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AUTOMATIC/EFFORTFUL PROCESSING IN INDIVIDUALS WITH AND WITHOUT MENTAL RETARDATION: THE LATERALIZED STROOP PARADIGM

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "Automatic/Effortful Processing in Individuals With and Without Mental Retardation: The Lateralized Stroop Paradigm" submitted by Anne-Marie E. Bergen in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

Automatic/effortful processing was assessed by employing discrete, self-initiated, lateralized Reading, Stroop and first Name trials, presented on a computer screen for 150 ms to individuals with mental retardation, children matched for mental age, and nonretarded adults. Ten males and ten females were in each of the three groups. A continuum from initial effortful processing of stimuli (right hemisphere) to the eventual automatic (left hemisphere) processing of skilled, learned responses, such as reading, was proposed, with specific application to the lateralized attentional processing in individuals with mental retardation. Inhibition of an automatic reading response was noted as being effortful, requiring attention. Correct vocal reaction times and percent errors were subjected to multivariate analyses of variance for the lateralized Reading, Stroop and Name Trials. Post-hoc orthogonal contrasts were conducted on significant group differences. Reading was equally fast and accurate for those of equal mental age. Mental age emerged as a significant factor in the latency of correct responding across all trials (Reading, Stroop and Name trials). The successful inhibition of the automatic reading response in naming the incongruent letter color of the lateralized Stroop trials, revealed greater attentional control efficiency for the child and nonretarded adult groups. The error data for Stroop and Name trials revealed attentional control deficiencies only for individuals with mental retardation, possibly suggesting metacognitive and/or structural limitations in right hemispheric processing. Results were discussed in terms of the right hemisphere and effortful processing. No hemispheric advantages were found for any of the groups on the Stroop and Name trials, however the child group revealed a significant left hemisphere advantage for the Reading trials. Overall, a left hemisphere advantage emerged on both dependent measures for the Reading trials. However, color words were processed with significantly fewer errors than neutral words, and were significantly faster, with fewer errors, when presented to the left visual half-field (right hemisphere) for the Reading trials. Results were discussed in relation to a right hemisphere advantage for image and color. For the Stroop trials, color words were significantly slower and generated significantly more errors compared to neutral words overall, suggesting greater semantic interference from the incongruent color words.

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TABLE OF CONTENTS

LIST OF FIGURES

PAGE

TITLE

LIST OF APPENDICES

INTRODUCTION

The human brain, critical to the processing of environmental information, seems to functionally control what is attended to, and how quickly one learns from that experience. Learning assumes an increase in cognitive competence, generally inferred from behavior. Memory for past events is assumed to direct an individual's response to current situations, attention captured by what has been particularly hazardous or helpful, if "learning from experience" has indeed occurred. In order to respond efficiently in critical situations, the individual must instantaneously recognize that which requires an immediate response. This would require the automatic recognition of familiar stimuli, without the capacity or control limitations of attentional processes.

Automatic processing seems to depend upon the amount of specific exposure and/or practice an individual has with an event or stimulus. Rate of "learning from experience" may be a function of the environmental situation and the person's ability to form associations. "Learning quickly" implies that few exposures are required in establishing the competence and performance of an automatic response, with one trial learning requiring only one exposure. Attention to a stimulus is thought to initiate the learning of associations and the appropriate responses. Efficient attentional monitoring of a person's surroundings for unexpected, possibly hazardous or novel stimuli, could well determine if any future learning will occur. Efficient attention enhances survival. Neutral situations do not necessitate immediate attention. The individual's effectual attentional control and processing of what is attended to, is therefore of some importance.

For humans, language is the ultimate human medium for teaching and learning. Research in the area of lateralized brain functioning has given predominance to language processing in the left cerebral hemisphere, and spatial processing in the right hemisphere. This lateralization of function has previously been viewed as verbal/nonverbal, verbal/spatial, analytic/holistic, focal/diffuse (Bradshaw & Nettleton, 1981). The present author proposes a functional continuum of information processing of stimuli from right to left hemisphere, determined by the degree of automaticity of processing experienced. Novel, unstable, or previously familiar stimuli rendered unrecognizable, are seen to initially require right hemispheric processing. With practice or further experience, stimuli which became fixed or remain constant in time and space, attain automatic associations to internal thoughts and cognitions, as well as other environmental stimuli. These automatic associations are processed more efficiently by the left hemisphere.

For individuals with mental retardation, lack of efficient information processing is a paramount concern. As automatic processing and processing efficiency would seem to be logically related, it is hypothesized that individuals with mental retardation, excluding individuals with organic etiologies but otherwise conforming to Grossman's (1983) definition of mental retardation, lack the amount of automatization in the left hemisphere experienced by individuals with normal functioning. Once automaticity is established, processing is comparable for individuals with and without mental retardation (Sperber & McCauley, 1984). Since lateralized language functions have been found in the left hemisphere of an overwhelming majority of normal, right handed individuals, a comparative assessment of lateralized functions in the mentally retarded (excluding organic etiologies, such as epilepsy, cerebral palsy, Down syndrome, brain trauma; Grossman, 1983), was the focus of the following study. The efficiency of attention is salient in the cognitive performance of individuals with mental retardation, as past research has confirmed attentional deficiencies in that group (Detterman, 1979; Nugent & Mosley, 1987). The lateralized Stroop paradigm (Stroop, 1935), allows the assessment of both semantic and attentional processing in either cerebral hemisphere. Compound Stroop stimuli, consisting of color words printed in an incongruent letter color, require effort to inhibit the automatic reading response, while naming the letter color. The lateralized processing efficiency of these stimuli should reveal differences in the efficiency of selective attention and lateralized language functioning.

Attention

The concept of attention is defined as an individual's awareness of sensations, thoughts and feelings, historically referred to as "consciousness" (James, 1890). This awareness is associated with a person's ability to choose what is attended to, and encompasses volition, effort, and the individual's control. A limited "span" or capacity is also noted (Stelmach & Hughes, 1983). If attention were unlimited, there would be no need for concern with its direction, as everything in the internal and external environment would be noticed and appropriately "attended" to. We are, however, creatures of finite limitations, and "doing two things at once" is inherently difficult without substantial practice in both. Control of this limited capacity is pivotal in directing all cognitive activities (Merrill, 1990; Mosley, 1987). The essential requirement for the retention of information, Mosley (1987) noted, is that "attention to the information be extended" (p. 190). Attention, as a volitional control process, exists paradoxically with attention involitionally "captured" by unexpected or vitally important internal or external events.

Individuals generally choose what they will attend to, but sometimes will have their attention "captured" by the unexpected, intense, or salient stimuli which prior experience has delineated as important. Memories of past experiences must alert the individual's attentional mechanisms in an orienting response (OR) to novel, startling, or critical events. Mosley (1987) and Cowan (1988) considered the OR to be a component of selective attention. The individual controls attention, which in turn controls what is attended to in the stimulus array, unless memories from previous experience determine something as novel, or critically important. In order to judge something as novel however, memories of past experiences must already have been accessed to allow that decision to be made. These memories capture and redirect attentional control to the relevant current stimuli. Schneider, Dumais and Shiffrin

(1984) conceived this to be the "automatization of attention" (p. 18), when automatic processes involitionally redirect attention to some triggering stimulus in the array. This redirecting could only occur if all previously learned stimulus associations were automatically accessed, as attention was obviously otherwise engaged. Automatic processes, by definition, require little, if any of the limited attentional resources (Hasher & Zacks, 1979; Schneider, Dumais & Shiffrin, 1984; Schneider & Fisk, 1983). The automatic access of information from memory would therefore depend on age, which determines length of time and amount of exposure, cognitive development, efficient retrieval of previously encoded information, proficiency or practice, and structural substrates which set the limits. Attention is therefore helped or hindered by the efficiency with which previous knowledge is retrieved. The greater the amount of information automatically accessed, the greater the efficiency of the attentional responses, illustrated by the child who is finally aware that a moving car is dangerous. Awareness is restricted by the amount of available, stored knowledge. Efficient attentional control is therefore seen to interact with previously encoded information, and determines how efficiently that information was encoded in the first place. In individuals with mental retardation, the encoding efficiency of attentional processes, both in capacity and selective control, have been found deficient (Detterman, 1979; Merrill, 1990; Mosley, 1987; Zeaman & House, 1979).

The aspect of choice, or volition, in directing attention incorporates concepts of control. The "self", which Cowan (1988) referred to as the "central executive", and Stelmach and Hughes (1983) see as the "the dynamic and active actor", is the controlling agent. Experience determines how effective the control is. The neonate has little if any experience to guide attention, and is indiscriminate in being "interested in everything", with particular interest in maternal speech (Turkewitz,1988), or speech sounds generally (Entus, 1977; Molfese, 1977). Everything is novel and therefore attended to. Lewis (1971) proposed that attention, by way of the orienting response (OR), could be used as a measure of cognitive functioning, with the neonate's rate of decrease in attentional responding to a novel stimulus being a direct measure of cognitive competence. Habituation to a stimulus was seen as related to the speed of building a "neuronal model" (Lewis, 1971, citing Sokolov, 1963b). The neural encoding of the stimulus was thought to occur during the attention/habituation process, and the speed at which this OR habituation progressed, was a measure of cognitive efficiency. If attending was not evident for further presentations of the same stimulus (continued habituation of the OR), it was assumed to be successfully represented in memory. When it no longer required attention/effort for retrieval, it could also be assumed to be automatically processed. Lewis found that the older the child, the greater the OR habituation rate, indicating faster formations of neural associations, or learning. Maturation and experience are therefore seen to interact in changing attentional requirements. It would seem that speed of learning predicts the amount of information automatically accessed, which in turn directs attentional control more efficiently by allowing the infant to avoid processing irrelevant information.

A habituation hypothesis of selective attention is proposed by Cowan (1988) and Mosley (1987). Cowan considered three circumstances for which the orienting response would occur, when the voluntary focus of attention was elsewhere: first, a change in physical characteristics of an unattended stimulus, second, the appearance of a stimulus of long-standing interest such as one's name, and third, primed information for an unattended aspect of a stimulus. Cowan also reported an orienting response being elicited in subjects who were unaware of the stimulus change responsible for the response, indicating automatic, not attentional processing. Habituation to stimuli of no particular current consequence to the individual, would suggest a process of automatization from novel to familiar. Although Cowan found support for "subjects attending selectively through habituation to unattended stimuli" (p. 178), and habituation-filtering is seen to occur automatically, the automatic recognition of familiar stimuli, by definition, does not require attention. Mosley (1987), citing Norman (1969), observed that all sensory signals were assumed to excite their representations in memory. Automatic associations assume simultaneous neural excitation, allowing instantaneous discrimination between those stimuli which are neutral and could be ignored (do not require attention), and those which are novel or significant, and require an immediate response. The degree of automatization of neural associations may have critical repercussions for the individual's survival.

Automatic Processing

The automatic processing of information increases the efficiency of cognitive functioning since it does not place demands upon limited attentional resources. Skills or behaviors which initially involve huge portions of available attention, will require less and less with practice, while proficiency and performance increase. Eventually, after extensive practice, the responses are executed without attentional resources and are described as automatic (Merrill, 1990; Schneider, Dumais & Shiffrin, 1984). Hasher and Zacks (1979) described automatic processes as requiring minimal attention, consistent, not interfering with other cognitive activities, nonintentional, and not benefiting from practice but originating in it. They considered the automatic encoding of space, time, and event frequency to be innate, while word meaning (extracted from reading) was a learned skill. Memory processes were seen to occur along a continuum, from effortful to automatic for "learned " processes (Hasher & Zacks, 1979, p. 369). Schneider, Dumais and Shiffrin (1984), and Schneider and Fisk (1983) delineated the parameters of consistent practice in establishing automaticity. They found increased consistent practice, or overtraining, was required for eventual task execution without need of any apparent attentional resources. Schneider and Fisk (1983) also noted the necessity for individuals to "let go ", or not devote attention to tasks which had become automatic, otherwise "substantial performance decrements" became evident (pp. 132-133). Apparently subjects had to learn to remove attention from a well-practiced task, allowing the automatic process to efficiently proceed. Any novice pianist could relate to the experience of performing flawlessly, automatically, many times during practice only to stumble in the critical performance, because they started to "think" about where they were in the piece. Direct attentional control does not allow the developing autonomous automatic process to efficiently continue, and efficiency is its defining feature, increasing speed, accuracy and coordination (Schneider & Fisk, 1983). Relating the results of one of their experiments, the previous authors reported that time for making automatic comparisons (2 ms), was 100 times less than the controlled processing time (200 ms).

Automatic processing is fast, parallel, fairly effortless, not limited in capacity and not under volitional control (Schneider & Fisk, 1983). In order to develop automatic processing, an individual must interact consistently with a stimulus over many trials. A stable, consistent relationship must exist between the stimulus and the response, or be "consistently mapped" (Schneider, Dumais & Shiffrin, 1984). A predictable response to a stable, predictable stimulus is the necessary condition for developing automaticity, while random or variable pairings would predictably not allow the individual to benefit from practice in establishing automatic responses. Evidence from training and overlearning for the consistent stimuli, suggest a continuum from novel/effortful to automatic/nonvolitional (Hasher & Zacks, 1979; Whitaker, 1983). Perhaps the strongly, partially and occasionally automatic processing proposed by Kahneman and Treisman (1984; see also Kahneman & Chajczyk, 1983), could be viewed as stages within the continuum. Once the individual has "let go", Schneider and Fisk (1983) concluded that automatic productions can simultaneously process different stimuli at different stages, facilitate coordinated behavior, are always ready, can be triggered by many relevant external conditions, and are extremely fast and require little, if any, attentional resources. They are also inflexible, requiring considerable attentional resources to alter, once established (Schneider, Dumais & Shiffrin, 1984).

Controlled/Effortful Processing

Controlled processes develop automatic processes (Schneider and Fisk, 1983). Controlled processes are characterized as volitional, effortful, conscious, requiring attentional resources, slow, generally serial, and are employed when information is novel or inconsistent (Hasher & Zacks, 1979; Schneider & Fisk, 1983). Effortful or controlled processes are expected in situations where responses vary from trial to trial, requiring constant monitoring and flexible responding. These "conscious strategies" regulate information flow under the individual's direction and are influenced by age, which determines exposure and cognitive development. The person's arousal and emotional state i.e., high anxiety or depression also influences information flow regulation. These were thought to change attentional capacity, and alter the efficiency of effortful processing (Hasher & Zacks, 1979). The capacity limitations of flexible, controlled processes are therefore complemented by multiple fixed automatic processes. Skilled performance exhibits a great deal of flexibility (Schneider & Fisk, 1983), thus the skilled automatic processes must be enabled by attentional control. Control processes are seen to initiate, maintain, and direct the encoding of stimuli, and continue in the direction of consistent practice for automatization processes to develop. The individual "selectively attends" to external stimuli and internal associations or processes. Complementary automatic processes redirect the focus of attention, or are being directed in skilled performance execution, thus overcoming attentional capacity limitations and automatic inflexibilty (Hasher & Zacks, 1979; Schneider, Dumais & Shiffrin, 1984; Schneider & Fisk, 1983; Stelmach & Hughes, 1983). The flexible direction of attention's limited capacity is of concern for individuals with mental retardation.

Mental Retardation and Attention

Detterman (1979) stated that no single deficit was better supported by research findings than attentional deficits in the mentally retarded (p. 745), although his final conclusions found every memory process to have some degree of deficit. Since attentional processes are assumed to be the mediators of almost all cognitive activities, they are particularly implicated in differences in cognitive performance of individuals with and without mental retardation (Merrill, 1990; Mosley, 1987). Merrill (1990) posited two major categories of attentional processes. The first, attention as a process of selection, determined what is attended to and what is ignored, with deficiences involving a failure to attend, or to successfully ignore what is irrelevant. The second, attention as capacity, implied a limited supply of processing resources which may not be efficiently allocated, or may be limited by task demands.

Mosley (1987) found that individuals with mild mental retardation failed to use relevant information to change their conditioned responses.

He concluded that the inefficient control of "selective attention", composed of an orienting response to the relevant external stimulus array and a simultaneous selection of internal associations/memories, resulted in superficial, ephemeral stimulus encoding in the mildly retarded. Zeaman and House (1979) found initial or preferred direction of attention in discrimination learning to qualitatively vary, with development and intelligence. Mentally retarded individuals were found comparatively deficient in selecting the appropriate dimension (color, shape, size). Merrill (1990) reported further evidence of a reduced ability by younger and less intelligent individuals to focus attention on information which had been previously singled out for further processing. There is, therefore, evidence of differences in the efficiency of selective attention for individuals with mental retardation and the young (Brooks, McCauley & Merrill, 1988; Merrill, 1990; Mosley, 1987; Zeaman & House, 1979).

Attention conceived as a limited capacity has the individual directing or allocating finite resources to cognitive tasks requiring varying amounts of this commodity. Differences in individual efficiency of allocation, or in the individual's specific need of attentional resources for specific task completion, may influence cognitive processing generally. Nugent and Mosley (1987) found that both adults with mental retardation and children matched for mental age (MA), were less efficient at attentional allocation, and had more limited attentional capacity than normal adults. Their conclusions of less efficiency in attentional allocation and capacity in developmentally immature populations are consistent with the evidence presented by Lane (1979; cited in Brooks, McCauley & Merrill, 1988), and Carr's, 1984 report (citing Manis, Keating & Morrison, 1978), of young children experiencing significantly more interference in a dual task paradigm, compared to older children and adults.

Increased speed of cognitive processing is thought to reduce attentional capacity limitations. Automatic processes developed over time will allow this, but the rate at which these develop may well depend on processing speed from sensation, to encoding, and eventual retrieval. Sperber and McCauley (1984) observed that passive processing, such as automatic semantic priming (outside of the individual's intent or awareness), repeatedly failed to reveal differences in the priming effect between individuals with and without mental retardation, while chronological age did produce effect differences (pp. 146-148). These results implicated experience rather than cognitive development as a primary factor in automatic retrieval. Results from their own experiment revealed effortful category verification was twice as long for the retarded compared to the nonretarded, while these same subjects showed equivalent priming effects (Sperber & McCauley, 1984). They concluded that active retrieval and decision making, rather than automatic retrieval processes, were required to assess retarded/nonretarded attentional differences. Stanovich (1985) arrived at somewhat the same conclusions.

Merrill (1990) reviewed evidence of retarded-nonretarded speed of processing differences in experiments where mentally retarded subjects' IQ test scores ranged from 50 to 70. He found a consistent difference across a variety of experiments and tasks, with the nonretarded subjects processing at twice the speed of the retarded subjects. He observed that " differences in semantic processing speed across different tasks may be mediated by a common component of the information-processing system" under conditions of effortful, not automatic, semantic processing (pp. 57-59). Facilitation from automatic processing showed similar effects for nonretarded and retarded individuals. Facilitation and inhibition due to effortful processing, however, was slower to develop in the mentally retarded, implicating less efficient allocation of attentional resources (Merrill, 1990). He also noted that the more difficult (effortful) the task, the larger the differences in semantic processing between individuals with, and without, mental retardation. Four explanations for the effortful processing differences in the mentally retarded were proposed. First, the rate of the development of automatic processing may be slower for retarded individuals, with the processing of complex tasks requiring most of the attentional resources therefore being limited. Second, retarded individuals may possess less control or less flexibility in the allocation of resources, resulting in insufficient resources being allocated. Third, retarded persons may possess an inability to allocate sufficient resources to a task because of a metacognitive lack of knowledge of their limitations and abilities, a position similar to Whitman's (1990) lack of metacognitive "self-regulation". Fourth, retarded individuals may possess a smaller attentional capacity generally. These explanations were not seen as mutually exclusive and may exist in combination (Merrill, 1990). Merrill tentatively concluded, on the basis of one of his experiments, that mentally retarded individuals do acquire automaticity more slowly than nonretarded individuals (pp. 74-78). He also cautioned that once established, automatic processes may decrease the relative flexibility of information processing in mentally retarded individuals, as the ability to override an automatic process requires substantial effort/attention, which is much more difficult for them (Ellis & Dulaney, 1991; Ellis, Woodley-Zanthos, Dulaney & Palmer, 1989; Merrill, 1990). Attentional requirements in controlling automatic processes, as well as in their establishment, are therefore implicated in the deficient cognitive processing of individuals with mental retardation.

Differences in the semantic functioning of the cerebral hemispheres, and differences in the effortful retrieval of information for individuals with and without mental retardation, suggest a paradigm which will allow the examination of effortful processing and lateralized functioning in these groups.

Lateralization

Lateralization refers to a division of functions between the two cerebral hemispheres. A lateralized stimulus is presented to only one cerebral hemisphere (Springer & Deutsch, 1989). Evidence for asymmetries in hemispheric function were first inferred by clinical observers, such as Broca and Wernicke, from the differential effects of brain injury to only one side of the brain. This clinical evidence suggested a left hemisphere (LH) "dominance" for processing language. The dominant use of the right hand, controlled by the contralateral LH, led to the assumption that language and manual dominance had their origins in brain organization (Geschwind & Galaburda, 1987; Springer & Deutsch, 1989). Functional asymmetries for both handedness and language were found in brain damaged and split-brain patients by using intrusive techniques such as direct electrical brain stimulation, or sodium amobarbital injection into the left or right carotid artery (the Wada test, Wada & Rasmussen, 1960). While these clinical techniques have established that over 95% of all right handed and 70% of left handed individuals without early brain damage, have speech and language controlled by the LH in clinical populations (Springer & Deutsch, 1989), their generalizability to normal brain populations is limited. Left-handedness is implicated in anomalous language dominance in the right hemisphere (RH) for a few individuals (Kinsbourne, 1988). Those with RH dominance for language processing and strong left handed preference are not easily accomodated by the present hypothesis of automatic processing occurring in the LH, effortful in the RH. A strong association between right handedness and language in the LH from clinical data, possibly implicates the skilled automaticity inherent in both.

Handedness

In a review of the incidence of left-handedness within normal populations, Bryden (1982) generally noted it to be at 10.39% in his survey of young adults in Canada. Historically this incidence has remained quite constant at 7-8%, while cultural-environmental variations from 1% to 30% were found in contemporary surveys (Bryden, 1982). These discrepant findings may be the result of differences in measuring handedness, as well as cultural variables. Measurement of hand preference or proficiency was shown to be most valid for the performance of frequent motor activities such as writing, drawing, using a toothbrush or pair of scissors and throwing a ball (Bryden, 1982). Due to the existence of ambidextrous individuals, Bryden postulated that being right or left handed was a continuous rather than a discrete variable. Strong right handedness, when measured by the methods noted above, best predicted LH language dominance for both clinical and normal populations (Bryden, 1982).

Other measures of human asymmetry relate to eye, ear and foot preferences (Bryden, 1982; Springer & Deutsch, 1989), with experimental evidence finding little relationship between eye dominance, an ear preference, and hemispheric asymmetry for language. In their review of the evidence for foot preference, Springer and Deutsch did observe that the largest correlations were obtained between hand and foot preferences. This suggested a second indicator of lateralized brain organization and functioning to be considered in subject selection, increasing the probability of language dominance in the LH. Another factor to be considered is gender.

<u>Gender</u>

Sex-related differences in the degree of lateralization or asymmetry of language functions have produced equivocal results. Some studies report sex-related differences, others do not (Bryden, 1982; Hahn, 1987; McGlone, 1980; Segalowitz & Bryden, 1983; Springer & Deutsch, 1989). Females have generally shown bilateral processing for language tasks, while males process such stimuli faster and more accurately with the LH. Developmental concerns regarding possible maturational processes impacting gender differences in brain lateralization, require segregating pre-pubertal and post-pubertal subject groupings, when examining sex-related differences.

McGlone's review (1980) of adult clinical and nonclinical studies generally supported the existence of sex-related differences in lateralization. Clinical data for LH trauma revealed greater verbal performance deficits in men than in women. Kertesz and Benke (1989) examined aphasias and the location of lesions only within the LH, by computerized tomography (CT). Based on LH lesion location and aphasia data, no sex differences were found intrahemispherically. This is suggestive of gender processing differences between hemispheres, rather than within .

In Piazza Gordon's (1985) first of three experiments, 32 males averaging 23.8 years, and 32 females average age 22.1 years, were presented 120 simultaneous pairs of 6 spoken stimuli in a dichotic listening paradigm. The task was to report stimuli from one ear at a time. Results, analyzed separately for each gender due to heterogeneity of variance between genders, revealed a significant LH advantage for males, but not for females.

Experimental evidence of sex-related differences in cerebral lateralized processing is unreliable however (Segalowitz & Bryden, 1983; Springer & Deutsch, 1989). The previous authors agree the evidence is equivocal, resting the strength of an argument for the possibility of gender differences on the variety of methodologies (clinical, dichotic, tachistoscopic, eletrophysiological), with the same conclusions of less lateralized functioning in females, Type 1 errors not withstanding (Bryden, 1982; Segalowitz & Bryden, 1983; Springer & Deutsch, 1989). The consistency of results across methodologies is interpreted as indicating true gender differences, small in magnitude and easily masked by other within and between subject variables (Springer & Deutsch, 1989, p. 222). Other authors, most notably Kinsbourne (1980), in reply to McGlone, found no convincing evidence for sex-related differences, structurally or functionally. However, the evidence for pre and post-pubertal differences in female lateralized processing, suggested gender be considered as a variable.

Age/Maturation

The processing of language has been reported as functionally localized in the LH almost from birth in normal, right-handed children (Hahn, 1987). In his review, Hahn (1987) discussed two current hypotheses concerning cerebral linguistic lateralized development: Lennenberg's (1967) view of hemispheric "equipotentiality" at birth with increasing specialization during the course of development in "progressive lateralization", and Kinsbourne's (1975) " invariant lateralization" of functions hemispherically localized from birth without gender differences (Hahn,1987, p. 376). The latter hypothesis would be supported by evidence of stable lateralization of functions across age and gender, while the former would predict less asymmetry in younger children of both sexes, with greater asymmetry controlled by rate of individual biological maturation until puberty, and consequent gender differences.

Satz, Strauss and Whitaker (1990) proposed a dynamic process of progressive laterality without equipotentiality or invariance. By reviewing postmortem anatomical and childhood aphasia data they posited differential maturation within the LH, without denying the possibility of an early LH anatomical or functional bias for language. A critical period for within and between hemisphere reorganization after injury to the LH, was determined at five to six years of age. Citing animal ablation work of Goldman and colleagues, Satz et al., (1990) proposed a possibility of greater plasticity and reorganization occurring when "neuronal structures are still functionally immature or uncommitted at the time of injury" (p. 608). A complimentary concept of progressive automatization of speech and language proposed by Whitaker (1983) suggests an increasing specialization of language organization in the LH. The maturation of either brain structure or functional organizational levels were seen as interdependent concepts, with structural maturation rate not necessarily determining functional maturation rate (Satz et al., 1990).

Maturational gender differences support possible sex-related differences in brain organization. Waber (1977), viewed females' earlier sexual maturation as a confounding variable when interpreting sex-related differences in lateralized processing. Her dichotic listening study matching boys and girls for sexual maturation, rather than chronological age, found no gender differences in ear asymmetries. Late maturers had a greater LH advantage for speech than early maturers of the same sex and age in the oldest age group (p. 34). No differences for early and late maturers were found on verbal ability tests, while late maturers performed better on spatial ability tests, independent of gender. Early maturers showed less LH superiority than late maturers of the same age for the dichotic verbal task. The influence of gender on maturational rate is hypothesized to determine the degree of LH language dominance, with late maturers experiencing the longer developmental period. Waber noted a decrease in magnitude of a LH advantage ,with age, among early maturers. This decrease in magnitude of the LH advantage would suggest early automatization of language in the LH of early maturers, as they were equally proficient, with progressively more RH involvement in language processing in older, early maturers. The less lateralized response, after earlier LH superiority, does not suggest a decrease in LH automatic language processing, rather an increase in RH processing. As the RH processes the emotional tone and imagery of linguistic stimuli (Bryden & Ley, 1983), perhaps the female propensity for emotional processing of stimuli could help explain this maturational trend (Suberi & McKeever, 1977).

Gender, or possibly the earlier maturation of most females, does seem to influence the degree of lateralized language functioning at different ages. The greater "plasticity" of young children suffering trauma to either hemisphere, and subsequent recovery of language, is nonetheless balanced by early evidence of LH linguistic superiority. Lateralized language functioning is therefore neither biologically "invariant" nor experientially "equipotential". The "progressive lateralization" proposed by Satz, et al., 1990, and Whitaker's (1983) "progressive automatization of speech", include the interaction of biology and experience when examining LH processing of linguistic stimuli.

Prenatal auditory functioning as early as 24 weeks after conception as well as neonatal responses to maternal speech suggest that learning of salient sounds occurs early in development (Turkewitz, 1988). Studies using dichoctic listening techniques with infants as young as 22 days found a LH advantage for syllables and a RH advantage for musical notes (Entus, 1977). In Hahn's review of lateralized language functioning in children (1987), children's ages varied from 22 days to 15 years, with age determining methodologies used. He tentatively concluded that the evidence supported LH specialization for processing linguistic stimuli, but that consistent gender differences did not exist (p. 388). In her review of gender differences generally, McGlone proposed that the relative lack of consistent gender differences in developmental lateralization studies may be influenced by sexual hormones (citing Waber, 1977) and are therefore evident after puberty. Bryden (1982) also found few consistent gender related differences in the dichotic verbal studies with children. He did report that the developmental literature revealed greater bilaterality of both language and spatial functioning in females (p. 235).

Age by Gender Considerations

In a series of three experiments already cited (p. 18), Piazza Gordon (1985) examined age and gender influences on lateralized language processing. In the second study, 64 pre-pubertal ($\underline{M}$= 9.4 years) and 64 pubertal ($\underline{M}$ = 13.0 years) children were given an auditory task consisting of six spoken stimuli dichotically presented in pairs to each ear. Subjects were to report both stimuli and encouraged to guess if necessary. Separate analyses were conducted for each gender, due to variance heterogeneity. Males were significantly more correct in reporting from their right ear (LH), and older males were significantly more accurate than the younger males. Females were also significantly more accurate in right ear (LH) reports, right handed females more accurate than the left handed, and older more accurate than younger. Of particular interest, the ear by age interaction indicated a significant LH advantage for speech processing in young females only, suggesting weaker speech lateralization with increasing age. Piazza Gordon interpreted this as evidence for sex-related changes in children's processing of speech. This evidence converges with Waber's (1977) findings of decreasing LH advantage for older, early maturers with increasing age.

Piazza Gordon's (1985) third experiment employed only strongly right handed children, eight males and eight females in each of two age groups, with means of 9.0 and 13.2 yrs respectively. The same dichotic verbal stimuli were used as for the other two experiments. They were again to report both stimuli, even if guessing was required. Both the younger and older children correctly reported more stimuli from the right ear (LH), than the left (RH). Older females made fewer errors overall compared to the males, but the older males showed a significant LH advantage for processing speech while the females did not. Younger children exhibited similar lateralization for speech while older children at the age of puberty showed gender differences comparable to adult studies, with females perhaps decreasing their reliance on LH processing strategies (p. 177). These results corroborate Waber (1977), and Satz, Strauss and Whitaker (1990), with decreasing LH superiority for older females or early maturers of either sex. Since females had fewer errors than the males, this increasing bilaterality of language functioning cannot assume a decrease in proficiency or automatic processing of language in the LH. Perhaps an increasing reliance on RH processing of the emotional context of linguistic stimuli, could explain this phenomenon.

Hemispheric Processing: Dichotomous or Continuous?

Although hemispheric asymmetries were viewed as dichotomous in the past, the present consensus is one of a continuum of functions between the two hemispheres (Bradshaw & Nettleton, 1981; Bryden, 1990; Hardyck, 1983; Hahn, 1987). The present author proposes that the right hemisphere is the processor of novel, unique or unstable stimuli, while the left hemisphere processes those stimuli which are practiced, skilled, stable across time and space, and thus have gained a degree of automaticity. A continuum of right hemisphere to left hemisphere processing is proposed for stimuli, with the degree of automaticity determining which hemisphere will be most efficient. Familiar stimuli with uncertain/changing characteristics cannot obtain fixed, automatic processing, and will therefore require attention and be most efficiently processed in the right hemisphere. Stimuli with fixed/stable characteristics will require little attention with consistent practice, and will be processed by the left hemisphere. The word "mother" can be fixed/stable (LH), or the same word may have contextual emotional, or spatial qualities (RH).

Right Hemisphere Processing

The RH processes stimuli which are new, unfamiliar, not immediately identifiable from previous experience, those stimuli which vary over time and space, are constantly in flux, such as facial expressions, emotions, spatial positions of objects within an environment where only change is certain. The individual's RH begins the initial processing and organization of novel stimuli, and integrates and creatively reorganizes the automatic associations which were previously established (Goldberg & Costa, 1981).

Goldberg and Costa (1981) proposed two distinctions in hemispheric processing based on neuroanatomy and information processing data. The RH was seen as critical in the initial acquisition process, in processing novel stimuli and in the integration of information, between senses and hemispheres. On the basis of differential neuroanatomy and recognizing that structure does not necessarily define function, Goldberg and Costa (1981) hypothetically proposed greater RH neuronal capacity for dealing with complex information and greater ability for processing "many modes of representation within a single cognitive task" (p. 148). Evidence was cited from clinical patients (Chapanis, 1977; Semmes, 1968, cited in Golberg & Costa, 1981) for RH superiority in the integration of all sensory modalities in complex tasks, as patients with RH lesions performed worse than those with LH lesions in all sensory combinations of cross-modal integration tasks. Goldberg and Costa predict a possible RH dominance in activating the entire cortex, as its greater interregional connectivity should excite more areas intrahemispherically, and subsequently influence larger homologous LH areas via the corpus callosum (p. 150). These authors also predict RH participation in both orienting to and assembling of information, a cognitive process which functionally transforms the information into a known "descriptive system" stored in the LH. "The formation of cognitive skills" (p. 155) is therefore not strictly verbal/nonverbal. However the comprehension and efficient production of language is central to future learning, with the formation of new "descriptive systems" automatically referenced from the LH once they become "routine". The RH effortfully transforms the "unknown" into the "known".

Language. Early auditory experience may affect RH proficiency for environmental sounds. Turkewitz (1988) suggested the acoustic environment of the developing fetus influenced hemispheric specialization, the advanced RH initially processing uterine "noise", while the LH specialized in processing of maternal speech at a later stage of prenatal development.

DeCasper and Spence (1986), reported neonates' responses to taped stories read by their mothers during the final six weeks of pregnancy. The three day old infants would significantly increase or decrease their nonnutritive sucking rate from a baseline measure, contingent upon hearing the taped familiar stories, but not for unfamiliar stories. The familiar stories were used to differentially reinforce the change in the infant's sucking rate. This recognition of the "same" stories, compared to matched "novel" stories, strongly indicated the newborn's response was not simply voice recognition, but a more specified response to other aspects of speech. Control infants without previous story exposure, showed no change from baseline sucking rate for any of the stories. This evidence of prenatal linguistic experience influencing post-natal responses, could explain obtained linguistic LH lateralized effects in neonates (Hahn, 1987; Molfese, 1977; Molfese & Betz, 1988). Without evidence of previous prenatal speech exposure, RH processing would be predicted.

Clinical data suggest that lesions incurred to either hemisphere before age one resulted in verbal performance deficits, implicating the RH as well as the LH in early language acquisition (Goldberg & Costa, 1981).

Left hemispheric superiority in processing language is seen as a function of language acquisition (Goldberg & Costa, 1981), with evidence cited of a RH-LH shift in normal children speaking their native language. Carmon, Nachshon and Starinsky (1976) examined the acquisition of reading and visual field asymmetries for Hebrew letters, 2 and 4 letter Hebrew words, and 2 and 4 digits. The stimuli were presented randomly to each visual hemifield. Children's ages ranged from 6 to 12 years; all were normal, right handed, without visual impairment. Hebrew letters and words are scanned from right to left, while Arabic digits are scanned from left to right, therefore scanning bias was no longer a confound. Results showed a significant RH superiority for first graders in the perception of single letters, while trend analysis revealed a LH superiority appearing only at the fifth grade. These results were consistent with those of Forgay's (1953) for children learning to read English, scanned from left to right. Carmon et al., (1976) reported younger children (grades one and three), showed significant LH superiority for only two letters presented bilaterally, while older children's LH advantage was significantly evident for all words, digits and letters, in either unilateral or bilateral presentation. The authors suggested that LH verbal superiority is the result of being well practiced, after initial RH spatial processing. This would also suggest increased automatic processing of verbal stimuli with increasing skill and educational experience.

A single case study involving Genie, an adolescent girl (13 years, 9 months) who survived 11 1/2 years of total isolation, and was punished by her father if she made a sound, is of particular interest for the study of lateralized functioning in learning to speak a first language after puberty. In a dichoctic listening test of familiar words, she showed an extreme left ear (RH) advantage, with a smaller left ear (RH) advantage for environmental sounds, as would be expected (Fromkin, Krashen, Curtiss, Rigler, & Rigler, 1974). Genie was noted to be right handed and exhibited normal RH lateralized functioning for environmental sounds, as well as mature performance on a test of RH functioning. Genie's RH superiority for verbal stimuli, however, would indicate the need for language experience and practice in order to allow automatic processing to develop in the LH, even for verbal material. This would not be predicted from the LH superiority shown for linguistic stimuli in neonates, unless exposure is critical. Although generalization from a single case study is tenuous, this pattern reveals a progression from initial effortful RH processing to automatic LH processing even for language, with age of acquisition also a consideration.

In a study examining the transfer of RH to LH dominance in the verbal naming of visually presented novel stimuli, Carmon and Gordon (1976) reported RH response time superiority in naming familiar numbers presented in unfamiliar binary and Gothic form, and unfamiliar digit symbols, at the beginning of the test, with a shift to the LH by the end of the session. Numbers in familiar Arabic script showed LH superiority throughout the session, supporting the hypothesis of automatic processing occurring for "readily nameable stimuli" (p. 1092). Developing a response to an unfamiliar or unrecognizable familiar stimulus begins in the RH, with a progression to the LH as automaticity is established. Carmon and Gordon noted that the verbal response is controlled by the LH, and therefore rendered a RH advantage as more convincing when the dependent measure was a verbal response. The authors also suggest initial recognition of language symbols occurs in the RH, with later development in the LH.

Ross (1983) observed that the reviewed evidence for cerebral asymmetry in deaf individuals was equivocal for both verbal and nonverbal stimuli. She suggested educational and linguistic experience, as well as individual competence in verbal and sign language, could be important variables to consider for efficient LH language functioning. Springer and Deutsch (1989) report that the results of deaf subjects with a reduced LH advantage for letters and words are puzzling, when congenitally deaf individuals born to deaf parents exhibited the normal LH advantage for alphabetical signs, and a RH advantage for meaningless signs. The discrepant findings for both groups of deaf individuals could not be explained by lack of normal auditory exposure to linguistic stimuli, and would not predict a difference in lateralized functioning. The congenitally deaf born to deaf parents, however, would have been exposed to their parents use of sign language soon after birth, while deaf children born to normal parents would presumably have this taught to them later on. The early consistent exposure predicts automatic LH processing of signing stimuli as was found, while later exposure predicts an attenuated LH or bilateral processing.

Vaid and Corina (1989) examined differences in processing of visually presented incongruent digits, words, or American Sign Language (ASL) signs, as a function of language skill in deaf individuals raised by deaf parents, hearing born to deaf, and hearing subjects who acquired ASL after adolescence but used it regularly in their profession. Interference for judging incongruent stimulus pairs (6 paired with the ASL sign for 2) was greater in the LH for a subject's skilled language, but greater in the RH for the less proficient ones. This study reported comparable hemispheric functional language processing for deaf individuals as for the hearing, and supports the proposed RH-LH shift for increasing proficiency, and increasing automaticity, in language processing.

Second language acquisition would predict RH processing initially, with a gradual shift towards the LH as processing becomes automatic. Vaid (1983) proposed the evidence for hemispheric specialization was not so much for particular stimuli as for types of processing (p. 317). In her review of language acquisition and brain lateralization, the factors of stage and age of language acquisition were discussed. LH participation was statistically significant only for the successful, or proficient in each group; proficient bilinguals acquiring their second language in adolescence revealed less of a LH advantage for the second compared to the first language (Vaid, 1983). This could be interpreted as evidence of greater RH involvement due to an incomplete proficiency (automaticity) in the second language. A paper presented by Hardyck (1980), cited in Vaid's review, found greater RH second language activation only for nonproficient bilinguals. Vaid (1983) also cited studies which did not support this hypothesis however, with caveats concerning task and proficiency levels. Springer and Deutsch (1989) reported evidence for less proficiency (and RH processing) of second language acquisition, taking age of acquisition into account. Vaid and Genesee (1980) found individuals who acquired their second language in infancy or early childhood, assuming greater proficiency, exhibited the same LH advantage as monolinguals. Individuals who acquired their second language after age 12 showed a RH advantage, as would be predicted by the present hypothesis of post-pubertal RH processing of less proficient/automatic language encoding.

A significant number of studies assessing reading disabilities and degree of lateralization (reviewed by Bryden, 1987) showed weaker lateralization in poor readers compared to good readers. These results were obtained with dichotic, visual and dichaptic techniques. If reading proficiency is determined by the degree of its automatization in the LH, poor readers would predictably have less of a LH advantage. Marcel and Rajan (1975) found good readers (7-9 years) to identify correctly more words and letters visually presented to the LH than poor readers, while normal RH processing superiority for facial recognition was also demonstrated across groups. Interestingly, boys who were poor readers exhibited a RH superiority for the word recognition task, while otherwise boys consistently show a clear LH superiority (Piazza Gordon, 1985). Goldberg and Costa (1981) contended that "normal readers establish adequate left-hemisphere-mediated descriptive systems for reading earlier than poor readers" (p. 158). Olson (1973) found LH superiority for lateralized word recognition in good readers from 7 to 11 years old, while poor readers younger than 9 years showed no significant hemispheric superiority. Olson's small group (n = 7) of poor readers with IQ's less than 90 showed a significant RH superiority (p. 346). Witelson (1977) obtained no hemispheric difference in dyslexic boys (6 - 14 years) in recognizing dichaptic shapes, greater but lower than normal LH accuracy for dichotic digits, but significantly greater RH accuracy for dichaptic letters. Witelson also observed the developmental dyslexia syndrome as exhibiting not only deficits in reading, but in speech, spelling, fine motor coordination as well; all skilled, automatic responses. The literature on poor readers or dyslexics is not unanimous however, with some studies showing no laterality differences between good and poor readers, while a few show a stronger LH laterality effect for the dyslexics (Bryden, 1987; Goldberg & Costa, 1981). The latter would not be predicted, as dyslexics have less efficient reading, and would predictably have less automatic processing of language in the LH. Task variables could be influential however, with simple verbal stimuli (e.g., letters, digits) also automatically encoded in the LH of older dyslexic children, and therefore exhibiting a LH superiority.

Highly familiar verbal stimuli which ordinarily reveal a LH advantage, revert to a RH advantage when the visual stimulus quality is reduced by using very brief exposure times, low luminance, greater eccentricity, unconventional typeface or stimulus degradation due to masking through a stimulus onset asynchrony (SOA) from 0 to 20 ms (McKeever & Suberi, 1974; Sergent, 1983). Sergent (1987) concluded the RH was more efficient as the quality of the stimulus decreased, but see Charman (1979) below (p. 40). This suggests that if immediate, automatic recognition of a known stimulus does not occur, RH processing is activated. Sergent reviewed suggestions of holistic processing, greater diffuse vigilance, and better performance of the RH in conditions of stimulus uncertainty or degradation, suggesting effortful processing.

Clinical studies (Millar & Whitaker, 1983) of RH damage revealed deficits in learning concrete, high frequency words but not abstract words, in the ability to integrate information by inferring the moral of a story, in affective speech expression and comprehension, and difficulty with semantic word associations while controlling for unilateral spatial neglect. Millar and Whitaker (1983) suggest the evidence from brain damaged subjects addresses brain-behavior correlates more directly. It could then be inferred that the RH processes concrete, high frequency words which can be visualized in space, interprets or expresses fleeting emotions in speech, extrapolates the point of a story and connects words which are related through meaning.

Verbal processing in the RH precedes LH processing when proficiency is not yet established, or when the familiar is difficult to recognize.

Normal RH processing of language is related to emotional and spatial contexts of words or phrases, semantic relationships, and story comprehesion. RH or bilateral processing is therefore predicted for the less proficient in any language at any age, with the exception of post-pubertal proficient females, whose bilateral language processing may be the result of RH emotional processing of words. Proficiency is seen as a valid indication of LH automaticity.

Nonverbal processing. A RH advantage has typically been found for intensity judgements, musical chords, timbre, melodies, environmental sounds, nonverbal vocalizations, emotional tones, intonation patterns and sonar signals (Bradshaw & Nettleton, 1981, p. 53). These authors noted the RH's major role in singing and musical processing in general, with exceptions. While musical stimuli typically reveal a RH superiority, experience seems to influence task performance. An experiment by Bever and Chiarello (1974) found the expected RH superiority for monaural identification of partial or whole melodies in nonmusicians, with an unexpected LH advantage demonstrated by experienced musicians. Gaede, Oscar, Parsons and Bertera (1978) found musical task differences influenced whether a RH or LH superiority occurred, with melody alteration revealing a LH superiority, while chord analysis advantaged the RH in experienced musicians (Gaede et al., 1978; Gordon, 1974). Goldberg and Costa (1981) reported a professional violinist manifesting musical deficits after a stroke to the LH, not thought of as the usual cerebral musical processor (p. 162). Other studies (Johnson, 1977; LaBarba & Kingsberg, 1990) report similar results for the LH, again suggesting a link between proficiency and hemispheric activation. The findings are not unanimous, however, as Gates & Bradshaw (1977) found no significant ear effects for familiar melodies in trained musicians. Musical tasks which generally show a LH effect are rhythm, duration, temporal order and sequencing (Bradshaw & Nettleton, 1981; Gates & Bradshaw, 1977), predictable events in time and space and related to Hasher and Zacks' (1979) hypothesis of innate automatic encoding of space, time and frequency (see p. 8 above).

Skilled Morse code operators displayed a LH advantage compared to unskilled operators who demonstrated a RH advantage, in complex sequences longer than seven elements (Papcun, Krashen, Terbeek, Remington & Harshman, 1974). They reported that pairs of Morse code letters, dichotically presented in lengths of 13 units or 7 units, elicited a RH transcription advantage for naive subjects only, for the 13 unit lengths. Experience and skill are again implicated as the determining factors in hemispheric processing i. e., more experience and greater skill resulted in LH processing. Skill also increased the number of units processed at one time, a capacity increase.

The RH has long been associated with visuospatial tasks, with clinical data suggesting the association (Bryden, 1982). Facial recognition is a complex visuospatial task generally engaging the RH. However, photographs of famous faces used as stimuli by Marzi and Berlucchi (1977) were more accurately indentified by the LH. Recognition of a famous face whose features have been stablized, has again implicated LH processing. Convergent evidence for LH superiority for recognition of well learned facial line drawings was cited by Sergent (1987). Immediate recognition of a stablized stimulus suggests automatic processing.

Bradshaw and Nettleton (1981) consider facial recognition as largely a function of the RH mediation in emotional recognition. Suberi and McKeever (1977) had females memorize a photograph of an "emotional" face and a "neutral" face, to be discriminated from unknown faces, with manual reaction times as the dependent measure. Emotional faces were processed fastest by the RH, with neutral faces also achieving significant RH superiority , but of a smaller magnitude than the emotional photos. Facial features, in reality, are constantly in transition and would require continuous monitoring, requiring multimodal integration for recognition of emotional expression and tone. Bryden and Ley (1983) reviewed evidence of RH superiority for recognizing the emotional tone of a spoken passage, while exhibiting a LH advantage for recognition of the verbal content of the same sentences. The RH is also implicated in assessing the emotional tone of musical passages (Bryden & Ley, 1983). These authors report that a LH advantage for word recall was attenuated, or even reversed to a RH advantage, when employing high imagery and/or highly emotional words. These word components are therefore another consideration for studying lateralized language superiority, as they would be expected to activate both hemispheres (Bryden & Ley, 1983). This may explicate stimulus dominance in dichotic listening experiments; if high imagery/highly emotional words were employed, both hemispheres would be activated (Mosley & Vrbancic, 1990, see p. 46 below).

Simple sensory discrimination tasks, such as color discrimination, matching or detection, have yielded a RH superiority (Pennal, 1977), while naming color stimuli produced a LH advantage (Bryden, 1982, p. 67). Bryden also reported equivocal clinical evidence, associating defects in color perception with both unilateral RH, and bilateral lesions. The naming of Stroop color-word stimuli has the possibility of activating the RH as well. If the color word automatically activates the color image, both hemispheres should be involved.

Nonverbal stimuli, such as photographs of faces and melody recognition, with normal RH superiority, shifted to a LH advantage with increasing skill, or degree of familiarity. Morse code recognition, a representation of language, also seems to involve RH processing until skill and proficiency allow LH processing. Bilateral processing of color words could be expected. Emotional tones in music, language or faces required RH processing. Accurate identification of emotions would also seem important to social interactions/relationships. Since emotions are transient, dependent upon environmental or linguistic contexts or events, the attentional requirements of constant monitoring again implicate effortful RH processing.

<u>Left Hemisphere Processing</u>

Stimuli and their associations which are immediately recognized, stable, predictable in time and space, fixed, determined by rules and/or logic and influenced by practice or experience, are functionally processed by the LH, the processor of information which can be automatically retrieved. Goldberg and Costa (1981) conceptualized cognitive processes as belonging in two classes: those which draw on preexisting codes of information, and those which do not. The automation of language, both in comprehension and production, can explain the involvement of the LH. As noted above, the process begins in utero (Turkewitz, 1988).

Language. Kimura (1967) first assessed lateralized functioning by the noninvasive technique of dichotic listening. The presentation of verbal or nonverbal stimuli to each ear, simultaneously, produced a behavioral measure of greater competence in either ear, thus implicating greater efficiency of processing in the contralateral hemisphere. Although Satz (1977) cautioned that the dichotic listening procedure only obtained a LH advantage in 70% of right handed patients, while the Wada test established LH language and speech in 95% of right handed patients prior to surgery, the reliability remains acceptable when predictions of LH language superiority are made for right handed individuals. In a longitudinal study spanning about 4 years, of handedness and LH language in children Kee, Gottfried, Bathurst & Brown (1987) found consistent right handed females, and both consistent and inconsistent males (18 months to 6 years) demonstrated significant interference in right hand (LH) tapping rate while reciting a nursery rhyme. No left hand (RH) interference was experienced except for the females with inconsistent hand preference.

Additional evidence of LH specialization for the perception of speech stimuli at infancy was demonstrated by Molfese (1977) in a series of three experiments. The first experiment compared infants (1 week - 10 months), children (4 - 11 years), and adults (23 - 29 years), on differences in auditory evoked potentials (AEPs) to speech stimuli (ba/da, boy/dog) and nonspeech (piano C+ chord/burst of noise) presented through a microphone placed one meter above their heads. The degree of increase in the auditory evoked potential (AEP) in the LH to speech stimuli, and RH increase for nonspeech stimuli, was greater in the infant than in the adult group. This may be an exaggerated physiological response of a developing brain, with habituation just newly established. The hemispheric effects were comparable for infants and adults.

In the third experiment Molfese compared infants less than 24 hours old, with adults (18 - 23 years), using a habituation paradigm, measured by change in hemispheric activity after altering the stimulus presentation. Adults exhibited an increase in LH amplitude with articulation change (ba/da), or when altering the voice onset time and "ba" sounded like "pa". Infants exhibited amplitude changes only for the latter condition, not for the ba/da articulation change, and notably in <u>both</u> hemispheres, again implicating the RH in early (less than 24 hrs old) speech processing.

Entus (1977) implemented a variation of the same paradigm by reinforcing nonnutritive sucking with dichotic stimulation. The presentation of the dichotic stimuli was contingent on the infant's sucking, with novel stimuli increasing the sucking rate initially, compared to baseline. By altering the stimulus to one ear (ma/ba,da/ba; da/ba,da/ga) the increased sucking rate gave a measurable response of hemispheric processing. The 48 infants were 22 to 140 days old, and evenly divided according to gender. Nonnutritive sucking had greater recovery (dishabituation) to LH presented speech stimuli in 71% of the infants, while music stimuli elicited greater RH recovery in 79%. The age difference of three weeks between infants (under 24 hours old) in Molfese's (1977) study and those in Entus' (1977) study, suggest an increase in LH lateralized processing, as infants' LH in the Molfese study did not discriminate the articulation between ba/da, but infants at three weeks of age did so in Entus' study. Experience/exposure and development seem to be the intervening variables for increased discrimination and LH linguistic processing.

Cross-cultural verification of LH linguistic processing was obtained by Endo, Shimizu and Hori (1978) for Japanese Kana words and nonsense syllables presented to the right visual field (LH), and random shapes were recognized faster in the left visual field (RH), supporting equivalent results in Europe and America. The study from Israel by Carmon, Nachshon and Starinsky (1976), previously cited, also confirms LH superiority for reading Hebrew words after grade five. Further evidence comes from Taiwan, with surgical confirmation of the Wada test and LH dominance for speech in most right handed Chinese (Hung, Tu, Chen & Chen, 1985). The same authors conducted a handedness survey of 15,865 Chinese schoolchildren and adults and found a stable left handed prevalence rate of 3.5% in both child and adult groups. Right handedness and language processing dominance in the LH is therefore robust, across races and cultures, with a caveat concerning proficiency and experience.

The automatic aspect of hemispheric lateralized processing is exemplified in Charman's 1979 study (referred to on p. 33 above) in the visual hemifield processing of both verbal and spatial elements of the same stimulus, presented at 15 and 30 ms duration. The first stimulus duration (15 ms) was phenomenologically perceived as only a flash. The second (30 ms) produced awareness of a stimulus, but not enough for conscious recognition. Identification in either visual hemifield of the target letters H,G,S,X, was the verbal task, while simultaneously locating the letter's spatial position on one of four diagonal points. Two points were given, one for correct letter identification and one for correct spatial position. At both 15 and 30 ms duration, the LH was more accurate for the verbal task, the RH for spatial location, with an increase to 30 ms increasing the accuracy for both hemispheres on their respective tasks. Charman (1979) concluded that information processed out of subjective awareness (attention), at the level of guessing, still triggered asymmetries of hemispheric functioning. Although this study may seem to contradict the finding of RH processing of a degraded stimulus through masking (Sergent, 1983), the presentation of a simple stimulus without a mask, for 15 ms, captured the automaticity of each hemisphere's functional response.

Kimura (1967) observed " One characteristic which seems to characterize left-hemisphere dependent stimuli is a high degree of familiarity. Digits and words are familiar stimuli and show a right-ear superiority.", not necessarily requiring verbal labels (p. 174). This statement contains the essence of LH processing of stimuli automatically encoded and retrieved.

Nonverbal Processing. Evidence supports the view that the LH is most efficient in processing familiar musical melodies, rhythms, and harmonies when musical training is established, for the recognition of photographs of famous people, in Morse code transcription accuracy by skilled operators, and the cross-cultural recognition of nonsense syllables. Semmes (1968) observed LH damage produced specific loss of functioning in sensory and motor capacities, suggesting focal organization for specific skills, such as fine manual skills and speech. Manual dexterity in writing, drawing or other fine motor movements are learned skills, requiring experience and practice to become skilled and eventually automatic. Bradshaw and Nettleton (1981) reported LH superiority in rhythm discrimination, in perceiving the temporal order of stimuli both acoustically and tactually, and in controlling fine, sequential motor movements of fingers, hands, limbs and the mouth, during speech. The stimuli and responses described are stable, certain, precise in their characteristics, fixed sequentially and/or temporally, may require prior experience and/or be enhanced by practice, may attain varying levels of skill, can be immediately recognized, and therefore define automatic retrieval from the LH, requiring little, if any, attentional resouces.

Converging Physiological Evidence for Functional Hemispheric Asymmetry

Converging evidence for lateralized functioning may be found in the anatomical structures of the hemispheres. While structure cannot define function, the associations between structure, function and converging behavioral and physiological measures increase the validity of inferences being made. In a review of anatomical measures of brain activity, Springer and Deutsch (1989) refer to the technique of measuring regional hemispheric blood flow by having patients breathe air mixed with Xenon-133 (a radioactive isotope), which allows simultaneous monitoring of brain, and concurrent physical and/or mental activity. Special detectors monitor regional blood flow from the low level of gamma radiation emitted by the isotope. During a spatial mental rotation task, males performed considerably better than females, with both genders showing greater RH activation, as measured by blood flow. Springer and Deutsch (1989) reported greater RH activation in women, which suggested greater effort and less efficient RH processing for this task, and another indication of sex-related hemispheric processing differences. They also noted that complex tasks would typically increase blood flow activation in many areas of both hemispheres (p. 120), arguing for a processing continuum rather than a dichotomy.

Regional blood flow indicated differences in hemispheric cell organization, as rate of flow in neuronal cell bodies (gray matter) is four times that in neuron dendrites and myelinated (white matter) axons. By measuring the resting cerebral blood flow in young males, results suggested more cell bodies relative to nerve fibres in the LH, compared to the RH. Springer and Deutsch (1989) report a suggestion of greater LH transfer of information within regions being subserved by dense, interconnected neurons, while RH transfer across regions would require more of the connecting nerve fibres (p.120). Consistent with this is Woodward's (1988) "anatomical model of hemispheric asymmetry". The LH is proposed to depend on "columnar circuitry" or vertical organization of the pyramidal axons and dendrites, with greater density of cell bodies assumed. The RH has "horizontal neocortical circuitry" with overlapping connections between cell groups (Springer & Deutsch, 1989, p. 318;

Woodward, 1988, p. 68). Thus the "focal" representations of "similar units" in the LH proposed by Semmes (1968), would have some anatomical correlates and support the precision of automatic retrieval. The more "diffuse" RH organization, supported by clinical evidence of dysfunction in several systems (hemineglect) after large RH lesions (Semmes, 1968), suggested a structural substrate for the integration of information across modalities. This would be necessary for monitoring an unstable environment, with limitless spatial possibilities, or creatively reorganizing known information across modalities. When blood flow was averaged across a variety of conditions, RH activation was greater than LH, especially for demanding tasks (Deutsch, Papanicolaou, Bourbon & Eisenberg, 1987; Springer & Deutsch, 1989, p. 121). This implies RH effortful (attentional) processing. Springer and Deutsch proposed the activation of the RH frontal regions may have been due to the RH's general role in attention or vigilance.

A further refinement in measuring brain activity is the measurement of cerebral metabolism, blood flow being an indirect measure of this. Since behavioral activity changes brain metabolic rate in consistent patterns in small regions of the brain, monitoring of radioactively labeled glucose, or other brain nutrients, allows for precise tracking of brain activation (Springer & Deutsch, 1989). Positron emission tomography, or the PET scan, measures pairs of photons traveling in exactly the opposite direction in specially labeled glucose, and produces three dimensional images of the glucose-oxygen metabolism in the living human brain

(p. 123). Springer and Deutsch report a recent study which varied the tasks from staring at a fixation "+", to seeing a noun, to saying the noun, and finally relating a verb to the presented noun. The researchers found bilateral flow increased when vocalizing occurred, but greater LH activity occurred while just "looking at" the words, suggestive of automatic LH processing. "The level of activity did not change in these areas of the left hemisphere during active reading/vocalization or the semantic task, supporting the idea that the subjects had already automatically done some form of linguistic analysis during passive presentation of the cue words." (Springer & Deutsch, 1989, p. 125), italics added. These new techniques allow inferences of behavioral and anatomical brain activity relationships, but Springer and Deutsch again remarked on the involvement of many brain areas for even simple tasks. Simple dichotomies therefore do not describe the more subtle aspects of functional cerebral specialization.

Functional cerebral specialization seems dependent on skill, proficiency and development for LH processing, with progressively fewer attentional demands required as automatic processing develops. The RH orientation process, or integration of complex tasks across modalities, requires attentional resources and leads to effortful processing. Evidence has been reviewed for clinical populations, normal individuals, the deaf, and individuals with reading difficulties. The question of lateralized brain functions in individuals with mental retardation will now be examined.

Mental Retardation and Lateralized Functioning

The question of reduced or anomalous lateralization in children and adults with mental retardation has produced considerable controversy in the past. Pipe (1988) discussed the two theoretical perspectives relating atypical cerebral asymmetries first with structural brain damage, or alternately, with developmental delay. Atypical lateralization has been associated with generalized retarded development, as there is double the incidence of left handedness in retarded groups, compared to the normal population (Pipe, 1988). However, in the normal population 70% of left handers still have language dominance in the LH. Left or mixed handedness is not a good predictor of RH language dominance in normal individuals (Satz, 1977), and is even less so in the retarded. In reviewing studies examining dichotic listening ear advantages in children with retardation, Pipe (1988) reported that except for children with Down syndrome or autism, the majority showed the usual LH advantage for language as measured by dichotic listening.

Mosley and Vrbancic (1990) also reviewed evidence of lateralized functioning in the mentally retarded, employing the dichotic listening paradigm. Although they concluded the ear advantages were in the same direction but of smaller magnitude relative to those of normal individuals, they urged caution in interpreting results. Four methodological considerations were seen as necessary before ascertaining ear advantages: specific attention to the acoustical properties of the stimuli, a reduction in the use of strategies by employing dichotic monitoring, a method of assessing performance reliability, and the elimination of stimulus dominance. Evidence of low test-retest reliability coefficients in ear advantages for consonants, vowels and musical notes was associated with factors such as task variables, attentional LH bias for language, strategy and memory factors. Mosley and Vrbancic (1990) also assert that the verbal/nonverbal distinction is an oversimplification, as the RH was shown to have some language comprehension and was not totally dominant for nonverbal stimuli, while the LH was not always superior for all linguistic stimuli. Citing a study by Pipe (1983), a 5 to 6 week auditory discrimination training procedure was introduced after initial dichotic test performance, followed by a repetition of the dichotic test. LH ear advantages were obtained for two developmentally retarded groups and the children with equal mental age. Of particular interest was the increase in LH advantage in all three groups following training, as would be predicted from the present hypothesis that increased practice and assumed strength of automaticity result in stronger LH processing.

Hornstein and Mosley (1986) presented spoken pairs of digits and pairs of musical notes, in a dichotic listening paradigm, to three groups: young adults with retardation, matched mental age (MA) children and matched chronological age (CA) adults, all males. The task required individuals to listen to a digit or a note, followed immediately by a single digit/note, and judge whether the two digits or notes were the same or different. The influence of memory was minimized by this procedure. Individuals with mental retardation found it easier to recognize the "same" digits or notes in the appropriate hemisphere (spoken digits-LH, notes-RH), but more difficult to recognize "different" in these hemispheres. Recognition of "same" could facilitate or automatically prime attention by the first presentation of the stimulus, while "different" required additional processing of the second stimulus and would be more difficult, with some interference from the first. The greater effort necessary for the "different" decision could possibly help explain the low success rate in the retarded group (58%). When processing of stimuli occurred in the less efficient hemisphere (notes-LH, spoken digits-RH), the processing difficulty was accentuated in all groups, but most noticeably in the retarded group. This deterioration in performance across groups could be interpreted as a further indication of functional differences in lateralized processing, with the less efficient hemisphere requiring the most effort for processing, the greatest attentional demands, and only chance success for the mentally retarded group.

Pipe and Beale (1983) asked children between the ages of 5 to 18 years, with and without mental retardation, to discriminate between dichotically presented digit pairs by pressing one of two buttons, and to point to the correct line drawing of a rhymed word pair, also dichotically presented. While the normal group of children showed significant LH advantages for two of the tests, and a trend favouring the LH for the third test, in the retarded group none of the tests reached significance, but the means did favour the right ear (LH). Pipe and Beale concluded that there was a greater incidence or magnitude of left ear/RH advantages in the retarded group, which reduced the group mean for LH superiority. The greater incidence of a RH advantage could be viewed as incomplete establishment of automatic processing of these linguistic stimuli, therefore still necessitating some RH processing. Pipe and Beale noted that "severe and pervasive language disabilities may be associated with an increased incidence of right-hemisphere specialization" (p. 96). The present hypothesis would propose that by definition, the specialization of the RH is in processing less proficient/automatic stimuli; its processing efficiency is predictably required for most individuals experiencing these conditions. Those less proficient in language would require RH processing.

Visual hemifield presentation of stimuli is a technique rarely used in past assessment of lateralized functioning in the mentally retarded. Smith, Cash, Barr and Putney (1986) presented meaningful/meaningless lexigrams on a computer, after the three subjects (6 & 7 year old females, 6 year old male) moved an empty circle over a dot in the center of the computer screen in order to establish central fixation. The results of dominant hemispheric superiority for meaningful lexigrams and nondominant hemispheric superiority for meaningless lexigrams, were not clear. The authors' assumption of hand and eye dominance determining the language dominant hemisphere is not correct (see Satz, 1977), and no data for subject hand dominance were given. If left handedness occurred, this would not reliably predict RH or LH dominance. Generalizability from three subjects is also rather limited.

Saccuzzo and Michael (1984) also used the visual hemifield paradigm in tachistoscopically presenting the letters "T" and "A" to four groups. Two groups were mentally retarded adults, one with dual diagnosis for schizophrenia. Two nonretarded groups, children matched for mental age (MA) and adults matched for chronological age (CA), participated in three separate experiments. The first experiment assessed simple detection (yes; no) of the two letters at exposure durations of 1, 2, and 3 ms. This was well below the 15 ms experienced as a flash by normal adults in Charman's (1979) study and yet above threshold in this study. The two nonretarded groups were significantly more accurate than the two groups with mental retardation, which did not differ from each other. As this threshold detection task found the same LH superiority across groups, the authors concluded that the retarded individuals showed the same pattern of hemispheric processing as the nonretarded, although they were slower. Saccuzzo and Michael (1984) interpreted this as a deficiency in information input, possibly structural, that adversely influenced further processing. Similar findings were reported by Hornstein and Mosley (1987) in determining critical target durations for two letter words and polygons, through incrementing masking SOA's in 1 ms steps, until five consecutive correct identifications were made. The mean for the mentally retarded adults was more than twice that of the MA group, and more than three times that of the matched CA group. Nettlebeck, Robson, Walwyn , Downing and Jones (1986) observed mildly mentally retarded adults required more than twice the target exposure duration as nonretarded adults for achieving error-free levels in making simple discriminations. The latter authors, and Saccuzzo and Michael (1984), suggest some dysfunction not under voluntary control influencing slower processing speed, while Hornstein and Mosley (1987) suggest control processes as a possibility.

In a second experiment, Saccuzzo & Michael (1984), required subjects to report and discriminate for each trial, whether T or A was presented. The results (but no data) were reported as similar to the first experiment, with hemispheric processing for the retarded and nonretarded subjects again found comparable. The third experiment presented the same two letter targets for 4 ms, stated as being above threshold for all subjects, and five masking conditions of SOAs of -20, 0, 40, 80, and 120 ms. Results did not reveal a main laterality effect, but the interaction showed both retarded adult groups as significantly less accurate than the adult nonretarded group for both LH and RH presentations, with the MA children in between, not significantly different from either of the extreme groups. All four groups were relatively the same in the forward masking, simultaneous or 40 ms backward masking conditions. At 80 ms and 120 ms backward masking, nonretarded adults and children were significantly more accurate than the two adult retarded groups. Mental age could not explain these differences as the MA children were equivalent with the CA adults at 120 ms. Slower processing speed for the two retarded groups could explain the MA-MR differences, with the authors proposing similar deficits for different reasons in the dual-diagnosed schizophrenics.

It is interesting to note the evidence of lateralized functioning in all groups when presentation and discrimination of simple stimuli was at 1, 2 and 3 ms, much less than even Charman's (1979) study of 15 and 30 ms duration for letter identification, but lack of a lateralized effect when the masking paradigm is implemented. The lateralized advantage for simple stimuli processed out of conscious awareness is evidence of automatic LH processing occurring in all groups, as would be predicted from evidence of the priming effect (Merrill, 1990; Sperber & McCauley, 1984). Stimulus degradation through masking has been shown to increase RH processing of stimuli (Sergent, 1983). All groups were equivalent on the forward masking, to 40 ms backward masking conditions, therefore showing equivalent processing confusion. Only after the 80 ms interstimulus interval (ISI) were there significant group differences in processing, without laterality effects in any of the groups. The masking paradigm may inhibit automatic LH access and induce RH effortful processing, and this could explain greater RH involvement across groups.

Evidence of lower LH advantage magnitudes, or bilateral language processing in individuals with mental retardation, could be attributed to inefficient establishment of language automaticity in the LH. The processing of two stimuli in the masking paradigm, with possible interference from the masking stimulus, would require greater effort and more attentional processing requirements. If a 4 ms simple letter presentation was above threshold even for the retarded adults in Saccuzzo and Michael's (1984) study, the additional 40 ms required in the masking paradigm by normal CA adults and the 80 ms required by the MA matched children, compared to the retarded adults, implicated effortful RH processing of the masking stimulus. A threshold stimulus duration of 4 ms is conceivably automatic, processed without conscious awareness, and did achieve LH superiority across groups. The significantly slower processing of the masking stimulus by both retarded groups, compared to the CA and MA groups, could implicate attentional demands placed on the RH. Developmentally, the MA children required 40 additional milliseconds (120 ms ISI) to attain the CA adult level of accuracy at 80 ms ISI. Predictably from past research (Hornstein & Mosley, 1987; Nettlebeck, Robson, Walwyn, Downing, & Jones, 1986; Saccuzzo & Michael, 1984), the mentally retarded adults should require twice that for effortful processing, or 80 ms (for a total of 160 ms ISI), which was not tested. Why effortful processing in individuals with mental retardation predictably requires twice as long as the same processing in normal adults may have structural deficiency components, such as shape abnormalities in dendritic spines, which have been correlated with decreases in excitatory synaptic transmissions (Steward, 1988). This could influence attentional capacity through processing speed requiring its control. The issue is perhaps not a question of either structure or function, but an interaction of both.

Employing the visual hemifield paradigm for assessing lateralized functional processing in individuals with mental retardation has been rare. Some general limitations of the paradigm will be discussed.

Visual Hemifield Presentation

The human visual system is seemingly ideally constructed for the examination of lateralized brain functioning, as all sensory inputs from each visual half-field are processed by the contralateral hemisphere (Bryden, 1982; Hardyck, 1986; Hellige, 1986; Sergent, 1983). As noted earlier, linguistic stimuli projected to the right visual field (RVF) have been found to be processed more quickly and more accurately compared to those projected to the left visual field (LVF) (Bryden, 1982,1990; Hellige, 1983; Segalowitz, 1983; Springer & Deutsch, 1989). Although the assessment of lateralized language functioning by the noninvasive visual half-field task is not accurate enough for assisting with surgical procedures, as is the Wada test, both methods were shown to be concordant in the majority of clinical cases assessed (Channon, Schugens, Daum &

Polkey, 1990). Some methodological concerns for this paradigm are fixational stability, saccadic eye movement latency and retinal eccentricity.

Fixation

Before stimuli are presented to either hemifield on a computer or tachistoscopically, there must be some control over eye fixation, as the stimuli must subtend at least 1° of visual angle to the right or left of central fixation, for lateral processing to occur (Sergent, 1983). Saccadic eye movements are initiated volitionally and/or involitionally within 150 to 200 milliseconds (Hardyck, 1986; Moscovitch, 1986; but see p. 76 below). Maximum stimulus exposure must therefore be constrained by these limits. Stimulus exposure at or below 150 ms does not allow the individual to bring the stimulus into foveal vision which accesses both hemispheres. Unilateral presentation of stimuli greater than 1° of visual angle from central fixation, and of less than 150 ms duration can control for saccadic eye movements. Controlling central fixation through the presentation of an identification task before presentation of the lateralized stimulus, has been found to influence in advance which hemisphere is advantaged. A "fixation control bias" has been reported by Hiscock (1988) in both adults and children. Children's laterality was reported as being reversed when the category of the fixation-control stimulus was changed, and this task change continued to influence data over 2 to 3 days (Hiscock, 1988, p. 150). The fixation-control stimulus should therefore not be specific to the processing in one hemisphere, as it seems to prime that hemisphere. In the absence of monitoring eye movements, a neutral central fixation stimulus is required (e. g., a stable dot) with instructions to always focus on the fixation stimulus prior to target stimulus presentation (Hardyck, 1986). Unilateral stimulus presentation must also be random, using positional uncertainty to control for a bias away from a central fixation point (Segalowitz & Bryden, 1983). This should yield stimuli projected to only the contralateral hemisphere without prior priming of either, and control for a scanning bias away from central fixation (Hellige & Sergent, 1986).

Retinal Eccentricity

Since it is required to project stimuli to the left or right of fixation for lateralized processing to proceed, and since acuity decreases proportionally with the degree of eccentricity from central fixation, the size of the stimulus, its duration, and its perceivable defining features become important in interpreting the data (Sergent, 1983). Sergent noted that with larger eccentricity and shorter stimulus durations, the RH was advantaged compared to the LH. She reported a LH advantage for small letters at 11° eccentricity presented for 150 ms, but a RH advantage for large letters at 11° presented for 20 ms (Sergent, 1983). Longer stimulus durations allow for the temporal summation of smaller subtended visual angles, when presented at greater degrees of eccentricity.

The acuity gradient of a word can vary according to word length, as the last letter in the RVF and the first letter in the LVF, horizontally presented, are furthest removed from central fixation. Control of the minimum angle of resolution for these letters is required, since acuity must be adequate to resolve the defining features of the letter at maximum eccentricity. An individual with normal 20/20 vision (Snellen Notation) can resolve a visual angle of 1' of arc at 20 feet at fixation. At 11° eccentricity the same person requires 11' of arc at 20 feet (Anstis, 1974; Mosley, 1978; Woodhouse & Barlow, 1982). If the adequate control of resolution at maximum letter eccentricity is not considered, lateralized functioning may be biased towards the LH for longer words, given that we read English words from left to right (Bryden, 1982, 1986; Tomlinson-Keasey, Brewer & Huffman, 1983). Subjects must therefore be assessed for acuity. The defining features of a letter at maximum eccentricity, must be large enough to allow an individual with less than standard visual acuity to identify it accurately. This holds for words that are presented horizontally. Another method for controlling the influence of the acuity gradient is presenting words vertically.

The vertical presentation of words to each hemifield has been suggested as a control for the acuity gradient and also a control for a left-right scanning bias for English words (Bryden, 1982; Howell & Bryden, 1987). A LH advantage was still obtained for Hebrew letters and words which are scanned from right to left (Carmon, Nachshon & Starinsky, 1976), therefore not supporting the position of a LH scanning bias advantage as a result of English being scanned from left to right, seen to favour the RVF (LH). Nor is there support for a RVF attentional bias, since hemispheric cueing (Hardyck, 1986), still resulted in a LH advantage for language. Vertical presentation of English words was suggested as a control by Bryden (1982), Hellige (1986), Hellige and Sergent (1986), then discouraged (Bryden, 1986; Howell & Bryden, 1987), due to an attenuated or absent LH advantage for linguistic stimuli, compared to horizontal presentation of the same stimuli. Howell and Bryden (1987) proposed that the novelty and greater difficulty of processing words displayed vertically, leads to RH involvement. Others also report attentuated LH advantages for vertically presented words (Tomlinson-Keasey, Brewer & Huffman, 1983). The vertical presentation of words as a control for the acuity gradient is therefore not without controversy.

Word length has been found to be related to LH superiority, with the longest words resulting in the greatest LH superiority because RH performance declines rapidly as word length increases, while the LH remains unaffected, a possible result of LH automatic processing (Bruyer & Janlin, 1989; Ellis, Young & Anderson, 1988). Bruyer and Janlin (1989) found that word/stimulus length was best defined by the number of letters, rather than physical size. The acuity gradient is worst for the longest words, since the initial letters in the LVF are at maximum eccentricity. The horizontal and vertical presentation of words should control for this , and the importance of the disadvantaged first letter in the LVF (Bryden, 1990; Tomlinson-Keasey, Brewer & Huffman, 1983). Concerns regarding adequate acuity also impact on stimulus characteristics.

Stimulus Characteristics

Stimulus size and viewing distance determine the critical visual angle of resolution required for adequate acuity of the most eccentric letter. The size of the gap required in a letter's defining features, at maximum eccentricity, for the individual with the worst visual acuity and an arbitrary viewing distance (angle° tangent = size of gap/arbitrary distance), should determine letter size (see p. 86 below). Sergent and Hellige (1986) warn that stimuli presented parafoveally cannot be processed as they would be during foveal fixation, leaving a considerable part of the visual cortex inactive. The implication is that normal lateralized functioning cannot be accurately assessed in visual half-field studies. However, the precise control of sensory input parameters such as size, eccentricity, duration, and contrast, define the quality of the percept and impact hemispheric processing efficiency (Sergent, 1983; Sergent & Hellige, 1986). Degradation of a stimulus generally results in RH processing (Sergent, 1983), while highly familiar verbal stimuli presented parafoveally at 4° eccentricity for 15 ms, produced a strong LH advantage (Lambert, Beard & Thompson, 1988). Familiarity is therefore another stimulus characteristic that should be considered. Control of sensory inputs help clarify lateralized functioning, but an examination of task factors is also necessary for a more precise determination of results.

Task Factors

After the initial reception of sensory inputs, the same stimulus may be processed in different hemispheres according to the task requirements (Bryden, 1982; Bryden & Ley, 1983; Hiscock, 1988). The precise processing demands made by a task, such as simple detection, identification, naming, lexical decision, matching, may all use the same stimulus but can result in different hemispheric advantages (Hellige & Sergent, 1986). Hellige and Sergent (1986) urged caution in the interpretation of the data when a verbal response was required, as verbal processing requires LH processing. However, a significant Visual Field X Task interaction producing a RH processing advantage, could not be attributed to the verbal nature of the response. A RH advantage under these conditions was considered to be very robust.

Dependent Measures

Two measures of task laterality are response accuracy and response latency (Hellige & Sergent, 1986; Sergent, 1983). Latency of response and accuracy are measures of efficient hemispheric processing. Automatic processing is fast and accurate, therefore making both reaction time (RT) and accuracy appropriate dependent measures. When processing is more effortful, it is expected to take longer and will generate more errors. Effortful tasks can also result in a speed-accuracy tradeoff, where increased speed is gained at the expense of making more errors, producing a negative relationship between the two dependent measures. Hellige and Sergent (1986) report the use of either or both dependent measures in assessing " ease of processing". For any given trial, identification accuracy is a dichotomous variable, while RT is a continuous variable. Floor and ceiling effects make accuracy a less sensitive dependent measure, while RT's to correct responses are also dependent on the number of correct responses (Hellige & Sergent, 1986). These authors suggested the specific perceptual and cognitive processes of experimental tasks should take precedence over arbitrary choice of a dependent variable (p. 213). Obvious differences in automatic or effortful processing should determine which dependent measures are implemented (Hellige & Sergent, 1986; Sergent, 1983).

A task which is universally seen to embody both automatic and effortful processing in one and the same stimulus, is the Stroop task.

The Stroop Task

The traditional Stroop task (Stroop, 1935) results in the semantic meaning of a printed color word interfering with the naming of its incongruent letter color e. g., RED printed in blue letters. Reading of the color word is experienced as obligatory, even when attempting to ignore the word to name its letter color. This compound stimulus has "a word stimulus and a color stimulus both . . . presented simultaneously" (Stroop, 1935, p. 659). The Stroop effect is generally measured by the difference between the amount of time it takes to name the letter color of an arbitrary list of incongruent color-words and an equal number of colored squares, or the time it takes to read the same number of color-words printed in black letters compared to reading the incongruent words, or a variation/combination of these measures (Hama & Hashimoto, 1985; Jensen, 1965; Klein, 1964; Stroop, 1935). Stroop found that the time taken to name a list of 100 incongruent letter colors, compared to simply naming 100 colored squares , was increased by 74.3%, while incongruent word reading was increased by only 5.6% from reading words printed in black letters. The interference from the unattended color was negligible compared to the interference from the unattended word. Stroop concluded this was the result of more practice in reading compared to color naming.

He consequently trained subjects in color naming over eight days, resulting in the color producing greater interference in reading, which has since been named the "reverse Stroop effect" (MacLeod, 1991). However, this newly developed interference dissipated rapidly over the next two days.

Stroop's conclusions of the greater effectiveness of strengthening old associations such as reading, compared to recently practiced color naming, is restated somewhat in Cohen, Dunbar and McClelland's (1990) model, where practice strengthens the pathways of a response, resulting in varying degrees of automaticity which create the Stroop effect. Cohen et al., (1990) did not find Stroop research results were adequately explicated by viewing reading as a completely automatic response, and color naming as a control process requiring attention. They concluded that differences in interference were not sufficient to distinguish between dichotomous automatic or controlled processing, with automatic processing supposedly never vulnerable to interference (see also Kahneman & Chajczyk, 1983; Kahneman & Treisman, 1984). Rather than dichotomous (automatic or controlled), Cohen et al., viewed processing as continuous (see also Hasher & Zacks, 1979; Whitaker, 1983). Modulated by attention which was allocated according to processing strength, processing was seen to proceed along pathways established and strengthened by practice. The greater the automaticity, the greater the probability of processing taking that path. MacLeod (1991), in his review of half a century of Stroop research, developed Cohen, Dunbar and McClelland's (1990) model of parallel distributed processing (PDP) further, without need of a limited-capacity response channel to account for empirical results related to the Stroop effect. At the core of the MacLeod (1991) and Cohen et al.'s, (1990) model is processing activation moving along pathways differing in strength, with degree of automaticity determining each pathways strength (pp. 192-193). MacLeod and Dunbar (1988) manipulated color naming and shape naming over 20 days of trials in their study, and concluded the Stroop effect was the result of competing tasks, which were on a continuum of automaticity. The amount of practice in color or shape naming determined the degree of interference it produced. The position on this continuum was influenced by practice or training and contextual demands, such as shape or color naming. Task demands were seen to determine if a process appeared automatic or controlled (Cohen, Dunbar & McClelland, 1990).

Although generally in agreement with the above authors' conclusions of a continuum of automaticity, not all tasks are seen by the present author as capable of attaining equal automaticity with enough practice. Aspects of the color naming task, compared to word reading, are seen to influence the "consistent mapping" which Schneider and Fisk (1983) delineated as necessary for automaticiy to develop. The sensation of color is also experienced along a continuum generally (blue-green, green-blue, turquoise, aqua, etc.), rather than as a discrete stimulus. Conversely, a word-semantic meaning relationship is precise. Unless a stimulus is discrete, consistent practice is not feasible. Color naming would predictably not be as automatic, unless some color stimuli relationships were stabilized, and then well practiced. Cohen, Dunbar and McClelland

(1990) noted as well that color names are frequently associated with varying semantic relationships compared to other words (e. g., "red" with heat, embarassment or stop, p. 340; see also Klein, 1964). Under normal conditions of color naming, the same degree of automaticity as semantic retrieval in reading, could not be established. Therefore, the color dimension was shown to not interfere with reading, without a great deal of practice in color naming, and only transiently, while the involuntary reading response produced reliable, significant conflict in color naming (Klein, 1964; Stroop, 1935).

MacLeod's (1991) model, developed from Logan (1980), states that accumulated evidence from all dimensions gather "weight" in the decision process, until a response threshold is reached. Two determinants of what each dimension contributes to the eventual decision were seen to be a stable, automatic aspect and a flexible, attentional aspect, summed in a composite decision process. "Total evidence at threshold is the sum of all evidence from all dimensions." (MacLeod, 1991, p. 191). This incorporates both automatic and effortful processing in any decision to respond, and both cerebral hemispheres by implication. Although attention is assigned a mimimal role, as a modulator without privileged status, the gradient of automaticity would predict greater attentional allocation required to overcome increasing automaticity, as demonstrated in the Stroop task. Attentional allocation and control is therefore seen as still necessary, requiring a great deal of effort when attempting to overcome automatic pathways. The degree of effort required to override automaticity should be positively related to the degree of automaticity or pathway strength.

Researchers report signs of strain and effort in normal subjects attempting to name the letter color, while inhibiting the reading response (Dyer, 1973; Izawa & Silver, 1988; Klein, 1964; Schiller, 1966). Amount of effort applied to the Stroop task was manipulated by researchers in a competition paradigm, by promising one extra course credit to one of two university students who responded the fastest in naming the incongruent letter colors. This resulted in faster responding than in the control condition without the incentive (MacKinnon, Geiselman & Woodward, 1985). The effortful attentuation of interference from the automatic reading response, suggests attentional control. The inhibition of the automatic reading response in the Stroop task, is consistently cited as an example of automatic/effortful processing in the attention literature (Carr, 1984; Davies, Jones & Taylor, 1984; Ellis, Woodley-Zanthos, Dulaney & Palmer, 1989; Hasher & Zacks, 1979; Kahneman & Treisman, 1984; Merrill, 1990; Schneider, Dumais & Shiffrin, 1984; Stanovitch, 1985). Although Kahneman and Treisman (1984) question the automatic strength of the reading response, the attentional effort required in its inhibition is not generally disputed. If reading automaticity is seen to emerge gradually on a continuum, rather than considered to be an "all-or-none dichotomy", (Cohen, Dunbar & McClelland, 1990; MacLeod, 1991; MacLeod & Dunbar,1988) then practice, experience, developmental maturity and individual proficiency are influential factors when assessing Stroop conflict across individuals with varying intelligence levels.

Development

In a study of Stroop interference effects from childhood to old age

(235 subjects, 7 to 80 years old), Comalli, Wapner and Werner (1962) reported the greatest interference at age 7, presumably just after reading was automatized, decreasing to young adulthood, and increasing again after the age of 60. Reading and color naming speed also decreased to young adulthood, but then remained stable, with reading consistently faster than color naming. This suggests automatic processing attains stability, while effortful processing does not. The Stroop interference effect was shown to be paradoxical developmentally, as reading and color naming proficiency increased with age, inhibition of the more proficient (automatic) reading response also became more efficient, suggesting the developmental control of attentional processes. Perhaps practice in attentional control also increases its efficiency. Converging evidence for this developmental trend was found by Schiller (1966) and Wise, Sutton and Gibbons (1975). Interestingly, Hama and Hashimoto's (1985) cross-cultural evidence from 721 Japanese subjects, 6 to 89 years old, replicated Comalli's et al., (1962) American study. Further cross-cultural evidence in young Tel Aviv adults, whose primary language was Hebrew (Ingraham, Chard, Wood & Mirsky, 1988), and in 120 Chinese-English Hong Kong bilinguals, Grade 2 to college (Chen & Ho, 1986), revealed equivalent results. For the bilinguals, the most proficient language engendered the most interference in the Stroop task, with a reported shift as proficiency increased in either (Chen & Ho, 1986; MacLeod, 1991). The developmental similarities reported across cultures and languages help establish the reliability of Stroop interference and attentional processes, which seem to develop universally at approximately the same rate in normal individuals. MacLeod (1991) concluded that virtually everyone who reads shows a robust Stroop effect (p. 185). A difference which may also be universal is the female ability to name colors faster, in both the incongruent and simple color conditions.

Gender

Stroop (1935) reported that females have a greater verbal facility in naming colors relative to men (p. 658). Hama and Hashimoto (1985) showed females as significanty faster in color naming for both the color and incongruent color-word cards, but there was no gender difference in the degree of conflict experienced. Izawa and Silver (1988) reported the 32 female college students had faster reaction times (RT's) than males in naming letter colors for 64 Stroop stimuli. They reported evidence of female superiority in color naming for school children, advanced age groups and even the learning disabled (Izawa & Silver, 1988, p. 224), suggesting that gender should be considered as a factor when examining absolute RT's. The Stroop effect itself did not show gender differences, however (MacLeod, 1991; Izawa & Silver, 1988). Net interference remained the same for both genders across studies, implying that attentional processes were equivalent.

Another aspect to be considered however, was the semantic relatedness of incongruent color stimuli (Klein, 1964).

Semantic Relatedness

Dyer (1973), in his review of the Stroop research, suggested that Klein's (1964) study was the most important since the original study by Stroop. In an intuitive expansion of the Stroop paradigm, Klein examined the semantic relatedness or meaning of the word, and its color name response. Degree of conflict interference increased as the words progressed from nonsense syllables, rare words, common words not color related, color-related words, color names not in the response set, and finally the color names in the response set. For all conditions, naming letter colors for the above words was significantly slower than simply naming colors alone (Klein, 1964). The automaticity of the reading response is most evident in conflict generated by nonsense syllables. Word meanings, with varying degrees of semantic relatedness, are automatically retrieved as well, with conflicting color associations producing the greatest interference. Schiller's (1966) experiment corresponded to Klein's, with semantically related incongruent word cards implemented for subjects from Grade 1 to college. Except for Grade 1, words were read faster than colors were named, and interference was greatest at Grade 2 and 3 for all conditions. This developmental progression of interference paralleled Comalli, Wapner and Werner's (1962) study, but to a lesser degree for alternate color words not in the response set (tan, gray, etc.), still less for color-related words (lemon, fire, etc.), and least for nonsense syllables. Amount of semantic knowledge automatically accessed was therefore measured by the amount of interference, and this was developmentally stable.

In his review, MacLeod (1991) also noted the importance of sequence in potential priming of the next discrete Stroop trial, with color or word congruence resulting in greater facilitation (faster and more accurate), or incongruence resulting in greater interference (longer RT's and more errors). The ability of a prime to influence consequent processing is also seen as a measure of the automatization the stimulus' associations (Sperber & McCauley, 1984).

Stroop interference seems to depend upon the degree of automaticity of the reading response and its consequent semantic activation, and the development of attentional control. Individuals with mental retardation have been noted for their particular problems with attentional control in effortful processing (Carr, 1984; Brooks, McCauley & Merrill, 1988; Davies, Jones & Taylor, 1984; Ellis, Woodley-Zanthos, Dulaney & Palmer, 1989; Merrill, 1990; Mosley, 1987; Schneider, Dumais & Shiffrin, 1984; Sperber & McCauley, 1984; Stanovitch, 1985; Zeaman & House, 1979). The Stroop paradigm is therefore especially suited for delineating attentional problems, as the degree of reading automaticity or proficiency is different for each individual, with the less proficient requiring less attention to inhibit it. This does not bias task difficulty against the mentally retarded, as less proficiency in their reading responses would predict less effort required to inhibit it as well. Effortful processing of Stroop stimuli by individuals with mental retardation who are able to read, allows assessment of attentional processing deficiencies.

Mental Retardation and the Stroop Task

Das (1969) found children with mental retardation (mean age 13.3 years) could name colors faster than read words at a Grade 1 level, and therefore had reduced Stroop interference. In a second study, Das (1970) compared 165 children, with and without mental retardation, from six consecutive mental age levels (7-12 years), on Stroop interference.

He found increased interference with increased mental age in the retarded children relative to nonretarded children, while color naming and word reading also became more proficient. This is in direct contrast with the normal developmental data reported earlier (Comalli et al., 1962; Schiller, 1966) and replicated in Das' (1970) study, where increased age and reading proficiency paradoxically had less Stroop interference in normal children. McFarlane and Sandy (1982), in their second experiment, compared 40 retarded and nonretarded adolescents on a Stroop analog picture-word interference task. They reported a semantic gradient of interference in their results, with substantially more errors made by the retarded subjects in semantic incongruence between a word and picture task, than made by normal subjects. Bassett and Schellman (1976) tested 32 institutionalized adolescents with mental retardation on 36 randomized, discrete trials, using index cards, and found significant interference for the incongruent stimuli. With increasing reading proficiency and mental age, individuals with mental retardation reveal more interference rather than less.

When comparing groups of retarded individuals, Silverstein and Franken (1965) employed the traditional Stroop Color-Word Test to two adolescent male groups (MA's from 6-0 to 7-11 years, & 9-0 to 10-11 years) and reported the expected interference, but no difference between the two intelligence groups. However, Wolitzky, Hofer and Shapiro (1972) tested 39 low and high IQ, noninstitutionalized retarded, and 32 normal young adults, on a modified color-digit Stroop task. The results revealed all three groups significantly different from each other, with high IQ subjects significantly faster than low IQ subjects, indicating more interference for the less intelligent. With a further manipulation of auditory distraction, Wolitzky et al., found only the retarded groups experienced a disruptive effect over and above the color-digit interference, which the authors attributed to limited attentional capacity in the retarded groups. Uechi (1972) compared three groups of mentally retarded or low IQ Japanese children in junior high school (IQ groups: < 52, 53-73, 74-91), in his second experiment. The lowest IQ subjects had significantly longer reaction times and more errors for the incongruent card than the other two groups. This again implicates greater Stroop interference for the lowest intelligence group. The much larger Stroop effect (more than twice as great) for young, mentally retarded adults, compared to college students, was presumed by Ellis, Woodley-Zanthos, Dulaney and Palmer (1989) to be the result of less attentional capacity in the retarded . The deficiency of effortful processing in retarded individuals for the inhibition of the automatic reading response, was tested further by these authors by developing an automatic color naming response, through extended practice. Ellis, et al., (1989), reported that automatized cognitive responses in retarded individuals persisted in what the authors called "cognitive inertia". Primary importance was given to inadequacies of effortful processing, or control over automatic cognitive "rigidity" in individuals with mental retardation (Ellis, Woodley-Zanthos, Dulaney & Palmer, 1989; Merrill, 1990). Further results by Ellis and Dulaney (1991) revealed that practice in the suppression of the reading response (by practicing incongruent letter color naming), continued to influence individuals with mental retardation for over three months, while nonretarded college students lacked interference after one month. This was interpreted as automatic processing increasing cognitive "rigidity" in the mentally retarded.

Evidence revealed increasing Stroop interference with increasing reading proficiency for the retarded, a reversal from normal developmental trends, and more interference for those with lower IQ's. Authors of the studies cited above generally concluded individuals with mental retardation suffered a deficiency in effortful, attentional control and/or capacity. Less reading proficiency in the retarded population should otherwise also require less effort to inhibit.

The linguistic, semantic nature of the Stroop task also suggested a methodology for examining the cerebral lateralized functioning for language, by presenting lateralized Stroop stimuli.

The Lateralized Stroop Task

Dyer (1973) failed to find a significant laterality effect for vertically presented Stroop stimuli. His discrete, short, laterally eccentric presentation of incongruent color words did not destroy the Stroop effect however. MacLeod's (1991) review of the evidence from the lateralized Stroop paradigm, concluded that the LH showed more interference than the RH for color naming incongruent color words generally, with some equivocal results. Stimulus and response characteristics were found influential in determining laterality effects. Chinese and Japanese Kanji idiographic characters produced more RH interference, a buttonpress response showed greater LH interference to

English Stroop stimuli than did a vocal response, error data were superior to vocal reaction time data in revealing a lateralized advantage, and stimulus presentation with divided dimensions (color and word separately) did not always produce the expected results of greater LH interference (Long & Lyman, 1987; MacLeod, 1991). Greater LH interference was nevertheless found for a variety of stimuli, e. g., auditory stimuli, picture-words, and measures, e. g., event-related potentials (ERP's), or the latency of the P300 wave in an evoked response (MacLeod, 1991).

Aine and Harter (1984a, 1984b) measured occipital and central ERP's to centrally presented Stroop stimuli. They concluded the left hemisphere processed complex information when a word was involved. Long and Lyman (1987), Experiment 2, presented colored rectangles as targets, at 3° eccentricity parafoveally, with verbal distractors (neutral, congruent, incongruent) presented foveally. By varying the stimulus onset asynchronies (SOA's) of the distractors (-200, -100, 0, 100, 200, 350 ms) they found longest vocal reaction times and the most errors for incongruent stimuli at SOA's of -100, 0 and 100 ms, with color naming significantly longer for the <u>RH</u> (Long & Lyman, 1987). This unexpected result of the right hemisphere's greater interference to the color naming task, may have been the result of the word stimuli being presented foveally (to both hemispheres), while the colored rectangles were lateralized. The automatic processing in the LH of foveally presented words (1 to 2 ms), would predictably reduce LH interference. Although the greater involvement of the RH in color processing is not clearly established (Bryden, 1982), the hemispheric difference in this study suggested this as a possibility. The method of stimulus presentation is therefore seen as influential. At 350 ms, there was no facilitation or interference, from which it could be inferred that all automatic and effortful processing had successfully occurred (Long & Lyman, 1987).

In a series of studies employing the Stroop paradigm, Hugdahl and Franzon (1985, 1986, 1987) and colleagues (1987) have innovatively combined the lateralized visual field Stroop paradigm with vocal reaction times, error data, heart rate and bilateral skin conductance responses. In the first study, Hugdahl and Franzon (1985) examined separately the vocal reaction times (VRTs) and errors of 20 right handed (Experiment 1), and previously screened for left dominance (Experiment 2), males. Twelve incongruent Stroop stimuli, in Swedish, and four color-bars subtending the same visual angles as the words, were randomly presented horizontally, for 200 ms, to either hemifield. Results showed significantly more right handed subjects obtained more errors in the RVF-LH, while VRTs did not reveal significant hemispheric differences. Significant differences were found between correct and incorrect VRTs. As incorrect VRTs were significantly faster, a speed/accuracy tradeoff may have been involved. For left handed subjects who had previously shown a left ear (RH) advantage in a dichotic listening paradigm, more errors, as well as significantly delayed VRTs to incorrect responses were found in the LVF-RH and suggested RH language processing. The authors concluded that accuracy was a more sensitive measure of hemispheric differences than vocal response latency (Hugdahl & Franzon, 1985).

Franzon and Hugdahl (1986) presented discrete color-words to either visual hemifield in a vertical orientation. Control stimuli were congruent color-words rather than color-bars. Subjects were both male and female, equally divided into left and right hand dominant. Vocal reaction times and error frequency were the dependent measures. A significant Visual Field X Handedness interaction for response latency revealed longer VRTs in the LH for the right handed subjects. Incorrect VRTs were again significantly faster than correct VRTs. Error frequency data revealed no hemifield differences for the two female groups, but significantly more errors in the LH for incongruent stimuli, in right handed males. This supports previous evidence of greater laterality in right handed adult males compared to adult females (Franzon & Hugdahl, 1986; Bryden, 1982; Springer & Deutsch, 1989). The authors concluded that horizontal or vertical presentation of word stimuli was of little influence.

Heart rate changes were recorded to incongruent Stroop stimuli and color-bars visually presented to either hemisphere for 200 ms, by Hugdahl and Franzon (1987). Deceleration of heart rate was noted to occur when orienting to a stimulus (OR), while acceleration occurred for emotional or intense stimuli. The RH was reported to be especially involved in autonomic perception of changes in heart-rate (p. 1204), suggesting physiological indices of changes in attentional processing. Results reported greater acceleration on trials with initial RH input, with heart rate changes hypothesized as possibly related to RH specialization.

The final study by Hugdahl, Kvale, Norby and Overmier (1987) uniquely combined incongruent color-words, visual hemifield presentation, classical conditioning (aquisition, habituation, extinction), with electrodermal skin conductance as the dependent measure. Only right handed adult males were employed as experimental and control subjects. Two incongruent Norwegian color-words (YELLOW "GUL" in green letters, BLUE "BLA" in red letters) were simultaneously, vertically, presented in either hemifield for 170 ms during the habituation phase. During acquisition, the color-words (CS) were presented with an intense noise (UCS) to both ears, for 290 ms, 4.17 seconds after CS onset, in a trace conditioning paradigm. The extinction phase consisted of bilateral displays of the two separate dimensions of the incongruent Stroop stimuli, color-words printed in grey, and color-bars, were on a grey background. A separate measure for each dimension (color and word), was taken within and between each hemisphere. Skin conductance was measured on both thumbs under all conditions, with the first extinction trial yielding a significantly larger skin conductance response to the word than to the color within the LH, and a larger LH response to words between the hemispheres. Color elicited more of a response than the words in the RH for the "first extinction trial", but this magnitude difference between colors and words quickly decreased over the other trials. The first extinction trial evaluated the strength of the conditioning response to each dimension of the conditioned compound Stroop stimuli. No lateralized effects were found for the control subjects. Hugdahl et al., (1987) concluded the RH asymmetry of conditioning to a color element was more transient than LH conditioning to a word element (p. 563). Differences between left and right hand skin conductance recording, revealed larger left hand (RH) responses to any change in stimuli, possibly again implicating the RH in orienting to environmental change, as found by earlier research (Bradshaw & Nettleton, 1981).

In the first three studies, the researchers employed electro-oculographic (EOG) recordings for assessing eye fixation, but found this procedure unnecessary for the final study cited (Hugdahl, Kvale, Norby & Overmier, 1987). Trials excluded for eye movements in the earlier studies, were from 2 to 3% (a negligble amount). Subjects were verbally instructed to move their eyes deliberately and the shortest latencies obtained were 180 to 200 ms (Hugdahl, Kvale, Norby & Overmier, 1987, citing Pirozzollo & Rayner, 1980), but Hardyck (1986) and Moscovitch (1986) reported a range from 150 to 200 ms for volitional and involitional eye saccades. Stimulus durations of less than this, random presentations, and instructions to fixate, were seen to adequately control for eye movements (Hugdahl, Kvale, Norby & Overmier, 1987).

In the studies cited, data analysis revealed Trials as consistently significant, with later trial blocks significantly faster than earlier trials or trial blocks (Franzon & Hugdahl, 1986; Hugdahl & Franzon, 1985; Hugdahl & Franzon, 1987; Hugdahl, Kvale, Norby & Overmier, 1987). This evidence of a practice effect over trials or trial blocks, suggested that the order of trials should be a consideration. It also suggests practice in attentional control increases its efficiency.

The lateralized Stroop paradigm has revealed more interference in color naming incongruent color letters in the LH of normal right handed adult males, usually university students, implicating automatic language processing for this hemisphere. Proficiency on a task such as reading, measured by speed and accuracy, gives an indication of where on the automatic-effortful continuum of processing the task is found. Color processing superiority in the RH has less evidence to support it, and seems more transient (Hugdahl, Kvale, Norby & Overmier, 1987; Long & Lyman, 1987). The present study will utilize lateralized Stroop stimuli to assess attentional processing and lateralized language functioning in adults with mental retardation, in normal young children matched for mental age, and in nonretarded adults. The lateralized Stroop paradigm is not known to have been employed for normal children, nor adults with mental retardation.

The Present Study

The present study was designed to assess attentional deficits and comparative cerebral lateralized functioning in mentally retarded adults, by employing a lateralized Stroop paradigm. Language proficiency, as manifested in reading trials, the efficiency of its attentional inhibition on the Stroop task, and cerebral hemispheric lateralization in the context of a RH-LH continuum defined by effortful to automatic processing, will be examined. The Stroop paradigm, believed to access automatic reading and semantic retrieval, requires effort in the inhibition of an established automatic response, such as reading (Carr, 1984; Hasher & Zacks, 1979; Klein, 1964; MacLeod, 1991). The less proficient reader should require less attention for the inhibition of a reading response, despite this the younger reader will require more, and those readers equated for reading proficiency and mental age would be expected to be equivalent in attentional functioning. This logical extension of mental age and reading proficiency equivalence in attentional functioning is not supported for individuals with mental retardation, however (Das, 1970; McFarlane & Sandy, 1982; Uechi, 1972; Wolitzky, Hofer & Shapiro, 1972), and will be examined in the present study.

Cerebral lateralized functioning, particularly for language, has been somewhat successfully assessed by the lateralized Stroop paradigm for adults of normal, or above normal intelligence (Aine & Harter, 1984a, 1984b; Franzon & Hugdahl, 1986; Hugdahl & Franzon, 1985, 1987; MacLeod, 1991). No studies are known to have employed a lateralized Stroop paradigm for normal children or persons manifesting mental retardation. It is predicted that stronger language automaticity will lead to greater LH interference, with normal attentional development attenuating interference into young adulthood (Comalli, Wapner & Werner, 1962; Hama & Hashimoto,1985; Schiller, 1966). As well as the proposed RH-LH continuum for effortful to automatic processing, the influence of chronological age and its impact on physiological maturity, gender, and lateralized functioning, are factors which will be considered (Piazza Gordon, 1985; Waber, 1977).

Tasks

Lateralized reading trials will assess the degree of proficiency in automatic processing as it relates to mental age, chronological age, gender and word type (Color-Words, Neutral-Words). Lateralized Stroop trials will assess the efficiency of the inhibition of the automatic reading response as it relates to cognitive development, experience determined by chronological age, gender, word orientation and type. Lateralized name trials will assess the automatic reading response of one's own first name randomly dispersed within the context of effortful inhibition of this automatic reading response for all other Stroop trials.

Lateralized Reading Trials

Automatic processing has been shown to be equivalent for individuals with and without mental retardation in a passive priming paradigm (Sperber & McCauley, 1984) and would therefore suggest an equivalence for reading as well for the highly familiar words employed in this paradigm. Less proficiency in reading would place this response in the RH, on the RH-LH continuum (Carmon, Nachshon & Starinsky, 1976), predicting possible Stroop interference in both hemispheres. Effortful processing of less proficient, skilled behavior has been proposed as the domain of the RH (Goldberg & Costa, 1981; Whitaker, 1983), in the establishment of automaticity. Proficiency should therefore anticipate lateral functioning efficiency. Gender-related considerations suggest physiological maturity impacting on laterality (Piazza Gordon, 1985; Waber, 1977), and would be assessed by differences in chronological age and gender effects.

Lateralized Stroop Trials

As noted earlier, the attentional difficulties of the mentally retarded seem to impact effortful processing on any task (Carr, 1984; Detterman, 1979; Merrill, 1990; Mosley, 1987; Sperber & McCauley, 1984; Stanovich, 1985). The Stroop task has been shown to be particularly difficult for them (Das, 1970; Ellis & Dulaney, 1991; Ellis, Woodley-Zanthos, Dulaney & Palmer, 1989; McFarlane & Sandy, 1982; Uechi, 1972; Wolitzky, Hofer & Shapiro, 1972). The attentional requirements of the Stroop trials would seem to be most difficult for individuals with mental retardation, less so for normal children, and least difficult for normal adults. Attentional processing requiring effort has been proposed as functionally involving the RH.

Effortful Stroop inhibition with greater LH interference has been shown in normal, right handed adult males, generally university students. Adult right and left handed normal females, were found to exhibit equivalent bilateral interference on the lateralized Stroop (Franzon & Hugdahl, 1986). The evidence therefore suggests greater LH interference for normal adult males and bilateral interference for normal adult females. For the children in this study with less established reading proficiency (Grades 2, 3 and 4), there is also the possibility of bilateral interference on the Stroop trials, as Forgays (1953) and Carmon, Nachshon and Starinsky (1976) only found an established LH reading superiority at the fifth grade. The reading proficiency of adults with mental retardation would not be assumed to be as strongly automatic as the nonretarded adults, requiring more RH processing, and greater Stroop interference in both hemispheres. Lateralization of functional language processing is proposed to depend on the level of automaticity established.

Lateralized Name Trials

The question of practice within the Stroop paradigm (Franzon & Hugdahl, 1986; Hugdahl & Franzon, 1985; Hugdahl & Franzon, 1987; Hugdahl, Kvale, Norby & Overmier, 1987) will be addressed by randomizing the order of the presentations of the Stroop and Name Trials, and by having subjects read and report their own first names on random trials, decreasing their abililty to ignore the word over trials. This is intended to encourage effortful processing on every trial. The importance of context in automatic or effortful processing is noted here as well, for the highly automatic reading of one's own first name while attempting to effortfully inhibit the reading response for the Stroop trials (MacLeod, 1991; MacLeod & Dunbar, 1988).

Individuals with mental retardation have shown attentional deficiencies on tasks requiring effortful processing and are expected to have the most difficulty with the lateralized Stroop task, as they are slower to establish automaticity, and once established, are unable to efficiently inhibit it (Detterman, 1979; Merrill, 1990). RH processing is implicated. This study will assess the degree of automaticity established in reading proficiency, its lateralization, and then assess the success of its lateralized inhibition.

METHOD

Subjects

Twenty subjects in each of the three groups were tested individually during one session lasting from 20 to 45 minutes. The mentally retarded group consisted of 10 females and 10 males (Chronological Age, CA = 30.07 years, SD = 7.39 years; Mental Age, MA = 11.14 years, SD = 2.86 years; IQ = 61.45, SD = 13.62) recruited from the clients of the Vocational and Rehabilitation Research Institute (V.R.R.I.), Calgary. One female was recruited from the clients of the Behavior Support Team at the University of Calgary. Individuals were personally informed of the study's nature and purpose, then asked to volunteer for the study subject to parent/guardian consent where required.

The second group of subjects consisted of 10 female and 10 male elementary school children, attending grades 2, 3 and 4 at St. Dominic Elementary School, Calgary (CA = 8.91 years, SD = .82 years; MA = 10.06 years, SD = 1.76 years; IQ = 109, SD = 13.81). These subjects were matched with the mentally retarded subjects for mental age by employing the Peabody Picture Vocabulary Test - Revised, Form L (Dunn & Dunn, 1981). School children were asked to volunteer after a brief description of the study was given to each classroom. Teachers indicated those volunteers who had no learning disabilities and who were reading at a grade 2 level or better. Informed consent letters were sent home with those volunteers and returned prior to testing, which occurred during regular school hours.

The third group of subjects was comprised of 10 female and 10 male undergraduate students (including one female graduate student) at the University of Calgary (CA = 23.95 years, SD = 6.85 years).

All subjects in the study were required to have normal color vision determined by using six plates (1, 2, 6, 10, 14 &18) of the Ishihara Tests for Color Blindness (Ishihara,1988). All subjects were required to be right hand and foot dominant as determined by using a pen for writing or printing their names, throwing a ball, brushing their hair, and kicking a ball placed equidistant from each foot. Near binocular visual acuity was assesssed employing the Bausch & Lomb Master Ortho-Rater (Cat. No. 71 - 21 - 40 - 65). A minimal binocular Snellen rating of 20/33 was required of all subjects. Snellen Notation ratings ranged from 20/17 to 20/29 (median of 20/20) for the Nonretarded Adults, 20/17 to 20/25 (median of 20/20) for the MA Children, and 20/17 to 20/33 (median of 20/22) for the MR Adults. The minimum reading level of the mentally retarded and equal MA nonretarded children was assessed using the grade 2 Graded Word List (Form A') from Johns' (1988) Basic Reading Inventory (4th edition). Subjects were to be fluent only in English. Voluntary participation was stressed. Monetary remuneration of $5 was given to the V.R.R.I. clients and the school children after the session was completed. University participants received $3 after the testing session.

Apparatus

All stimuli were generated on a MicroVAX II LAB/GPX Station minicomputer, with a 19" 8 bit color monitor (Model VR260), extended keyboard (Model LK201) and mouse, manufactured by the Digital

Equipment Corporation. Vocal reaction times (VRTs) in milliseconds were collected on a KWV11 clockboard, with a resolution time of 1 ms. Once the participants released the middle button on the mouse, the clock on the clockboard would start counting at 1 kHz or 1 ms. A word stimulus would be displayed for 150 ms, after which the word display would clear and the program would wait for a voice response. The individual's voice response was monitored by a Dynamic Microphone (Model UD - 836), combined with a Voice Activated Relay Key (Model 18010) manufactured by the Lafayette Instrument Company. The relayed voice signal went to the TTL (Transistor Transistor Logic) voltage input on the clockboard causing it to stop the timer. The software read the elapsed time from the clockboard, creating the Vocal Reaction Times (VRTs) as a dependent measure for each discrete stimulus. A black fixation dot always remained at the centre of the screen (see p. 86 below).

Each subject's VRTs for all trials (Lateralized Reading, Practice, Stroop and Name) were recorded on a Sony tape recorder (Model TC-158SD) with a Sony Dynamic Microphone (Model F - 27S). The experimenter also manually recorded any errors which occurred.

While testing offsite from the University of Calgary, all equipment was attached to a Hammond Constant Voltage Transformer (Cat. No. CV500AFB).

A comfortable chair with two armrests and an adjustable head-restraint held the respondent's head so that the eyes were a constant 50 cm from the center of the screen monitor.

Stimuli

The computer generated stimuli consisted of the four Color-Words: RED, BLUE, GREEN, PURPLE and four Neutral-Words: DAY, WORD, STORE, FRIEND, yoked with the Color-Words for length. Color-Words were always in incongruent colored letters for the Lateralized Practice and Stroop trials (e. g., RED printed in blue, green or purple, never in red, uppercase letters, 18 pitch, monospaced, Roman Style Bold Font). These were also the letter colors of the Neutral-Word DAY (i. e., yoked with RED). The Color-Words (RED, BLUE, GREEN and PURPLE) were chosen because they defined the colors used in the response set. The Neutral-Words (DAY, WORD, STORE and FRIEND) were chosen to match the Color-Words for letter length, their position (at or below Grade 2) in the Basic Reading Inventory (Johns, 1988), their salience for individuals at the V.R.R.I., their lack of producing a precise image or emotions (a RH advantage), and their frequency in spoken (Dahl, 1979), and in written (Kucera & Francis, 1967) American English. The order of written word frequency, from most to less frequent, according to Kucera and Francis (1967) was: DAY, WORD, RED, BLUE, FRIEND, GREEN, STORE and PURPLE; the order for spoken American English according to Dahl (1979) was: DAY, WORD, FRIEND, STORE, BLUE, RED, GREEN and PURPLE. These words were therefore established as being highly familiar for all participants.

Horizontal Array. Each letter was .8 cm in width and .7 cm in height thus subtending visual angles of .92° (55') horizontally and .80° (48') vertically at a viewing distance of 50 cm. Letters were spaced .2 cm apart. The words RED and DAY subtended a horizontal visual angle of 3.2°

(192.3'), BLUE and WORD subtended a horizontal visual angle of 4.35° (261'), GREEN and STORE 5.48° (329'), PURPLE and FRIEND 6.62° (397.2'). The subjects' first names (Name (check) Trials) varied in length from 3 to 9 letters and therefore subtended horizontal visual angles ranging from 3.2° (192.3') to 9.98° (598.8'), depending upon letter length, with .80° (48') being the vertical visual angle.

Vertical Array. Vertically , each letter was .7 cm and spaced .3 cm apart. RED and DAY subtended a vertical visual angle of 3.09° (185.5'), BLUE and WORD 4.23° (254'), GREEN and STORE 5.37° (322.2'), PURPLE and FRIEND 6.5° (390'). All vertical arrays subtended a horizontal visual angle of .92° (55'). Again, the subjects' first name's vertical visual angles varied from 3.09° (185.5') to 9.87° (592.2') depending on letter length.

Since the minimum resolvable angle is nearly directly proportional to horizontal eccentricity (Anstis, 1974; Woodhouse & Barlow, 1982), at 6.6° of maximum eccentricity, a space of .0962 cm would have been sufficient for resolving the letters (1' at 50 cm = .0145 cm x 6.6167° = .0962 cm). A .2 cm space would therefore only require half the 20/20 visual acuity, or 20/40 Snellen Notation for adequate resolution at maximum letter eccentricity. All white spaces between and within the letters were at least .2 cm (2 mm) in height and width.

Fixation Dot. The black dot, which remained in the center of the screen, had a diameter of .3 cm and subtended a visual angle of .34° (20.63') at 50 cm. Each discrete stimulus was centered either directly to the right or left of this central fixation dot, at a distance of 1.7 cm or 2° from the center of the dot to the word's inside edge.

Dependent Measures. Latency of vocal responses (VRTs) on correct trials assessed each hemisphere's processing efficiency and attentional success by the speed of correct responding (Hellige & Sergent, 1986; Sergent, 1983). Vocal latency has not proven to be a consistent laterality measure, particularly as it relates to the lateralized Stroop paradigm (Hugdahl & Franzon, 1985; MacLeod, 1991), but was employed for this study, along with response accuracy measured in error percentage, for the following reasons. Greater speed and accuracy define automatic processing, and are therefore an indication of its establishment. Also, the Nonretarded Adults were expected to make few if any errors, while the MR Adults were expected to have great difficulty in producing correct responses to Lateralized Stroop Trials, therefore only measuring accuracy of responding would be inadequate, due to possible floor and ceiling effects. Finally, the findings of Hugdahl and Franzon (1985, 1986) for normal adults, revealed a possible speed/accuracy tradeoff occurring for the Stroop task, as incorrect responses were significantly faster than correct responses. These all indicated both accuracy and latency to correct responses should be implemented as dependent measures. Therefore both latency of correct responding (VRTs), and accuracy of responding in error percent (ER%) were implemented.

Procedure

Pretesting. All subjects signed the consent form, the experimenter noting the hand used for writing/printing of their name. They were then asked to take the brush and brush their hair, then given and asked to throw the ball. The ball was placed equidistant from each foot, and the subject was asked to kick it to the experimenter.

Normal color vision was assessed with the six Ishihara plates which required the subject to identify a number. If all six numbers were identified correctly pretesting would continue. Next, the Johns' Graded Word List required each person in the MA Children and MR Adults groups to read 19 out of 20 words correctly (Johns' criterion) on the grade 2 list. When these tests were successfully completed, acuity was measured using the Bausch & Lomb Master Ortho-Rater. As noted above, the .2 cm (2 mm) of space at maximum eccentricity would only require 20/40 visual acuity. A minimum near binocular visual acuity of 20/33 Snellen Notation conservatively allowed for adequate resolution of the stimuli. Equal MA nonretarded children and individuals with mental retardation were then tested for mental age and IQ using the PPVT-R. If all the criteria were met, individuals were asked to randomly pick an unseen marble from a box (one for each gender) and tell the experimenter the number on the marble, determining their Lateralized Stimulus Order (1-10). Ten marbles of equal size (a set for each gender) with the numbers from 1 to 10 were used for subjects to randomly choose their Lateralized Stroop experimental Order. The subject's first name was then typed into the computer to be used for the Lateralized Name (check) trials. After insuring the participant was comfortably seated with their eyes 50 cm from the center of the monitor and head-band secured, the Lateralized Reading Trials began.

Lateralized Reading Trials: Reading trials consisted of the eight words presented directly to the right or left of the central fixation dot, at a minimum of 2° of horizontal visual angle, inside edge. All letters were black, uppercase, against a white background, presented horizontally for 150 ms. Each word was presented twice, once to each hemifield, with the order of words progressing from shortest (3 letters) to longest (6 letters) and visual field presentation balanced in the second set of eight words, for a total of 16 discrete trials. Participants were asked to read the words aloud as quickly and as accurately as possible. It was stressed that they were to fixate on the central black dot when pushing the button, as the words would appear very fast. They were to respond "don't know" if they saw the word but could not read it. Responses were manually checked for accuracy on the response sheets and were also recorded on a cassette tape.

Lateralized Practice Trials. These consisted of a random selection of 12 of the 96 experimental Stroop trials and 2 first Name (check) trials, for a total of 14 practice trials also presented for 150 ms. Individuals were instructed to fixate on the central black dot and press the button, after which a word would briefly appear. They were asked to consider this a "computer game"; the trick was to not read the words but say the letter color, except when their first name appeared (Lateralized Name trials), then they were to say their name as quickly as possible. The practice trials allowed the participants to become acquainted with the " game" and correct their responses. It also allowed the experimenter to assess the participant's understanding of the required responses. By conceptualizing the Stroop trials as a "computer game", it was thought to alleviate anxiety over making errors, and sustain or increase motivation to "beat the computer". Individuals were praised when producing the correct responses to the stimuli during practice trials, at the same time it was explained that the game was "tricky" and some errors were to be expected.

Lateralized Stroop Trials. The four "color" and four "neutral" words printed in four colors with the caveat that a Color-Word (and its yoked Neutral-Word) would not be printed in its own color, were presented either horizontally or vertically to each hemifield, (8 words x 3 colors x 2 visual fields x 2 orientations = 96) creating 96 trials. In addition, 20 trials were interspersed throughout the 96 trials in which the subject's first name would appear (Lateralized Name trials), printed in one of the four colors and in black. Five different pseudo-random orders were drawn from the Stroop and Name stimuli, with the caveat that neither a word nor a color could precede or succeed itself, thus preventing a priming effect and attempting to insure effortful processing on every trial. The 5 orders were reversed, creating the 10 experimental Lateralized Stroop and Name Orders, randomly drawn by the participants. Each discrete trial presentation was 150 ms.

Following the practice trials, individuals were told they could proceed at their own pace for the next trials. As each trial was self-initiated after fixating on the central dot, as soon as they released the button the stimulus was displayed on the screen for a very brief time (150 ms). They were to name the letter color as quickly and accurately as possible. If their response was anything other than the correct letter-color only, or their first name for the Lateralized Name trials, it was manually recorded as an error. All responses manually recorded were later verified by the audiotape recording. The computer program allowed for vocal responses which did not activate the voice key to be presented again at the end of the experimental Lateralized Stroop and Name trials. Participants were encouraged to rest between trials, if they felt fatigued in any way.

Lateralized Name Trials: Participants' first names were used as a check against adopting a color-naming only strategy during the Lateralized Practice and Stroop trials. They were asked for the first name by which they had most frequently been called all their lives by family and friends. This was then typed into the computer to become the 20 Lateralized Name trials randomly presented within the 96 Lateralized Stroop trials, and the 2 Name trials within the 12 Lateralized Practice trials. Respondents were to read their names rather than name the letter color. Letters colors were black, red, blue, green or purple, in both horizontal and vertical presentations (5 colors x 2 orientations x 2 visual fields = 20 trials) for 150 ms per trial.

RESULTS

The SPSS-X computer programmes were employed with the significance level for all analyses set at p = .01. The first set of analyses examined matching variables. No significant differences were found for mental age between school children (M = 10.06 years, SD = 1.76) and adults from the V.R.R.I. (M = 11.14 years, SD = 2.86). The Nonretarded Adults (M = 23.95 years, SD = 6.85), were just significantly younger, t (38) = 2.72, p = .010, than the MR Adults (M = 30.07 years, SD = 7.39). Four individuals in the MR group (2 males, 2 females) obtained IQ scores over 70 on the PPVT-R. As a consequence, their data on the Lateralized Stroop trials were compared to the remaining individuals in the MR group in a series of t-tests, with no significant differences detected.

A multivariate analysis of variance (MANOVA) for repeated measures, on each of the two dependent measures, was adopted for the remaining analyses. The dependent measures were vocal reaction time (VRTs) for correct responses measured from stimulus presentation to vocal response initiation and error percentage (ER%), calculated by having the frequency of wrong responses divided by frequency of wrong plus frequency of correct responses, multiplied by 100 (see Appendix A). Since there were violations of homogeneity and normality for both dependent measures in the Lateralized Stroop and Name trials, this made the multivariate repeated measures analysis of variance preferable to the univariate mixed model analysis (Bray & Maxwell, 1985; Maxwell & Delaney, 1990, pp. 674-676). Pairwise comparisons for Groups were planned, but were executed via orthogonal contrasts.

In order to determine if a significant relationship existed between the two dependent measures (VRTs & ER%), Pearson r correlations were computed (see Appendix B). Overall correlations across all groups found three of the eight within cells to be significantly correlated. There were eight within (repeated measures) cells, which delineated the dependent measures for the multivariate repeated measures analyses (see Appendix B, Table 1a & 1b). However, no significant correlations between the dependent measures within the MR Adults and MA Children groups were evident, and only one was found for the Nonretarded Adults group. The general lack of significant correlations between the two dependent measures overall, and within groups, failed to reveal the expected speed/accuracy trade off and did not support their combination for further analyses. The multivariate repeated measures analysis of variance on each dependent variable was therefore consistently employed for Lateralized Reading, Stroop and Name trials.

Lateralized Reading Trials

Correct VRTs. A Group (MR Adults, MA Children, Nonretarded Adults) X Gender (Male, Female) X Visual Field (Right Visual Field, Left Visual Field) X Wordtype (Color-Word, Neutral-Word) MANOVA was conducted, with repeated measures for Visual Field and Wordtype.

A significant main effect for Group, $F(2, 54) = 6.72$, $p = .002$, was obtained. A post-hoc orthogonal contrast analysis revealed a significant difference between the MR Adults (M = 1,009.28 ms, SD = 296.33) and the Nonretarded Adults (M = 743.60 ms, SD = 162.14), $F(1, 54) = 12.88$,

p = .001, however no difference was found between the MR Adults and MA Children groups, nor the MA Children and Nonretarded Adults groups (Table 2a & Table 6a). An adjustment was made for the increasing probability of Type 1 errors by dividing the alpha level by the number of comparisons (α = .01/3 = .003) for the post-hoc significance level.

The Visual Field main effect also reached significance $F(1, 54) = 12.35$, $p = .001$. Correct responses for the Right Visual Field (M = 878.46 ms, SD = 276.66) were significantly faster than those for the Left Visual Field (M = 906.52 ms, SD = 263.95).

The Visual Field X Wordtype interaction effect, $F(1,54) = 13.82$, $p = .0001$, was also significant (see Figure 1). A post-hoc one-way analysis of variance (ANOVA) for Wordtype (Color-Words, Neutral-Words) was conducted on each Visual Field. No difference was found between the two Wordtypes for the RVF, but Neutral-Words (M = 1021.96 ms, SD = 404.03) took significantly longer than Color-Words (M = 791.09 ms, SD = 194.21) in the LVF, $F(1,59) = 25.95$, $p < .0001$. In a one-way ANOVA of Visual Field on each Wordtype, no significant differences were found for Color-Words between Visual Fields, while correct VRTs for Neutral-Words were significantly slower in the LVF, $F(1,59) = 12.17$, $p = .001$ (Table 2j).

Errors. A multivariate analysis of variance (MANOVA) for Group (MR Adults, MA Children, Nonretarded Adults) X Gender (Male, Female) X Visual Field (Right Visual Field, Left Visual Field) X Wordtype (Color-Word, Neutral-Word) with repeated measures for Visual Field and Wordtype, was carried out for percent errors (ER%).

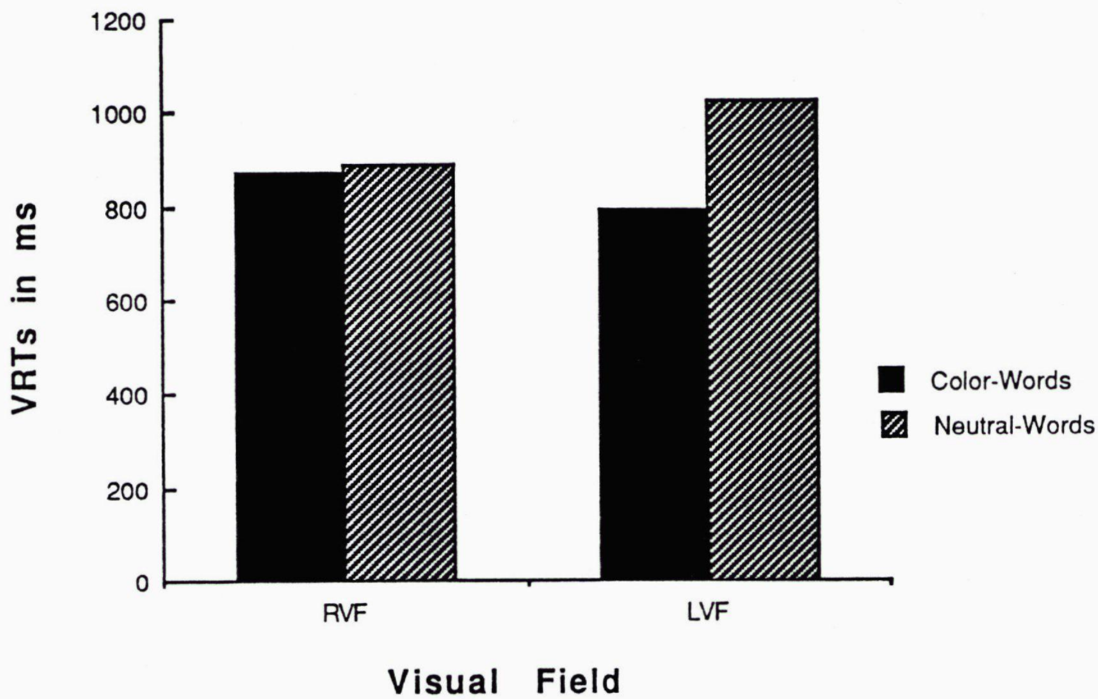

Figure 1

VRTs for the Lateralized Reading Trials:
Visual Field X Wordtype Interaction

The Group main effect, $F(2, 54) = 10.26$, $p = .0001$, was significant. Post-hoc orthogonal contrast analyses revealed a significant difference between the Nonretarded Adults (M = 7.50%, SD = 6.28) and both the MR Adults (M = 25.00%, SD = 16.60), $F(1, 54) = 16.49$, $p = .0001$, and MA Children (M = 23.75%, SD = 14.85), $F(1, 54) = 14.21$, $p = .0001$, with the latter two not differing (Table 2b, 3b & 6a).

The Visual Field main effect, $F(1, 54) = 69.45$, $p = .004$, was also significant. The error percent (ER%) for the RVF (M = 15.21%, SD = 15.45), was significantly lower than for the LVF (M = 22.29%, SD = 18.71).

The main effect for Wordtype, $F(1, 54) = 13.20$, $p = .001$, was also significant. Color-Words had a significantly lower error percentage (M = 7.29%, SD = 12.24) than did Neutral-Words (M = 30.21%, SD = 24.17).

A significant Group X Visual Field interaction was obtained $F(2, 54) = 6.22$, $p = .004$, (Figure 2, Table 2i). Post-hoc MANOVA's for each Group (MR Adults, MA Children, Nonretarded Adults) on each Visual Field (RVF, LVF) revealed no significant difference in errors made on the two visual fields by the MR Adults and the Nonretarded Adults, but the MA Children made significantly more errors in the LVF (M = 30.00%, SD = 20.03) than in the RVF (M = 17.50%, SD = 13.69). While the MR Adults and Nonretarded Adults made more errors in the LVF as well, they were not significantly different (Table 2i).

The Visual Field X Wordtype interaction, $F(1, 54) = 6.12$, $p = .017$, just failed to reach significance.

No other main or interaction effects reached significance.

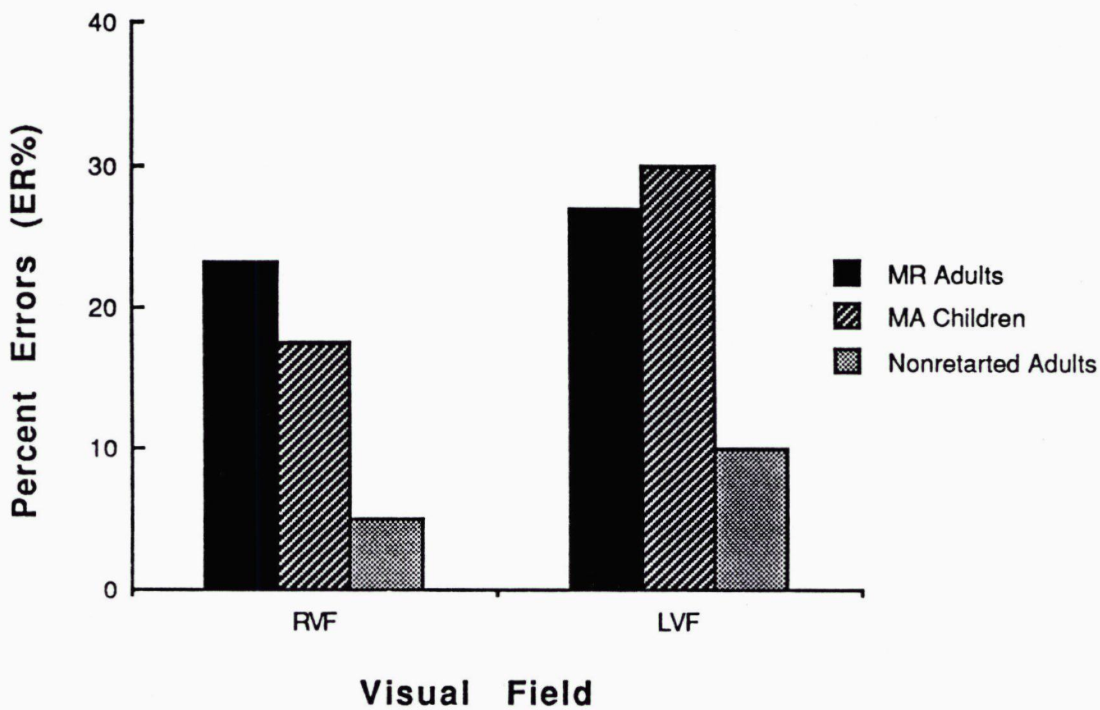

Figure 2

ER% for Lateralized Reading Trials:
Group X Visual Field Interaction

Lateralized Stroop Trials

The 10 pseudo-random Orders randomly drawn by the subjects, were collapsed across Group. An analysis of variance (ANOVA) was carried out, with Order (10) and Gender (Male, Female) the between variables, and Visual Field (RVF, LVF), Wordtype (Color-Word, Neutral-Word) and Orientation (Horizontal, Vertical) the within variables. All Order main effect and interactions were nonsignificant for both the correct VRTs and percent errors (ER%), and Order was dropped from subsequent analyses, except by blocking the first and second half of the Stroop Trials for the examination of possible differences in attentional control from the first to the second half. The reversed Orders allowed an opportunity for analyzing the occurrence of an improvement in the second half of the Stroop Trials i.e., a practice effect, or a reduction in performance, which may be associated with a decrease in sustained attention. Two Group (MR Adults, MA Children, Nonretarded Adults) X Gender (Male, Female) X Blocks (1st 48 Stroop Trials, 2nd 48 Stroop Trials) repeated measures ANOVAs, with Blocks the within variable, were separately conducted on both average VRTs and errors as the dependent variables. Only one significant interaction was obtained for the average VRTs on Groups X Blocks, $\underline{F}(2,54) = 7.91$, $\underline{p} < .01$ (see Table 2k). The MA Children were significantly slower in the second half compared to the first half of the Stroop Trials ($\underline{F}(1,54) = 21.48$, $\underline{p} < .001$), while the adult groups showed no difference. Scheffé comparisons found the children to be significantly slower for the second Block of Stroop Trials than the two adult groups

($F(2,54) = 15.60$, $p < .01$). No differences were shown for the errors. Order was not included in any further analyses.

Correct VRTs. A Group (MR Adults, MA Children, Nonretarded Adults) X Gender (Male, Female) X Visual Field (RVF, LVF) X Wordtype (Color-Word, Neutral-Word) X Orientation (Horizontal, Vertical) repeated measures MANOVA was performed on the VRTs for naming the letter color of the word, with repeated measures on the last three variables.

The main effect for Group, $F(2, 54) = 33.15$, $p < .0001$, was significant. Post-hoc orthogonal contrast comparisons of the MR Adults and MA Children revealed no difference (Table 6b). A highly significant difference between the MR Adults and the Nonretarded Adults, $F(1, 54) = 42.45$, $p < .0001$, and between the MA Children and the Nonretarded Adults, $F(1, 54) = 56.06$, $p < .0001$, was obtained (Table 6b).

The main effect for Wordtype, $F(1, 54) = 18.24$, $p = .0001$, was also significant. Vocal reaction time took significantly longer for Color-Words ($M = 1519.78$ ms, $SD = 527.86$) relative to Neutral-Words ($M = 1246.90$ ms, $SD = 227.88$).

The Group X Wordtype interaction failed to reach significance, $F(2, 54) = 3.20$, $p = .049$.

No other main or interaction effects were significant.

Errors. A Group (MR Adults, MA Children, Nonretarded Adults) X Gender (Male, Female) X Visual Field (RVF, LVF) X Wordtype (Color-Word, Neutral-Word) X Orientation (Horizontal, Vertical) MANOVA, with repeated measures on the latter three variables, was carried out for percent errors (ER%).

This analysis revealed a significant Group main effect, $F(2, 54) = 19.45$, $p < .0001$. Post-hoc orthogonal contrasts yielded a significant difference for the MR Adults ($M = 26.04\%$, $SD = 19.46$) compared to the MA Children ($M = 9.85\%$, $SD = 4.94$), $F(1, 54) = 20.11$, $p = .0001$, and predictably the MR Adults and the Nonretarded Adults ($M = 4.38\%$, $SD = 3.64$), $F(1, 54) = 35.97$, $p < .0001$. However, the contrast for the MA Children and Nonretarded Adults revealed a nonsignificant difference in errors made, $F(1, 54) = 2.29$, $p = .136$ (Table 6b).

The Wordtype main effect, $F(1, 54) = 36.46$, $p = .0001$, was also significant. Neutral-Words ($M = 10.01\%$, $SD = 13.02$) generated fewer errors than Color-Words ($M = 16.82\%$, $SD = 17.61$) as established by the overall MANOVA.

No other main or interaction effects reached significance.

Lateralized Name Trials

Names were randomly presented throughout the experimental Stroop trials, in order to insure that reading was occurring on every trial. They were printed in the four experimental colors and in black, presented to each visual field and in each orientation, generating 20 trials with one observation per cell for every individual. An overall repeated measures MANOVA (Group X Gender X Visual Field X Color X Orientation) could not be conducted on the error data with only one data point per cell. Therefore color was collapsed across Visual Field and Orientation in order to establish a Percent Correct dependent measure for every color. Due to so few errors for Lateralized Name trials in the MA Children and Nonretarded Adults groups, a Percent Correct instead of an error percent as dependent measure allowed for sufficient variability to proceed with the analysis for Color.

A Group (MR Adults, MA Children, Nonretarded Adults) X Gender (M, F) X Color (Red, Blue, Green, Purple, Black) repeated measures MANOVA was conducted, with Color as the only within variable. No significant results for Color were found.

An overall ANOVA with Group (MR Adults, MA Children, Nonretarded Adults) X Gender (M, F) X Color (5) X Visual Field (RVF, LVF) X Orientation (H, V) for VRTs also yielded no significant main effect for Color or interactions with it. This allowed the collapse across Color for both sets of analyses on each dependent measure, with repeated measures MANOVA's with Group (MR Adults, MA Children, Nonretarded Adults) X Gender (M, F) X Visual Field (RVF, LVF) X Orientation (H, V), for correct VRTs and error percent (ER%), now the dependent measures for the Lateralized Name trials as well. These statistical analyses were consistent with the Lateralized Stroop and Reading trials.

Correct VRTs. The time (ms) required to read one's name aloud from its computer screen onset was employed in a Group (MR Adults, MA Children, Nonretarded Adults) X Gender (M, F) X Visual Field (RVF, LVF) X Orientation (H, V) repeated measures MANOVA.

A significant main effect for Group was obtained, $F(2, 54) = 6.18$, $p = .004$. Post-hoc orthogonal contrast analyses established MR Adults ($M = 1166.40$ ms, $SD = 611.95$) $F(1, 54) = 10.85$, $p = .002$, as being significantly slower than the Nonretarded Adults ($M = 785.33$ ms, $SD = 51.65$). The MA Children ($M = 1099.02$ ms, $SD = 206.25$)

$F(1, 54) = 7.35$, $p = .009$, just missed being significantly different from the Nonretarded Adults at the adjusted alpha level, $p = .01/3 = .003$. The MA Children and MR Adults groups were comparable to one another (Table 2g, Table 6c).

No other significant main or interaction effects were obtained.

Errors. A repeated measures MANOVA was conducted on percent errors employing a Group (MR Adults, MA Children, Nonretarded Adults) X Gender (M, F) X Visual Field (RVF, LVF) X Orientation (H, V) analysis, with Visual Field and Orientation being the within factors.

The Group main effect was significant, $F(2, 54) = 8.48$, $p = .001$. A post-hoc orthogonal contrast analysis of the Group main effect revealed that the MR Adults ($M = 26.56\%$, $SD = 31.35$) made significantly more errors than both the Nonretarded Adults ($M = 4.50\%$, $SD = 4.84$) $F(1, 54) = 13.44$, $p = .001$, and the MA Children ($M = 5.75\%$, $SD = 7.12$) $F(1, 54) = 11.96$, $p = .001$. The latter two groups did not differ (Table 6c).

No other significant main effects and interactions were found.

DISCUSSION

The results revealed that groups matched for mental age performed equivalently on the lateralized Reading Trials, but despite this equivalence in mental age, the individuals with mental retardation showed significantly less attentional control efficiency than the children with normal intelligence, who did not differ from the nonretarded adults. Processing requiring attentional control has consistently been found deficient in individuals with mental retardation, with some evidence that individuals matched for mental age allocate attention with the same efficiency (Nugent & Mosley, 1987). Other findings suggest differences beyond mental age, implicating deficiencies related to intelligence, such as Das' (1970) study which obtained greater Stroop interference in children with mental retardation despite their increasing mental age and reading proficiency, a reversal of results reported for children of normal intelligence (Comalli, Wapner & Werner, 1962; Schiller, 1966). Attentional efficiency is proposed as lateralized in the RH and is therefore implicated in the attentional difficulties of the mentally retarded.

The Lateralized Reading Task

Reading is a learned skill. Cognitive development and more experience increases proficiency and automaticity over time (Cohen, Dunbar & McClelland, 1990; Goldberg & Costa, 1981; Kahneman & Treisman, 1984; MacLeod, 1991; Merrill, 1990; Schneider & Fisk, 1983; Whitaker, 1983). Automatic processing is defined by greater speed and accuracy, requiring little if any attention (Hasher & Zacks, 1979; Merrill, 1990).

Differences in correct VRTs between the MR Adults and the Nonretarded Adults were obtained in the present study, but there were no differences between the MR Adults and the MA children matched for mental age. As well, the children just missed significantly differing from the Nonretarded Adults ($\underline{p} = .018$), suggesting a processing equivalence for these two groups matched for mental age. A significant difference between the MR Adults and matched MA children was not revealed in the error data, but both of these groups differed significantly from the Nonretarded Adults. The agreement on both dependent measures for MR Adults and MA children, suggests that mental age is an influential factor in the automatic processing of the reading response. It further suggests that normal children and retarded adults are equally proficient (see Table 2a & 2b) i.e., reading manifesting the same degree of automaticity for the stimuli in the present study. Any concerns regarding adequate acuity in individuals with mental retardation would no longer be relevant in light of their equivalent reading performance to the children matched for mental age.

Since the nonretarded university adults and the MR Adults just differ significantly in chronological age ($\underline{p} = .010$), with the MR Adults being older, the significant difference in the speed and accuracy of reading seems dependent upon mental age. Both adult groups had more experiential time chronologically, while the MA children had less time but equivalent mental age. This is consistent with Merrill's (1990) conclusions that automatic processing requires longer to become established in individuals with mental retardation. Automatic processing, as indicated by reading proficiency, is viewed as requiring less attentional processing along the automatic/effortful continuum and is "improved" by increasing cognitive development and practice (Comalli, Wapner & Werner, 1962; Hama & Hashimoto, 1985).

The Visual Field main effect data revealed both a faster and more accurate reading of words presented to the RVF for all groups, compared to those presented to the LVF. The left hemisphere can be viewed as the automatic processor, particularly of language (Whitaker, 1983), and the present data support this position. As noted earlier, LH superiority for language has been well established in normal right handed males, as well as in both males and females before puberty (Bryden, 1982, 1987, 1990; Piazza Gordon, 1985; Sergent, 1983; Springer & Deutsch, 1989; Waber, 1977), with similar but attenuated laterality for mentally retarded adults (Mosley & Vrbancic, 1990; Pipe, 1988; Saccuzzo & Michael, 1984).

For the significant Visual Field X Wordtype interaction on correct VRTs, there were no differences in the LH processing of neutral or color words indicating equal speed of automatic processing, but there was a highly significant difference in the RH as a function of wordtype (Table 2j). Color-Words were processed much faster in the RH than were Neutral-Words, suggesting a RH advantage for Color-Word processing. Evidence for RH color processing superiority has been equivocal in the past (Bradshaw & Nettleton, 1981; Bryden, 1982; Pennal, 1977). Since the Color-Words were printed in black block letters on the computer screen, the stimuli were devoid of color. However, a visual image of the color's semantic meaning may have primed RH processing of the Color-Words. In this case, the retrieval of the color's image in the RH could facilitate processing and may explain even faster processing of Color-Words in the RH compared to the LH, not an expected result. The superior RH processing of high imagery words may be applicable here (Bryden & Ley, 1983).

Millar and Whitaker's (1983) evidence from clinical studies suggested a RH superiority in the processing of concrete, high frequency words which could be visualized in space. Although the conditioning advantage for color processing in the RH was transient in Hugdahl, Kvale, Norby and Overmier's (1987) study, the initial response was greatest in that hemisphere. In the present study, Color-Words were processed significantly faster than Neutral-Words in the RH ($\underline{p} < .0001$), and also generated fewer errors in the RH, but this just failed to reach significance ($\underline{p} = .017$). Color-Words were processed with significantly fewer errors than Neutral-Words overall as well ($\underline{p} = .001$). These data cannot be explained by word frequency or assumed familiarity which indicate strength of automatization. Instead they suggest a RH facilitation through the automatic retrieval of the color's visual image, which would increase both speed and accuracy of the reading response. The Neutral-Words are not concrete words easily imagined in space, but are highly familiar and frequent. A RH advantage would not be anticipated for them.

The significant Group X Visual Field interaction for errors revealed a lack of significant visual half-field differences for the adult groups, suggesting less lateralized processing. The MA Children however, made significantly more errors in the LVF, showing LH processing superiority for both males and females. Although MR Adults and MA Children were equally proficient, only the children showed a significant laterality effect. This does not preclude the possibility of a RH-LH shift in the automatic reading proficiency of the MR Adults, but does support reading automaticity in children since they manifested a significant RVF advantage. Most of the present children were below the grade 5 reading proficiency thought necessary to establish LH superiority (Carmon, Nachshon & Starinsky, 1976; Forgays, 1953), but the present data clearly revealed a LH advantage for these children.

Although no significant gender differences were found, gender may have influenced the pre-pubertal children's error data. Piazza Gordon (1985) reported that normal young females have a significant LH advantage for speech processing, with decreasing lateralized processing occurring in post-pubertal females, even though the post-pubertal females exhibited increasing proficiency. The present data revealed less lateralized processing in the two adult groups, consistent with Piazza Gordon (1985) and Waber (1977). If the females in the two adult groups generally exhibited reduced lateralized processing, as would be expected (Bryden, 1982; McGlone, 1980; Piazza Gordon, 1985; Segalowitz & Bryden, 1983; Waber, 1977), this could attenuate the visual field differences for these groups. Conversely, if the pre-pubertal children exhibited more laterality for both genders, this could explain the lack of a main effect for gender since the greater laterality of the pre-pubertal females would attenuate overall gender differences. Although the MR Adults made significantly more errors relative to the Nonretarded Adults, the magnitude of the difference is the same for both hemispheres

(see Figure 2). Since the children matched for mental age displayed a significant LH advantage for reading in the error data, while both adult groups did not, this suggests a chronological age, rather than a mental age influence on the lateralized processing of the automatic reading response. An increase in chronological age generally suggests an increase in physiological maturation as well.

The rate of physiological maturation has been shown to influence the LH advantage for language processing in normal children and adults (Entus, 1977; McGlone, 1980; Molfese, 1977; Molfese & Betz, 1988; Piazza Gordon, 1985; Satz, Strauss & Whitaker, 1990; Waber, 1977; Whitaker, 1983). The pattern is one of early LH advantage in neonates of both genders (Entus, 1977; McGlone, 1980; Molfese, 1977; Molfese & Betz, 1988; Turkewitz, 1988), with an increase in lateralized language functioning (LH) in normal, consistently right handed children with normal language experience (Kee, Gottfried & Bathurst, 1987). Right handed normal males or later maturing males maintained a LH advantage for language processing from birth to adulthood. Normal right handed females exhibited a LH language advantage in the neonatal through childhood years, but then showed a nonsignificant LH advantage or greater bilateral processing post-pubertally, despite increasing proficiency in language processing (Entus, 1977; McGlone, 1980; Molfese, 1977; Piazza Gordon, 1985; Waber, 1977). The present demonstration of a chronological age difference in the lateralized processing of the automatic reading response is consistent with this literature of a greater LH language advantage in pre-pubertal children compared to post-pubertal female adults, comprising 50% of the present adult groups.

Wordtype was found significant for the error data, but not for correct VRTs. The reading of Color-Words produced significantly fewer errors relative to the reading of Neutral-Words. These data cannot be explained by word frequency or familiarity, as the Neutral-Words DAY and WORD, have a much greater frequency in both written (Kucera & Francis, 1967) and spoken (Dahl, 1979) American English than RED, BLUE, or the other colors (see p. 85, above). Greater frequency would anticipate greater automaticity.

In summary, the automatic processing of the reading response revealed a mental age equivalence on both dependent measures for the MA children and the MR adults. Greater efficiency on both was shown by the Nonretarded Adults. The lateralized processing of the automatic reading response however, seemed to be influenced by chronological age. Reading proficiency did not seem to clarify a hemispheric advantage as proposed, since MA children and MR Adults did not differ significantly in proficiency but did in laterality. The MA children manifesting a LH reading superiority would suggest the children's reading skill for the stimuli in the present study, was automatic. Greater RH processing of the reading stimuli for individuals with mental retardation may therefore suggest greater RH involvement on the proposed RH-LH continuum, possibly explained by the attentional inability to "let go" of a newly established automatic response (Schneider & Fisk, 1983). If attentional release of a newly automatic response is a difficult task for normal individuals, it would be expected to cause particular difficulty for individuals with mental retardation.

It is also notable that homogeneity of variance was exhibited for both dependent measures in the repeated measures design of the Lateralized Reading Trials. This similiarity of variability is evidence of an equivalence of task difficulty for all participants, as would be predicted for an automatic processing response.

The Lateralized Stroop Task

Data for correct VRTs revealed the same latency of correct responding in the MR Adults and the MA matched Children, with both of these groups differing significantly from the Nonretarded Adults. These findings suggest that mental age may also be influential in the effort to inhibit the automatic reading response. The Nonretarded Adults were significantly faster for both the reading and the Stroop tasks. Average processing speed was 1.4 times longer on the Lateralized Reading Trials for the MR Adults compared to the Nonretarded Adults, and 1.6 times longer on the Stroop trials. This is consistent with earlier studies which predicted about twice the length of time would be required for mentally retarded individuals to process stimuli (Hornstein & Mosley, 1987; Merrill, 1990; Nettlebeck, Robson, Walwyn , Downing & Jones, 1986; Saccuzzo & Michael, 1984). Comparatively, for the MA Children average processing speed was 1.2 times longer for the lateralized reading trials, and 1.6 times as long for the Stroop trials, than the means for the Nonretarded Adults. The evidence therefore suggests mental age is a controlling factor in vocal speed of correct responding for both automatic and effortful processing.

The efficiency of processing as it relates to accuracy, however, is not comparable for retarded and nonretarded individuals in this study. For the error data, the MR Adults were significantly different from both their MA matched children and from the Nonretarded Adults, who did <u>not</u> differ significantly from one another. This is a reversal from the VRT Stroop Trial results, and for the VRT and error data on the Reading Trials, where MR Adults and MA Children did not differ from each other on speed and accuracy, but were significantly different from the nonretarded adult group. The ability to inhibit the reading response does not seem to be affected by mental age, but rather by intelligence. Clearly the equivalence of the children matched for mental age and the MR Adults on both dependent measures of the Lateralized Reading Trials, suggests equal proficiency in this automatic response. The latency of correct responding on the Stroop trials also seems to be related to mental age. The efficiency of effortful inhibition measured by errors, however, cannot be explained by mental age. Normal intelligence in the MA Children and Nonretarded Adults seems to determine the effectiveness of attentional control, as these two groups do not differ significantly from each other in errors despite chronological age differences. Experience cannot be a determining factor, as the children are much younger than the Nonretarded Adults. In comparison to the MR Adults with an average error percentage of 26.04%, the MA matched Children only made mistakes on 9.85% of the Stroop trials, while the Nonretarded Adults were at a low 4.38%.

The increase in the attentional ability to successfully inhibit the automatic reading response with increased chronological age for normal individuals, is also illustrated in the above data and is consistent with the literature (Comalli, Wapner & Werner, 1962; Schiller, 1966). The increased Stroop interference for individuals with mental retardation found by Das (1970) and Ellis, Woodley-Zanthos, Dulaney and Palmer (1989), was also revealed in this study employing the lateralized Stroop task. Differences in the levels of intelligence within mentally retarded groups, revealed significantly more Stroop interference in those with lower intelligence for some studies (Ellis & Dulaney, 1991; Uechi, 1972; Wolitzky, Hofer & Shapiro, 1972), but not for others (Silverstein & Franken, 1965). Intelligence has therefore previously been associated with the ability to successfully control unwanted interference from an established automatic response (Das, 1970; Uechi, 1972; Wolitzky, Hofer & Shapiro, 1972).

As noted earlier, Schneider and Fisk (1983) observed the difficulty normal individuals had in allowing attention to "let go" of tasks which had become automatic. For some tasks, subjects had to practice the removal of attention from a newly established automatic task (Schneider & Fisk, 1983). Merrill (1990) and Whitman (1990) suggested metacognitive deficiencies in individuals with mental retardation. Attentional control generally would constitute metacognitive control over limited resource allocation or reallocation, with an awareness of one's own limitations and successes from previous experience. Normal adults learn to successfully control the Stroop interference within the same experiment, revealing a practice effect across trials (Hugdahl & Franzon, 1985, 1987). Normal children learn more efficient attentional control with increasing age (Das, 1970; Comalli, Wapner & Werner, 1962; Schiller, 1966). Individuals with mental retardation do not seem to have this "awareness of control" even as adults. "Cognitive inertia" (Ellis, et al., 1989, 1991) may be an inability to know when to "let go" and when to control.

This reiterates Detterman's (1979) findings of attentional deficits in the mentally retarded. While some of the literature suggests the same attentional deficits are related to the mentally retarded and the young (Brooks, McCauley & Merrill, 1988; Carr, 1984; Merrill, 1990; Nugent & Mosley, 1987; Zeaman & House, 1979), the present study does not support differences due to mental age. Merrill (1990) also observed larger differences in semantic processing with increasing task difficulty between individuals with and without mental retardation. Merrill's explanations of less flexibility and control in the allocation of resources, or a lack of metacognitive ability to assess how much attention should be devoted to a task, or simply fewer resources overall, are all possible influences in the attentional deficiencies of the mentally retarded, and as Merrill noted, are not mutually exclusive. These influences could also apply to the results of the present study. Attentional deficits due to low mental age are not a feasible explanation, however, as the children matched for mental age and with far less experience chronologically than either the MR or Nonretarded Adults groups, displayed a significant superiority on the Stroop trials relative to the MR Adults.

Greater RH interference for the MA Children and the MR Adults may be the result of their relatively reduced proficiency in automatic processing (reading) compared to the Nonretarded Adults. It was expected the MA Children, with a LH reading advantage, would show greater LH interference for the Stroop trials. This was not evident however.

The aspect of practice or sustained attentional control was examined by analyzing the first and second half of the Stroop trials, and only the children showed a significant slowing for the second half of the blocked trials. Neither mental age nor intelligence could parsimoniously explain this slowing of responses, while possible fatigue or fear of making errors are speculated as an influencing factor. As there were no significant differences in the errors made within or across groups between the two trial blocks, a speed/accuracy tradeoff cannot be assumed. Possible fatigue in sustaining attentional control in the younger children may have been more influential when compared to the sustaining of attention in both adult groups. MR Adults did not show a worsening in sustaining their attentional control between the first and second half of the Stroop Trials, but exhibited significantly more interference in errors made overall to both MA matched Children and the Nonretarded Adults.

The influence of attentional deficiencies in the MR Adults combined with a RH link to effortful processing would implicate this hemisphere in MR processing deficiencies. Semmes (1968) noted the comprehensive attentional effects of RH trauma in normal individuals, with hemineglect being the most notable. While the MA Children were as proficient as the MR Adults in the Reading Trials and gave clear evidence of a LH advantage, the MR Adults did not give this evidence of a LH advantage. Perhaps they had not yet "let go" and allowed the automatic reading process to proceed in the LH. Also, the greater length of time required to establish automaticity in the MR Adults (Merrill, 1990) would again implicate RH effortful processing.

Structurally, if dendritic spines are not as efficient in individuals with mental retardation (Steward, 1988), this would have greater impact in the efficiency of information integration across modalities in the RH (Goldberg & Costa, 1981), while specific, focalized automatic processes in the LH would show less of a deficit, as the literature has indicated (Semmes, 1968; Whitaker, 1983). The structural diffuseness of neuronal dendrites and axons horizontally connected across sensory modalities (Goldberg & Costa, 1981; Woodward, 1988), and evidence of integrative processing of novel or known information (Goldberg & Costa, 1981), all suggest effortful processing. At the same time, greater skill and proficiency has been shown to activate the focally organized vertical columns of the LH (Springer & Deutsch, 1989; Whitaker, 1983; Woodward, 1988). RH processing is implicated as the effortful/attentional regulator of novel environmental information and the enabler of stored automatic processes (Deutsch, Papanicolaou, Bourbon & Eisenberg, 1987; Goldberg & Costa, 1981; Schneider & Fisk, 1983; Springer & Deutsch, 1989).

The greater RH involvement in the equally proficient reading trials for the MR Adults compared to the MA Children, could well be the inability to know when to control and when to allow automatic processing in the LH to proceed. Metacognitive abilities which suggest an awareness of the success of control from past experience and possible resource limitations, also implicate knowledge derived from the integrative processing and structural diffuseness of the RH. Any attentional/effortful processing control and "awareness of control" would therefore require RH involvement.

The Stroop task is known for its difficulty i.e., the effortful inhibition of an automatic reading response. The more attentionally efficient, normal Nonretarded Adults, would require less RH processing to successfully inhibit the automatic reading response, and would therefore be faster and more accurate. The attentionally less mature, most notably children, would require more processing time and more experience to learn to control, as is evident from the literature. The MR Adults do not give evidence of efficient control. Structural evidence may converge in explicating this. Deficiencies in any of the neuronal dendritic spines of the RH could be seen as reducing the integrative potential across modalities for the horizontally connected neurons, as their excitatory synaptic transmissions are decreased (Steward, 1988). The efficiency of the RH, structurally and functionally, is therefore seen as critical for the integration of both novel and known information.

Abnormalities in dendritic spines and the focal organization of the neurons in the LH would predict less of a disruption in the "columnar circuitry" (Woodward, 1988) of focally organized "similiar units" (Semmes, 1968; Whitaker, 1983; Woodward, 1988). A disruption of processing in one vertical column would predictably be functionally provided by the neighboring column. Automaticity would therefore not be easily disrupted. The present data are consistent with this view.

Wordtype was significant for both VRTs and error data, with the time taken for naming the letter colors of the Color-Words being significantly longer and resulting in significantly more errors than naming letter colors for the Neutral-Words. This is also an expected finding (Klein, 1964; Schiller, 1966), since the semantic relatedness of the incongruent Color-Words is directly related to the amount of interference. The degree of semantic interference was shown by Schiller (1966), to be developmentally stable. Because of this "reversed priming effect", the automatic retrieval of the word's semantic meaning interferes with naming an incongruent letter color, even when words have some color connotations, such as "grass" or "lemon" (Klein, 1964). The significance of Wordtype across both visual hemifields on the Stroop trials suggests equivalent hemispheric conflict in the processing of Color-Words, as they took longer and generated more errors for both visual half-fields. RH processing of these incongruent words should yield greater conflict, as semantics and color image collide. Color-Words were expected to produce the most interference and errors compared to Neutral-Words, according to the literature on semantic interference (Klein, 1964; Schiller, 1966). The present results confirmed these expectations.

The Lateralized Name Task

The Lateralized Name Trials were employed in order to prevent individuals from consistently inhibiting the reading response as a task strategy. By randomly presenting each individual's first name among the experimental Stroop trials, it was anticipated that the salience of these stimuli would "capture" the person's attention and induce the automatic reading response. Normally, the reading of one's own name would be expected to be the most automatized of reading responses.

The influence of context on a clearly automatic response is evident in this paradigm. By requesting individuals to ignore the "word" and name the letter color, the task becomes one of inhibiting the automatic response for 96 trials. However, randomly for 20 trials, the task is to read one's name. The two tasks are in conflict, inducing effortful processing on every trial. Processing speed results for these stimuli again revealed that the MR Adults and the MA Children were comparable, while differing significantly from the Nonretarded Adults in reading their names. Mental age again seems to be influential in effortful processing speed. The error data for the Name trials converged with the error data for the Stroop trials i.e., the MR Adults made significantly more errors than both the MA Children and the Nonretarded Adults, who did not differ from each other. Whether the task was to inhibit the reading response in the Stroop trials, or to allow the automatic reading response to proceed in the Name trials, the MR Adults had equal difficulty when measured by the errors made (Stroop ER% = 26.04%, Name ER% = 26.56%). The degree of attentional failure, as it is measured by the errors made, is seen to be determined by intelligence rather than mental age. Both equal MA Children and Nonretarded Adults showed little difficulty in successfully switching tasks i.e., the attentional control of inhibition (naming the letter color), then disinhibition of the automatic reading response (reading one's name). For MR adults, this task change was as difficult as the Stroop task itself. This is quite similiar to the "letting go" and controlling mentioned earlier as a metacognitive "awareness of control", and possibly related to the automatization strength of other contextual pathways (Cohen, Dunbar

& McClelland, 1990; MacLeod, 1991; Schneider & Fisk, 1983; Whitman, 1990). Mental age again influenced the speed of correct responding on an effortful task. Since the tasks are both effortful but otherwise exactly the opposite (Stroop inhibition of the automatic reading response vs the automatic reading of one's name), the evidence for mental age determining the speed of a correct responding is further substantiated.

Individuals with mental retardation have again shown clear deficiencies when compared to children matched for mental age on the error data. The data are consistent with the literature on attentional problems and Stroop interference for individuals with mental retardation. Attentional difficulties for the Name trials required knowing when to control and when to allow automatic processing to proceed. Individuals with mental retardation were unable to accomplish this for over one quarter of the Name trials, and the Stroop trials as well. This is proposed to be related to deficiencies in effortful processing in the RH.

Conclusions

Automatic processing, as it is measured by processing speed and errors on the reading trials, has been shown to be equivalent for individuals matched for mental age, despite differences in chronological age. The speed of correct responding to effortful processing (Stroop and Name trials) also seems to be equivalent for individuals with mental retardation and children matched for mental age. Attentional failure as measured by errors, however, revealed that the nonretarded child and adult groups did not differ significantly from each other in the percentage of errors made for either the inhibition of the automatic reading response in the Stroop trials, or the ability to change from inhibition of reading to automatic reading of their first names.

Attentional control is most difficult for individuals with mental retardation. RH processing is implicated in this deficiency. Even when mental age is taken into account, and disregarding the difference in years of experience between children matched for mental age and the mentally retarded, the differences are substantial. This suggests that successful attentional control is evident quite early in terms of chronological age, and becomes increasingly more efficient into young adulthood, as reported in the Stroop literature for individuals with normal intelligence (Comalli, Wapner & Werner, 1962; Das, 1970; Hama & Hashimoto, 1985; Schiller, 1966). Adults with mental retardation were not able to achieve this control despite the experience that accrues with increases in chronological age. This was seen to affect the establishment and enabling of automatic processes (Schneider & Fisk, 1983).

The effortful establishment of automaticity has also been proposed to impact lateralized processing from initial right hemisphere to a progressive left hemisphere continuum, for skilled or learned responses. The efficiency of the RH is critical in the establishment of an automatic response, in the attentional ability to "let go" once established, and in the enabling of established skilled automatic processes which require the RH's integrative abilities. Proficiency anticipates automaticity and therefore lateralized functioning.

Proficiency of the reading response was measured by latency of correct responding and resulting errors made for the Reading Trials. No significant differences were found between the children matched for mental age and the adults with mental retardation suggesting equal automaticity. However, only the children provided a significant LH language superiority for these trials, perhaps implicating again the lack of the RH ability to "let go" of an automatic process in the mentally retarded. Although the Nonretarded Adults were far more proficient in reading than the mentally retarded adults, both groups failed to demonstrate the LH superiority found for the equal MA Children. The comprehensive literature review revealed proficiency influencing LH superiority across tasks, individuals, chronological ages, and experience, in individuals of normal intelligence. A LH superiority for language was seen to differ however, for adult males and females. Gender as a main effect and all interactions with it were found nonsignificant in this study however. The failure to find a significant LH advantage for the Nonretarded Adults in either of the Lateralized Reading or Stroop Trials, although displaying superior proficiency in the reading trials, is inconsistent with proficiency predicting laterality. The less proficient children showed a clear LH advantage for the Reading Trials but none for the Stroop trials. This suggests that proficiency alone does not predict laterality for the present data.

Attentional efficiency is proposed as being RH dependent however. Although the present data do not allow a conclusion of proficiency determining laterality of functioning, the results support the possibility of greater RH involvement in attentional processing, combined with a consistent difficulty with effortful processing in individuals with mental retardation in the literature and the present data. The lack of a LH advantage for all groups on the Lateralized Stroop and Name Trials, noted for the effort required in task completion, may then suggest the necessary involvement of the RH in the effortful/attentional inhibition across groups of the automatic reading response, or the task change for the Name trials. As the individuals with mental retardation experienced the greatest difficulty for both these trials (as measured by the error data) compared with the nonretarded children and adults, the efficiency of RH processing may be implicated. Latency of correct vocal responses revealed mental age consistency for both automatic and effortful processing.

The greater impact of structural deficiencies in dendritic spines of the horizontally organized neurons in the RH was proposed as a possible factor in the attentional difficulties evident in individuals with mental retardation. While structure cannot define function, converging evidence suggests an interaction of structural and attentional deficiencies. Implications in the literature are concerned with evidence of structural deficiencies precluding educational interventions. A concern is also presented that denial of their possible existence may limit the success of the interventions employed. Acknowledgement of possible structural limitations, accompanied by alternatives which will minimize their impact for individuals with mental retardation, may produce a challenge to those whose innovative attentional processes are without deficiencies. Past experience suggests the challenge is eventually met with success.

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APPENDIX A

Error Coding for All Lateralized Trials

Four codings for errors were:

1. On 2.8% of the Reading Trials, and .37% of the Stroop and Name Trials the individual would respond correctly but the microphone failed to register this reponse and the experimenter did not have time to depress the space bar to reset the trials, therefore these trials were scored (3), the VRTs were late but <u>correct</u>. With the exception of technical error, these trials would not have been response errors.

2. For .66% of Stroop and Name Trials, if the subject responded with "didn't see", the coding was a (2). These trials indicated a lack of fixation and were therefore not considered a true error.

3. Trials with impossibly fast reaction times for the Stroop Trials i.e., less than 423 ms (the fastest Reading Trial over all subjects), were coded as a (9) and presumed to be mechanical errors. The average VRT for "primed" congruent trials in Franzon and Hugdahl's (1986) study for nonretarded adults was 416.35 ms, for correct Stroop trials they averaged 583.63 ms, making Stroop Trial reaction times of less than the 423 ms in this study an unlikely occurrence. These constituted only .2% of the Reading and .14% of the Stroop Trials.

4. With the exception of the above, all other trials were considered to be clear errors and coded as (1's), where the letter color name, or subject's first name, was said with any ommission or intrusion of sound.

Trials coded 2, 3 or 9 totalled 3% of Reading and 1.17% of Experimental and Name trials. For the dependent measure of error percent (ER%), the number of wrong responses over the number of right plus wrong responses times 100 was translated into:

$$\frac{1\text{'s}}{1\text{'s} + 0\text{'s} + 3\text{'s}} \quad X \quad 100 = ER\%$$

Thus trials which were correct but late, were not included in the error data, but were included as correct in the denominator of ER%. Trials coded 2, 3 or 9 were otherwise deleted from data analysis.

APPENDIX B

Pearson r Correlations for VRTs and ER%

Table 1a

Pearson *r* Correlations Between the Dependent Measures VRTs and ER%, Right Visual Field, Within Cells

WITHIN	VRTs			
Visual Field	Right Visual Field			
Wordtype	Color-Words		Neutral-Words	
Orientation	Horizontal	Vertical	Horizontal	Vertical
GROUPS				
	ER%			
Overall	*r* = .27 (*p* = .03)			
MR Adults	*r* = .03 (*p* = .90)			
MA Children	*r* = .07 (*p* = .75)			
Nonretarded Adults	*r* = .36 (*p* = .11)			
		ER%		
Overall		*r* = .53 (*p* = .0005)*		
MR Adults		*r* = .51 (*p* = .02)		
MA Children		*r* = .32 (*p* = .17)		
Nonretarded Adults		*r* = .68 (*p* = .001)*		
			ER%	
Overall			*r* = .17 (*p* = .19)	
MR Adults			*r* = .09 (*p* = .72)	
MA Children			*r* = -.11 (*p* = .63)	
Nonretarded Adults			*r* = -.32 (*p* = .18)	
				ER%
Overall				*r* = .37 (*p* = .004)*
MR Adults				*r* = .25 (*p* = .29)
MA Children				*r* = .28 (*p* = .24)
Nonretarded Adults				*r* = .10 (*p* = .67)

* p = .01

Table 1b

Pearson r Correlations Between the Dependent Measures VRTs and ER%, for Left Visual Field, Within Cells

WITHIN	VRTs			
Visual Field	Left Visual Field			
Wordtype	Color-Words		Neutral-Words	
Orientation	Horizontal	Vertical	Horizontal	Vertical
GROUPS				
	ER%			
Overall	r = .43 (p = .001)*			
MR Adults	r = .31 (p = .19)			
MA Children	r = .44 (p = .05)			
Nonretarded Adults	r = .49 (p = .03)			
		ER%		
Overall		r = .20 (p = .13)		
MR Adults		r = .04 (p = .85)		
MA Children		r = -.07 (p = .76)		
Nonretarded Adults		r = .31 (p = .18)		
			ER%	
Overall			r = .30 (p = .02)	
MR Adults			r = .31 (p = .18)	
MA Children			r = -.18 (p = 45)	
Nonretarded Adults			r = -.14 (p = .55)	
				ER%
Overall				r = .20 (p = .12)
MR Adults				r = -.07 (p = .77)
MA Children				r = .15 (p = .54)
Nonretarded Adults				r = -.09 (p = .70)

* p = .01

APPENDIX C

Group Means and Standard Deviations for Lateralized Trials

Table 2a

Group Means (Standard Deviations) for Correct VRTs (in milliseconds) for Lateralized Reading Trials

Lateralized Reading Trials		VRTs			
Visual Field		RVF		LVF	
Wordtype		C-W	N-W	C-W	N-W
	N	M (SD)	M (SD)	M (SD)	M (SD)
MR Adults	20	1058.28 (492.70)	974..25 (298.84)	905.08 (230.48)	1099.51 (412.88)
MALES	10	972.48 (378.41)	970.56 (291.11)	845.05 (179.48)	980.78 (362.45)
FEMALES	10	1144.08 (594.07)	977.95 (322.12)	965.13 (268.18)	1218.25 (444.06)
MA Children	20	830.15 (191.76)	984.54 (338.32)	788.76 (139.42)	1094.90 (375.63)
MALES	10	856.13 (231.97)	970.40 (202.75)	745.74 (153.98)	1045.65 (242.36)
FEMALES	10	804.18 (149.40)	998.68 (447.31)	831.78 (114.96)	1144.14 (483.48)
Nonretarded Adults	20	723.00 (187.76)	700.52 (193.98)	679.42 (133.21)	871.46 (399.45)
MALES	10	701.38 (116.72)	745.61 (153.98)	713.81 (176.41)	794.79 (219.05)
FEMALES	10	744.65 (244.47)	655.43 (94.96)	645.03 (60.95)	948.13 (525.17)

Table 2b

Group Means (Standard Deviations) for Error Percent (ER%) for Lateralized Reading Trials

Lateralized Reading Trials		ER%			
Visual Field		RVF		LVF	
Wordtype		C-W	N-W	C-W	N-W
	N	M (SD)	M (SD)	M (SD)	M (SD)
MR Adults	20	15.00 (20.52)	31.25 (24.16)	12.50 (17.21)	41.25 (28.42)
MALES	10	17.50 (20.58)	30.00 (22.97)	10.00 (17.48)	42.50 (31.29)
FEMALES	10	12.50 (21.25)	32.50 (26.48)	15.00 (17.48)	40.00 (26.87)
MA Children	20	2.50 (7.69)	32.50 (24.47)	10.00 (14.96)	50.00 (31.41)
MALES	10	2.50 (7.90)	30.00 (19.72)	7.50 (12.08)	47.50 (24.86)
FEMALES	10	2.50 (7.91)	35.00 (29.34)	12.50 (17.68)	52.50 (38.10)
Nonretarded Adults	20	0.00 (0.00)	10.00 (17.01)	3.75 (9.16)	16.25 (16.77)
MALES	10	0.00 (0.00)	17.50 (20.58)	2.50 (7.91)	17.50 (16.87)
FEMALES	10	0.00 (0.00)	2.50 (7.91)	5.00 (10.54)	15.00 (17.48)

Table 2c

Group Means (Standard Deviations) for Correct VRTs (in milliseconds) for Lateralized Stroop Trials in the RVF

Lateralized Stroop Trials		VRTs			
Visual Field		RVF			
Wordtype		C-W		N-W	
Orientation		H	V	H	V
	N	M (SD)	M (SD)	M (SD)	M (SD)
MR Adults	20	1460.50 (497.12)	1710.01 (1577.62)	1220.18 (232.22)	1273.57 (349.81)
MALES	10	1318.82 (380.81)	2040.46 (2210.50)	1156.80 (265.87)	1168.69 (210.86)
FEMALES	10	1602.17 (576.27)	1379.55 (354.06)	1283.56 (185.01)	1378.45 (435.23)
MA Children	20	1459.85 (181.03)	1454.23 (233.20)	1396.26 (253.65)	1409.15 (175.33)
MALES	10	1408.76 (178.61)	1416.56 (166.28)	1325.47 (173.18)	1361.94 (167.40)
FEMALES	10	1510.94 (177.43)	1491.91 (289.84)	1467.05 (307.74)	1456.36 (178.67)
Nonretarded Adults	20	933.72 (115.12)	950.74 (121.56)	815.85 (82.16)	837.33 (93.26)
MALES	10	944.85 (84.62)	947.59 (71.59)	842.17 (87.43)	868.44 (74.59)
FEMALES	10	922.59 (143.33)	953.89 (161.40)	789.53 (71.18)	806.23 (103.18)

Table 2d

Group Means (Standard Deviations) for Correct VRTs (in milliseconds) for Lateralized Stroop Trials in the LVF

Lateralized Stroop Trials		VRTs			
Visual Field		LVF			
Wordtype		C-W		N-W	
Orientation		H	V	H	V
	N	M (SD)	M (SD)	M (SD)	M (SD)
MR Adults	20	1506.94 (567.72)	1401.69 (339.01)	1222.28 (237.52)	1271.56 (274.73)
MALES	10	1410.37 (455.95)	1350.46 (379.99)	1183.22 (241.65)	1258.34 (333.83)
FEMALES	10	1603.50 (672.18)	1452.93 (303.98)	1261.34 (239.40)	1284.79 (217.96)
MA Children	20	1540.33 (303.29)	1494.05 (281.29)	1461.70 (241.75)	1435.50 (296.43)
MALES	10	1534.92 (293.10)	1476.48 (343.78)	1411.43 (231.22)	1307.53 (194.65)
FEMALES	10	1545.73 (328.97)	1511.62 (219.47)	1511.97 (253.58)	1563.46 (333.50)
Nonretarded Adults	20	967.72 (119.49)	959.36 (111.85)	837.31 (82.90)	848.20 (79.36)
MALES	10	1001.96 (101.98)	983.73 (107.62)	825.65 (70.83)	863.16 (65.30)
FEMALES	10	933.47 (130.90)	934.99 (116.23)	848.97 (95.87)	833.24 (92.39)

Table 2e

Group Means (Standard Deviations) for Error Percent (ER%) for the Lateralized Stroop Trials in the RVF

Lateralized Stroop Trials		ER%			
Visual Field		RVF			
Wordtype		C-W		N-W	
Orientation		H	V	H	V
	N	M (SD)	M (SD)	M (SD)	M (SD)
MR Adults	20	28.37 (27.46)	32.39 (26.34)	19.07 (19.77)	24.76 (20.85)
MALES	10	20.91 (28.63)	27.95 (27.95)	10.38 (13.53)	17.58 (17.73)
FEMALES	10	35.83 (25.47)	36.82 (25.29)	27.75 (21.79)	31.94 (22.11)
MA Children	20	14.16 (12.42)	11.74 (10.65)	7.12 (9.09)	7.53 (5.35)
MALES	10	15.83 (11.42)	10.00 (8.60)	9.17 (11.42)	7.58 (4.75)
FEMALES	10	12.50 (13.75)	13.48 (12.60)	5.08 (5.88)	7.50 (6.15)
Nonretarded Adults	20	5.42 (7.29)	8.33 (10.47)	2.92 (4.08)	1.25 (3.05)
MALES	10	3.33 (5.83)	7.50 (9.98)	2.50 (4.03)	.83 (2.64)
FEMALES	10	7.50 (8.29)	9.17 (11.42)	3.33 (4.30)	1.67 (3.51)

Table 2f

Group Means (Standard Deviations) for Error Percent (ER%) for the Lateralized Stroop Trials in the LVF

Lateralized Stroop Trials		ER%			
Visual Field		LVF			
Wordtype		C-W		N-W	
Orientation		H	V	H	V
	N	M (SD)	M (SD)	M (SD)	M (SD)
MR Adults	20	33.83 (25.13)	30.45 (23.71)	17.08 (12.29)	22.35 (21.84)
MALES	10	28.79 (25.98)	22.42 (17.70)	11.74 (10.52)	16.36 (21.11)
FEMALES	10	38.86 (24.54)	38.48 (27.02)	22.42 (12.05)	28.33 (21.94)
MA Children	20	11.53 (9.78)	11.50 (10.96)	7.20 (6.80)	7.92 (8.32)
MALES	10	8.33 (8.78)	10.50 (9.66)	6.82 (5.33)	7.50 (7.30)
FEMALES	10	14.73 (10.11)	12.50 (12.58)	7.58 (8.30)	8.33 (9.62)
Nonretarded Adults	20	6.25 (5.97)	7.92 (8.75)	1.25 (4.08)	1.67 (4.36)
MALES	10	5.83 (5.62)	5.00 (5.83)	0.0 (0.0)	1.67 (3.51)
FEMALES	10	6.67 (6.57)	10.83 (10.43)	2.50 (5.62)	1.67 (5.27)

Table 2g

Group Means (Standard Deviations) for Correct VRTs (in milliseconds) for Lateralized Name Trials

Lateralized Name Trials		VRTs			
Visual Field		RVF		LVF	
Orientation		H	V	H	V
	N	M (SD)	M (SD)	M (SD)	M (SD)
MR Adults	20	1180.48 (743.82)	1068.64 (367.65)	1222.16 (794.47)	1194.33 (742.71)
MALES	10	981.65 (208.07)	980.72 (268.34)	932.65 (124.06)	1009.61 (200.60)
FEMALES	10	1379.31 (1018.26)	1156.57 (442.90)	1511.69 (1063.41)	1379.04 (1023.94)
MA Children	20	1114.13 (284.08)	1090.37 (210.83)	1101.14 (229.39)	1090.44 (252.76)
MALES	10	1105.52 (373.11)	1061.40 (210.92)	1105.50 (304.86)	1001.53 (181.95)
FEMALES	10	1122.75 (176.05)	1119.34 (217.91)	1096.79 (134.56)	1179.35 (290.18)
Nonretarded Adults	20	768.01 (64.05)	782.74 (64.89)	801.54 (76.37)	789.04 (66.12)
MALES	10	750.90 (67.39)	781.93 (75.94)	772.49 (46.41)	784.60 (64.08)
FEMALES	10	785.13 (58.90)	783.54 (56.36)	830.60 (91.01)	793.48 (71.28)

Table 2h

Group Means (Standard Deviations) for Error Percent (ER%) for Lateralized Name Trials

Lateralized Name Trials		ER%			
Visual Field		RVF		LVF	
Orientation		H	V	H	V
	N	M (SD)	M (SD)	M (SD)	M (SD)
MR Adults	20	22.00 (31.72)	26.75 (34.73)	30.50 (33.28)	27.00 (35.70)
MALES	10	24.00 (40.88)	34.00 (40.06)	32.50 (37.80)	36.00 (45.02)
FEMALES	10	20.00 (21.08)	19.50 (28.72)	28.50 (30.00)	18.00 (22.01)
MA Children	20	5.00 (8.89)	6.00 (9.40)	3.00 (7.33)	9.00 (16.51)
MALES	10	6.00 (9.66)	6.00 (9.66)	0.00 (0.00)	10.00 (21.60)
FEMALES	10	4.00 (8.43)	6.00 (9.66)	6.00 (9.66)	8.00 (10.33)
Nonretarded Adults	20	5.00 (8.89)	5.00 (8.89)	6.00 (11.42)	2.00 (6.16)
MALES	10	2.00 (6.32)	4.00 (8.43)	8.00 (13.98)	4.00 (8.43)
FEMALES	10	8.00 (10.33)	6.00 (9.66)	4.00 (8.43)	0.00 (0.00)

Table 21

Error % Means and Standard Deviations on Lateralized Reading Trials for the MR Adults, MA Children and Nonretarded Adults Groups, as a Function of Visual Field

GROUP		RVF		ER% LVF			
	N	M	SD	M	SD	F	p
MR Adults	20	23.13	17.34	26.88	19.14	1.21	.285
MA Children	20	17.50	13.69	30.00	20.03	10.55	.004*
Nonretarded Adults	20	5.00	8.51	10.00	8.70	3.62	.072

* $p = .01$

Table 2j

VRTs (in milliseconds) Means and Standard Deviations on Lateralized Reading Trials for Color-Words and Neutral Words, as a Function of Visual Field

WORDTYPE VRTs	N	RVF M	RVF SD	LVF M	LVF SD	F	p
Color-Words	60	870.48	348.21	791.08	194.21	4.62	.036
Neutral-Words	60	886.44	308.76	1 021.96	404.03	12.17	.001*

* p = .01

Table 2k

Group Means (Standard Deviations) for Average VRTs (ms) on the First (Block 1) and Second Half (Block 2) of the Stroop Trials

GROUP	BLOCK 1	BLOCK 2	Difference
MR Adults	956.0 (270.5)	941.1 (319.3)	14.9
MA Children	1195.3 (233.3)	1339.3 (203.9)	-144.0
Nonretarded Adults	843.0 (82.8)	847.0 (70.1)	-4.0

APPENDIX D

MANOVA Source Tables for Lateralized Reading, Stroop and Name Trials

Table 3a

Source Table for Main MANOVA on VRTs for Lateralized Reading Trials

Source of Variation	SS	df	MS	F	p
Group (G)	2 947 152.61	2	1 473 576.31	6.72	.002*
Sex (S)	225 109.06	1	225 109.06	1.03	.315
G X S	168 848.37	2	84 424.19	.39	.682
ERROR	11 834 019.52	54	219 148.51		
Visual Field (VF)	913 848.99	1	913 848.99	12.35	.001*
G X VF	351 229.48	2	175 614.74	2.37	.103
S X VF	7 546.01	1	7 546.01	.10	.751
G X S X VF	15 765.12	2	7 882.56	.11	.899
ERROR	3 996 591.07	54	74 010.95		
Wordtype (WT)	47 257.25	1	47 257.25	1.34	.252
G X WT	61 528.00	2	30 764.00	.87	.423
S X WT	111 913.21	1	111 913.21	3.18	.080
G X S X WT	3 743.20	2	1 871.60	.05	.948
ERROR	1 900 657.53	54	35 197.35		
VF X WT	692 792.83	1	692 792.83	13.82	.000*
G X VF X WT	40 135.97	2	20 067.99	.40	.672
S X VF X WT	135 078.29	1	135 078.29	2.69	.107
G X S X VF X WT	127 813.76	2	63 906.88	1.27	.288
ERROR	2 707 545.63	54	50 139.73		

* p = .01

Table 3b

Source Table for Main MANOVA on ER% for Lateralized Reading Trials

Source of Variation	SS	df	MS	F	p
Group (G)	15 250.00	2	7 625.00	10.26	.000*
Sex (S)	0.0	1	0.0	0.0	1.000
G X S	562.50	2	281.25	.38	.687
ERROR	40 125.00	54	743.06		
Visual Field (VF)	31 510.42	1	31 510.42	69.45	0.000*
G X VF	5 645.83	2	2 822.92	6.22	.004*
S X VF	93.75	1	93.75	.21	.651
G X S X VF	437.50	2	218.75	.48	.620
ERROR	24 500.00	54	453.70		
Wordtype (WT)	3 010.42	1	3 010.42	13.20	.001*
G X WT	895.83	2	447.92	1.96	.150
S X WT	260.42	1	260.42	1.14	.290
G X S X WT	83.33	2	41.67	.18	.833
ERROR	12 312.50	54	228.00		
VF X WT	1 041.67	1	1 041.67	6.12	.017a
G X VF X WT	270.83	2	135.42	.80	.456
S X VF X WT	41.67	1	41.67	.24	.623
G X S X VF X WT	395.83	2	197.91	1.16	.320
ERROR	9 187.50	54	170.14		

* $p = .01$
a $p < .05$

Table 4a

Source Table for Main MANOVA on VRTs for Lateralized Stroop Trials

Source of Variation	SS	df	MS	F	p
Group (G)	29 948 167.80	2	14 974 083.90	33.15	0.000*
Sex (S)	176 512.29	1	176 512.29	.39	.535
G X S	360 739.32	2	180 369.66	.40	.673
ERROR	24 390 944.41	54	451 684.16		
Visual Field (VF)	531.08	1	531.08	.004	.951
G X VF	297 278.17	2	148 639.09	1 .08	.346
S X VF	39 804.62	1	39 804.62	.29	.593
G X S X VF	81 972.23	2	40 986.12	.30	.743
ERROR	7 424 807.76	54	137 496.44		
Wordtype (WT)	2 730 817.05	1	2 730 817.05	18.24	.000*
G X WT	957 948.63	2	478 974.32	3.20	.049a
S X WT	170 177.16	1	170 177.16	1.14	.291
G X S X WT	86 013.00	2	43 006.50	.29	.751
ERROR	8 085 977.14	54	149 740.32		
Orientation (O)	41 352.86	1	41 352.86	.36	.553
G X O	125 939.25	2	62 969.63	.54	.584
S X O	173 415.15	1	173 415.15	1.50	.227
G X S X O	463 192.35	2	231 596.17	2.00	.145
ERROR	6 257 045.09	54	115 871.21		
VF X WT	41 503.53	1	41 503.53	.39	.533
G X VF X WT	132 361.43	2	66 180.72	.63	.538
S X VF X WT	40 982.24	1	40 982.24	.39	.536
G X S X VF X WT	538 150.98	2	269 075.49	2.55	.088
ERROR	5 701 905.21	54	105 590.84		

Table 4a (continued)

Source Table for Main MANOVA on VRTs for Lateralized Stroop Trials

Source Variation	SS	df	MS	F	p
VF X O	187 700.89	1	187 700.89	1.41	.240
G X VF X O	153 404.97	2	76 702.48	.58	.565
S X VF X O	176 411.91	1	176 411.91	1.33	.255
G X S X VF X O	188 609.57	2	94 304.79	.71	.497
ERROR	7 188 900.60	54	133 127.79		
WT X O	356.62	1	356.62	.002	.959
G X WT X O	9 095.94	2	4 547.97	.03	.966
S X WT X O	236 684.78	1	236 684.78	1.81	.184
G X S X WT X O	489 304.53	2	244 652.26	1.87	.164
ERROR	7 063 575.45	54	130 806.95		
VF X WT X O	112 236.53	1	112 236.53	.83	.365
G X VF X WT X O	195 696.12	2	97 848.06	.73	.488
S X VF X WT X O	158 317.10	1	158 317.10	1.18	.283
G X S X VF X WT X O	467 192.42	2	233 596.21	1.74	.186
ERROR	7 265 581.34	54	134 547.80		

* p = .01
a p < .05

Table 4b

Source Table for Main MANOVA on ER% for Lateralized Stroop Trials

Source of Variation	SS	df	MS	F	p
Group (G)	40 610.31	2	20 305.16	19.45	.000*
Sex (S)	3 357.54	1	3 357.54	3.22	.078
G X S	3 639.12	2	1 819.56	1.74	.185
ERROR	56 360.50	54	1 043.71		
Visual Field (VF)	14.19	1	14.19	.21	.652
G X VF	4.13	2	2.06	.03	.971
S X VF	16.61	1	16.61	.24	.626
G X S X VF	136.00	2	68.00	.99	.380
ERROR	3 723.92	54	68.97		
Wordtype (WT)	5 573.69	1	5 573.69	36.46	0.000*
G X WT	794.29	2	397.15	2.60	.084
S X WT	46.81	1	46.81	.31	.582
G X S X WT	86.35	2	43.17	.28	.755
ERROR	8 255.49	54	152.88		
Orientation (O)	154.50	1	154.50	1.75	.192
G X O	214.08	2	107.04	1.21	.306
S X O	4.64	1	4.64	.05	.820
G X S X O	23.91	2	11.96	.14	.874
ERROR	4 779.67	54	88.51		
VF X WT	32.53	1	32.53	.38	.538
G X VF X WT	158.78	2	79.39	.94	.397
S X VF X WT	40.36	1	40.36	.48	.493
G X S X VF X WT	45.21	2	22.61	.27	.766
ERROR	4 566.06	54	84.56		

Table 4b (continued)

Source Table for Main MANOVA on ER% for Lateralized Stroop Trials

Source of Variation	SS	df	MS	F	p
VF X O	15.29	1	15.29	.22	.643
G X VF X O	157.25	2	78.62	1.12	.334
S X VF X O	7.99	1	7.99	.11	.737
G X S X VF X O	318.06	2	159.03	2.26	.114
ERROR	3 798.08	54	70.33		
WT X O	54.28	1	54.28	.66	.420
G X WT X O	328.93	2	164.46	2.00	.145
S X WT X O	5.17	1	5.17	.06	.803
G X S X WT X O	13.89	2	6.94	.08	.919
ERROR	4 438.66	54	82.20		
VF X WT X O	56.06	1	56.06	.77	.383
G X VF X WT X O	103.74	2	51.87	.72	.493
S X VF X WT X O	22.86	1	22.86	.32	.576
G X S X VF X WT X O	110.21	2	55.11	.76	.472
ERROR	3 908.27	54	72.38		

* p = .01

Table 5a

Source Table for Main MANOVA on VRTs for Lateralized Name Trials

Source of Variation	SS	df	MS	F	p
Group (G)	6 617 433.69	2	3 308 716.84	6.18	.004*
Sex (S)	1 455 692.45	1	1 455 692.45	2.72	.105
G X S	1 527 794.53	2	763 897.27	1.43	.249
ERROR	28 913 152.25	54	535 428.75		
Visual Field (VF)	62 898.80	1	62 898.80	1.76	.190
G X VF	85 913.96	2	42 956.98	1.20	.308
S X VF	104 196.11	1	104 196.11	2.92	.093
G X S X VF	83 797.93	2	41 898.96	1.17	.317
ERROR	1 926 270.71	54	34 671.68		
Orientation (O)	49 254.70	1	49 254.70	.89	.350
G X O	54 243.30	2	27 121.65	.49	.615
S X O	34 095.33	1	34 095. 33	.62	.436
G X S X O	271 505.60	2	135 752.80	2.45	.096
ERROR	2 987 965.52	54	55 332.69		
VF X O	8 126.04	1	8 126.04	.14	.711
G X VF X O	31 716.83	2	15 858.41	.27	.764
S X VF X O	8 329.95	1	8 329.95	.14	.708
G X S X VF X O	18 779.42	2	9 389.71	.16	.852
ERROR	3 165 202.52	54	58 614.86		

$* p = .01$

Table 5b

Source Table for Main MANOVA on ER% for Lateralized Name Trials

Source of Variation	SS	df	MS	F	p
Group (G)	24 572.71	2	12 286.35	8.48	.001*
Sex (S)	617.60	1	617.60	.43	.517
G X S	1 437.71	2	718.85	.50	.612
ERROR	78 253.13	54	1 449.13		
Visual Field (VF)	100.10	1	100.10	.78	.381
G X VF	307.71	2	153.85	1.20	.309
S X VF	75.94	1	75.94	.59	.445
G X S X VF	304.38	2	152.19	1.19	.313
ERROR	6 930.63	54	128.34		
Orientation (O)	30.10	1	30.10	.21	.647
G X O	302.71	2	151.35	1.07	.352
S X O	495.94	1	495.94	3.49	.067
G X S X O	319.38	2	159.69	1.12	.332
ERROR	7 670.63	54	142.05		
VF X O	87.60	1	87.60	.72	.401
G X VF X O	457.71	2	228.85	1.87	.164
S X VF X O	37.60	1	37.60	.31	.582
G X S X VF X O	122.71	2	61.35	.50	.609
ERROR	6 613.13	54	122.47		

* p = .01

APPENDIX E

Post-hoc Orthogonal Group Contrast Tables

Table 6a

Post-hoc Orthogonal Group Contrasts: Lateralized Reading Trials

Reading Trial Contrasts		VRTs SS	F	p
GROUP TOTAL	F(2, 54)	2 947 152.62	6.72	.002**
1. MR vs MA	**F(1, 54)**	**286 942.43**	**1.31**	**.258**
MR+MA vs NR	F(1, 54)	2 660 210.18	12.14	.001*
2. MR vs NR	**F(1, 54)**	**2 823 527.49**	**12.88**	**.001***
MR+NR vs MA	F(1, 54)	123 625.12	.56	.456
3. MA vs NR	**F(1, 54)**	**1 310 259.00**	**5.98**	**.018**
MA+NR vs MR	F(1, 54)	1 636 893.61	7.47	.008
ERROR TERM	54	11 834 019.52	(MS = 219 148.51)	

Reading Trial Contrasts		ER% SS	F	p
GROUP TOTAL	F(2, 54)	15 250.00	10.26	.000**
1. MR vs MA	**F(1, 54)**	**62.50**	**.08**	**.773**
MR+MA vs NR	F(1, 54)	15 187.50	0.44	.000*
2. MR vs NR	**F(1, 54)**	**12 250.00**	**16.49**	**.000***
MR+NR vs MA	F(1, 54)	3 000.00	4.04	.050
3. MA vs NR	**F(1, 54)**	**10 562.50**	**14.21**	**.000***
MA+NR vs MR	F(1, 54)	4 687.50	6.31	.015
ERROR TERM	54	12 312.50	(MS = 228.01)	

MR = MR Adults, **MA** = MA Children, **NR** = Nonretarded Adults
** p = .01, * p/3 = .003

Table 6b

Post-hoc Orthogonal Group Contrasts: Lateralized Stroop Trials

Stroop Trial Contrasts		VRTs SS	F	p
GROUP TOTAL	F(2, 54)	29 948 167.80	33.15	0.000**
1. MR vs MA	**F(1, 54)**	**426 818.19**	**.95**	**.335**
MR+MA vs NR	F(1, 54)	29 521 349.61	65.36	0.000*
2. MR vs NR	**F(1, 54)**	**19 173 601.15**	**42.45**	**0.000***
MR+NR vs MA	F(1, 54)	10 774 566.65	23.85	0.000*
3. MA vs NR	**F(1, 54)**	**25 321 832.36**	**56.06**	**0.000***
MA+NR vs MR	F(1, 54)	4 626 335.44	10.24	.002*
ERROR TERM	**54**	**24 390 944.41**	**(MS = 451 684.16)**	

Stroop Trial Contrasts		ER% SS	F	p
GROUP TOTAL	F(2, 54)	40 610.31	19.45	.000**
1. MR vs MA	**F(1, 54)**	**20 988.98**	**20.11**	**.000***
MR+MA vs NR	F(1, 54)	19 621.33	18.80	.000*
2. MR vs. NR	**F(1, 54)**	**37 538.05**	**35.97**	**0.000***
MR+NR vs MA	F(1, 54)	3 072.26	2.94	.092
3. MA vs NR	**F(1, 54)**	**2 388.44**	**2.29**	**.136**
MA+NR vs MR	F(1, 54)	38 221.88	36.62	0.000*
ERROR TERM	**54**	**56 360.50**	**(MS = 1073.71)**	

MR = MR Adults, **MA** = MA Children, **NR** = Nonretarded Adults
** p = .01, * p/3 = .003

Table 6c

Post-hoc Orthogonal Group Contrasts: Lateralized Name Trials

Name Trial Contrasts		VRTs SS	F	p
GROUP TOTAL	F(2, 54)	6 671 433.69	6.18	.004**
1. MR vs MA	**F(1, 54)**	**181 616.28**	**.34**	**.563**
MR+MA vs NR	F(1, 54)	6 435 817.41	12.02	.001*
2. MR vs NR	**F(1, 54)**	**5 808 556.03**	**10.85**	**.002***
MR+NR vs MA	F(1, 54)	808 877.66	1.51	.224
3. MA vs NR	**F(1, 54)**	**3 935 978.23**	**7.35**	**.009**
MA+NR vs MR	F(1, 54)	2 681 455.46	5.01	.029
ERROR TERM	54	28 913 152.25	(MS = 535 428.75)	

Name Trial Contrasts		ER% SS	F	p
GROUP TOTAL	F(2, 54)	24 572.71	8.48	.001**
1. MR vs MA	**F(1, 54)**	**17 326.41**	**11.96**	**.001***
MR+MA vs NR	F(1, 54)	7 246.30	5.00	.029
2. MR vs NR	**F(1, 54)**	**19 470.16**	**13.44**	**.001***
MR+NR vs MA	F(1, 54)	5 102.55	3.52	.066
3. MA vs NR	**F(1, 54)**	**62.50**	**.04**	**.836**
MA+NR vs MR	F(1, 54)	24 510.21	16.91	.000*
ERROR TERM	54	78 253.13	(MS = 1 449.13)	

MR = MR Adults, **MA** = MA Children, **NR** = Nonretarded Adults
** p = .01, * p/3 = .003

APPENDIX F

Copies of Ethical Approval and Informed Consent Forms

THE UNIVERSITY OF CALGARY

EDUCATION JOINT RESEARCH ETHICS COMMITTEE

CERTIFICATION OF INSTITUTIONAL ETHICS REVIEW

This is to certify that the Education Joint Research Ethics Committee at The University of Calgary has examined and approved the research proposal by:

Applicant: Anne-Marie E. Bergen

of the Department of: Psychology

entitled: Automatic-Effortful Processing in Nonretarded and Mildly Mentally Retarded Individuals: Cerebral Hemispheric Processing of Stroop Stimuli

(the above information to be completed by the applicant)

89-12-06
Date

W. R. [signature]
Chair, Education Joint Research Ethics Committee

CALGARY ROMAN CATHOLIC SEPARATE SCHOOL DISTRICT #1/CATHOLIC SCHOOL CENTRE
300 - 6TH AVE. S.E., CALGARY, ALTA. T2G 0G5/TEL. 298-1411

December 8, 1989

Dr. W. R. Unruh,
Associate Dean (Research and Resources)
and Chairman, Ethics Committee,
Faculty of Education,
The University of Calgary,
2500 University Dr. N.W.,
Calgary, Alberta
T2N 1N4

Dear Dr. Unruh:

Re: Research Proposal, "Automatic-Effortful Processing in Nonretarded and Mildly Retarded Individuals: The Cerebral Hemispheric Processing of Stroop Stimuli," by Anne Marie E. Bergen

I have reviewed the above mentioned research proposal.

This study appears to warrant approval, in my opinion.

Sincerely,

JOSEPH W. QUINN

Assistant Superintendent
STUDENT SERVICES

JWQ:ml

THE UNIVERSITY OF CALGARY

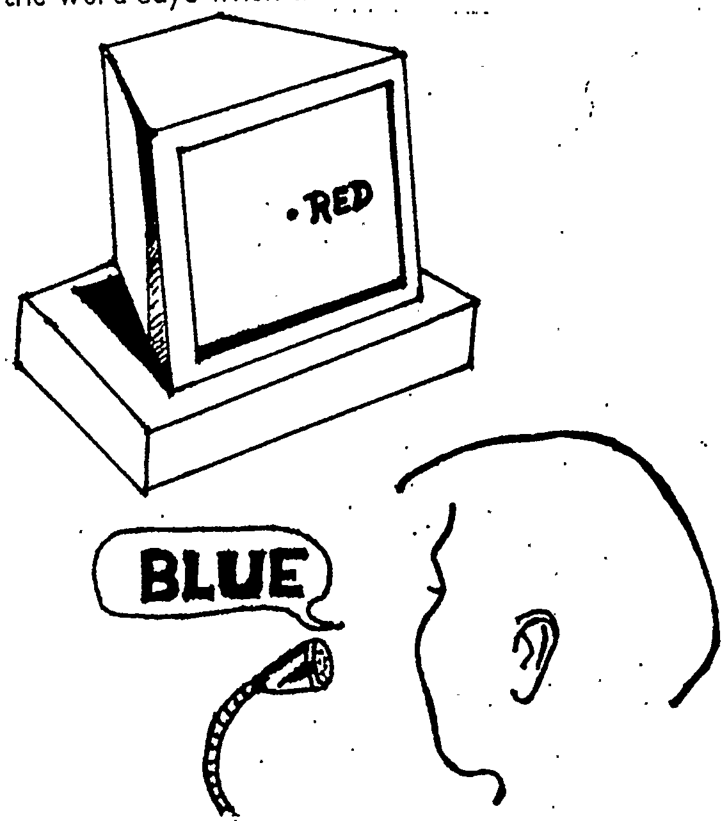
Faculty of SOCIAL SCIENCES
Department of PSYCHOLOGY

2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4

Telephone (403) 220-5561
Fax (403) 282-8249

INFORMED CONSENT

Past studies have told us that practice makes reading easy and fast. Once this happens, it is hard to see a word and **not** read it. This study looks at how well people like you can say the color of a word's letters instead of naming what the word says when the word is off to one side of a dot. For example:



Before you try this "computer game", your eyes will be tested to see how well they can see colors and words at close distances. You will be asked to read a list of words and you will be asked the meaning of some words. All these are necessary to help you do what comes next. You will be asked to read aloud words as they are shown **very fast** on a computer screen. After these short tests we will know if the "game" will be a fair one for you to try. Please read (or listen as it is read to you) the enclosed letter and sign it, if you feel you would like to take part.

THE UNIVERSITY OF CALGARY

2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4

Faculty of SOCIAL SCIENCES
Department of PSYCHOLOGY

Telephone (403) 220-5561
Fax (403) 282-8249

INFORMED CONSENT

The present study will require you to name the color of the letters for the color-words RED, BLUE, GREEN, PURPLE and the common words DAY, WORD, STORE, FRIEND. Letter colors will always be different from the color word and its matching common/neutral word e. g., RED and DAY will be printed in blue, green and purple letters, never in red letters. The words will be shown on a computer screen, to the left or right of a black dot in the middle of the screen. Every person will be asked to name the letter color out loud, as quickly and correctly as possible. On a few occasions, you will be asked to read your own first name.

If you agree to participate you will be given a complete explanation of what you are to do. There will also be some practice before the experimental trials, allowing you time to get used to the task. Approximately 30 minutes will be required.

Involvement in this study is completely voluntary and you have the right to quit at any time before or during the study. The investigator also reserves the right to stop the experiment at any time. Confidentiality is guarateed, so your name will never be reported, and only group information will be used.

The investigator does not anticipate any risk for any person participating in this study.

I have been informed of the nature and purpose of this study. I understand what is required of me, and I agree to participate.

____________________ ______________________________

Date Participants Signature

I, the undersigned, have fully explained the investigation to the above individual.

____________________ ______________________________

Date

A. M. Bergen
Graduate Student
Department of Psychology

THE UNIVERSITY OF CALGARY

2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4

Faculty of SOCIAL SCIENCES
Department of PSYCHOLOGY

Telephone (403) 220-5561
Fax (403) 282-8249

PARENT/GUARDIAN INFORMED CONSENT

To the Parent or Guardian:

Please let me introduce myself. My name is Anne-Marie Bergen and I am a MSc student in the Department of Psychology, at the University of Calgary. This study will be the basis for my Masters Thesis. Your consent agreeing to your child's voluntary participation is therefore greatly appreciated.

The present study will require individuals to name the color of the letters for the color-words RED, BLUE, GREEN, PURPLE, and the common words DAY, WORD, STORE, FRIEND. Letter colors will always be different from the color-word and its matching common/neutral word e.g., RED and DAY will be printed in blue, green and purple letters, never in red letters. The words will be shown on a computer screen, to the left or right of a central black dot. Each individual will be asked to name the letter color out loud, as quickly and accurately as possible. On a few occasions, they will be asked to read their own first names.

All participation is of course completely voluntary, and your child may withdraw from the study at any time. Confidentiality is guaranteed as only group information will be used. Full explanations of what the task requires will be given to each person and no risk is anticipated for anyone participating in this study.

Should you have any questions or concerns, please contact Dr. J. L. Mosley (220-6287) or myself (220-5218).

If you agree to your child's participation, please sign the following:

I/We, the parent(s)/guardian(s) of __________ ______________ consent to our child's involvement in this study.

Date____________________

Signatures of Parents/Guardians

____

____

THE UNIVERSITY OF CALGARY

Faculty of SOCIAL SCIENCES
Department of PSYCHOLOGY

2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4

Telephone (403) 220-5561
Fax (403) 282-8249

PARENT/GUARDIAN INFORMED CONSENT

TO THE PARENT OR GUARDIAN:

Please let me introduce myself. My name is Anne-Marie Bergen and I am a Master of Science student in the Department of Psychology, at the University of Calgary. This study will be the basis for my Master's thesis. Your consent, agreeing to your child's voluntary participation, is therefore greatly appreciated.

The present study will ask your child to name **the color of the letters** for the color-words **RED, BLUE, GREEN, PURPLE,** and the common words **DAY, WORD, STORE, FRIEND.** Letter colors will always be different from the color-word and its matching common/neutral word e. g., RED and DAY will be printed in blue, green and purple letters, never in red letters. The words will be shown on a computer screen, to the left or right of a central black dot. Each child will be asked to name the letter color out loud, as quickly and accurately as possible. On a few occassions, they will be asked to read their own first names. It is like a "computer game".

All participation is of course completely voluntary, and your child may withdraw from the study at any time. Confidentiality is guaranteed, as only group information will be used. Full explanations of what the task requires will be given to each person. No risk is anticipated for anyone participating in this study.

Should you have any questions or concerns, please contact myself (220-5218) or Dr. J. L. Mosley (220-6287).

This study has the approval of Dr. Joseph W. Quinn, Superintendent of Student Services, Calgary Catholic Board of Education, as well as the administration of St. Dominic School.

If you agree to your child's participation, please sign the following:

I/We, the parent(s)/guardian(s) of______________ ______________ consent to our child's involvement in this study.

Date____________________

Signature(s) of Parent(s)/Guardian(s)

____

____

If you would like summary results, please give your address below.

____

____