of cases.

CHAPTER II

METHOD

Subjects

Ten mentally retarded male subjects were selected from the population in training at the Vocational and Rehabilitation Research Institute (VRRI) and voluntarily participated in the study. IQ and mental age (MA) were assessed by individually administering the Peabody Picture Vocabulary Test (PPVT). The mean CA was 21.3 yrs., S.D. = 3.40; the mean MA was 10.45 yrs., S.D. = 2.01; and the mean IQ was 67.9, S.D. = 10.20. All subjects were free of visual and auditory impairments. All subjects were assessed for near binocular visual acuity. Only subjects receiving near binocular acuity scores (Snellen Notation) of 20/30 or better (corrected or uncorrected) were included in the study (median = 20/22; range = 20/20 - 20/29). Auditory sensitivity was determined on a diagnostic audiometer at frequencies ranging from 250 - 8000 Hz. Air conduction audiometry was used, and audiograms were constructed showing the decibel threshold for each subject's left and right ear at each of the test frequencies. Subjects with impaired hearing were excluded from further participation in the study. Laterality (handedness, eye dominance and footedness) was determined and only right-handed, right-eyed and

right-footed subjects were used. Each retarded subject was free from organic etiological involvement as determined by his clinical record to preclude possible confounding due to specific perceptual deficits produced by organic abnormalities; each subject was not receiving medication on a continuing basis, nor at the time of this study.

Ten intellectually average male subjects matched with the retarded subjects for chronological age (CA) were selected from the subject pool of psychology undergraduate students at the University of Calgary (mean CA = 22.5 yrs., S.D. = 3.52). Visual acuity was assessed (median = 20/20; range = 20/17 - 20/22). Auditory sensitivity was also determined. These subjects were also required to be right-handed, right-eyed and right-footed.

A second group of ten nonretarded males matched with the retarded subjects for MA as determined by the P.P.V.T. were selected from among the students at the St. Sylvester Elementary School (mean CA = 10.1 yrs., S.D. = 0.65; mean MA = 12.1 yrs., S.D. = 2.64; mean IQ = 114.4, S.D. = 17.41). Consent forms were passed out to all the groups and relevant signatures were obtained. Furthermore, participation was voluntary. Visual acuity was again assessed (range = 20/17 - 20/22) and auditory sensitivity determined. These subjects were also required to be right-handed, right-eyed and right-footed.

Apparatus and Materials

Visual. A six-channel Scientific Prototype Tachistoscope (Model N-1000) was used. The optical system was fitted with a simple right-angle star prism. The six solid-state timers controlled the sequencing of the stimulus fields (three fields for each eye) and the exposure durations. Viewing was monoptic and dichoptic at 65 cm. A dim, centrally presented small red dot was provided by the optical system as a fixation point. The stimulus fields, blank fields, and masking fields were of equal luminance (7.0 ft-lamberts). A dim pre-trial - post-trial field was employed.

The stimuli consisted of 35 mm. slides of centrally-presented two-letter words (e.g., to, of, it, at, an, if, in, on, or, is, as, us, no, oh). The two-letter words served as verbal stimuli. When projected tachistoscopically, each word, printed in upper case letters (Helvetica Bold), subtended approximately 1.2 degrees of visual angle vertically and horizontally. Polygons (12 point) from the pool scaled by Vanderplas and Garvin (1959) served as the figural stimuli. Each polygon spanned approximately .65 degrees of visual angle horizontally by 1.1 degrees vertically and was chosen so that it had a low likelihood of having an associated verbal label.

Response cards were constructed using index cards (20.2 x 12.6 cm.), each with either four words or four polygons arranged horizontally. One of the words or polygons was the target while the other three were non-targets. Target position on the card was randomized. In addition, single polygons were centrally located on individual cards for a sorting task.

A masking stimulus, which consisted of cross-hatched lines of the same width as those in the forms and letters (1 mm. - .22 degrees of visual angle) was used. During dichoptic presentations, the mask was presented to the eye opposite to the one in which the target stimulus was presented. During monoptic presentations, the target stimulus and the mask were presented to the same eye.

Auditory. A Tandberg (Model TCD440A) dual channel cassette stereophonic tape recorder and Koss Pro 4AA earphones were used to present dichotic stimuli tapes. A Maxell UDXLII-S low noise magnetic tape cassette was used to present spoken pairs of different digits (numbers 1 - 9 inclusive) and spoken digit probes (mean intensity approximately 65 dB as measured by a sound level meter). Onset alignment and regular spacing of the stimulus probes and words on channels 1 and 2 during recording was achieved by using a digitizing programme (the speech editor) in concert with a PDP 11/34 computer. Another Maxell UDXLII-S low noise magnetic tape cassette was used

to present complex tones which were square waves with fundamental frequencies corresponding to the eight notes in the octave between C4 and C5 on the major scale (i.e., middle C[264 Hz]; D[297 Hz]; E[330 Hz]; F[352 Hz]; G[396 Hz]; A[440 Hz]; B[495 Hz]; and C[528 Hz]). Tones were produced by a function generator. The frequencies and duration of each stimulus were adjusted using the speech editor digitizing programme of the PDP 11/34 computer. This programme also aided in the onset alignment and regular spacing of the probe tones and stimulus tones. Audio outputs were adjusted to approximately 65 dB per channel using a sound level meter.

Procedure

All subjects participated in 5 one hour sessions on five consecutive days.

Preassessment. The Peabody Picture Vocabulary Test was administered to the retarded and equal-MA subjects.

Session I (Assessment). Each subject was assessed for visual acuity using a Bausch and Lomb Master Orthorater. Sighting dominance was determined by cutting a small hole in a piece of cardboard and requiring the subject to concentrate on a wall target (black "X" on a white card) approximately 3 m. in front of him. The subject held the cardboard at arm's length and gradually brought it toward his face. The eye which finally was used to sight

the target through the hole was designated as the dominant eye.

Audiometric testing was accomplished using a MA22 Advanced Diagnostic Audiometer.

Handedness was determined by the demonstrated use of the same hand for writing, hammering a nail, brushing teeth, combing hair and swinging a racquet.

Footedness was determined by requiring the subject to kick a ball placed equidistant from each leg 30.48 cm. in front of the subject.

For each subject, the critical target duration interval (visual modality) was established for each type of stimulus (two-letter words and polygons) by initially exposing the stimulus for 2 ms and subsequently increasing the exposure duration in 1-ms steps until a criterion of five consecutive correct identifications or recognitions were achieved. This procedure was repeated for both the right and left eyes. The obtained duration was then used for all subsequent stimulus presentations for each subject in the visual masking experiment. This procedure was undertaken in an attempt to ensure that for all groups comparable information was available for processing.

Session II (Visual-Figural). Each subject was seated in front of the eyepieces of the tachistoscope in a dimly-lit, quiet room and told that after he pressed a hand-held button, the following sequence would be initiated: red dot,

a figure, and some lines. Then the subject was instructed to look at the response card, and point to the figure that had been presented. The experimenter frequently underscored the importance of maintaining attention to the task since the stimulus would be present for a very short time.

Following these instructions, questions were answered and the experimental trials begun. The figural stimuli were presented to each subject for the target duration established in Session I. Mask onset was at SOAs of 0, 20, 70, 120, and 220 ms. Mask duration was 50 ms on each masking trial. There were 5 trials/SOA. In addition, there were 10 no mask trials per subject for a total of 60 trials. The order of SOA's and no-mask trials were randomized with the constraint that no SOA or no-mask trial could follow itself, and each subject received the same randomized pattern.

Subjects were confronted with both the monoptic and dichoptic conditions. The order of the conditions alternated as follows: dichoptic, monoptic, for subject 1; monoptic, dichoptic for subject 2; etc. The use of eye in the monoptic and dichoptic conditions was randomized, such that, within each condition (monoptic, dichoptic), there were equal presentations of stimuli to each eye. There was a short rest period after a block of 30 trials (i.e., after the first condition had been administered).

Immediately upon mask offset, the subject was required to recognize the target from the response card by pointing to it. The subject was allowed to view the response card for as long as required to make a response.

Session III (Visual-Verbal). The procedure for this session was the same as for Session II with the exception that verbal stimuli were used, (i.e., to, of, it, at, an, if, in, on, or, is, as, us, no, oh).

Session IV (Auditory-Digits). Subjects were tested individually in a quiet room, seated at a small table on which the tape recorder (Tandberg Model TCD440A) was placed. The experimenter monitored the stimuli through earphones connected to the tape recorder. The earphones were reversed after each subject in order to counter-balance for any asymmetries in the stimulus tapes or apparatus. Twenty-eight dichotic pairs (e.g., 8-2) with probes were constructed, and then randomized into four orders of presentation with each order representing a block of trials. Each block was constructed such that on half of the trials the probe item was the same as one digit of the dichotic pairs, with left and right ear matches equally likely. The remaining half contained probes that differed from both digits of the dichotic pairs. Across trial blocks, probe type varied such that each digit of the dichotic pairs was probed. There was a 500 ms interval between the dichotic pair and its

probe and a 5-second inter-trial interval. Digit duration was approximately 250 ms.

Actual testing was preceded by instructions and 16 practice trials. There were short (2 minute) rest periods in between each block of trials. Thus, the sequencing of events in this session was as follows: (a) instructions, (b) 16 practice trials and (c) 4 blocks of 28 trials each.

After each stimulus-probe presentation the subject responded "yes" if the probe matched one of the two dichotic stimuli and "no" if there was not a match.

Session V (Auditory-Tones). Subjects were tested as before (session IV), but instead of digits, complex tones were used.

When the experimental sessions for all subjects were completed (i.e., after session #5), subjects were presented with single cards each containing a single polygon. From a total of 240 polygons, 180 were selected consisting of 60 targets plus 120 nontargets from the response cards. Each card was coded on the reverse side as to being the target ($N = 60$) or a non-target ($N = 120$), and as to top or bottom. Subjects were asked to sort the 180 cards into 3 piles of roughly equal number. They were told that they could take as much time as they needed. Upon completion of the task, the experimenter asked the subject to describe the characteristics of each pile. This procedure aided in determining to what extent the polygons could be

labelled verbally.

After all sessions were completed, the subject was paid and thanked for participating.

CHAPTER III

RESULTS

To insure that the variability of the mildly retarded group was consistent with that of the equal-MA and equal-CA groups, the F_{\max} test (Kirk, 1968) was carried out for all analyses of variance employed in this dissertation. Unless otherwise indicated the F_{\max} test failed to reveal heterogeneous variances.

Assessment of the Critical Target Duration Interval (Visual Modality)

The critical target duration intervals in milliseconds (see page 120) were subjected to an analysis of variance. For the present analysis of variance the F_{\max} test revealed heterogeneity of the variances. As such, an inverse sine transformation (Kirk, 1968) was performed and the data subjected to a Group (2) X Eye of Presentation (2) X Stimulus Type (2) analysis of variance with Eye of Presentation and Stimulus Type being repeated measures. The analysis of variance summary table is presented as Table 1.

The Group main effect, $F_{(2,27)} = 5.98$, $p < .01$, was the only significant finding. The mildly retarded subjects required significantly longer critical target duration intervals ($\bar{M} = 24.35$ ms) relative to the equal-CA ($\bar{M} = 7.13$ ms) and the equal-MA ($\bar{M} = 10.75$ ms) groups which did not differ. For the present and all subsequent analyses of variance the Newman-Keuls procedure was/will be employed

Table 1
Summary of the analysis of variance
for critical stimulus duration intervals

<u>Source</u>	<u>Sum of Squares</u>	<u>d.f.</u>	<u>Mean Square</u>	<u>F</u>
Group (A)	.09	2	.045	5.98**
Error	.20	27	.008	
Stimulus Type (B)	.009	1	.009	3.97
AXB	.004	2	.002	.81
Error	.06	27	.002	
Eye of Presentation (C)	.0002	1	.0002	3.78
AXC	.0003	2	.0002	3.25
Error	.001	27	.0001	
BXC	.0000	1	.0000	.06
AXBXC	.0001	2	.0001	1.32
Error	.001	27	.0001	

** $p < .01$.

Table 2
Means and SDs for group critical
stimulus duration intervals

<u>Group</u>	<u>Mean (ms)</u>	<u>SD</u>
mildly retarded	24.35	14.52
equal-MA	10.75	8.79
equal-CA	7.13	1.88

to examine all main (where appropriate) effects. Interaction effects were examined by calculating simple main effects. All findings reported as significant were at $p \leq .05$ or better.

Visual Modality

The number of correct recognitions was subjected to a Group (3) X Stimulus Type (2) X Mask Condition (2) X SOA (5) analysis of variance with Stimulus Type, Mask Condition and SOA being repeated variables. The analysis of variance summary table is presented as Table 2.

The main effect of Group was significant, $F_{(2,27)} = 7.68$, $p \leq .01$, indicating that the performance of both the CA- ($M = 2.74$) and MA- ($M = 2.89$) matched subjects was significantly better than that of the mildly retarded subjects ($M = 1.90$). Furthermore, the performance of the MA-matched subjects did not differ from that of the CA-matched subjects. The accuracy of performance across SOA increased, $F_{(4,108)} = 12.25$, $p \leq .001$, with significant increments for all intervals beyond 70 ms (Figure 1).

The analysis of the significant Group X SOA interaction effect, $F_{(8,108)} = 2.65$, $p \leq .05$, is presented in Table 3. Significant group differences occurred at the 120- and 220 ms SOAs (Figure 1). Furthermore, the equal-CA

Table 3
Summary of the analysis of variance
for correct recognitions

<u>Source</u>	<u>Sum of Squares</u>	<u>d.f.</u>	<u>Mean Square</u>	<u>F</u>
Group (A)	113.88	2	56.94	7.68**
Error	200.06	27	7.41	
Stimulus Type (B)	37.00	1	37.00	20.32***
AXB	0.97	2	0.49	0.27
Error	49.175	27	1.82	
Mask Condition (C)	103.335	1	103.335	52.67***
AXC	12.04	2	6.02	3.07
Error	52.975	27	1.96	
BXC	1.60	1	1.60	0.79
AXBXC	1.65	2	0.83	0.41
Error	54.495	27	2.02	
SOA (D)	106.66	4	26.665	12.25***
AXD	46.12	8	5.765	2.65*
Error	235.02	108	2.18	
BXD	9.14	4	2.285	2.18
AXBXD	7.46	8	0.93	0.89
Error	113.00	108	1.05	
CXD	49.77	4	12.44	9.08***
AXCXD	7.63	8	0.95	.70
Error	148.00	108	1.37	
BXCXD	13.97	4	3.49	2.90*
AXBXCXD	12.05	8	1.51	1.25
Error	129.98	108	1.20	

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 4
Significant group differences for each
stimulus-onset asynchrony (SOA)

<u>SOA (ms)</u>	<u>Group difference</u>
0	
20	
70	
120	MA > Ret CA > Ret
220	MA > Ret CA > Ret

Note: CA - equal-CA subjects, MA = equal-MA subjects,
Ret - retarded subjects.

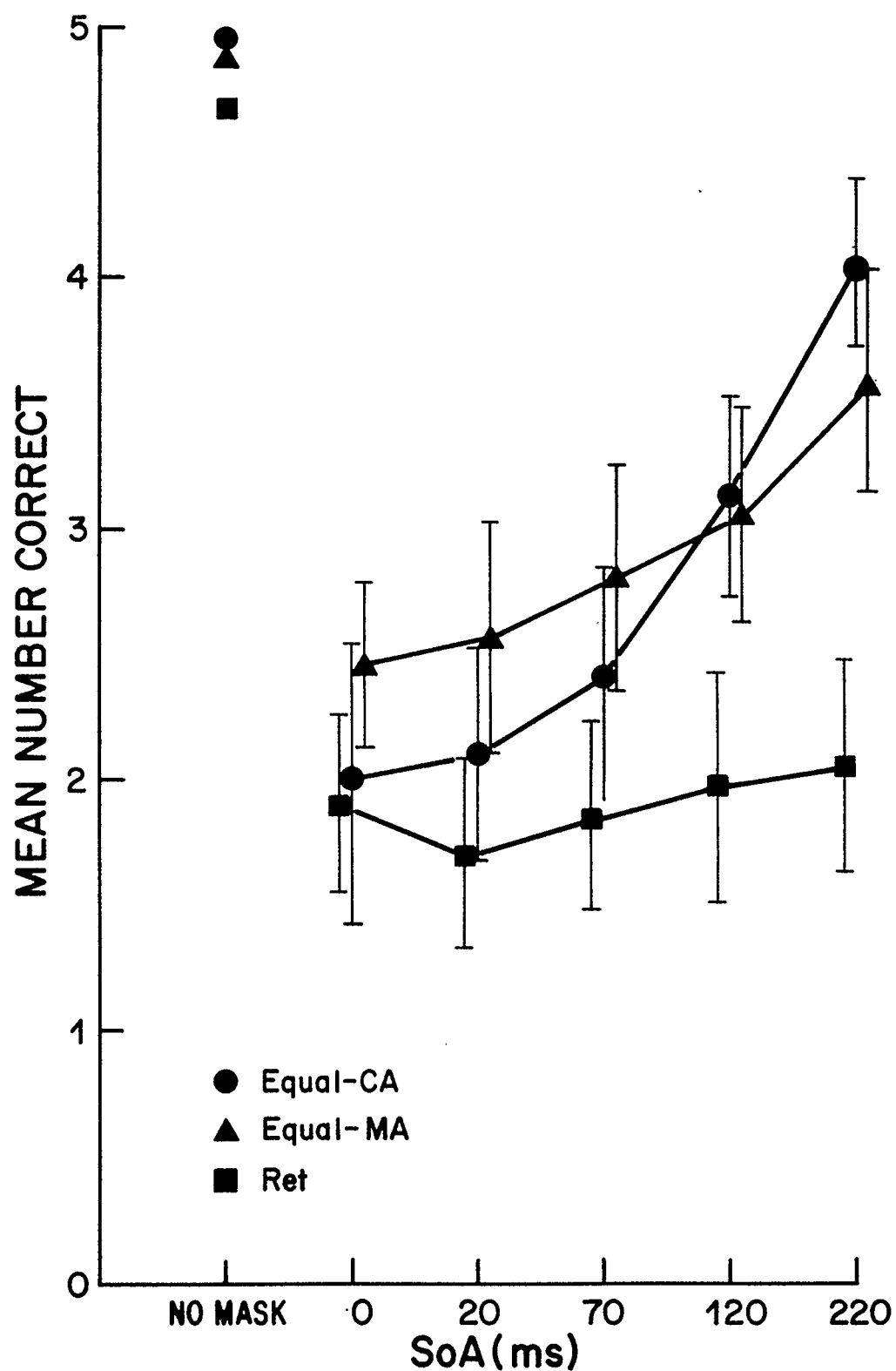


Figure 1. The mean correct recognitions for mildly retarded, equal-MA, and equal-CA groups across the five stimulus-onset asynchronies (SOAs).

subjects also performed significantly better than the mildly retarded subjects at the 120- and 220 ms SOAs. At the 120- and 220 ms SOAs there were no differences in recognition accuracy between the equal-CA and equal-MA subjects.

The equal-CA and equal-MA subjects showed significant increments in performance across SOA. However, the mildly retarded subjects' performance remained consistent at low levels relative to the other two groups and did not demonstrate any increments across SOA.

It has been suggested earlier that differences in the performance of retarded and nonretarded subjects based upon stimulus type may involve strategic differences especially when verbal and nonverbal stimuli are employed. Therefore, in order to draw any conclusions concerning a retarded specific deficit in iconic memory it is necessary to reduce the potential influence of strategic differences. As such, separate analyses of the verbal and nonverbal performances will be undertaken.

Verbal Stimuli. A Group (3) X Mask Condition (2) X SOA (5) analysis of variance with Mask Condition and SOA as repeated measures was carried out on the number of correct recognitions. The summary of this analysis of variance is presented as Table 5.

Table 5

Summary of the analysis of variance for correct
recognitions using verbal stimuli

<u>Source</u>	<u>Sum of Squares</u>	<u>d.f.</u>	<u>Mean Square</u>	<u>F</u>
Group (A)	63.05	2	31.52	5.08*
Error	167.50	27	6.20	
Mask Condition (B)	65.33	1	65.33	29.31**
AXB	5.29	2	2.64	1.19
Error	60.18	27	2.23	
SOA (C)	83.11	4	20.78	14.86**
AXC	29.09	8	3.64	2.60*
Error	151.00	108	1.40	
BXC	50.30	4	12.58	11.68**
AXBXC	10.58	8	1.32	1.23
Error	116.32	108	1.08	

** $p < .001$.

* $p < .05$.

Again, the main effect of Group was significant, $F_{(2,27)} = 5.08$, $p < .05$, indicating that the performance of both the CA- ($M = 2.95$) and MA-matched ($M = 3.19$) subjects was significantly better than that of the mildly retarded subjects ($M = 2.12$). Furthermore, as before, the MA-matched subjects did not perform significantly better than the CA-matched subjects. The accuracy of performance across SOA increased, $F_{(4,108)} = 14.86$, $p < .001$; that is, performance at the 0-, 20-, and 70-ms SOAs was not significantly different, but there were significant increments between these points and the 120- and 220-ms SOAs. Furthermore, performance at the 120- and 220-ms SOAs was significantly different (Figure 3).

The analysis of the significant Group X SOA interaction effect, $F_{(8,108)} = 2.60$, $p < .05$, is presented in Table 6. Significant group differences occurred at all SOAs except 0 and 20 ms (Figure 2). In each case, the performance of the equal-MA and equal-CA subjects was superior to that of the retarded subjects. In addition, at the 70 ms SOA, the equal-MA subjects' performance was superior to that of the equal-CA subjects. At 120 ms there was no difference in recognition accuracy between the equal-CA and equal-MA subjects, but at the 220 ms SOA the performance of the equal-CA subjects was superior to

Table 6

Significant group differences for each stimulus-onset
asynchrony (SOA) using verbal stimuli

<u>SOA (ms)</u>	<u>Group difference</u>
0	
20	
70	MA > Ret CA > Ret MA > CA
120	MA > Ret CA > Ret
220	MA > Ret CA > Ret CA > MA

Note: CA = equal-CA subjects, MA = equal-MA subjects,
Ret = retarded subjects.

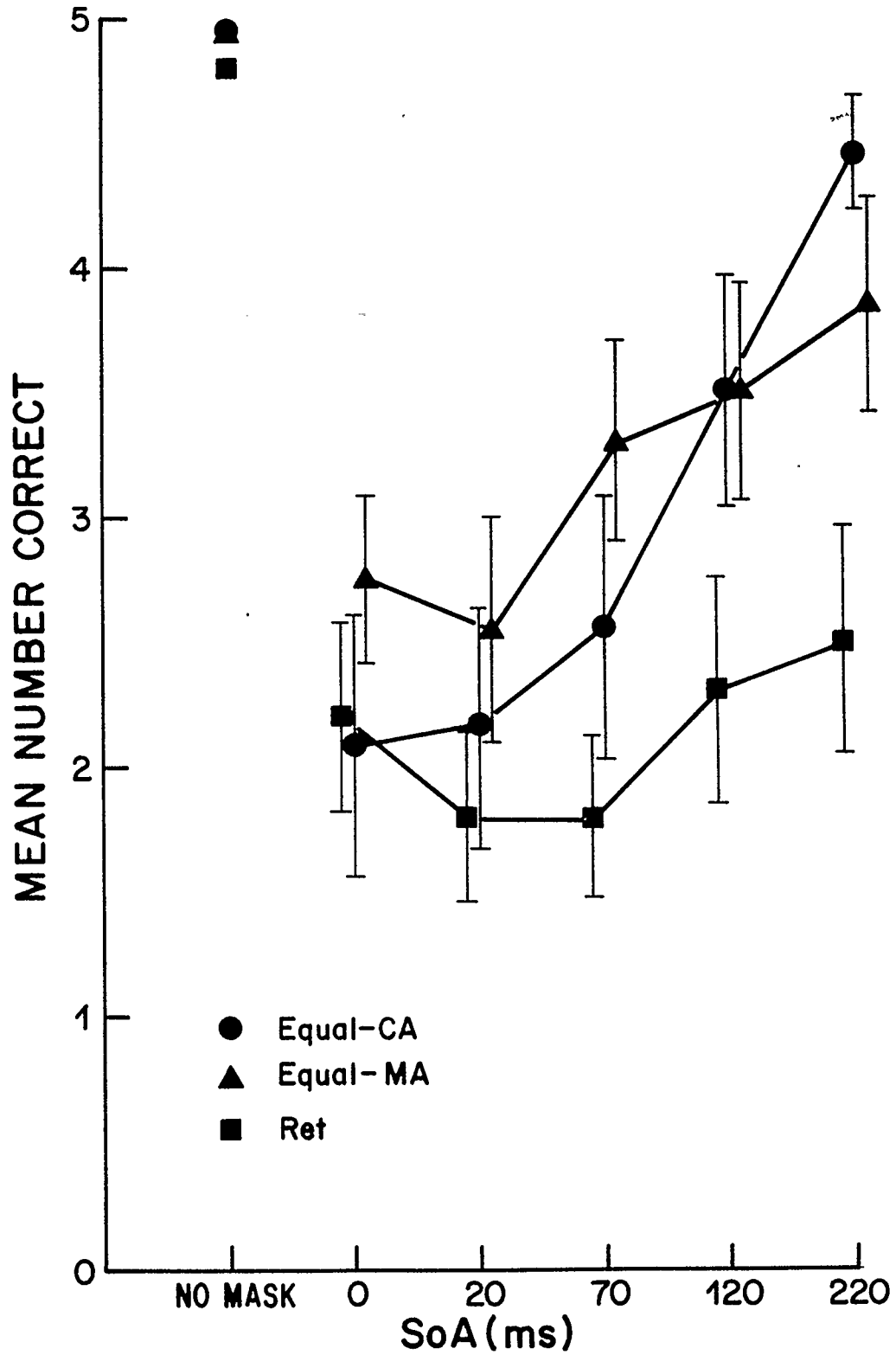


Figure 2. Mean correct recognitions for mildly retarded, equal-MA, and equal-CA groups across the five stimulus-onset asynchronies (SOAs) using verbal stimuli.

that of the equal-MA subjects.

The equal-CA and equal-MA subjects demonstrated significant increments in performance across SOA. The mildly retarded subjects showed significant performance increments only between the 20- and 220-ms and the 70- and 220-ms SOAs.

The main effect of Mask Condition, $F_{(1,27)} = 29.31$, $p < .001$, revealed that monoptic masking ($M = 2.29$) was more effective than dichoptic masking ($M = 3.22$) in impairing recognition. The significant Mask Condition X SOA interaction effect, $F_{(4,108)} = 11.68$, $p < .001$, demonstrated that at the 0-, 20-, and 70-ms SOAs recognition accuracy under the monoptic masking condition was inferior to that under the dichoptic masking condition (Figure 3). At the 120- and 220-ms SOAs there were no significant performance differences. For the dichoptic masking condition there was a significant decrement in performance from the 0- to 20-ms SOA and then a significant increase from the 20- to 220-ms SOA. No other increments were significant across SOA. In the monoptic masking condition all increments were significant except for the changes between 0- and 20 ms, 20- and 70 ms, and 120- and 220 ms SOAs.

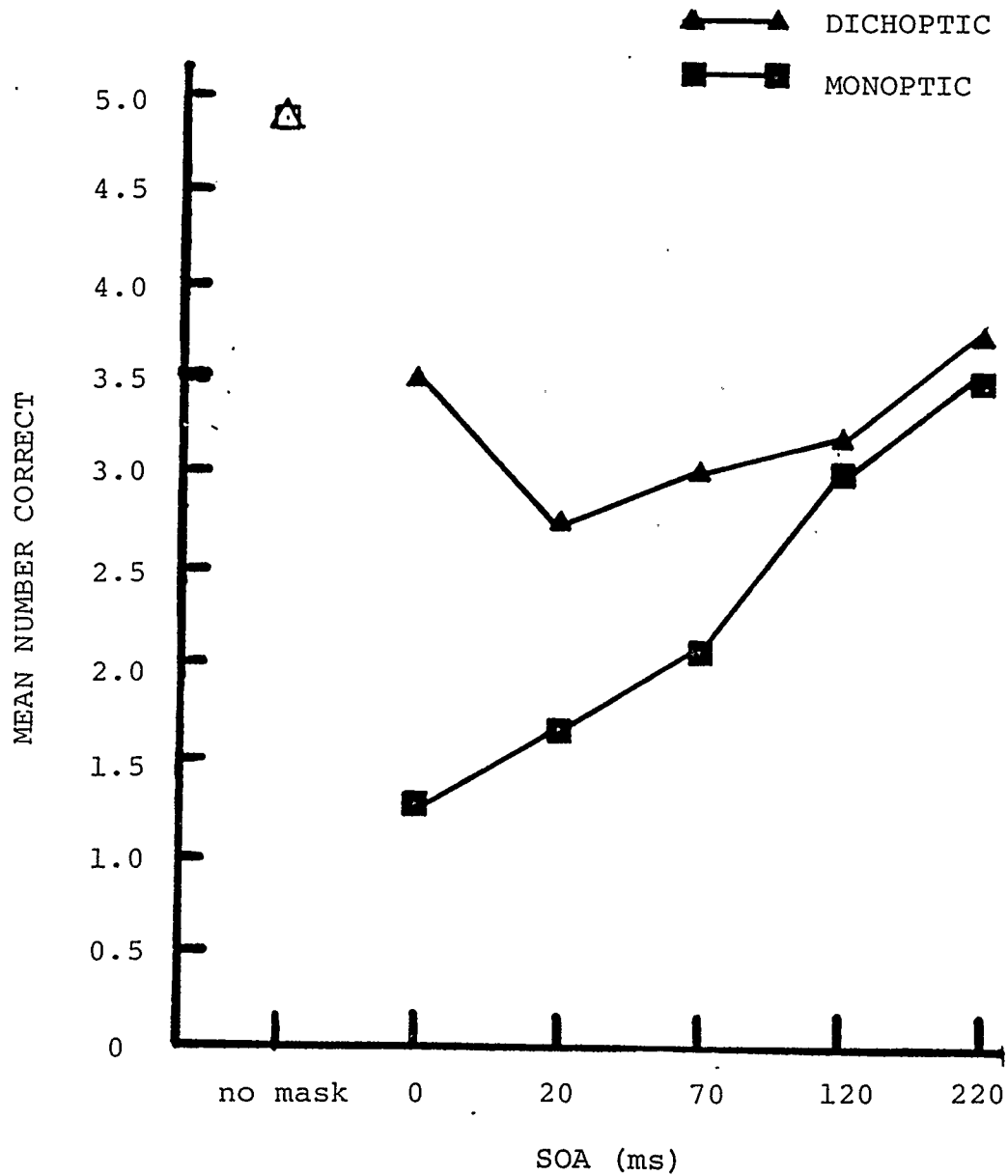


Figure 3. Mean correct recognitions under the dichoptic and monoptic masking conditions, across the five stimulus-onset asynchronies (SOAs) using verbal stimuli.

Nonverbal Stimuli. A second Group (3) X Mask Condition (2) X SOA (5) analysis of variance with Mask Condition and SOA being the repeated variables was carried out on the correct recognitions with the nonverbal stimuli. The summary of this analysis of variance is presented as Table 7.

The main effect of Group was significant, $F_{(2,27)} = 8.56$, $p < .01$, indicating that the performance of both the equal-CA ($\underline{M} = 2.52$) and equal-MA ($\underline{M} = 2.58$) subjects was significantly better than that of the mildly retarded ($\underline{M} = 1.67$) subjects. The accuracy of performance across SOA (Figure 6) increased, $F_{(4,108)} = 4.48$, $p < .01$, with significant increments between all points and 220 ms SOA. Interestingly, there was no significant Group X SOA interaction. The only other significant result was the main effect of Mask Condition, $F_{(4,108)} = 4.48$, $p < .01$, which indicated that performance under monoptic masking ($\underline{M} = 1.89$) was inferior to that under dichoptic masking ($\underline{M} = 2.62$).

Returning to the overall analysis of variance (Table 2), verbal stimuli ($\underline{M} = 2.75$) were recognized more accurately than nonverbal stimuli ($\underline{M} = 2.26$), $F_{(1,27)} = 20.32$, $p < .001$, and monoptic masking ($\underline{M} = 2.09$) was more effective than dichoptic masking ($\underline{M} = 2.61$) in impairing recognition,

Table 7

Summary of the analysis of variance for
correct recognitions using nonverbal stimuli

<u>Source</u>	<u>Sum of Squares</u>	<u>d.f.</u>	<u>Mean Square</u>	<u>F</u>
Group (A)	51.81	2	25.90	8.56*
Error	81.73	27	3.03	
Mask Condition (B)	39.60	1	39.60	22.61*
AXB	8.41	2	4.20	2.40
Error	47.29	27	1.75	
SOA (C)	32.69	4	8.17	4.48*
AXC	24.49	8	3.06	1.68
Error	197.02	108	1.82	
BXC	13.45	4	3.36	2.25
AXBXC	9.09	8	1.14	0.76
Error	161.66	108	1.50	

* $p \leq .01$.

$F_{(1,27)} = 52.67$, $p < .001$. Furthermore, the significant Mask Condition X SOA interaction effect, $F_{(4,108)} = 9.08$, $p < .001$, revealed that at the 0-, 20-, and 70-ms SOAs recognition accuracy under the monoptic masking condition was inferior to that under the dichoptic masking condition (Figure 4). At the 120- and 220-ms SOAs there were no significant performance differences. For the dichoptic masking condition there were no differences in performance between the 0-, 20-, 70-, and 120-ms SOAs, but all these points were significantly different from the 220-ms SOA. For the monoptic masking condition, with the exception of the increment from 0 to 20 ms, all other increments were significant across SOA.

Auditory Modality

The number of correct recognitions was analyzed to examine the cerebral functional asymmetry of the equal-MA, equal-CA and mildly retarded groups in the context of a potential verbal processing advantage enjoyed by nonretarded individuals. The auditory modality was selected to vitiate some of the inherent methodological difficulties arising from the assessment of hemispheric laterality using the visual modality. In addition, the number of correct rejections was analyzed to assess the potential for guessing in the auditory task.

The number of correct recognitions was subjected to a

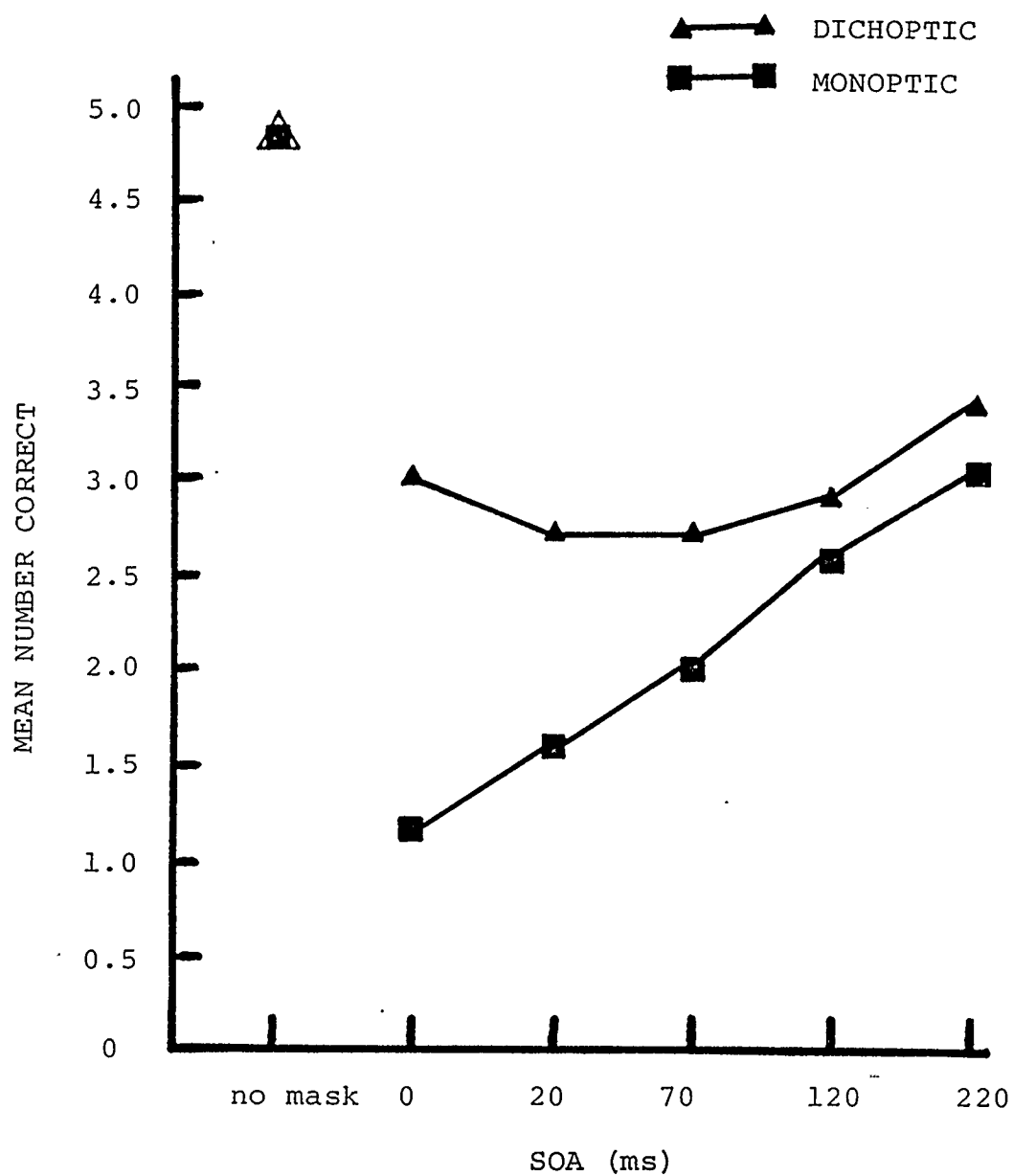


Figure 4. The mean correct recognitions under the dichoptic and monoptic masking conditions across the five stimulus-onset asynchronies (SOAs).

Group (3) X Stimulus Type (2) X Ear of Presentation (2) analysis of variance with Stimulus Type and Ear of Presentation being the repeated measures. The summary of this analysis of variance is presented as Table 8.

The main effect of Group was significant, $F_{(2,27)} = 83.63$, $p < .001$, indicating that the performance of both the equal-CA ($M = 10.48$) and equal-MA ($M = 9.98$) subjects was significantly better than that of the mildly retarded ($M = 8.28$) subjects. Furthermore, the equal-CA subjects performed significantly better than the equal-MA subjects.

Verbal material ($M = 9.76$) was correctly recognized more accurately than nonverbal material ($M = 9.38$), $F_{(1,27)} = 18.10$, $p < .001$. The significant Group X Stimulus Type interaction effect, $F_{(2,27)} = 6.71$, $p < .001$ indicated that both the equal-CA and equal-MA subjects performed more accurately with the verbal (equal-CA $M = 10.85$; equal-MA $M = 10.20$) than the nonverbal (equal-CA $M = 10.10$; equal-MA $M = 9.75$) stimulus material while the mildly retarded subjects' (verbal $M = 8.25$; nonverbal $M = 8.30$) performance did not differ (Figure 5). Furthermore, the mildly retarded subjects' performance was poorer than that of the equal-CA and equal-MA subjects when verbal material was used in contrast to nonverbal material.

The significant Stimulus Type X Ear of Presentation interaction, $F_{(1,27)} = 220.07$, $p < .001$, suggested that verbal material was more accurately recognized when presented

Table 8
Summary of the analysis of variance
for correct recognitions

<u>Source</u>	<u>Sum of Squares</u>	<u>d.f.</u>	<u>Mean Square</u>	<u>F</u>
Group (A)	106.40	2	53.20	83.63***
Error	17.175	27	.064	
Stimulus Type (B)	4.41	1	4.41	18.10***
AXB	3.27	2	1.63	6.71***
Error	6.575	27	.244	
Ear (C)	.208	1	.208	.33
AXC	.867	2	.433	.68
Error	17.175	27	.636	
BXC	130.21	1	130.21	220.07***
AXBXC	5.07	2	2.53	4.28**
Error	15.975	27	.592	

*** $p < .001$.

** $p < .01$.

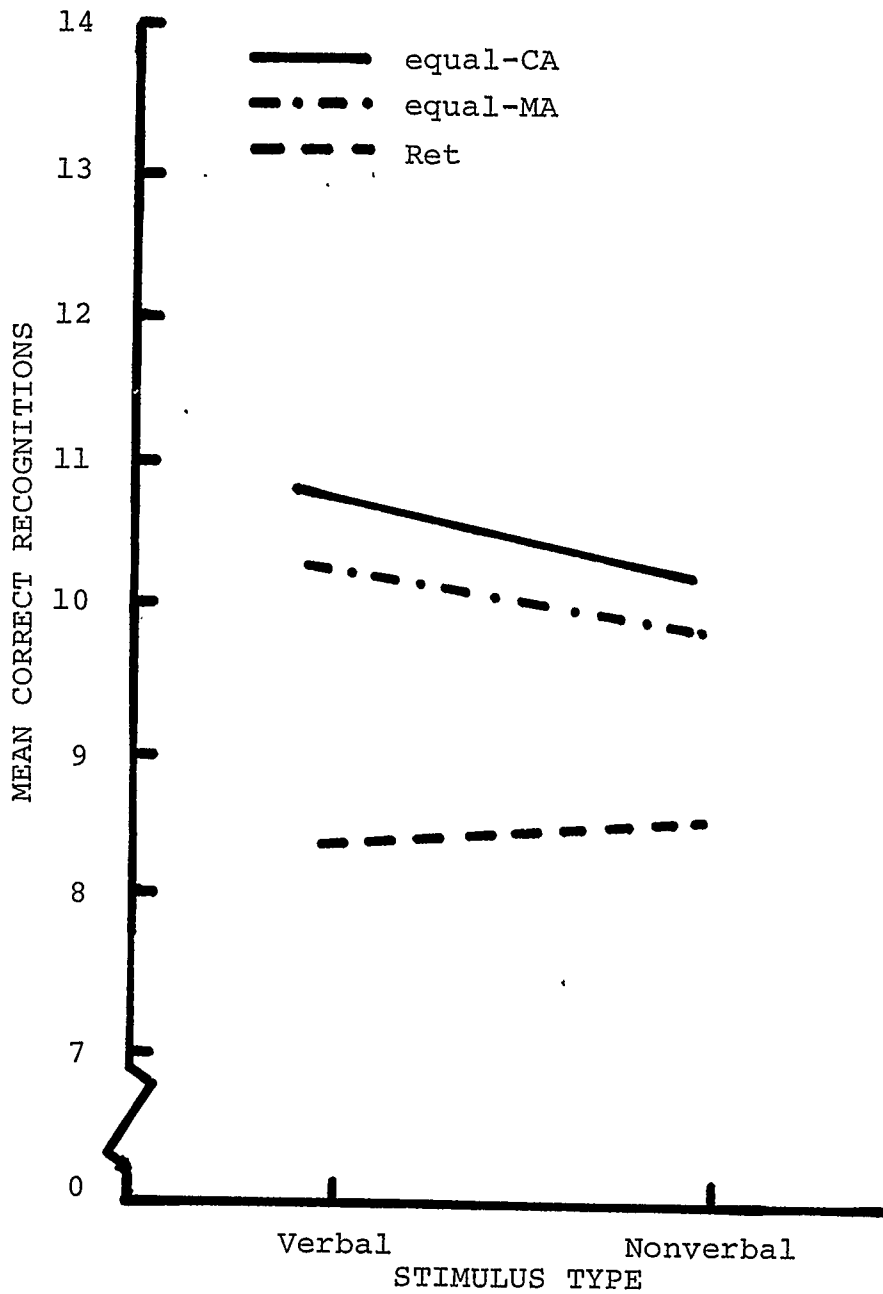


Figure 5. Mean correct recognitions for mildly retarded, equal-CA and equal-MA subjects using verbal and nonverbal stimulus material.

to the right ($\underline{M} = 10.77$) as opposed to the left ($\underline{M} = 8.77$) ear (Figure 6). Conversely, nonverbal stimuli were more accurately recognized when presented to the left ($\underline{M} = 10.47$) ear as opposed to the right ($\underline{M} = 8.30$) ear.

The Group X Stimulus Type X Ear of Presentation interaction effect was also significant, $F_{(2,27)} = 4.28$, $p < .01$. Simple main effects analyses were carried out to examine the group differences for this interaction (Figure 7). For the right ear, the verbal stimulus performance accuracy for the mildly retarded group ($\underline{M} = 9.20$) was significantly poorer than that of the equal-MA group ($\underline{M} = 10.90$) which was significantly poorer than that of the equal-CA group ($\underline{M} = 12.20$). For the nonverbal stimuli the performance of the mildly retarded group ($\underline{M} = 7.10$) was significantly poorer relative to both the equal-MA ($\underline{M} = 8.90$) and equal-CA ($\underline{M} = 8.90$) groups which did not differ.

For the left ear the verbal stimulus performance accuracy for the mildly retarded group ($\underline{M} = 7.30$) was significantly poorer than that of both the equal-MA ($\underline{M} = 9.50$) and equal-CA ($\underline{M} = 9.50$) groups which did not differ. For the nonverbal stimuli the performance of the mildly retarded group ($\underline{M} = 9.50$) was significantly poorer than that of both the equal-MA ($\underline{M} = 10.60$) and equal-CA ($\underline{M} = 11.30$) groups which did not differ.

The number of correct rejections was subjected to a Group (3) X Stimulus Type (2) analysis of

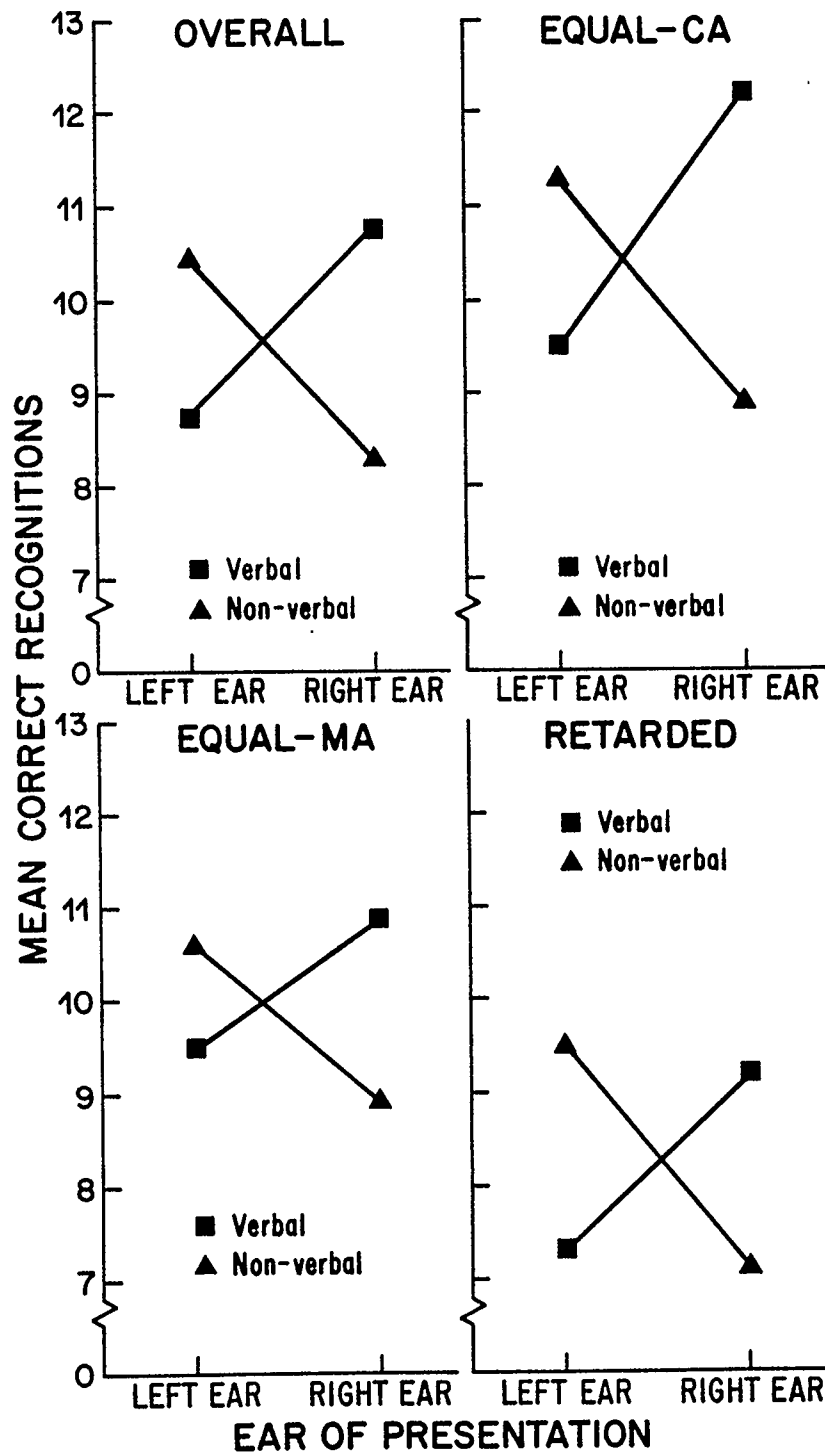


Figure 6. Mean correct recognitions for verbal and nonverbal stimulus material across left and right ears overall and for all three groups.

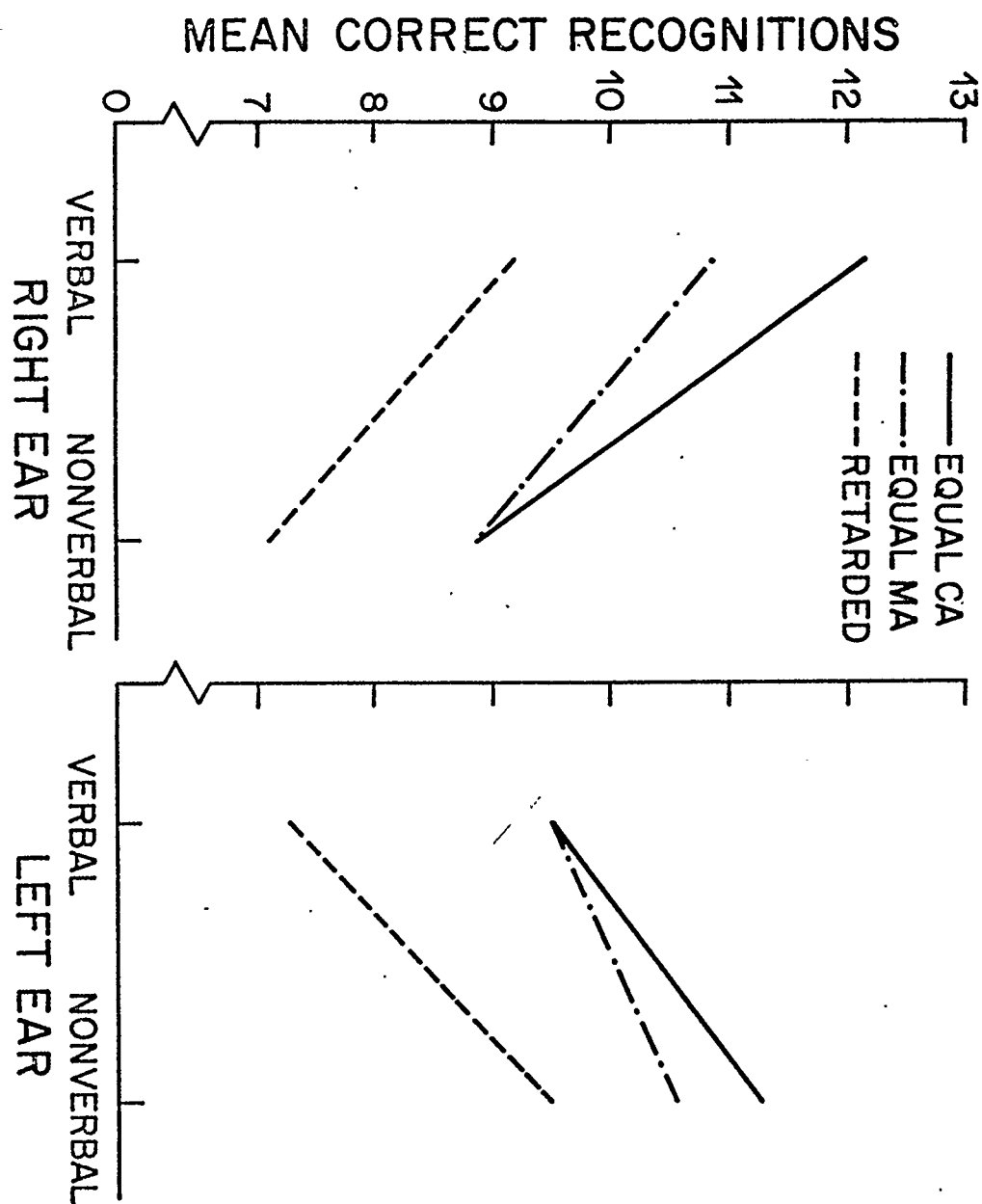


Figure 7 . Mean correct recognitions using verbal and nonverbal stimulus material across left and right ears for equal-CA, equal-MA and mildly retarded subjects.

variance with Stimulus Type being the repeated measure. The analysis of variance summary table is presented as Table 9.

The main effect of Group was the only significant finding, $F_{(2,27)} = 49.84$, $p < .001$, indicating that the performance of both the equal-CA ($M = 21.65$) and equal-MA ($M = 21.85$) subjects was significantly better than that of the mildly retarded ($M = 16.45$) subjects. Furthermore, the equal-CA and equal-MA subjects' performance was not significantly different.

Out of a total of 28 correct rejections the CA-matched group achieved a proportion correct of .77, the MA-matched group .78 and the mildly retarded group .58. The mildly retarded group's low proportion of correct rejections indicated that they were indeed having some difficulty with the task.

Sorting Task

Subjects were asked to sort 180 cards consisting of targets and non-targets into three piles of roughly equal number and then to describe the characteristics of each pile.

All subjects in the equal-CA group were able to construct three categories based on the characteristics of the stimuli, but were unable to consistently label the shapes verbally. Only five of the equal-MA subjects

Table 9
Summary of the analysis of variance
for correct rejections

<u>Source</u>	<u>Sum of Squares</u>	<u>d.f.</u>	<u>Mean Square</u>	<u>F</u>
Group (A)	374.93	2	187.47	49.84***
Error	101.55	27	3.76	
Stimulus Type (B)	0.15	1	0.15	.05
AXB	12.40	2	6.20	2.26
Error	73.95	27	2.74	

*** $p < .001$.

employed categories based on stimulus characteristics, while the remainder could not say and simply placed the cards into the piles in a random fashion. Of the ten retarded subjects, six were unable to describe their sorting categories, three placed the polygons into their respective piles based on position on the table, and only one employed categories dependent on characteristics of the stimuli.

CHAPTER IV

DISCUSSION

Critical Target Duration Interval

The mildly retarded subjects in this study required longer critical target durations for criterion performance than did the equal-CA and equal-MA control groups which did not differ. Furthermore, these group differences were consistent regardless of the type of stimulus (i.e., verbal vs. nonverbal). These results support those obtained by Saccuzzo et al. (1979) who observed that both the minimum stimulus duration for criterion accuracy and the minimum interval between presentation of a target and presentation of a masking stimulus were longer in mildly retarded subjects than in controls matched for CA and MA. Saccuzzo et al. (1979) interpreted their findings as indicating that the limitations in the early stages of information processing in mildly retarded persons cannot be explained on the basis of low mental age. They suggested that the significantly longer stimulus durations required by the mildly retarded groups indicated a reduced input capability and thus supported the existence of a deficiency at the level of processing encompassed by iconic storage.

Stanovich and Purcell (1981a) challenged Saccuzzo et al.'s conclusions by highlighting some conceptual and methodological problems. For example, the failure to manipulate variables known to affect icon capacity and encoding rate obviated the possibility of obtaining the crucial interactions that would have been indicative of an association between mild retardation and iconic memory processing deficits. Stanovich and Purcell (1981a) suggested that Saccuzzo et al. (1979) only demonstrated a task performance difference between the mildly retarded and the equal-MA and equal-CA subjects but did not convincingly make a case for the existence of deficiencies in the iconic memory functioning of mildly retarded individuals. Saccuzzo (1981) responded to Stanovich and Purcell (1981a) by challenging some of their speculations and incorrect interpretations and concluded that the poor minimum stimulus duration performance of the mildly retarded subjects may have been due to input limitations, but noted that the issue of specific iconic memory deficits in the mildly retarded can only be resolved by a consensus of evidence in the literature.

As has been noted earlier, a review of the literature does not lead to unequivocal conclusions concerning the existence of specific iconic memory deficits in the mildly

retarded. The present findings, nonetheless, do support Saccuzzo et al.'s (1979) suggestion of the existence of a quantitative input limitation for mildly retarded subjects, which is not explainable by low mental age alone since the mildly retarded subjects in the present study required longer target durations than did their MA-matched controls.

Interestingly, Stanovich (1978) and Stanovich and Purcell (1981a) have criticized many of the previous studies for their bias toward the use of alphanumeric stimuli because the performance of mildly retarded individuals is systematically underestimated when such stimuli are employed as a result of differential experience in favour of nonretarded individuals. In the present study, nonverbal and verbal stimuli were used and even under these circumstances the mean critical target duration intervals required by the mildly retarded subjects to reach criterion accuracy were longer than those for the equal-CA and equal-MA subjects.

A plausible explanation for the inferior performance of the mildly retarded subjects comes from two sources. First, Mosley (1980), Saccuzzo (1981) and Stanovich and Purcell (1981a) have suggested that the mildly retarded may be less able than their MA- and CA- matched peers to hold onto the potentially salient features of the stimulus event

that could serve as cues for the recognition task. It is probable that the mildly retarded subjects were inefficient in the feature extraction process and therefore demonstrated poor recognition performance relative to the equal-CA (and perhaps the equal-MA) subjects.

Second, Nettelbeck and Lally (1976) and Lally and Nettelbeck (1977) have highlighted slower perceptual processes in the mildly retarded using reaction time tasks. Silverman (1974) further concluded, using a memory-scanning paradigm with non-alphanumeric, letter-like, geometric forms, that the mildly retarded subjects' memory comparison is similar qualitatively to that of the nonretarded, although at a much slower rate. Silverman's (1974) data, however, must be interpreted cautiously. Dugas and Kellas (1974) have also demonstrated slower memory-scanning rates in the mildly retarded. Moreover, Mosley (in press) has provided indirect support for the conclusion that the significantly slower choice mean reaction times for the errorless performance demonstrated by the mildly retarded group may be due to the binary decision process. That is, the mildly retarded subjects were significantly slower to respond to Chinese characters relative to English letters. In addition, in responding to Chinese characters the NO responses were significantly slower than the YES responses.

This suggested that mildly retarded subjects may have been less certain of their correct Chinese character responses relative to their correct English letter responses and least certain of their correct NO Chinese character responses independent of process differences in memory scanning or encoding "per se". Since a correct response was required in Mosley's (in press) study, the lack of certainty should lead to longer mean choice reaction times. Such was the case.

Taken together, less efficient feature extraction would lead to less certainty with respect to response decision which, in turn, would be reflected in longer critical target duration intervals.

Establishing the critical target duration interval in the current study was intended to ensure that all subjects had sufficient sensory input upon which to base the information processing. As such, factors thought to influence icon formation time (e.g., ability to fixate on the stimulus; importance and/or use of fragmentary stimulus information in making recognition/recall responses) were not manipulated. Therefore, the longer critical target durations required by the mildly retarded subjects do not necessarily implicate deficits in iconic memory "per se". The critical target duration findings suggest that the

nature and magnitude of the memory impairment shown by the mildly retarded subjects may be a consequence of a control process which influences perceptual/response organization (Borkowski, Peck & Damberg, 1983; Detterman, 1979; Lewis, 1971; Posner, 1982). Future studies which attempt to investigate the nature of iconic memory in mildly retarded subjects must control for the factors thought to influence icon formation time.

Visual Modality

The use of a backward visual masking (monoptic) paradigm in combination with a manipulation of the SOA parameter were employed to examine temporal features of iconic memory. The significant Group X SOA interaction effect revealed that significant group differences occurred at the 120 and 220 ms SOAs. An examination of this effect for each stimulus type follows (rationale p. 132).

Verbal Stimuli. Consistent with Felsten and Wasserman (1980), it appears that the subject's scan of the word in the sensory register yields information that is degraded as a result of the integration of the target and the monoptic mask which produces a consequent reduction in the signal-to-noise ratio at the shorter SOAs. As the SOAs increased, all groups showed a recovery of performance and,

at the 220 ms SOA, the equal-CA subjects' performance was superior to that of the equal-MA subjects.

In the current context, the relatively poor performance of the mildly retarded subjects at the shorter SOA could be due to an inefficiency in their ability to hold onto the potentially salient features of the stimulus event which could serve as cues for recognition of the words before the monoptic mask arrived. Mildly retarded subjects have consistently demonstrated a failure to durably encode stimuli (Borkowski, Peck, & Damberg; 1983; Stanovich, 1978) and to produce efficient strategies for learning/remembering (Brown, 1974; Borkowski & Wanschura, 1974). Support for this interpretation was demonstrated when the mildly retarded subjects were not time-limited in their processing of nonverbal stimuli (i.e., the sorting task). Performance on the sorting task revealed that only one of the mildly retarded subjects employed sorting categories that were based upon verbalizing the features of the nonverbal stimuli (e.g., like a box, like a triangle). These findings suggest that the mildly retarded subjects may not have durably encoded the stimulus features when the task time was open-ended. In time-limited situations, therefore, it would not be reasonable to assume that they would shift their strategy.

The poorer performance of the mildly retarded and equal-MA subjects at the longer SOAs is not likely related to the influence of the monoptic mask, since responding at these SOAs was well above the chance level for all groups. When a stimulus is presented and processing time is interfered with by the monoptic mask, the subject must employ a strategy that will keep the target stimulus active in the short-term memory. Therefore, the strategy employed must bridge this variable retention interval. In the case of the equal-MA subjects the strategy is less efficient relative to the equal-CA group, but significantly more efficient relative to that of the mildly retarded group.

The extremely poor performance of the mildly retarded subjects at the longer SOAs suggests that they were not able to keep the relevant information active for a long enough period so that the relevant cues for recognition could be accessed from previously stored information. If the mildly retarded subjects were using some kind of ephemeral visual code, the increase of SOA would be accompanied by a decay of the information available for use and the observed poor performance at the longer SOAs. This would suggest an inadequacy in the encoding processes used by the mildly retarded subjects.

The performance superiority of the equal-MA subjects

relative to that of the equal-CA subjects disappeared at the 120 and 220 ms SOAs. This is consistent with evidence which suggests that visual information processing in children and adults is comparable (e.g., Lawrence, Kee, & Hellige, 1980) until processes such as rehearsal become pre-eminent (i.e., at longer SOAs). It has been suggested that at such a time children are less efficient relative to adults (Chi, 1976; Kail & Hagen, 1977).

Nonverbal Stimuli. The nonverbal stimuli consisted of polygons (after Vanderplas & Garvin, 1959). When the geometric shapes served as the target stimuli, the Group X SOA interaction was not significant. At this point, only group performance differences were evident with the equal-CA and equal-MA subjects performing significantly better than the mildly retarded subjects.

When verbal stimuli are presented to equal-CA subjects, verbal encoding is usually immediately attempted. However, when nonverbal stimuli are employed the subject may attempt to verbally encode the stimulus first, but this being unsuccessful, may then abandon verbal encoding. This would negatively bias the performance of equal-CA subjects at short SOAs since it would require processing time to switch between verbal and visual encoding. A more effective strategy may involve some combination of verbal and visual

encoding, depending on the nature of the nonverbal stimuli.

The existence of the Group X SOA interaction with verbal stimuli and its absence when nonverbal stimuli were employed suggests that stimulus type may be a significant variable in the poor performance demonstrated by the mildly retarded subjects. This statement must be qualified with the caveat that the main analysis failed to reveal a significant Group X Stimulus Type X SOA interaction effect. Furthermore, even though each subject was given sufficient viewing time (critical target duration interval), mildly retarded-nonretarded performance differences were still evident. This further supports the view that stimulus type is a significant contributor to such performance differences.

The current interpretation is also consistent with results obtained by Hornstein and Mosley (1979) and Mosley (1980). Further, Stanovich (1978) and Stanovich and Purcell (1981a, b) have stated that group performance differences as demonstrated by main effects could be due to a variety of nonspecific factors such as attentiveness, motivation, stereotypic response patterns, inconsistent strategy selection, failure to inhibit incorrect verbal responses, and failure to maintain optimum performance levels (see also Ryan & Jones, 1975). Furthermore, these

authors have suggested that it may be more fruitful to examine control processes rather than the structural (memory) differences between retarded and nonretarded subjects.

With verbal stimuli at the longer SOA the equal-MA subjects appeared to have used a less efficient strategy relative to the equal-CA subjects. When nonverbal stimuli were used, the overall performance accuracy of the equal-CA and equal-MA groups decreased but was comparable. This again emphasizes the importance of stimulus type.

When the equal-CA group was exposed to verbal stimuli, they attempted an encoding strategy which impaired their performance relative to the equal-MA group at the shorter SOA (70 ms). At the longer SOAs the equal-CA group started to show a recovery of performance as they had more time to utilize their strategy, and at the longest SOA showed superior performance relative to the other two groups. Support for this interpretation was also demonstrated when the equal-CA subjects attempted to employ sorting categories that were based upon features of the nonverbal stimuli. This seems to indicate that the equal-CA subjects attempted to durably encode the stimulus features, but at the shorter SOA they had insufficient processing time for successful completion of the process.

When verbal stimuli were used, it seems that strategic behaviour contributed most heavily to the existence of group performance differences. The lack of any Group X SOA interaction effect with nonverbal stimuli highlighted the importance of the role of and need to control for stimulus type in any interpretation of information processing differences.

In summary, with verbal stimuli the mildly retarded subjects consistently demonstrated significantly inferior performance relative to that of the equal-MA and equal-CA groups. Furthermore, the lack of any Group X SOA interaction effect when nonverbal stimuli were employed leads to the conclusion that stimulus type is a significant contributor to the inferior performance of the mildly retarded group.

In addition, the monoptic backward visual masking curves produced by varying SOA revealed that the mask had its most significant effect at the short SOAs (0-70 ms) for all three groups. At the longer SOAs (120 and 220 ms), there was a recovery of performance, although for the equal-MA and mildly retarded groups, this recovery did not reach no-mask levels. However, the increase in response accuracy across SOA is consistent with the literature which

suggests that the duration of iconic storage is approximately 250 ms under normal viewing conditions.

Backward Visual Masking and Iconic Memory

The dichoptic/monoptic backward visual masking procedures were employed to examine the locus of iconic memory (peripheral vs. central). For all groups monoptic masking was more effective than dichoptic masking suggesting that more retinal processes were implicated in the locus of iconic memory.

The current shape of the monoptic function is consistent with that obtained in previous research (i.e., masking magnitude decreases monotonically as the absolute SOA value increases) and resembles a "Type A" masking effect. The shape of the dichoptic masking function most resembles that of a "Type B" masking effect (i.e., the masking magnitude varies in a nonmonotonic, U-shaped fashion - Breitmeyer & Ganz, 1976). It seems somewhat contradictory that the monoptic masking effect should focus on retinal processes whereas the existence of a U-shaped function (dichoptic masking) is consistent with the interruption theory which is a more central phenomenon. However, the U-shaped function does not necessarily implicate more central mechanisms. Breitmeyer & Ganz

(1976) have suggested that U-shaped functions, which have been obtained monoptically, and dichoptically, do not necessarily depend upon interruption theories, since the integration of excitatory processes activated by the target and inhibitory processes activated by the mask can also produce U-shaped functions.

The monoptic masking curve obtained in the present study, revealed that the mask significantly impaired recognition at the short SOAs (0, 20, and 70 ms). In monoptic masking the target and mask shared receptors and, at these SOAs, the TS and MS overlapped or fell into a temporal frame such that target-mask integration was most significant and most likely involved more retinotopic processes.

In contrast, the dichoptic masking did not affect response accuracy as much as monoptic masking. It appears that enough retinal processing occurred such that when the inputs from the two eyes were combined at a more central locale, the dichoptic mask did not have as much impact. This, of course, does not necessarily mean that iconic memory is solely a retinally fixed phenomenon. Indeed, Haber (1983) in a thought-provoking and controversial re-evaluation of the iconic memory literature has suggested that since the visual world which provides the stimuli for

perception is continuous and not chopped up by tachistoscopes, and since our eyes and head are rarely motionless, no realistic circumstances exist in which having a frozen iconic storage of information could be useful. Rather, he suggests that the presence of such an icon interferes with perception and it may be more beneficial to discard the concept of the icon.

Nonetheless, in an open peer commentary on Haber's (1983) comments Adelson (1983), Allik and Bachman (1983), Banks (1983), Breitmeyer (1983), Bridgeman and Mayer (1983), DiLollo (1983), Goldberg (1983), Hauske, Wolf, and Deubel (1983), Jonides (1983), Meyer (1983), and Navon (1983) have all suggested that Haber's (1983) view of the icon as a series of static pictures is too simplistic. For example, Allik and Bachman (1983) suggest that there is a need in vision for the storage of sequential visual inputs since visual processing takes time and consequently at every stage of processing it is necessary to preserve previously computed results. They suggest that the iconic store is such a stage. Banks (1983) and Jonides (1983) have suggested that there are two forms of persistence. One is tied to retinal coordinates and is subject to masking by stimulation locked to retinal coordinates. The other is spatiotopic and preserves poststimulus images in

spatial coordinates. They indicate that rather than adopting a restricted retinotopic view of the icon, it is plausible to see iconic storage as a process that codes information by spatial and perhaps also retinotopic coordinates. Indeed, such a dual-stage process of iconic memory has been suggested earlier and by Breitmeyer and Ganz (1976) who have distinguished between a peripheral icon (ISp) which is more peripheral, preconscious sensory processing and a central icon (ISc) which is more cortical, synthetic, contour forming processing. What backward visual masking serves to do is impair visual processing at the ISp, particularly at short SOAs, and prevents the transfer of visual information (retinotopic and spatiotopic) to the ISc. As the time interval between target and mask presentation increases, progressively more information is passed on to the ISc before the mask arrives and interferes with the peripheral (i.e., retinotopic) processing. Nonetheless, visual information passed on to the ISc remains unaltered, and is reflected by an increase in response accuracy across time. Dichoptic masking is less effective because sufficient retinotopic and spatiotopic information is passed on to the ISc and is resistant to masking.

In summary, all current views of iconic memory are

moving away from a restrictive snap-shot conceptualization. What emerges is a multi-functional approach to iconic memory which has retinotopic and spatial components, but may also reflect a variety of forms of persistence, involving various levels of visual processing. Nonetheless, the masking data obtained in the present study suggest that retinal processes are preeminent over central processes in explaining the primary processing locale for iconic memory. Moreover, all three groups performed similarly under the dichoptic and monoptic masking conditions, suggesting that the "locale" of iconic memory for all three groups is similar. The absence of a Group X Mask Condition and/or a Group X Mask Condition X SOA interaction effect suggests that the masks seemed to operate similarly for all three groups.

Auditory Modality

In the present study both verbal and nonverbal stimuli were employed to examine the influence of stimulus type in the context of iconic memory processing. In addition, the question of a potential verbal advantage enjoyed by nonretarded individuals (equal-CA and equal-MA groups) was assessed through the use of a dichotic listening task. This task was chosen because of some procedural

difficulties inherent in the tachistoscopic presentation of stimuli to the visual hemifields. Specifically, in order to ensure that information from one visual field is initially projected only to the contralateral hemisphere, the stimulus must be presented to the right or left of fixation. Furthermore, the greater the retinal eccentricity the less likely is information to be received by the ipsilateral hemisphere. However, it has been demonstrated that visual acuity decreases with increases in retinal eccentricity (Banks & Barber, 1977; Brown, Graham, Leibowitz & Ranken, 1953; Mote & Keeseey, 1973). Therefore, if one attempts to ensure reception of information by the contralateral hemisphere by using larger retinal eccentricities, the legibility of the information is likely to be low, and this would confound any measurements of accuracy. Another problem flows from the above considerations. That is, in order to ensure that visual information is presented to the left or right of fixation it is necessary to have the eyes consistently fixated. Thus, it becomes critical to monitor eye movements, since any displacements will affect which hemisphere receives the input and potentially contaminate the data. It is difficult to ensure visual fixation.

All groups demonstrated the expected left ear advantage

for nonverbal stimuli and right ear advantage for verbal stimuli. However, in all cases, the performance of the mildly retarded subjects was significantly poorer than that of the equal-CA and equal-MA groups. Furthermore, verbal material was correctly recognized more accurately than nonverbal material by the equal-MA and equal-CA subjects, but not by the mildly retarded group.

These data suggest that mildly retarded subjects are less efficient in the processing of verbal stimuli and further highlight the need to consider stimulus type (i.e., verbal-nonverbal) when investigating any potential processing differences between mildly retarded and nonretarded groups.

In addition, correct rejections were analyzed separately to assess the extent to which guessing contributed to the results. Any subject's ability to correctly reject means that he/she has to accurately recognize the item and then compare it to the probe item in order to say whether it is the same or different. By chance alone, the proportion of correctly rejected items would be .50. The mildly retarded group's low proportion of correct rejections (proportion correct rejections=.58) indicated that they were indeed having some difficulty with

the task relative to the equal-CA and equal-MA groups (.77 and .78 respectively).

Conclusions

The significantly longer critical target duration intervals required by the mildly retarded subjects relative to the equal-MA and equal-CA groups suggests the inefficient operation of feature extraction (encoding) combined with response uncertainty. Both processes focus on the control aspect of the memory system, as opposed to the structural aspect.

With verbal stimuli the mildly retarded subjects demonstrated significantly inferior performance relative to that of equal-MA and equal-CA groups. It was suggested that the mildly retarded subjects were not able to durably encode the stimulus features. Furthermore, the lack of a Group X SOA interaction effect when nonverbal stimuli were employed supported the conclusion that stimulus type may be a significant contributor to the poor performance of the mildly retarded individuals.

The increase in response accuracy across time which was demonstrated when the monoptic backward visual masking paradigm was employed was consistent with the literature suggesting that the duration of iconic storage is

approximately 250 ms under normal viewing conditions. The three groups of subjects performed similarly in that there was an increment in performance accuracy across time in the monoptic backward visual masking paradigm.

The current masking data suggested that retinal processes were preeminent over central processes in explaining the primary processing locale for iconic memory. This was a consistent finding regardless of the group being examined.

The dichotic listening task performance revealed that mildly retarded individuals are less efficient in the processing of verbal stimuli and further highlighted the need to consider the influence of stimulus type when investigating processing differences between mildly retarded and nonretarded groups.

Since the three groups differed qualitatively only in those situations in which control processes were most important it seems more profitable to investigate those processes rather than any theoretical structural differences.

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APPENDIX A

Means and SD's for group performance with verbal and nonverbal stimuli under: (1) dichoptic and monoptic visual masking conditions, (2) left and right ear auditory presentations

Subject	Visual-Verbal				Visual-Nonverbal				Auditory-Verbal				Auditory-Nonverbal			
	Dichoptic		Monoptic		Dichoptic		Monoptic		Left Ear		Right Ear		Left Ear		Right Ear	
	M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	S.D.
C.A.	1.6	.81	2.0	1.0	2.3	.94	1.6	.96	8.0	.83	13.0	1.01	12.0	.68	8.0	.90
	5.0	.32	4.8	.28	3.2	1.04	2.6	.35	10.0	.64	11.0	1.25	11.0	.71	9.0	1.00
	4.6	.35	2.8	.94	1.6	.96	2.4	.96	10.0	.62	12.0	.82	12.0	.86	8.0	1.10
	1.8	1.30	2.8	.94	2.0	1.48	2.4	1.15	9.0	.56	14.0	1.10	11.0	.36	10.0	.54
	3.6	.35	2.6	1.46	3.2	.82	2.0	1.0	9.0	1.12	13.0	1.0	11.0	.64	10.0	.52
	2.2	.89	2.8	.94	3.4	.72	2.0	1.18	10.0	.57	13.0	.88	11.0	.83	9.0	.65
	4.8	.28	2.2	1.04	2.4	1.31	3.4	.57	9.0	.71	12.0	.70	10.0	.68	9.0	.80
	2.4	1.06	2.4	1.15	3.4	1.06	2.4	.72	10.0	.63	12.0	1.10	12.0	.70	9.0	.64
	2.8	.82	1.8	1.30	3.0	.45	1.6	1.31	10.0	.70	11.0	.86	12.0	.71	9.0	.70
	3.6	1.06	2.4	1.36	2.6	1.06	2.4	.57	10.0	.62	11.0	1.33	11.0	.58	8.0	.56
	3.4	.35	2.4	.85	2.0	.77	2.2	.89	9.0	.70	11.0	1.10	11.0	.50	10.0	1.35
	1.4	1.31	1.2	.53	1.2	.53	1.2	.53	10.0	.25	12.0	.80	11.0	.30	9.0	.52
MA	3.8	.82	2.6	.72	2.6	1.06	1.4	1.06	10.0	.50	11.0	1.05	10.0	.52	10.0	.90
	4.2	.82	2.8	1.22	3.6	.72	2.4	.72	9.0	.83	12.0	.59	11.0	.60	8.0	.60
	4.8	.28	3.0	.89	3.8	.84	2.2	.82	9.0	.36	11.0	.52	10.0	.50	8.0	.65
	4.8	.28	3.0	.48	4.0	.63	3.0	.77	10.0	.40	11.0	.65	10.0	.72	10.0	.88
	5.0	.32	2.4	.96	3.4	.72	1.4	1.23	9.0	.55	10.0	.85	11.0	.36	9.0	.95
	5.0	.32	3.4	.57	4.4	.57	2.2	1.48	10.0	.53	11.0	.61	11.0	.95	9.0	1.10
	2.4	.57	2.6	1.47	3.0	1.00	2.2	1.64	9.0	.60	10.0	.70	10.0	.30	8.0	.88
	3.2	.94	2.4	1.23	3.8	.82	1.6	1.15	10.0	.54	10.0	.56	10.0	.46	8.0	.90
	2.2	.82	1.2	.28	1.2	.53	1.4	.37	7.0	.30	10.0	.8	10.0	.65	7.0	1.2
	3.2	1.04	1.0	.63	1.4	.57	1.2	.82	8.0	.70	10.0	.8	10.0	.82	7.0	.61
Ret.	2.8	.82	2.0	.89	2.2	1.04	.6	.35	7.0	.30	9.0	.2	9.0	.62	8.0	.56
	4.6	.35	2.2	.82	3.2	.53	2.6	.72	8.0	.70	8.0	1.2	9.0	1.10	8.0	1.02
	2.4	.72	2.0	.77	1.6	.85	1.6	.96	7.0	.30	9.0	.2	9.0	.58	8.0	.70
	3.2	.94	1.6	.85	2.8	.53	2.2	.53	7.0	.30	10.0	.8	9.0	.55	7.0	.52
	1.6	.37	1.4	.57	1.4	.72	1.6	.57	7.0	.30	10.0	.8	10.0	.71	7.0	1.07
	1.6	.75	1.8	.53	1.2	1.04	1.4	.85	8.0	.70	9.0	.2	11.0	.65	7.0	.62
	2.4	.85	1.8	1.22	1.6	.96	.8	.69	7.0	.30	9.0	.2	9.0	.70	6.0	.65
	2.2	.53	1.2	.69	2.0	.71	.8	.53	7.0	.30	8.0	1.2	9.0	.62	6.0	.45