ADULT AGE DIFFERENCES IN A VISUAL SEARCH, LUMINANCE CONTRAST DISCRIMINATION TASK

By

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Abstract

This thesis examined the ability of younger and older adults to use peripherally presented word cues in a luminance contrast discrimination task. Observers were ten older adults (aged 55 to 69) and ten younger adults (aged 23-29). All observers were screened using the Wechsler Test of Adult Reading and the Digit Symbol subscale of the Wechsler Adult Intelligence Scale (WAIS-III). Stimuli were presented on a 13 X 16° high-resolution monochrome monitor with an average background luminance of 70 cd/m^2. Target (distractor) stimuli were 1°-diameter luminance-incremented (decremented) discs. The spatial location of the targets were cued using luminance decremented 'YES' or 'NO' words presented in 9 x 9 array prior to the presentation of a 9 x 9 array containing one target and eight distractors that were positionally congruent to the cued array. The discriminability (<u>d</u>') between target and distractors was varied and the contrast increment threshold needed to just detect the target was calculated. Contrast increment thresholds and mean correct yes response times were analyzed using a mixed two (Age Group) x two (Sex) x three (Cue Validity) x two (Relevant Set Size) mixed ANOVAs. Pre-testing did detect sensorimotor deficits in the older observers, but there were no significant main effects of Age Group or Sex with respect to contrast increment thresholds or response time. Neither group was able to take advantage of the word cues to allocate visual attention. In fact the sensitivity and response times of all observers improved as cues became less informative. This suggests that the ability to discriminate luminance contrasts is relatively preserved in older adults and that the inhibitory effect of the cues appeared to effect both age groups in a similar manner.

Introduction

Many human aging studies demonstrate a general decline in sensory and motor functioning with age (Fozard & Gordon-Salant, 2001; Ketcham & Stelmach, 2001). In most psychophysical visual search studies, age-related declines have been found in both response time (RT) and accuracy (percent correct response) in both simple detection tasks and in discrimination tasks (Gottlob & Madden, 1998; Ho, Scialfa, Caird, & Graw, 2001; Madden, Gottlob, & Allen, 1999; Ratcliff, Thapar, & McKoon, 2001). Additionally, a recent literature review reported that declines are also demonstrated in cognitive functions such as explicit memory, divided attention, and language (Albert & Killiany, 2001).

Although there is a great deal of research supporting an overall age-related performance decline in visual search tasks, many of these studies only examined RT and/or percent correct as the dependent variable(s). Recently, it has been demonstrated that although older adults are slower in responding to targets in a luminance detection and discrimination visual search task, the words "YES" and "NO", which cued the spatial location of a low-contrast target in a search array, elicited enhanced contrast sensitivities in elderly observers (St. Pierre & Wesner, 2001; Wesner, 2001). In fact, with word cued trials, the young observer sensitivities were actually lower than those found with the elderly. The use of spatial geometric cues such as annulus disks, however, provided no such age advantages. Because word cues require semantic processing, the above researchers hypothesized that the older adults might be taking advantage of some form of higher cortical compensatory mechanism unavailable to the young observers. In order to further examine the effect of word cues with older observers, this study presented similar arrays of word cues that varied in their target validity using a similar luminance discrimination search task.

The following discussions examine the essentials of visual search, Signal Detection Theory (SDT), and theories of visual attention. A short review of recent research delineating the possible mechanisms by which attention improves performance follows. Finally, an overview of age-related differences in visual attention is followed by an examination of research regarding possible compensatory mechanisms that may be associated with age-related RT performance declines. The evidence for such compensatory mechanisms includes results from psychophysical, neuroimaging, and neurometric research.

Visual Search

Visual search is a task that most individuals engage in most of the day, from looking for a toothbrush in a drawer to watching for pedestrians on a busy thoroughfare. The ease with which a target object is detected is largely a function of its uniqueness as compared to its surroundings (Verghese, 2001). Typically, visual search experimenters present observers with a visual display containing a variable number of targets and distractors. A target is a pre-specified stimulus that is placed within an array of distractor stimuli that differ from the target along one or more dimensions. These dimensions could be perceptual attributes such as colour, luminance, size, orientation, or speed of motion. A target can also be presented in some trials and not in others to allow for signal detection analyses. The subject is usually asked to determine as quickly as possible whether or not the target is present. The experimenter can then manipulate different target and/or distractor attributes and measure RT, percent response accuracy, and/or (with more recent research) target-attribute thresholds. The present study employed a simple search paradigm in which targets and distractors varied along the luminance contrast dimension.

In the past, visual search results have been described either as the consequence of serial or parallel information processing. These two models have been differentiated based on the change in RT as a function of number of stimulus elements in a display. Generally, parallel search RTs do not increase when the number of distractors in a visual field increases; however, serial search RTs increase with increases in the number of elements. This is because researchers (Duncan & Humphreys, 1989; Treisman & Gormican, 1988) have suggested that linear increases in RT with linear increases in element number reflects the time it takes a subject to process each element in a display before making a decision about the target or nontarget status of each element (Verghese, 2001).

High-Threshold Theories of Visual Search

High threshold theories of visual search are based on the assumptions that the relevant representation of a stimulus is discrete, such that the target is detected or it isn't, and that the absence of a target never causes a false alarm. An erroneous response occurs only as a result of improper guessing (Palmer, Verghese, & Pavel, 2000) and not from the energy of a distractor.

Two major high-threshold theories of visual search are feature integration theory (Treisman & Gelade, 1980) and attentional engagement theory (Duncan & Humphreys, 1989). These theories emphasize mechanisms such as serial processing or limited capacities and although popular and used quite extensively as a model for a number of RT research, recently these theories have been discredited, particularly for simple detection and discrimination tasks that measure percent accuracy and thresholds in addition to RT (Palmer et al., 2000). With the assumption of stimulus signal and noise properties, recent visual search research entered the realm of psychophysics and this has led to a much broader understanding of search including those processes associated with visual attention, learning, and memory (Ahissar & Hochstein, 1993; Cameron, Tai, & Carrasco, 2002; Lieb, Brucker, Bach, Els, Lucking, & Greenlee, 1999; Smith, 2000).

Low-Threshold Theories: Signal Detection Theory and Psychophysics

Palmer et al. (2000) suggest that visual search research should be based on theories of simple detection and discrimination found in visual psychophysics, and that emphasis should be on the contributions distractors make towards the observer's ability to detect a target. Palmer et al. argue that signal detection theory (SDT) is the optimal method of analysis to study these properties. SDT, a common model used to predict human sensitivity, can successfully predict detection and discrimination responses without the assumptions of a limited resource or a second stage serial processor. Many SDT search models propose an initial parallel stage followed only by a simple decision stage in which the elements in a visual scene are represented internally as independent, continuous noisy variables (Verghese, 2001). SDT makes no assumptions regarding the specific characteristics of the monitored target; rather the observer is monitoring the output of a matched filter, which is the detector of the located target. In this case, the filter is a hypothetical construct that represents a group of neurons tuned to a particular dimension. The response to repeated presentations of such a target result in a Gaussian distribution of response strengths due to the internal noise within the visual system.

According to Verghese (2001), physiological evidence of the low-threshold psychophysical model of attention has also been demonstrated in several studies (McAdams & Maunsell, 1999; Reynolds & Desimone, 1997; Reynolds, Pasternak, & Desimone, 2000; Treue & Martinez Trujillo, 1999; Treue & Maunsell, 1996). In these studies, the effect of visual attention was found to increase the responses of individual isolated neurons in V2 and V4 neurons in trained Macaque monkeys. Verghese argued that this supports the characterization of the effects of attention as either a hypothetical SDT construct representing the strength of neural response or as the actual neural spike rate. The decision as to whether an element is a target or a distractor is based upon whether an element produces a higher response rate in a selective filter than the possible distractors. The ability to discriminate between targets and distractors is, therefore, a function of the difference between response rates (i.e., signal to noise ratio). Considering the noise of the visual system that is added to each stimulus, the more similar a target is to a distractor, the closer the response rate of a distractor is to the response rate of the target and the higher the probability of an error. Unlike high-threshold theories that assume that the relevant representation of a stimulus is or is not detected, and that errors arise only as a result of guessing, low-threshold theories share the idea that a distractor can produce a target-detect state when a distractor produces sufficient evidence to pass the "low threshold" criterion (Palmer et al., 2000). SDT includes a distinct decision process that incorporates the effects of both bias and sensitivity and performs a comparison between the internal representation of the stimulus and an internal representation of a comparison standard. Palmer et al. (2000) examined three low-threshold theories that fit within the framework of SDT. These theories are described as the ideal observer, maximum of outputs, and maximum of differences. Palmer et al. conducted a series of experiments to investigate the ability of high- and low-threshold theories to predict performance in simple visual search tasks. It was found that the high-threshold theory failed to predict results in almost all testable situations; however all three low-threshold SDT models well predicted human visual search performance.

Covert versus Overt Attention

The massive amount of information contained in most visual scenes necessitates the continuous monitoring and selection of pertinent stimuli that are important the survivability of an organism. The attention to specific stimuli can be overt through the movement of the head and eyes, or covert through involuntary or automatic responses without any type of body movement. Spatial attention makes it possible for an observer to select visual information at a cued location in a voluntary or involuntary manner, and to give this information priority for further processing (Carrasco & McElree, 2001).

Studies investigating covert orienting have often used spatial cues that locate the area in which a target might appear. Typically, the observer is instructed to make use of the cues and respond to the target based on a predefined dimension that differed from nontarget distractors. Target cueing usually results in faster RTs (Ashton-Jones, Desimone, Driver, Luck, & Posner, 1999). Such experimentation resulted in debate over whether cueing improves allocation of attention or simply biases observers through decision-making processes towards the cued area. In order to answer this question, experimenters developed methods that used discrimination rather than simple detection tasks to measure accuracy and RT. If the presence of spatial cues decreases RT due to a less cautious attitude, then the response accuracy should also decline. If RTs decrease and accuracy is not impaired, however, one might argue that cue effects are not due to a less cautious approach, but rather from an enhancement of perceptual and/or decision-making cognitive processes. In discrimination tasks, although the location of the target may be cued, the observer must still discriminate the target attributes from the distractors rather than just simply respond to the appearance of a stimulus in the cued area. As well, the use of near-threshold stimuli allows for signal detection analyses as pointed out above based on the low-threshold models of search. Also, the use of covert orienting of attention eliminates saccades and associated motor processes, which may be more susceptible to age-related declines or practice effects.

Beauchamp, Petit, Ellmore, Ingeholm, & Haxby (2001) recently suggested that similar neural networks subserve overt and covert shifts of attention. To support this hypothesis, Beauchamp et al. determined fMRI neuroimaging similarities and differences between the neural mechanisms that are activated during an overt and/or covert shift of attention. Observers were required to make both forms of attentional shifts in order to detect small luminance-decremented targets. Targets consisted of small round targets (0.15° circles) that remained stationary (control) or were changed so that they disappeared from their former position and reappeared at an uncued location 8° average eccentricity from fixation. In the covert task, observers were required to maintain central fixation throughout the experiment, while in the overt task observers were allowed to move their eyes to the target. It was found that regardless of the rate at which the changing target reappeared, neural activations occurred in the precentral sulcus, intraparietal sulcus, and occipital cortex, and that these activations occurred with greater magnitude in the case of overt shifts of attention. The authors attributed this greater activity to the execution of eye movements and proposed that overt and covert shifts in attention are subserved by similar neural mechanisms with the exception of greater levels of response in areas necessary for motoric eye movements.

A similar neuroimaging study supporting this contention examined the relationship between covert shifts of attention and saccadic eye movements (Nobre, Gitelman, Dias, & Mesulam, 2000). It was found that both attentional commands activated overlapping cortical areas including lateral and medial prefrontal areas, the anterior cingulate cortex, bilateral posterior parietal areas, right hemisphere posterior temporal areas, bilateral posterior inferior/middle temporal cortex, and the left ventral striate areas. However, it was also found that although there were no distinguishing patterns of activation between the two activities, there were higher levels of activation during the covert attention task in the common parietal and frontal areas, the anterior cingulate cortex and the anterior insula.

It appears that physiological properties of overt and covert attentions differ mainly in the added neural activity required to facilitate the orientation of the eyes. Because it is generally accepted that older adults suffer age-related motor decline (Desrosiers, Hebert, Bravo, &

Rochette, 1999; Ketcham & Stelmach, 2001), we argue that controlling for eye movements will provide a less ambiguous measurement of the aging process associated with visual attention.

Endogenous Versus Exogenous Cues

Endogenous cues are generally presented in the center of the visual display while exogenous cues are presented peripherally, eccentric from foveal fixation. It is hypothesized that peripheral cues result in automatic involuntary orienting of attention while central foveal cues require more of a voluntary shift towards the target (Theeuwes, 1994).

Simple detection or discrimination studies as well as visual search studies may employ central endogenous informative cues that predict likely target areas in order to induce the observer to voluntarily shift covert or overt attention toward the indicated locus (Ashton-Jones et al., 1999). Exogenous peripheral cues generally offer cues to the exact location of the target stimulus by occupying a similar area in which the target may appear.

Neurometric study of central versus peripheral cueing show that the two cue types result in the employment of two different neural substrates (Ashton-Jones et al., 1999). This finding suggests that results from experiments using one type of cueing cannot be generalized to others and that the ability to shift attention efficiently may be dependent upon the type of cue employed or the type of task demanded of the observer. Some researchers would argue that endogenous cues that require voluntary response, might involve higher cortical attentional function (Posner & Petersen, 1990). We hypothesize that the employment of word cues that require higher level semantic processing may facilitate the allocation of higher cortical attentional functioning associated with endogenous cues. Others argue that multi-element peripheral word cues act similarly to central word cues and require voluntary shifts of visual attention and longer stimulus onset asynchronies (SOA) for the process to occur. SOA can be defined as the time interval between the offset of a cue and the onset of a target. This is due to the fact that peripheral word cues must interpreted beyond spatial positioning of the cue and therefore require the endogenous allocation of spatial attention (Chastain & Cheal, 1998, 1999).

Possible Mechanisms of Visual Attention

Recent research has attempted to develop methods that illuminate the characteristics of attentional mechanisms using the addition of external noise (Dosher & Lu, 2000; Lu & Dosher, 1998). Although it has been demonstrated that cuing an observer to the location of a stimulus will result in faster RTs and greater accuracy (or sensitivity based on threshold measures), the mechanism by which this facilitation is achieved is not well understood. Lu and Dosher (1998) suggest that there are three likely mechanisms by which attention might enhance human information processing: (1) signal enhancement in which attention increases the strength of the signal, (2) distractor exclusion in which attention narrows a processing filter-so that distractors or external noise signals are excluded, and (3) the reduction of internal noise associated with perception. Internal noise is a hypothetical construct that represents physical and biological inefficiencies within the central and peripheral nervous systems.

Lu and Dosher (1998) developed the noisy Perceptual Template Model (PTM) along with mathematical predictions for the performance of the PTM. The PTM consists of four major components: a perceptual template, a multiplicative internal noise source, an additive internal noise, source and a decision process. The perceptual template is a spatial frequency filter, with a center frequency and bandwidth that permits a range of spatial frequencies to pass through. Signals that closely match the filter's transmittance properties receive a maximum gain in strength while those signals that match less closely still pass through but with correspondingly smaller gains. Other filter templates might exist for a specific alphanumeric character, a colour, or some other target attribute. External noise added to the stimulus (by the experimenter) is passed through the perceptual template along with the stimulus signal. Signal detection is limited by the properties of the stimulus (e.g., signal contrast and external noise) and by the limits of the human observer. Physical or biological factors such as neural randomness, limitations of coding, and loss of signal limit the efficiency of observer's internal perceptions during information transmission. The model makes no specific attempt to delineate or explain these individual sources of noise but rather characterizes them together as equivalent internal noise.

Equivalent internal noise is defined as the amount of random internal noise that is required to equal the inefficiency present in the perceptual system. They are modeled either as multiplicative or additive. Multiplicative noise is modeled as an independent noise source whose magnitude is a function of the contrast of the external stimulus and is modeled as a gaussian random variable. Additive internal noise is modeled, as a limit of human processing that does not vary with signal strength and becomes negligible at high signal strength. The decision process is fed the output from the template match in addition to both the multiplicative and additive noises. Lu and Dosher (1998) suggest that this model can predict findings from detection, discrimination or forced choice yes/no response tasks.

Elaborating further on this model, Lu and Dosher (1998) developed an attention plus external noise paradigm to examine the possible mechanisms of attention in a concurrent location-cued orientation discrimination task. In such a task, targets and distractors occur in square frames concurrently to the left and to the right of central fixations and cues. Lu and Dosher hypothesized that it is possible to identify the perceptual processes by studying the changes in task performance resulting from increased amounts of external noise. In this paradigm, white, random Gaussian noise is added to a stimulus (Gabor patches), while the observer is cued as to which side of the display a target will be located. From this data, psychometric functions comparing signal contrast responses to those of external noise contrast were constructed for each level of attention (attended, equal attention, and unattended). Attention was manipulated through specific instructions to the observers in each condition. The PTM predicts that signal enhancement (i.e., increase in the gain of the perceptual template) due to attention will demonstrate an effectiveness at low but not high-levels of external noise because signal enhancement will not be effective in situations where external noise dominates (i.e., both signal and noise are enhanced). Distractor suppression, on the other hand, predicts improved performance due to attention at high but not low-levels of external noise. Multiplicative internal noise reduction predicts improved performance due to attention at both low- and high-levels of external noise (Lu & Dosher, 1998). Therefore, since attention must exert its effects in low external noise, high external noise or both, this model predicts a pattern of results, which can then be empirically tested.

To obtain the data, Lu and Dosher used a two-alternative forced choice (2AFC) method where observers were asked to judge Gabor orientations. Threshold signal contrasts were estimated for each of the three attention conditions in which observers were instructed to employ a specific strategy for each level of added external noise (0.000, 0.021, 0.041, 0.082, 0.123, 0.164, 0.246 and 0.328 proportion contrast). In one condition, the observers were instructed to attend to the left or right, while in a second condition, they were instructed to attend to both sides of the visual display. In the third condition they were instructed to attend to neither location. The psychometric functions derived from the signal enhancement prediction of PTM fit closely to the data, leading the authors to conclude that in this orientation discrimination task, attention reduces threshold contrast (or increases sensitivity) by enhancing signal strength after multiplicative internal noise contributions or equivalently through a reduction of additive internal noise. The difficulty with PTM is its inability to differentiate the two theoretical constructs of multiplicative internal noise and additive internal noise.

Later, Dosher, and Lu (2000) used an attention plus external noise paradigm to examine the effects of varying the validity of central cues. This experimental paradigm consisted of presenting central cues that were 62.5% or 37.5% valid, an additional peripheral report cue, and four Gabor patches in each corner of a display. The central cue indicated which of the four Gabor patches the observers should attend. In the case of valid cues, a following report cue (a small peripheral arrow) also pointed to the same corner of the display. For invalid cues, the second arrow pointed to a different location. If the second peripheral cue did not agree with the initial central cue, the central cue was not valid. This experiment used a relatively simple task in which attention did not initially affect performance. External noise was then added using eight different proportional contrast levels (0.00, 0.02, 0.04, 0.08, 0.12, 0.16, 0.25, and 0.33). Nine signal contrast levels were used based on practice data for each individual subject. Contrast thresholds were estimated and psychometric functions for valid and invalid cue conditions were fitted to the data to compare three of the nine signal contrast levels (50%, 62.5%, and 75%) with the eight levels of external noise proportional contrast. These psychometric functions closely resembled those derived mathematically from the PTM that assumed an external noise reduction mechanism. This finding indicates that in this task, attention served to exclude external noise since attention did not improve performance in this simple task until high levels of external noise were added.

A recent series of experiments examined the effect of covert spatial attention on contrast sensitivity when a target was presented in the absence of distractors or with a post-target local mask positioned in the same location as the target (Carrasco, Penpeci-Talgar, & Eckstein, 2000). Earlier studies that employed distractors and local post masks have found support for an externally mediated noise reduction model of how attention improves visual search (e.g., Lu & Dosher, 1998). Carrasco et al. also determined whether precuing of location would improve spatial detection, but the study was unique in that the Gabor targets they used appeared without distractors and encompassed a broad range of spatial frequencies. Attentional benefits appeared with or without a post-stimulus mask, at different performance levels, and in three different tasks: discrimination, detection, and localization. Attention improved contrast sensitivity in the absence of the conditions that demonstrated external noise reduction, leading the authors to infer that the demonstrated benefits of covert attention were at least in part due to signal enhancement (Carrasco et al., 2000). In other words, the signal strength of stimuli in the spatial area where attention was deployed increased.

Carrasco and McElree (2001) examined whether covert attention accelerates visual information processing using a response-signal speed-accuracy (d') trade-off (SAT) procedure. Two different types of trials were used: one in which a 30 ° tilted Gabor target had to be detected amongst vertical Gabor distractors, and one in which the same target was accompanied by distractors that had the same 30 ° orientation or the same spatial frequency as the target. Thus, in the second condition observers had to process both orientation and spatial frequency to accomplish the task. The authors created hypothetical psychometric functions (d' versus response time) that predicted the shape of cued versus uncued functions based on whether attention improves discriminability or increases the speed of information processing. Processing time was defined as the time interval defined by the onset of the cue and the observer's response to the target. If attention improved only sensitivity, it was predicted that the psychometric function for the cued condition would display higher d' scores after reaching their asymptote than the uncued condition. If attention improved only speed of processing, it was predicted that the cued and uncued functions would asymptote at the same d' level but that the cued curve would do so at a lower processing time. Psychometric functions were plotted for the actual data and compared to the hypothetical functions. Comparison of the hypothetical to the actual plots indicated that peripheral cues not only improved discrimination but also increased the rate of information processing to allow for more efficient operation in a visual scene.

Yeshurun and Carrasco (1999) used peripheral cues (green horizontal bar) to examine the effect of covert attention on spatial resolution performance in a series of three experiments that measured gap and vernier resolution. The bar indicated the location of the target but not the orientation of the gap (left or right, Experiment 1), whether the line was broken or solid (Experiment 2), or whether an upper line was displaced to the left or right of a lower line. Results indicated that as gaps or offsets became smaller, RTs increased and percent correct accuracy dropped. However, it was found that precuing improved both RT and percent correct accuracy as compared to uncued trials. From these results the authors inferred that spatial attention improves performance, at least in part, from enhanced spatial resolution at the cued location (Yeshurun & Carrasco, 1999).

The empirical evidence reviewed thus far supports the contentions that spatial attention improves performance through signal enhancement, external noise reduction, increased spatial resolution as well as increasing the speed of information processing. At the same time, other studies support the hypothesis that similar neural networks subserve covert and overt spatial attention (Beauchamp et al., 2001). Continued research will further reveal how visual attention improves visual search. It is likely that spatial attention improves visual detection, discrimination and search through a variety of mechanisms that include signal enhancement, external noise reduction, and improved resolution depending upon the task at hand. Additionally, these attentional mechanisms may be differentially modified by aging processes such as slower neural signaling coupled with learned cognitive strategies that compensate for aging decrements. These modifications may be very task specific, so much so that age-related changes may produce either a decrement or an improvement in performance depending on the paradigm used in an experiment.

Although it would be impossible to state conclusively the mechanism(s) by which visual attention functions in any search task, it is a reasonable assumption that the deployment of attention enhances visual search performance. It is also reasonable to assume that if performance improves with certain types of cues, then the cues enhance the allocation of attention.

Age-Related Differences in Visual Spatial Attention

Visual spatial attention has been an area of interest in aging research due to its importance in everyday life (Gottlob & Madden, 1999). Studies that have examined age-related differences have yielded mixed results regarding the task specific abilities of older adults. This lack of consensus may be due in part to the multitude of paradigms used that include covert and overt attention, central versus peripheral cuing and the use of highly divergent display times that make it very difficult to compare results across studies.

Gottlob and Madden (1998) hypothesized that the inconsistency in studies examining age-related declines in visual attention may be the result of sensory and motor systems decline. They attempted to control for age-declined motor responses by establishing baseline performances derived from the results of an initial motor and sensory experiment. The first experiment quantified age-related sensory and motor declines in older adults in order to make accommodations for a second experiment in which older adults were presented with targets and cues of greater size and duration than those presented to younger adults. This resulted in cue duration of 16.7 ms for younger and 33 ms for older adults. Once these values were used to account for age-related changes, the time needed to allocate attention did not differ between age groups. The authors argued that the use of accuracy as a dependent variable along with manipulations to equate performance through baseline performance corrections, allowed for the isolation of attentional processes. They further concluded that attentional processes showed the same time course across age groups, which provided an example of cognitive processes that are spared general slowing. If true, then experiments that eliminate motor processes such as saccadic shifts might also be able to better highlight compensatory attentional mechanisms that occur with age-related experience.

In two separate experiments, Atchley and Kramer (2000) examined the ability of younger and older observers to control spatial attention at different visual stereoscopic depths. This task was accomplished by having observers view two sets of lines that overlapped in two-dimensional space but appeared to be at different depth locations in three-dimensional space. Stereographic displays were presented on a 21° wide computer monitor and fusion was accomplished with the use of high-speed liquid crystal shutter glasses. At all times observers were presented with 24 gray line segments (4.1 cd/m) half of which were tilted, the other not tilted from 0° vertical. Half of the lines appeared to be in a depth plane closer to the observer and the other half appeared to be in a distant depth plane. After the initial presentation of the two sets of lines (that appear to be at different planes) a red square appeared in one of planes acting as a 100% valid cue that the target would appear subsequently in the same plane. Finally, one of the tilted gray line segments became "red" at a luminance of 4.1 cd/m^2 indicating that this line was the target. On some trials a non-tilted target (in either plane) would also turn "red" to act as a distractor that varied in luminance (2.5, 4.1, or 5.7 cd/m^2). The cue and search displays in each trial were presented for 200 ms to prevent overt eye movements. In the second experiment, the distractors were different colours than the targets. The authors found that distractors resulted in greater RTs for both groups, however this effect was less if the distractor was at a different depth than the target. More importantly, it was found that this effect was greater for older observers than for younger with low luminance distractors. This indicated that older adults were more efficient at using luminance in addition to orientation to eliminate the effect of distractors than younger observers. In the second experiment it was found that the older group were better able to ignore coloured distractors than the younger group. The authors argued that these findings support the contention that attention allocation from one spatial plane to another and the inference of different stimulus features is resilient to aging effects.

The effects of aging on attentional processes have also been studied neurometrically through the use of event-related potentials (ERP). Curran, Hills, Patterson, & Strauss, (2001) examined the effects of attention on a visuospatial task while also measuring ERPs. The task involved the presentation of a central symbolic cue (arrow), which directed attention towards a possible peripheral target location. Sometimes the arrow was a valid cue, other times it was invalid. The authors found that both younger and older adults had reduced RTs following the valid cues. Although the magnitude of improvement was greater for older adults, the authors added that when improvements were viewed in proportion to non-cued RTs, the improvements were similar in both groups. The electrophysiological patterns found in this study were similar between groups; however early ERP components following a target stimulus presentation were faster for the younger than older adults. An observed latency in ipsilateral but not contralateral amplitudes due to aging was also ascribed to age differences in interhemispheric transfer times. Curran et al. hypothesized that this difference was due to age-related reductions in the size of the corpus callosum with accompanying decreases in interhemispheric transmission rates. These results provide neurometric support for age-related declines in cognitive function with, at the same time, age-related improvements in the ability of older adults to take advantage of symbolic central cues to reach the same performance level as younger adults.

As reviewed by Curran et al. (2001), studies investigating age differences in the ability to use endogenous central cues are mixed, some showing greater disadvantages for older adults, while others revealing similar patterns for both young and old. Studies that have used endogenous cues have for the most part presented arrows to indicate the probable spatial location of a subsequently presented target. As well, the tasks employed were generally simple detection tasks using RTs as the dependent variable. Most studies indicate an aging disadvantage in the use of central cues, especially with shorter stimulus onset asynchronies (SOAs). Other studies measuring RTs have demonstrated a greater cuing effect for older adults with central cues and no age differences for peripheral cues (Greenwood, Parasuraman, & Haxby, 1993; Hartley, Kieley, & Slabach, 1990).

Possible Compensatory Mechanisms

Based on a review of functional neuroimaging data, Cabeza (2002) has postulated a model for the effects of aging on cognitive performance called HAROLD (Hemispheric Asymmetry Reduction in Older Adults). This model hypothesizes that within the domains of episodic memory, semantic memory, working memory, perception, and inhibition control, older adults' prefrontal activity tends to be less lateralized than younger brains. The author suggest that such a mechanism may have a compensatory function in that these bilateral activation tends to be correlated with performances in older adults that are similar to those of younger adults. Although this review did not include studies examining attention, Cabeza notes that a possible compensation mechanism has been demonstrated in memory tests of recall and recognition for both verbal and pictorial stimuli. According to Cabeza, these age-related changes are a robust and general phenomenon centered in the prefrontal cortex (PFC); an area integral to most proposed attentional networks.

Reuter-Lorenz, Jonides, Smith, Hartley, & Marshuetz (2000) provide support for a compensatory model with older adults who showed a bilateral pattern of prefrontal cortex (PFC) activity when doing a verbal working memory task, which was performed faster than younger adults. Attention and working memory are both executive functions that are highly integrative with other regions of the brain, and if spatial working memory is subject to increased bilaterality with aging, then the same phenomenon might occur in the case of spatial attention. However, empirical data does exist to support the argument that many of the cortical areas that process verbal memories are involved in spatial attention (Reuter-Lorenz et al., 2000).

A recent study examined the neuroanatomical overlap between verbal working memory and spatial attention networks in an fMRI within-subjects comparison Labar, Gitelman, Parrish, & Mesulam (1999) and found that a common set of brain activations included the intraparietal sulcus, ventral precentral sulcus, supplementary motor area, frontal eye fields, thalamus, cerebellum, left temporal neocortex, and right insula. Similarly, Coull & Frith (1998) revealed heightened right posterior parietal cortex activation during spatial attention, nonspatial attention and working memory tasks. Coull and Frith further found that posterior parietal activation was highest for working memory tasks, especially those involving visual working memory, leading the authors to conclude that these activations were probably due to a combination of activities dealing with spatial perception, attention, and working memory. Additionally, data from this experiment supported the contention that right intraparietal sulcus is involved in both spatial attention and working memory.

A recent study found support for a compensatory mechanism in observers suffering from Alzheimer's disease (AD) (Woodard, Grafton, Votaw, Green, Dobraski, & Hoffman, 1998). In this PET study, neuroanatomical correlates were compared between six healthy older adults and six patients suffering with mild symptoms of Alzheimer's disease. The two groups were compared during the rehearsal of a word list for the purpose of a reading task. It was found that the right dorsolateral prefrontal cortex was similarly activated in both groups during this task. The lists to be rehearsed consisted of double syllable nouns matched for imagery and recallability. The authors hypothesized that the five-word lists were relatively simple for both groups to memorize as five words can be held in working memory. They further hypothesized that the ten-word lists and the thirty-word lists provided increasing cognitive loads and magnified the deficits in working memory in the AD patients. As the list of words to rehearse became longer, both groups showed increased activations in the anterior areas of the cortex. In normal controls, however, the activation was increased unilaterally in the right frontal cortex, while the older adults with mild AD showed a bilateral activation that was found in frontal areas. This led the authors to suggest that demanding tasks result in the recruitment of areas in the CNS that are in addition to those that are normally associated with such activities. Again, although these findings do not provide direct evidence of cortexual compensatory mechanisms, they do provide support for the possibility of compensation in executive functions such as working memory and attention.

A recent review examining the aging brain (Reuter-Lorenz, 2002) described emerging trends in the area of neuroimaging. Findings have indicated the existence of under-activation in older adults supporting the existence of a neural substrate for cognitive decline. Also younger and older adults exhibit different patterns of neural activation even when their performance is equal. Many neuro-imaging studies show that older adults display bilateral activations during activities such as working memory that are associated with lateral activity in younger adults. These patterns are suggestive of compensatory mechanisms in the aging brain. The latter trend in which bilateral activations in older adults accompanied by improved performances is obviously intriguing; Reuter-Lorenz offers several plausible alternatives to the compensatory-recruitment hypotheses. One such hypothesis contends that older adults find most tasks more difficult than younger adults and generate greater effort recruiting additional brain resources. Another hypothesis argues that perhaps these neuroimaging findings actually are displaying the effects of dedifferentiation, a reversal of early developmental processes in which rather than specializing, neural systems generalize resulting in the recruitment of additional areas of the brain in older adults. Another plausible explanation for such results could be that aging reduces the ability of older adults to achieve task-relevant focal activation as well as the ability to inhibit task-irrelevant activities. Although this area of research is still in a state of relative infancy, these types of empirical findings provide support the hypothesis that compensatory mechanisms exist in the aging brain.

Overview

It has been shown experimentally that the presence of cues prior to target displays can improve accuracy (% correct) and RT in many simple cuing paradigms (Posner, 1980; Posner & Cohen, 1984). It is hypothesized that cues can facilitate the allocation of spatial attention to the cued area. However, the ability of cues to facilitate this allocation depends upon a variety of factors such as the type of cue, the number of cues, the time interval between the cues and target (stimulus onset asynchrony), the type of target, the number of targets, the number of distractors, the number and type of attribute differences between targets and distractors, the presence of fixation cues and the duration of presentation of targets (Bachman, Mager, Sarv, Kahusk, & Turner, 1999; Chastain & Cheal, 1998, 1999; Cheal & Chastain, 2001; L. R. Gottlob, Cheal, & Lyon, 1999; Lupianez & Milliken, 1999; Pratt & Fischer, 2002). Stimulus onset asynchrony

(SOA) is defined as the time interval between the onset of a cue and the onset of targets and distractors. Although this list is not exhaustive, it does illustrate the complexity of this area of research. For example, cues can take on many forms and have a large impact on search performance. Cues can be presented centrally in the visual field or peripherally, eccentric from fixation. Cues can be 100% valid (in which case they always informative), partially valid (sometimes informative) or invalid (never informative). Single element cues can pop out and elicit involuntary attention, while multiple element cues may require a visual search in order to garner the information offered. This short discussion of cues highlights the need for thoughtful planning of methodology in visual search experiments and the difficulty in comparing results from one experiment to the next.

The combination of the number of cues, type of cues, and duration of presentation can have a significant impact on the usefulness of cues. For example sudden onset single element cues that are thought to draw attention involuntarily (exogenously) can often result in a phenomenon known as inhibition of return (IOR) that is highly dependent upon the time interval between the cue and the target (Chastain & Cheal, 1999; Pratt & Abrams, 1999; Pratt & Castel, 2001; Pratt & McAuliffe, 2001). It has been demonstrated many times that RTs and error rates (%) rise for targets that occur in previously cued locations with longer SOAs (Klein, 2000; Lupianez & Milliken, 1999; Posner, 1980; Posner & Cohen, 1984). IOR is thought to be an adaptive mechanism intended to facilitate search efficiency by preventing the search of an area of the visual field that has already been examined. However, the mechanism by which IOR is initiated (i.e., whether it is an attentional or oculomotor process) has been the subject of intense investigation and debate. Posner and Cohen (1984) originally argued that IOR was due to the inability to return attentional resources to a previously searched area as a result of a peripheral cue. Subsequent examination of this phenomenon (Rafal, Calabresi, Brennan, & Sciolto, 1989;

Taylor & Klein, 1998) implicated the activation of midbrain oculomotor pathways in preparation of a saccade regardless of whether the saccade took place. Rafal et al. demonstrated that the priming of the oculomotor system to prepare for eye movements is sufficient to initiate IOR for both exogenous and endogenous cuing. Further investigation has shown that IOR is likely composed of a general attentional element that is found in many tasks and a motor component that is specific to oculomotor processes (Kingstone & Pratt, 1999). From their results, Kingstone and Pratt suggest that IOR is greater when saccades occur and for reflexive (exogenous) shifts of attention rather than for voluntary (endogenous) orienting. The implication of this suggestion would be to eliminate eye movements while displaying multiple cues as well as multiple distractors to reduce the possibility of IOR being a factor in an experiment. The initiation of IOR is also highly dependent upon the time interval between the offset of the cues and the onset of the target (SOA). In general a cue can have a facilitatory effect when the SOA is shorter than 200-300 ms or an inhibitory effect when the SOA is longer than 200-300 ms (Klein, 2000). Most studies that examine IOR use tasks that involve uninformative spatial cues in simple detection tasks. However, it has been shown that IOR occurs in some discrimination tasks but at longer SOAs (> 400ms) than in detection tasks (200-300 ms) (Lupianez & Milliken, 1999; Pratt & Abrams, 1999). As can be seen from this short discussion of cues, SOA and IOR, the design of visual search studies is complicated and has a tremendous impact on whether cues result in a facilitation of response or and inhibition of response and the time course of the phenomena.

Purpose and Rationale

The main purpose of this thesis is to examine whether older adults will display an advantage over younger adults in a visual discrimination task that uses peripheral word cues intended to aid in the allocation of visual attention. If such an advantage is indicated, it is speculated that through the manipulation of cue validity, patterns will emerge to indicate the manner in which the cues are employed to facilitate the allocation of spatial attention. Palmer et al. (1994) made several suggestions regarding the design of studies examining attentional effects in visual search experiments, which they term "The Threshold Search Paradigm". In this paradigm, Palmer et al. suggested minimizing sensory effects through the use of brief displays, with widely spaced stimuli and measuring performance accuracy through the determinations of threshold rather than strictly by RT. Palmer et al. also argued that by maintaining display set size at a constant number, while varying relevant set size (i.e., number of relevant cued areas of the display) any significant effects due to relevant set size differences are attention and not sensory based. The design of this thesis experiment will be based upon these tenets.

The effects of aging are often difficult to isolate from other factors such as illness or sedentary lifestyle. In order to minimize these effects it was decided to seek a sample of healthy, high functioning older adults. Older adults from the faculty of Lakehead University who were over 55 years of age provided such a sample. Once this decision was made, it seemed obvious that a sample of graduate students might provide a convenient and complementary population from which to draw the younger sample. Drawing equal numbers of participants from both sexes allowed for the examination of possible sex differences.

This thesis examined possible aging effects using a visual search paradigm that encourages covert attentional shifts in observers. Word cues were presented peripherally to determine the differences in the ability of younger and older adults to take advantage of such cues to allocate spatial attention in a luminance contrast discrimination task. Such low-threshold, visual search paradigms allow for the elimination of other executive functions such as memory, while time frames and instructions that encourage the use of covert attention eliminate the complications of oculomotor saccades. The methodology employed by Wesner (2001) was unique in that the use of word cues seemed to be the one factor that drew out an aging advantage. A review of the pertinent literature was unable to find other studies that used such cues. Although Wesner (2001) provided evidence of an age-related advantage at using multiple words used as spatial cues, interpreting the results in terms of a higher-level compensatory mechanism is difficult since it is possible that observers were able to use covert or overt shifts of spatial attention, or some combination of the two. In addition, as discussed later, possible saccades may affect whether IOR is a factor.

An important question that arises from the Wesner (2001) findings is how do the older observers process the cues that give them the performance advantage? If the position of the word cue was used to establish a conspicuous visual lobe surrounding the likely target position, why did the symbolic cues (Gabor patches or annulus disks) used in previous experiments not give the elderly the same advantage? This would suggest that the meaning of the words was being used in the search task to help locate target position. Perhaps the location of the word cue and the meaning interacted to better facilitate the allocation of attention in older adults or possibly, the mere presence of word cues invoked some compensatory activation in older adults beyond spatial location cuing.

It remains unclear as to why the performance of the younger observers deteriorated in the presence of word cues in Wesner's study. Wesner suggested that the younger observers, through their inexperience with the quick processing of visual elements in a search array, might have experienced a "bottom-up" sensory spatial masking of the targets instead of a "top-down" cognitive attentional advantage from the presence of the cues.

If the older adults in Wesner's study used the semantic meaning of the word cues to facilitate the allocation of visual attention to the cued areas, then the manipulation of the validity of these cues should provide a closer examination of this possibility. In this study, peripheral word cues were similarly employed, however the validity of these cues was systematically decreased. Unlike Wesner's methodology, the word cues did not have contrast differences to avoid exogenous involuntary orienting. All the words were luminance-decremented relative to a gray background. We speculate that this manipulation would ensure that the observers read the words and then voluntarily search the cues, which in turn, would produce voluntary rather than involuntary attentional allocation to the target position. As well, a second fixation cross-interval was inserted between the cue and the target intervals. This was done for two reasons: (1) to reorient the observer's gaze to the center of the visual display after cuing intervals, and (2) to allow time for the observer to process the meaning of the word cues and to allocate attention to the cued area. Additionally, it has been shown that abrupt onset peripheral stimuli that capture attention during a fixation do not result in an involuntary saccade unless a saccade was already planned (Tse, Sheinberg, & Logothetis, 2002). All target screens consisted of either one target and eight distractors or nine distractors in order to eliminate sensory contributions as the possible cause of any differences in contrast thresholds (Palmer, 1994).

We hypothesized that if older adults were using the word cues, their contrast thresholds would increase (i.e., sensitivities would decrease) as the validity of the cues decrease because the invalid cues would have attention allocation misdirected towards wrong spatial target positions. Studies of the effect of cue validity indicate that the more likely an observer believes a cue to be valid the more likely s/he will attention to the target (Gottlob et al., 1999). Because of the importance of maintaining the observers' cognitive interpretations of the cues as being valid and useful, the present study used practice sessions (240 trials) and the initial two blocks trials (120 trials in each block) that had 100% cue validity. The next two blocks were then 60 % valid, followed by two blocks that reversed the validity to 0%. If the younger adults are unable to use the cues to allocate visual attention, the validity of the cues should have no effect on their performance. Trials that presented cued words to all possible target positions (i.e., cues which offered no useable information about location) served as control trials to determine any sensory contributions generated by the presence of the cues.

Method

Observers

Observers consisted of ten older adults (ages 55 and over, five female, five male) and ten younger adults (ages 29 and under, five female, five male) recruited from the Lakehead University community. The average age of the younger and older observers were 25.8 years (SD = 2.44) and 61.4 years (SD = 3.47) years, respectively. All observers were fully informed of the requirements and expectations of the experiment, and of the confidentiality of the results. Signed consent was obtained (see Appendix A) and the observers were instructed that they could end their participation at any point in time.

Procedure

Screening procedures. All observers underwent a computerized visual acuity test to ensure normal or corrected-to-normal acuity. In order to compare the experimental groups, all subject were administered the Wechsler Test of Adult Reading (WTAR; The Psychological Corporation, 2001) and Digit Symbol Coding subscale of the Wechsler Adult Intelligence Scale – III (WAIS-III; The Psychological Corporation, 1997). The WTAR provides a good indication of an individual's intellectual functioning and takes only a few minutes to complete, while the Digit Symbol subscale is a measure of sensorimotor and cognitive function. The number of correct symbol transcriptions that were completed within the allocated time for the Digit Symbol tasks was measured. Demographic information collected included age and level of education (EDU) for the purposes of post hoc comparison of sample groups. Observers were asked to list any medication they were taking in order to screen for medications that might impair cognitive function. Medications were analyzed using web-based screening tool SMART (Screening Medications: Aging Research Taxonomy) to obtain information regarding the cognitive, sensory, and motor side effects associated with specific medication (Batsakes, Hancock, Rogers, & Fisk, 2002).

Psychophysics procedure. All stimuli were presented on a monochrome Nanao 90801 monitor (13 X 16 ° display) with an average background luminance of 40 cd/m^2. To prevent configurational positioning, stimulus elements were randomly jittered (one element per segment) within a three x three array. A minimum center-to-center of elements of spacing of 2.5 ° was employed. Targets consisted of 1°-diameter luminance-incremented discs.

Luminance contrast thresholds in both experiments were determined using a 2AFC method of constant stimuli, where the target contrast proportions were varied along 8 predefined levels that were autoscaled for a range between 0.2050 and .5000. Thus, the discriminability (d') between target and distractors was varied and the contrast increment threshold (%) needed to just detect the target was estimated. Contrast increment threshold is defined as the incremental amount of contrast over and above the distractor contrast needed to correctly detect the target 75% of the time. Half of the trials contained a target and half did not. Actual set sizes were held constant at nine elements, while the "relevant" (attention-based) set sizes, which depended on cued location of a possible target position, varied at three, six or nine elements. RT for all trials was measured.

All observers were seated in a darkened booth for ten minutes to allow for dark adaptation. They sat 70 cm from the computer screen and head movement was minimized by the use of a chin rest. A response box was placed in front of the observer, which could be moved to a comfortable position. The observer pushed a button marked yes to indicate that the target was present or pressed the adjacent button marked "NO" to indicate the target was not present. A trio of beeps followed incorrect responses.

In order to minimize eye movements, observers received the following specific instructions: "During this experiment you are asked to minimize eye movements by focusing on the central crosses that appear twice throughout each trial. The cues and targets appear on the screen for only a very short time period and moving your eyes will actually impair your performance. In order to maximize your performance, focus your gaze upon the crosses that appear in the middle of the screen: "This type of instruction has been used and shown to minimize eye movement (saccades) in previous studies of covert spatial attention (Curran et al., 2001). Each observer received this instruction four separate times, once during briefing, once before the initial practice session, once before the second practice session, and finally once before the actual experimental trials. Observers were also instructed to: " Be as accurate as possible, answering as quickly as possible. However, emphasis should be placed upon accuracy. Do not sacrifice accuracy for speed. Use the words 'Yes' as cues to the area in which a target may occur if a target is present. The cues will be accurate more often than not." This instruction was repeated four times in a similar fashion to the previously discussed instructions.

In each trial, a central fixation cross was presented for 500 ms followed by an array of word cues that was presented for 500 ms, as depicted in Figure 1. Areas that contained the word "Yes" indicated the likely presentation position of the target. The word "No: indicated an area in which a target was unlikely. Following the cues, another interval containing a central fixation cross was presented for 250 ms, followed by an array containing distractors and a target (if present). This display was presented for a period of 500 ms. The next trial did not begin until the observer responded as to whether a target was present.

Each observer completed two practice sessions of 120 trials to become familiar with the task. The actual experiment consisted of seven blocks of 120 trials that varied in Relevant Set Size (3, 6 & 9 of 9) and Cue Validity (0%, 60%, 100%). In all, each participant completed 1180 trials. Between each block of trials observers were allowed a short rest period and restarted the experiment when ready.

Results

Statistical analyses began with the examination of demographic and pre-testing data in order to compare age groups through the use of ANOVAs and MANOVAs. Percent contrast increment thresholds and RT data were then analyzed with four-way mixed ANOVAs using SPSS Repeated Measures. An alpha value of .05 was used for all statistical tests unless otherwise stated.

Demographic and Pre-Testing Data

Means and standard deviations for age, years of education, Digit Symbol Coding scores, and Wechsler Test of Adult Reading scores are displayed in Table 1. Initially, the possibility of investigating the effects of Age Group (Young/Old) and Sex (Male/Female) in a MANOVA on three dependent variables, DSC, WTAR and EDU, was considered. The three dependent variables were examined using various SPSS methods for univariate and multivariate outliers, for assumptions of normality, and homogeneity of variance. Given that the assumption of homogeneity of variance was violated, and that there was a significant correlation ($r = .57$, $p < .01$) between WTAR and EDU, it was decided that an ANOVA would be conducted on DSC and a separate MANOVA would be conducted on WTAR and EDU. Significance levels were adjusted using a Bonferroni method to .017 to compensate for multiple comparisons and the increased likelihood of a Type I error. A two (Age Group: Young/Old) x two (Sex: Male/Female) ANOVA on DSC scores indicated a significant main effect for Age Group, F (1,

16) = 15.7, $p < .001$, eta squared = .50. Upon examination of the means of these variables it was found that the younger age group scored significantly higher on the DSC meaning that they were able to complete significantly more symbol transcriptions in the allowed time. A two (Age Group: Young/Old) x two (Sex: Male/Female) MANOVA on EDU and WTAR yielded no significant results.

Percent Contrast Increment Thresholds

The mean percent contrast increment thresholds as a function of age group are displayed in Table 2. Four univariate outliers with extreme z scores were identified but retained after being changed to reduce their impact by adding or subtracting 1° from the next most extreme score (Tabachnick & Fidell, 2001). To further improve skewness, kurtosis, and homogeneity of variance a log transformation was performed on the variables. A two (Age Group: Young/Old) x two (Sex: Male/Female) x three (Cue Validity: 0%, 60%, 100%) x two (Relevant Set Size: three/six) mixed ANOVA with Cue Validity and Relevant Set Size as within-observer factors were conducted on the transformed contrast threshold percentages. The Cue Validity main effect was significant, $F(2, 32) = 5.26$, $p = .01$, eta squared = .25. A trend analysis indicated a significant linear relationship ($F(1, 16) = 16.15$, $p < .01$, eta squared = .50) indicating that as Cue Validity decreased contrast increment thresholds decreased in a linear manner for all observers. This trend is demonstrate in Figure 2 where Percent Contrast Increment Threshold collapsed across the age groups is plotted as a function of Cue Validity

A significant Cue Validity x Relevant Set Size x Sex interaction was indicated, $F(2, 32) = 5.20$, $p = .011$, eta squared = .25. Female observers had a significantly lower log transformed contrast threshold for 6 cued elements at 60% validity ($M = 1.491$, $SD = 0.01$) than with 3 cued elements (M = 1.52, SD = 0.01), F (1, 16) =13.7, p = .002, eta squared = .46. No other significant effects were found.

Mean Correct "Yes" RT

Analyses were also carried out on the mean correct yes response times (MCYRT) as displayed in Table 3. The MCYRT for each combination of Cue Validity by Relevant Set Size, were examined for assumptions of normality, outliers, and errors. A two (Age Group: Young/Old) x two (Sex: Male/Female) x three (Cue Validity: 0%, 60%, 100%) x two (Relevant Set Size: three/six) mixed ANOVA with Cue Validity and Relevant Set Size as within-observer factors was conducted on the MCYRTs. The Cue Validity main effect was significant, F (2, 32) = 20.05, $p < .001$, eta squared = .56. Trend analysis indicated a significant linear relationship, F (1, 16) = 27.59, $p < .001$, eta squared = .63. This would show that as cue validity decreased MCYRT decreased in a linear fashion as shown in Figure 3.

Also significant was a Cue Validity x Relevant Set Size interaction, F (2, 16) = 4.77, p = .015, eta squared = .23, using a Bonferroni adjusted alpha of .0167. The significant interaction between Cue Validity and Relevant Set Size was examined through three paired t-tests. It was found that MCYRTs were significantly lower when six relevant 100% valid cues (M = 809.6, SD = 42) were presented as opposed to three relevant 100% valid cues (M = 760.2, SD = 45), t (19) = 2.71, p = .014, again using a Bonferroni adjusted alpha of .017. As illustrated in Figure. 4, MCYRTs were significantly lower in the Six Relevant - 100% Valid Cue condition than in the Three Relevant - 100% Valid Cue condition.

Discussion

This thesis was designed to explore the manner in which older adults process and take advantage of word cues in a luminance discrimination task. It was hypothesized that the efficiency of older adults would be adversely affected by decreasing cue validity, whereas younger adults would not be affected. Although older adults did not perform significantly different that the younger adults, the results did not provide support for the supposition that older adults were better able to use word cues as found by Wesner (2001). In fact this study found that the word cues inhibited performance for both groups. Possible reasons for this discrepancy will be discussed as well as the implications of such results.

The most remarkable aspect of this thesis is the lack of significant between-age group findings. The results showed that both number of relevant cues and cue validity had an effect on performance, but these were found for within rather than between group effects and interactions. Although this null finding does not allow the inference that no differences exist, it does permit one to speculate why no differences were found. Trends in the data revealed that younger adults were slightly more accurate and faster in responding in a luminance contrast discrimination task. The hypothesis that older adults would suffer greater deficits in performance as cue validity dropped received only minor support. This discussion will first examine possible explanations of the current findings. Also discussed will be possible methodological issues then opportunities for future research.

Effects of Aging on Luminance Discrimination

The results of this study indicated no meaningful differences between age groups in the ability to discriminate contrast luminance. With respect to pre-testing screening, significant age group differences were found only on sensorimotor and cognitive skills as measured by the DSC. This test involves short-term memory, visual spatial skills as well as motor skills and this finding suggests that significant age related deficits exist in these areas. No meaningful differences were indicated on measures of visual acuity, reading ability (indicator of verbal intelligence) or levels of education. The most obvious conclusion regarding the lack of significant differences between age groups in luminance contrast discrimination tasks would be that under some conditions contrast luminance discrimination is relatively preserved in older adults despite sensorimotor deficits due to aging. Alternatively, it might also be proposed that the luminance contrast discrimination test used was insufficiently sensitive to find significant differences or that the study lacked the power necessary to find the small differences that do exist significant. However, previous studies using similar methodologies have found age related deficits under some conditions (St. Pierre & Wesner, 2001; Wesner, 2001).

Presence of Word Cues

This thesis was designed to further examine the finding that peripheral word cues facilitated the performance of older adults in a luminance contrast discrimination task, but inhibited the performance of younger adults (Wesner, 2001). These findings led to the hypothesis that perhaps interpreting the word cues invoked some form of higher cortical compensatory mechanism in older adults that facilitated the allocation of attention resulting in improved performance with the task. With respect to Wesner's findings alternative hypotheses do exist. It could be that luminance-contrasted peripheral word cues impart more information than spatial cues such as luminance-contrasted discs. Due to the contrast differences used in the word cues in Wesner's study, an involuntary orienting of attention, in addition to the meaning of "Yes" or "No", could have imparted additional, more robust attention towards the targets. The use of different contrast words (i.e., luminance decremented and incremented "YES" and "NO" cues and vice versa, respectively) may have reduced uncertainty as to which cues indicated the area necessary for proper attention allocation. If the word cues were more effective than spatial position cues they may have increased the ability of both groups to allocate spatial attention. Rather than inhibiting the performance of the younger adults ability to allocate attention, this type of cueing may have speeded the processing of the cues to the point where younger adults had sufficient time to disengage attention from the cues and or primed the ocular motor system to the point that IOR became a factor. This proposed circumstances could have resulted in the initiation of IOR with the younger but not the older observers. Although Wesner's study did not employ a central fixation cross following the word cues to involuntarily disengage the observer's attention, the conditions under which IOR is initiated can vary. For example, Rafal et al. (1989) argued that there is a reflexive nature to the phenomenon of IOR. The findings of Wesner's study could be due to the differential initiation of IOR between age groups. In Wesner's study, SOA varied randomly to an average of 750 ms. Rather than having an Age Group by Cue Type interaction, there could possibly have been an Age Group by Cue Type by SOA interaction that went undiscovered due to the averaging of the range of SOAs used. In other words, it is possible that the different age groups experience IOR under different conditions (Cue Type and SOAs). Perhaps older adults require a longer SOA in order for IOR to be initiated. If the younger observers were able to execute saccades in the time allowed and the older adults were not, this would further increase the likelihood or effect of IOR. The implication of longer SOAs in the initiation of IOR may reflect the time needed to allocate visual attention and/or the time to withdraw visual attention. A delay in the allocation of attention might result in a delay in the arousal of IOR. It might be argued that if younger adults are able to process the word cues more efficiently and more quickly allocate attention than the older observers, the SOAs needed to initiate IOR for both age groups may be different. If the initiation of IOR is delayed in older observers, there may have been sufficient time for the young (and not the old) to initiate IOR, thus resulting in performance impairments. Such findings supporting the initiation of IOR under different conditions in different groups have been found in neuropsychological studies that indicate the delayed onset of IOR in schizophrenics as compared to normal adults (Larrison-Fauchera, Brianda, & Serenoa, 2002). The citing of this research in no way suggests a comparison between aging and schizophrenia, but merely raises the possibility that delays in the onset of IOR exist between different groups.

A less likely inference from this study's findings may be that any attempt to interpret the meaning of word cues is, in itself, sufficient to improve performance in a luminance discrimination task without any attentional changes. This second interpretation is not dependent on the allocation of attention or on the validity of the cues, and would predict no significant between-group differences in any of the experimental conditions. However, in the present study, the age group performances were quite similar under all conditions. If the older adults were actually using the cues to allocate attention to a greater ° than the young, then the reduced validity of the cues should have hampered their ability to discriminate targets from distractors. No such performance declines occurred. This suggests that rather than the older adults actually using the cues to allocate attention to a specific cued area, the mere act of reading the cues or the act of processing the meaning of the words during the cueing interval allowed older adults to perform the following visual search task at a level of efficiency similar to younger adults. In other words, rather than facilitating the allocation of visual attention, the mere act of reading the cues could have improved the older adults ability to attend to the entire visual field due to some form of experiential compensatory mechanisms, perhaps through the recruitment of bilateral resources.

Inhibitory Effect of Cues

In Wesner's (2001) study it was shown that older adults were better able to take advantage of word cues that differed in contrast luminance between the "YES" and "NO" cues. Because the word cues in this thesis did not have contrasting luminance, and did not therefore "pop out" during the cuing interval, it is possible that there was insufficient time for the scan, identification and processing of the peripheral word cues with subsequent inadequate allocation of spatial attention. Chastain & Cheal (1998) examined the effect of multiple elements and found ineffective cuing at shorter SOAs but improvement with longer SOAs, up to 650 ms. Chastain and Cheal suggested that multiple peripheral cues must be identified through visual search and then interpreted for meaning and voluntary attention allocation. Perhaps there was insufficient time in the present study for either age group to allocate attention before the cues were presented.

Interestingly, there was a slight trend towards a lower contrast increment threshold for relevant set sizes of six as compared to three. As well, a significant interaction indicated that female observers enjoyed improved sensitivity when presented with six relevant 60% cues as opposed to three. This is in contrast to past studies, which show increases in thresholds with increases in relevant or display set sizes. However, our trend may be consistent with the hypothesis that the observers in both groups had difficulty in searching, identifying, processing the cues and allocating voluntary attention. If the task of searching out the "YES" cues was difficult, it might be argued that the six of nine 'Yes' cues may have been more conspicuous and may have 'popped out' because they created a larger, more conspicuous visual lobe. If it was easier to search the six of nine positions relevant cue condition, the allocation of attention may have proceeded with relatively greater ease than in the six relevant cue condition resulting in the sensitivity increase.

According to Palmer et al. (1993) the effect of attention can be observed by plotting percent contrast increment thresholds as a function of relevant size on logarithmic x and y axes, in which the data are fitted to a power functions. According to Palmer et al., when display set size is held constant (as in this thesis) the slope of such a function is a measure of attention effects with no sensory contribution, if the relevant and actual set sizes reveal differences with different slopes. Inspection of the plots in Figure 5 indicate small slopes that are slightly negative from the three to six cue condition and more importantly are almost the same as the nine of nine control condition (see separated nine of nine cued data points to the left of the figures). These nearly flat functions represent negligible effects of attention. In other words, the expected benefit of attention with the smaller relevant set size over the larger or no-relevant set size is virtually absent. In all cases, we are looking at nine sensory elements that have no attentional relevance in the display array.

In the context of a low-threshold theory, if cues are associated with decreased contrast sensitivity it should be due to a decrease in the signal to noise ratio. In other words the difference between the relative strength of the target signal and the magnitude of the noise produced mainly by the distractors is reduced in the presence of the cues. According to SDT this results in more errors due to distractors being mistaken for targets. The question becomes how do cues that are intended to facilitate visual attention by increasing contrast sensitivity do just the opposite? If visual attention is allocated to the area that a future target will be presented, we postulated that sensitivity will increase (i.e., signal to noise ratio increases) through various mechanisms: the enhancement of the target signal, reduction of distractor signals, reduction of internal noise (biological inefficiencies) or through the enhancement of information processing. If the cues were difficult to search and interpret, it is possible that they were inefficient at allocating attention, thereby preventing signal enhancement and/or possibly interfering with the speed of information processing.

Inhibition of Return (IOR)

A specific methodology was employed that was intended to minimize eye movements and the possibility of interference from phenomena such as IOR. Multiple cue arrays were used with large relevant set sizes that encouraged endogenous allocation of covert attention. Furthermore, specific instructions were used as well as a time interval with a fixation cross was displayed prior to the onset of the target and distractors to return the observer's gaze to the center of the visual screen. An SOA of 750 ms was used and did allow for the possibility of IOR. Although, the second fixation cross was deemed necessary for that purpose, it may have contributed to the initiation of IOR by encouraging the withdrawal of attention. As earlier discussed, Kingstone and Pratt & Abrams (1999) demonstrated that IOR is likely composed of both attentional and oculomotor processes. In this experiment, if visual attention was allocated to the word cues and then disengaged due to the sudden onset of the central fixation cross, IOR could be initiated under some SOAs. In this scenario, with an SOA of a sufficient duration, the observers would have difficulty returning attention to the cued area. As well, if the observers were able to find and interpret the "YES" cues prior to the onset of the fixation cross it is possible that the oculomotor system becomes primed and ready to saccade to the cued area (regardless of whether or not the saccade was ever completed) which would also serve to initiate IOR given the required SOA. Finally, even though measures to discourage eye movements were employed, there still exists the possibility that saccades were employed in the search of the cue array, especially for the three relevant cue situation which spatially extends into a smaller conspicuity lobe than the six relevant cue situation. As demonstrated by Kingstone and Pratt a completed saccade would increase the relative strength of IOR if initiated. Because eye movement, which increases the effect of IOR, is more likely with three relevant cues, it is expected that IOR would have a greater effect in the three-cued condition as opposed to the six-cue condition. As shown in Figure 6, as the validity of relevant cues decreases RTs decrease for all observers. The significant interaction that showed MCYRTs as slower in the 100% Valid 3 Cue condition as opposed to the 100% Valid 6 Cue Condition lends further support to this conjecture. The arousal of IOR that may be present in this study necessitates the consideration of IOR and SOA in multiple word cuing. It could be that the SOA used (750 ms) in this study was of sufficient duration to allow the initiation of IOR. If IOR were a factor in this study, one would predict that observers would be slower and less efficient in cued trials than in uncued trials. This suggests that observers should be faster and more efficient as cue validity decreases (i.e., IOR benefits performance when cue validity is 0% because the cue directs observers away from regions containing distractors). With respect to mean correct yes response times, this is exactly what was found as shown in Figure 6. Also, the trend for contrast sensitivity to decrease in a linear manner as cue validity decreases as depicted in Figure 3 is consistent with the presence of IOR. Both of these trends point towards IOR as being a possible causal factor in the inability of both age groups to take advantage of the cues. This raises the questions that if IOR is a factor, why were the older observers not disproportionally affected and still able to perform in a similar manner as the young observers, especially with respect to RT. These findings call for the further examination of IOR in experiments that employ multiple word cues over a range of SOAs (e.g., 50, 150, 250, 350, 450, 650, 1000 ms) as well as for possible time course differences in the initiation of IOR due to aging. The possibility could exist that in this type of task, IOR is initiated for different SOAs with different age groups. A better understanding of how IOR may be implicated in this type of visual search paradigm would be crucial to understanding the effects of aging.

The discussion of RTs in a thesis that takes a low-threshold signal detection model stance may seem incongruous. Most IOR research involves the examination of RTs and accuracy in terms of error rate. The effects of IOR on accuracy, when defined by threshold measures rather than % correct, have not been examined. It could be argued that low-threshold theories are not incompatible with the phenomenon of IOR and its relation to RTs. However, although IOR research mainly involves RT data, the model does not inherently preclude low threshold models in that it does not make assumptions about errors. The main tenant of IOR is the inability to allocate attention to a previously cued location. On the other hand, if IOR affects contrast sensitivity, it could be the result of spatial attention being allocated to an area away from the cue resulting in the enhancement of distractor signal (or a lack of target signal enhancement), rather than causing guessing. Furthermore, IOR presupposes that some form of attention is involved in the search process. However, it is important to note there was little evidence for attentional effects in this study as revealed in the percent contrast increment threshold vs. relevant cue plots (see Figure 5).

If IOR was the root cause of the cues decreasing contrast sensitivity and increasing response time, how might this be explained in a low-threshold model? IOR is generally described as the inability to return attention to a previously cued location and is most often expressed as the increase in RT and decrease in percent correct response. How then might IOR reduce the signal to noise ratio and reduce contrast sensitivity as well as RT? When IOR is aroused in the presence of valid cues, visual attention is prevented from being allocated to the location of the target and is in a sense by default allocated to an area populated by distractors. Obviously signal enhancement seems to be unlikely if attention cannot be allocated to the target area, but the possibility of the reduction in relative signal strength is likely. As well, it might be possible that noise associated with the distractors in the area of allocated attention actually increases. One or both of these possibilities would result in a reduction of signal to noise ratio. If IOR occurred with invalid cues the opposite scenario could exist. Attention could not be returned to the previously attended invalid area but would likely be allocated to an area the target is likely to appear. In this situation, attention could serve to enhance the strength of the signal target or reduce noise of distractors resulting in a net gain in signal to noise ratio and enhanced sensitivity and response time in the presence of invalid cues. Of course all of these above speculations emphasize the need to examine IOR from a low-threshold perspective.

Percent contrast increment thresholds generally represent the threshold necessary to detect the target 75% of the time, which corresponds to a d' value of approximately 1.35. The majority of analyses in this study examined the effects of cues at this level of sensitivity. Another manner in which sensitivity can be explored is through the use of psychometric functions that plot d' as a function of target contrast (transducer functions). In these plots the data is fitted to a Weibull function in a characteristic 'S' pattern. Transducer functions allow the examination of the effects of attention across a wider range of sensitivities. Transducer functions were plotted for all subjects in the three and six Relevant Set Size conditions, as seen in Figure 7. The horizontal line in each figure represents the percent contrast threshold that was the main focus of analyses. It is speculated that if IOR was a factor in this study, as validity decreased, sensitivity should have increased. Additionally, if eye movement increases the relative strength of IOR it could be argued that IOR should have greater effects in the three-cue condition as opposed to the six relevant cue condition. It could be further argued that the effect of eye movement would be inhibitory in the valid cue conditions but would be facilitate sensitivity when the cues were invalid. This would predict that sensitivity would be highest in the 3 cue 0% valid condition (where IOR would direct attention towards targets and lowest in the 3 cue 100% valid condition (where IOR would prevent attention from returning to cued location). Inspection of the Figure 7 indicates a trend that Relevant Set Size effected sensitivity (d') at suprathreshold levels. As can be seen in Figure 7, above the horizontal line indicating the 75% Contrast Threshold level in the Relevant Set Size of Three, there is a trend for the observers to be most sensitive in the 0% Valid Cue condition and least sensitive in the 100% Valid Cue condition as predicted by the presence of IOR. Inspection of the Transducer Functions in the 6 Relevant Set

Size condition shows that the functions are homogenous with respect to shape and slope. While the results displayed in these Transducer Functions did not reach statistical significance the trends do provide further indications that IOR was a factor in this study and deserve further investigation with sensitivity measures as well as accuracy and RT since the effects of attention may not be apparent at any one specific percent contrast increment threshold level.

Sampling Issues

The stated purpose of this thesis was to examine aging differences, not the effects of increased illness or sedentary lifestyle that often accompany aging. In the pursuit of that goal it was decided to pursue an active healthy sample, especially in the case of the older group. It was decided to pursue a sample of older adults still active in the Lakehead University community that met these criteria and that was also a convenient sample. The sample that was achieved consisted of a large majority of university professors, health care professional and those active in volunteer organizations. In a sense the study of aging is an examination of human development so it was decided to attempt to find a sample of young adults that was similar to the older group. The university community seemed like a proper place to recruit a complimentary group. The younger sample was made up largely of graduate students from the same university. Since a rather homogenous sample was chosen for the older group it seemed necessary to have a similar homogenous comparison sample. Although this decision may limit the generalizability of any findings, we contend that this cost would be acceptable if it allows the more explicit examination of aging. It is possible that choice of populations to sample contributed to the lack of significant age group differences. The sample of older adults was high functioning and the results of this thesis most likely do not generalize to older population at large. However it was hoped that a high functioning active group of older adults who were screened for major illnesses and medications would allow a closer examination of aging effects without confounds of illness or selective cognitive dysfunctions. In that respect, the results indicate that the choice of populations to sample was successful in that this group of sixty year olds performed similarly to a group of younger adults in their twenties.

Limitations of this Thesis and Future Research Suggestions

Baseline Measure.

The baseline performance in this study was measured in a block of trials in which nine of nine elements were cued in an array of all YESs. This condition was included because it was hypothesized that the older observer were interpreting the meaning of the word cues and this type of array offered no useful information but still included the array of word cues. The results of this study showed that neither group was able to take advantage of the word cues, in retrospect it may have been preferable to have a block of trials in which no cue array was presented at all as a truer measure of baseline performance. The possibility exists that the mere presence of multi-element word cues may have impacted search performance. The use of no-cue trials would have allowed for the comparison between cue and no-cue effects.

Increased numbers of practice trials.

It is likely that an increase in the number of trials and sessions may have led to more reliable estimates of contrast thresholds. In the design of this study, a major concern was the role that fatigue would play, especially in the older group. For that reason the number of total trials including practice trials were kept to a compromise level. As it was, each observer spent nearly two hours completing the experiment. It could also be reasonably argued that the results of this research might be different given a well-practiced set of observers. However, this would require extended periods of testing and multiple sessions of testing. Given the difficulty in finding suitable observers willing to participate in such a long testing period-such an assessment would have been logistically prohibitive.

Practice Effects.

Another issue that should be addressed with respect to the methodology of this thesis is the possibility of practice effects that could have arisen due to the sequential nature of the blocks of trials. Undoubtedly, in a study of this type, practice effects play some role in that often performance will improve with experience in unpracticed observers. However, the question of whether practice effects would be of sufficient influence to warrant randomization of the blocks of trials in this study was difficult to decide. In this study it was important that the observers perceive the validity of the cues. In other words, it was important that the observers in both groups believed that the cues were providing valid information, so that as the validity of the cues decreased, changes in performance would be attributed to the use of the cues. As well, the focus of this study included between group comparisons at each combination of cue validity and number of relevant cues, as well as within group comparisons as validity changed. For these reasons it was decided that each individual in each group would be presented with the same order of blocks of trials, in which validity would begin at 100° and drop to 60 and then 0°. It was believed that with sufficient practice trials prior to the actual test trials, possible practice effects would have minimal impact. The block order ensured that by the time the cues began to drop, each subject had encountered 400 trials in which the cues had been 100% valid. Because some trials with high levels of contrast pop out for most observers, there existed the likelihood that some observers would perceive at some point the invalidity of the cues. It was argued that the early experience of high cue validity would ensure continued observer attempts to use the cues to facilitate the allocation of visual attention. A post hoc questionnaire regarding the perceptions of the observers would have shed insight into such matters and will definitely be employed in any follow up experiments. Alternatively, if in fact most of the observers stopped attempting to process the cues early on in the study, they would be less likely to notice any changes in validity.

SOAs, IOR and Aging.

It has been demonstrated that the arousal of IOR is highly dependent upon SOA. As discussed earlier if the arousal of IOR is delayed in older adults than the results of aging studies of cued visual searches could be confounded by the use of specific SOAs that differentially produce IOR between age groups. Experiments using cues and targets as in this thesis with the addition of several levels of SOA ranging from perhaps 100 ms to 1000 ms are necessary to systematically study the effects of IOR on contrast sensitivity as well as RT.

Central Word Cues

A follow-up investigation to this thesis should employ central word cues (e.g., "top", "down", "mid", "left", "right") versus central symbolic cues (e.g., arrows) followed by a central fixation cross followed by the same target and cue arrays employed within this study. Furthermore, it is probably best if cues and targets were presented for shorter periods of time (sub 300 ms) to reduce the likelihood of saccades (eye movements). Since central cues do not require a search this reduction in presentation time should not impair the observers ability to allocate covert visual attention as may have occurred with the word arrays employed in this thesis. We speculate that presenting central word cues and measuring discrimination tasks with thresholds will better illuminate the aging mechanisms of spatial attention. Central word cues eliminate any possible involuntary allocation of attention and possible eye movements to peripheral cues that could result in IOR and that raise the issue of age-related motor declines. Central cues would potentially simplify the effort needed to process the cues since it would eliminate the need to search an entire array of elements to achieve cue coding, leaving only the semantic interpretation of the central cue. The implication of the priming of the ocular motor system in the initiation of IOR would still be a factor necessitating the careful choice of SOAs. It is suggested that the use of central word cues, in a similar discrimination task used in this study, as compared to symbolic cues in conjunction with above suggestions would serve to better examine the role of word cues in contrast discrimination tasks. It would be also helpful to compare the results of using a central word cue to that of multiple peripheral word cues in a discrimination task in order to see if the results would be similar using threshold measures (low-threshold model) as those of Cheal et al., where accuracy measures consisted of percent correct (high-threshold model).

Summary

Few significant between group differences were found in this thesis. Reliable age group differences were found in the DSC scores. There were no between group significant differences in education, WTAR scores or on luminance contrast thresholds. Results indicated that the number of word cues or the validity of the word cues had no significant effect upon luminance contrast threshold (%) or response times between the two age groups. However cue validity had a significant effect upon all observers in that decreasing cue validity resulted in improved contrast sensitivity and decreased response times. Although it appeared that the multiple word cues did not facilitate the allocation of visual attention, the older adults did not suffer disproportionally and were able to perform this task at a level not significantly different than the younger adults. The trends for all observers to be faster and more efficient (decreased percent contrast threshold) as cue validity decreased raises the possibilities that the cue arrays were too difficult to search and interfered with the allocation of attention or conversely that the observers were able to efficiently allocate attention but that IOR influenced the results. Percent contrast increment threshold data tends to support the former possibility while RT data lends credence to the latter supposition.

Conclusions

This thesis showed no significant age differences in the luminance contrast thresholds or in RT despite the apparent inhibitory effect of the cues. These null findings are particularly interesting given the sensorimotor differences detected in the data from the DSC administration. It was expected that the older adults would be significantly slower in responding regardless of their relative level of accuracy. The results of this study provide few specific conclusions, but they do provide tremendous fodder for speculation and for several hypotheses that could be tested in the future. Future research needs to compare the effects of multiple word cues and central word cues in similar discrimination tasks using multiple SOAs to fully appreciate the possible presence and effects of IOR on covert and overt attention. It is also recommended that IOR be examined with respect to its effects upon thresholds as opposed to percent accuracy measures. It is possible that the performance of the older adults in this study dovetail with the findings that high levels of education are associated with reduced levels of cognitive decline in aging (Abate, Ferrari-Ramonda, & Di Orio, 1998; Elwan, Madkour, Elwan, Mostafa, Helmy, Abdel-Naseer, Shafy, & El Faiuomy, 2003).

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Table 1

Demographic Information and Screening Test Scores

	AGE		WTAR		DSC		EDU	
Group[a]	M	SD	M	SD	M	SD	M	SD
Younger Adults	25.80	2.44	41.90	6.70	69.20	8.24	18.60	0.84
Older Adults	61.40	3.47	43.70	7.81	52.80	10.70	19.00	3.68

Note. [a]n = 10 for each group.

Table 2

Contrast Thresholds (%) for Age Groups as a Function of Cue Validity and Relevant Set Size

	100% Valid Cues			60% Valid Cues		0% Valid Cues	
Group[a]	3 Cues	6 Cues	9 Cues	3 Cues	6 Cues	3 Cues	6 Cues
Younger							
M	33.10	32.54	31.19	32.53	31.38	31.64	31.68
SD	1.89	2.31	4.06	2.66	2.25	1.39	2.73
Older							
M	34.75	35.67	31.96	33.93	33.51	33.23	33.31
SD	4.48	4.86	4.19	2.09	4.28	4.22	3.44

Note. [a]n = 10 for each group.

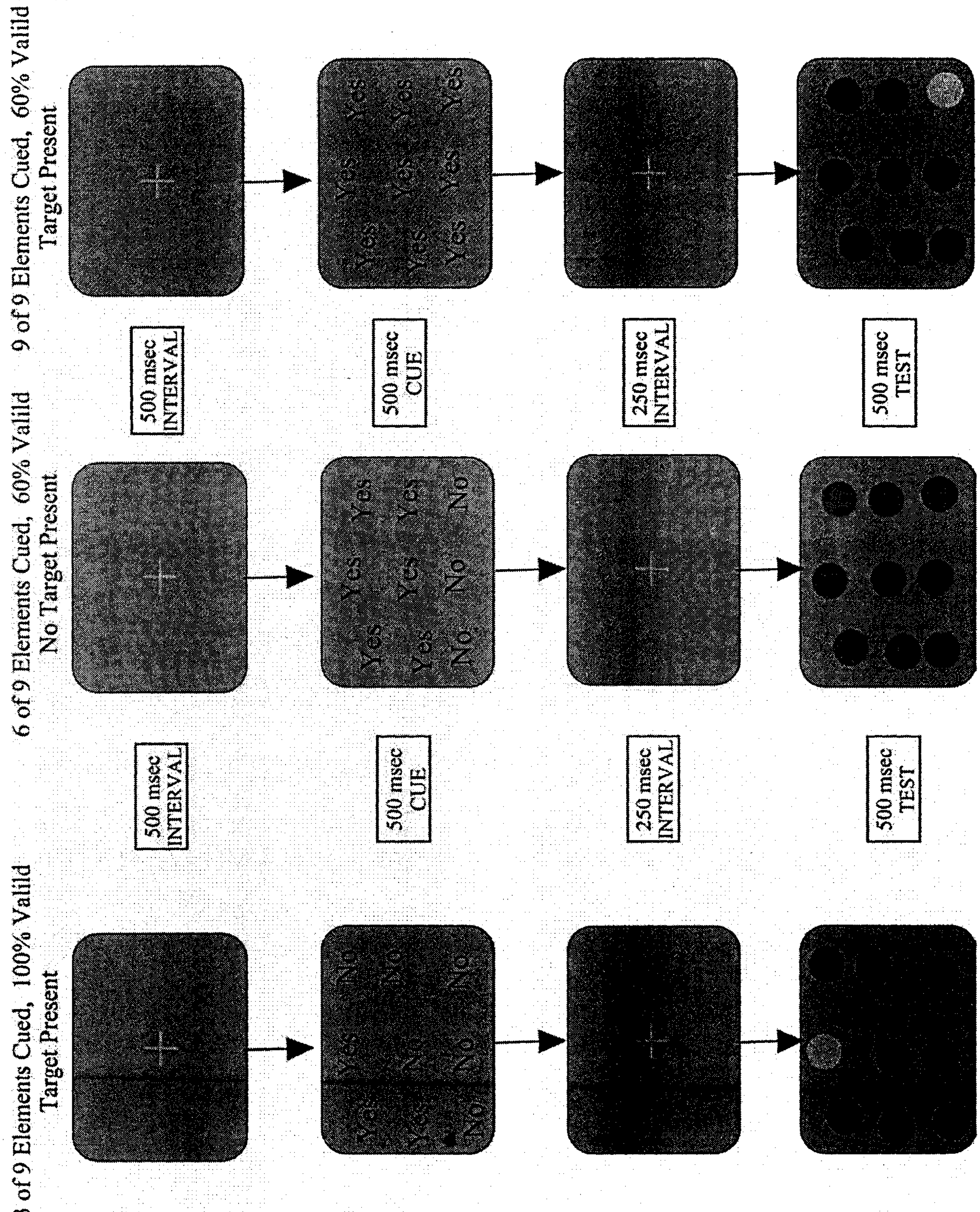
Table 3

Mean Correct Yes Response Times for Age Group as a Function of Cue Validity and Relevant Set Size

	100% Valid Cues			60% Valid Cues		0% Valid Cues	
Group[a]	3 Cues	6 Cues	9 Cues	3 Cues	6 Cues	3 Cues	6 Cues
Younger							
M	811.63	729.35	602.89	686.11	677.08	645.35	644.74
SD	154.40	130.47	111.50	122.12	132.25	105.58	90.20
Older							
M	807.49	791.13	726.64	780.11	774.65	736.33	735.54
SD	226.55	258.2	163.95	226.31	222.74	194.78	183.84

Note. [a]n = 10 for each group.

Figure 1. Illustrations of typical trials, displaying relevant set sizes of 3, 6, and 9 Elements Cued.



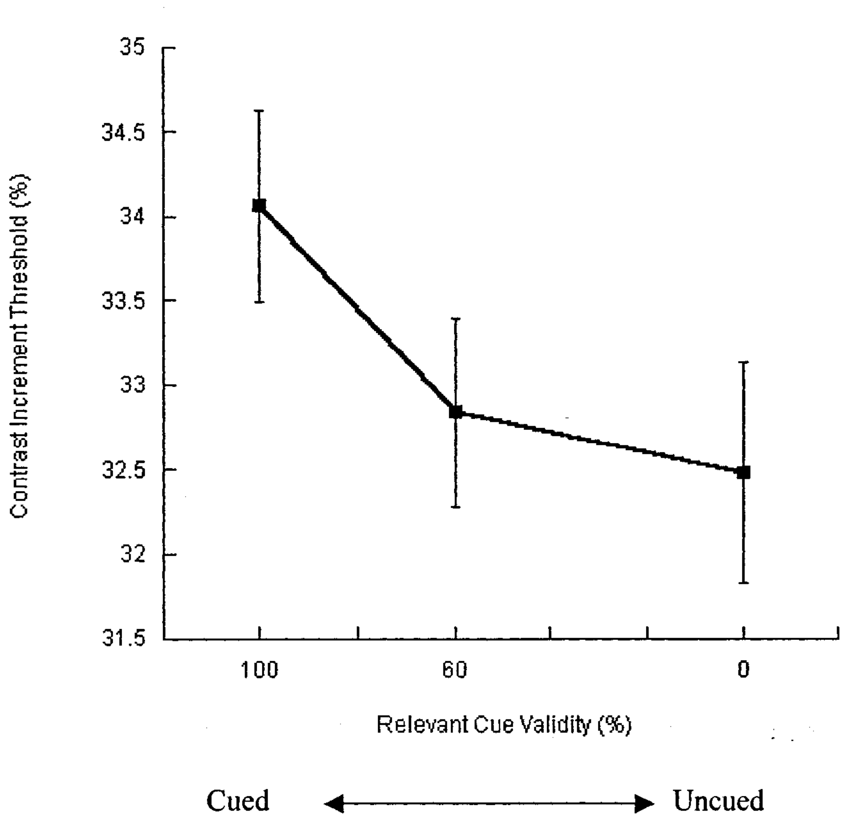


Figure 2. Percent Contrast Increment Threshold collapsed across Relevant Set Size and Age Group as a function of Cue Validity (%). The arrow below the plot indicates that the 100% Valid Cue condition is analogous to the Cued condition referred to in most IOR research and that the 0% Valid Cue condition relates to the Uncued condition in most IOR research. The 60% Valid Cue condition is mixture of the two previously discussed conditions with 60% of trials corresponding to a Cued condition and 40% of trials corresponding to Uncued conditions. Error bars denote ±SEM.

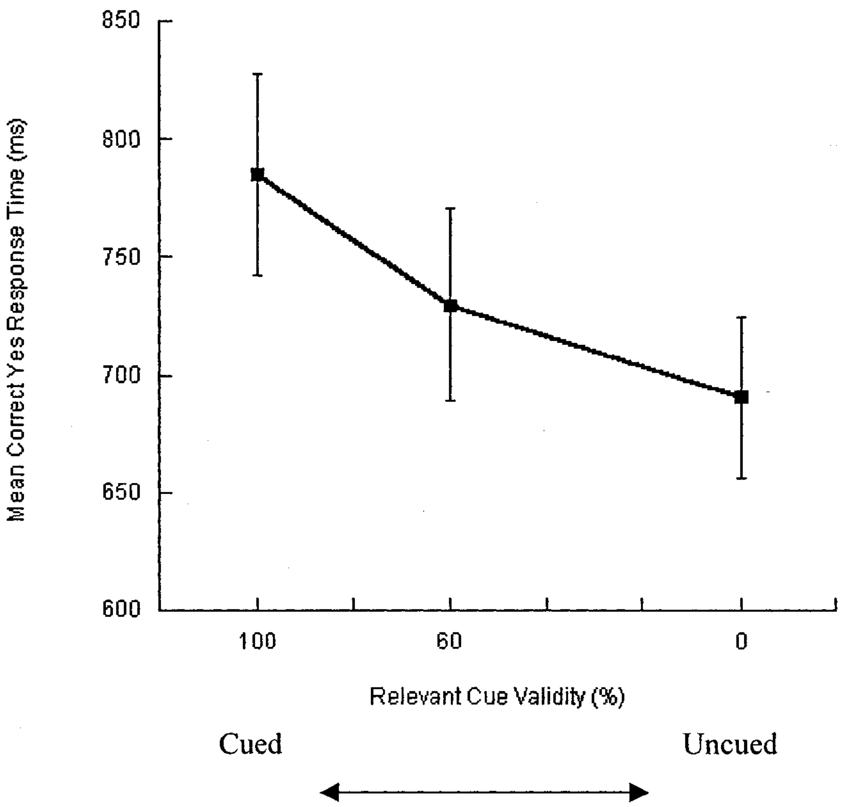


Figure 3. Mean Correct Yes Response Time (ms) collapsed across Relevant Set Size and Age Group as a function of Cue Validity (%). The arrow below the plot indicates that the 100% Valid Cue condition is analogous to the Cued condition referred to in most IOR research and that the 0% Valid Cue condition relates to the Uncued condition in most IOR research. The 60% Valid Cue condition is mixture of the two previously discussed conditions with 60% of trials corresponding to a Cued condition and 40% of trials corresponding to Uncued conditions. Error bars denote ±SEM.

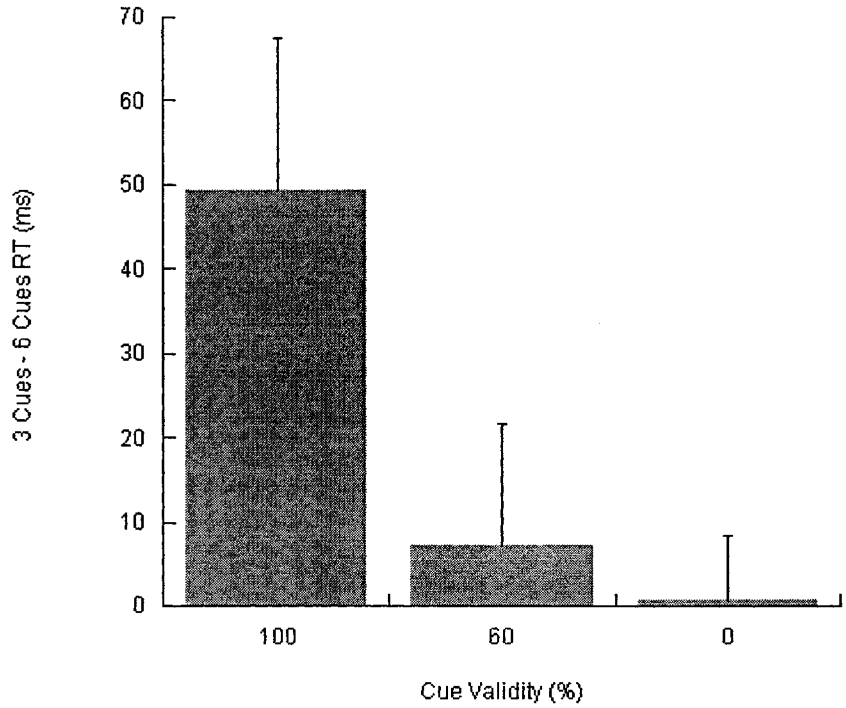


Figure 4. 3 Relevant Cues RT – 6 Relevant Cues RT collapsed across Age Group as a function of Cue Validity demonstrating interaction between Cue Validity and Relevant Set Size. Error bars denote ±SEM.

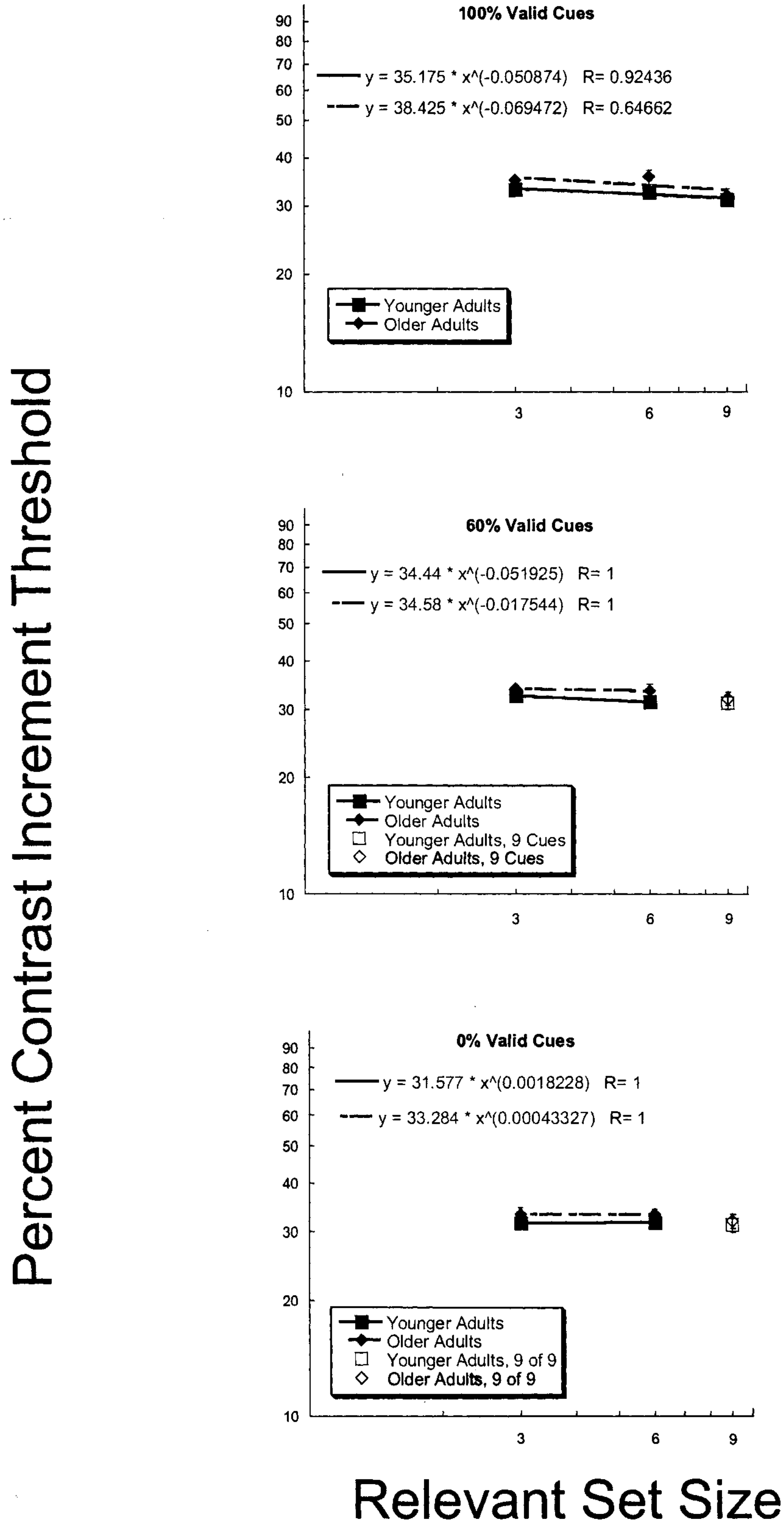

100% Valid Cues
y = 35.175 * x^(-0.050874) R= 0.92436
y = 38.425 * x^(-0.069472) R= 0.64662
Younger Adults
Older Adults
60% Valid Cues
y = 34.44 * x^(-0.051925) R= 1
y = 34.58 * x^(-0.017544) R= 1
Younger Adults
Older Adults
Younger Adults, 9 Cues
Older Adults, 9 Cues
0% Valid Cues
y = 31.577 * x^(0.0018228) R= 1
y = 33.284 * x^(0.00043327) R= 1
Younger Adults
Older Adults
Younger Adults, 9 of 9
Older Adults, 9 of 9
Percent Contrast Increment Threshold
Relevant Set Size

Figure 5. Contrast increment threshold as a function of Relevant Set Size and Cue Validity plotted on logarithmic axes. The 9 Relevant Set Size condition scores are displayed for both Age Groups as single points in the 60% and 0% Cue Validity plots for comparison purposes.

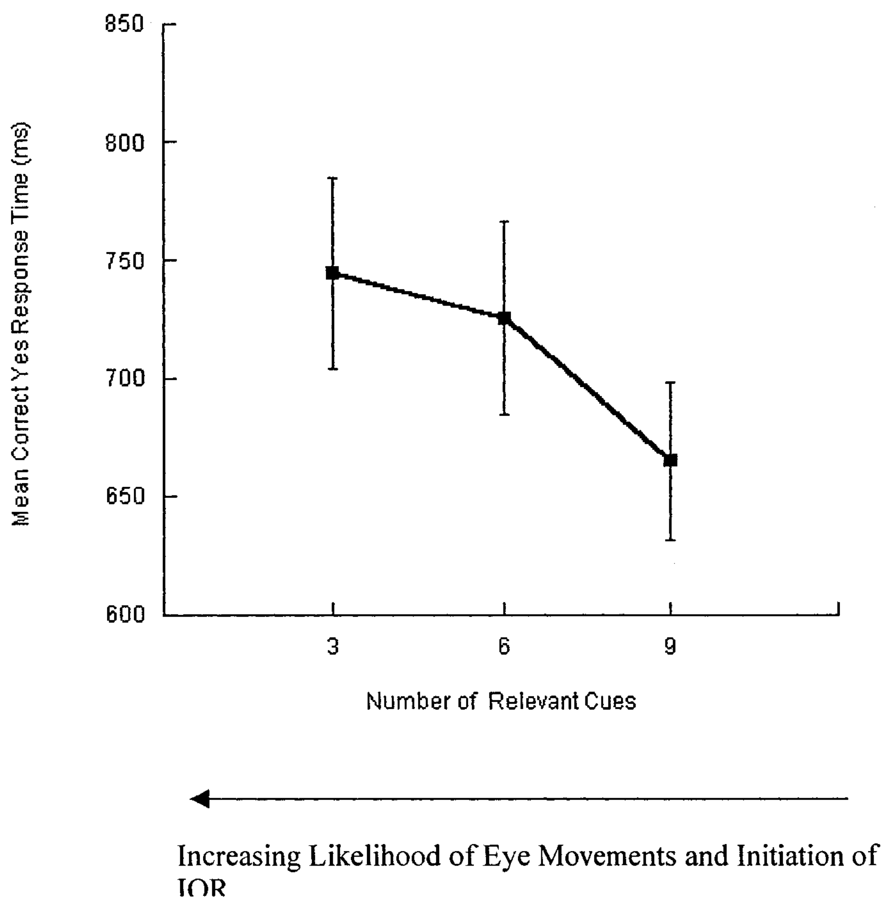


Figure 6. Mean Correct Yes Response Time (ms) collapsed across Cue Validity and Age Group as a function of Relevant Set Size. The arrow below the figure indicates the hypothesis that IOR should be greatest in the 3 relevant cue conditions and lowest in the 9 relevant cue conditions due to the likelihood of eye movements. Error bars denote ±SEM.

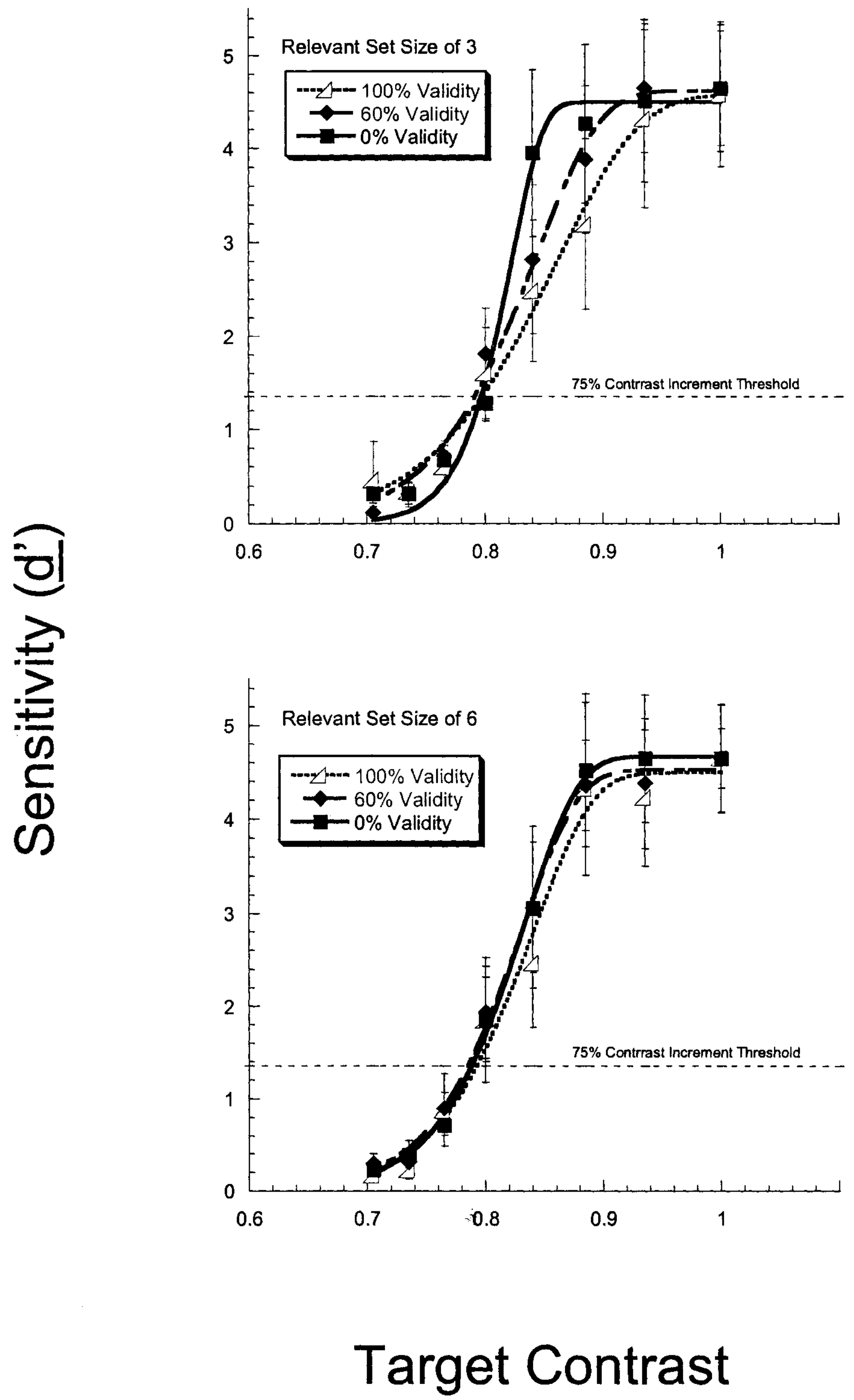

Relevant Set Size of 3
100% Validity
60% Validity
0% Validity
75% Contrrast Increment Threshold
Relevant Set Size of 6
100% Validity
60% Validity
0% Validity
75% Contrrast Increment Threshold
Sensitivity (d')
Target Contrast
0
1
2
3
4
5
0.6
0.7
0.8
0.9
1

Figure 7. Sensitivity (d') Collapsed across Age Groups as a Function of Target Contrast and Relevant Set Size

Appendix A

Dear Participant:

The intent of this research project is to investigate age-related changes in the use of peripheral word cues versus in a visual search task. To accomplish this goal, we would like you to respond to a questionnaire regarding demographic and health information, complete a small battery of cognitive tests (15 minutes) and to participate in a computerized visual search task (45 minutes).

All information you provide will remain confidential and securely stored at Lakehead University for seven years. However, the findings of this project will be made available to you at your request upon the completion of the project.

Thank you for your cooperation.

Sincerely,

Albert P. Gouge
Master's Candidate
Lakehead University

Consent Form

1. Peripheral Cues and Covert Shifts of Attention in Aging

2. I, ____________________ consent to take part in a study which will examine the use of peripheral word cues in a visual luminance discrimination task involving covert shifts of attention.

3. Albert Gouge, the principal investigator, has explained to me that that I will be required to report personal demographic and health information, complete a short neuropsychological test battery (15 minutes) and a computerized luminance discrimination task (45 minutes).

4. I understand that as a volunteer, I may withdraw from the study at any time, even after signing this form. Any information that is collected about me during this study will be kept confidential, and if the results are published, I will not be identified in any way.

5. There is no risk of physical or psychological harm from participating.

6. Data from this study will be held in a secure place at Lakehead University for a period of seven years.

7. I will receive a summary of the project, upon request to the address below, following the completion of the project.

Signature of
Participant__________________________________ Date _______________

7. I have explained the nature of the study to the patient and believe he/she has understood it.

Signature of
Researcher_______________________________ Date _____________

Demographic and Health Information

ID #: ____________________

Age: ___________

Handedness: Left Right

Visual Acuity: ______________________

WRAT: ______

Digit Symbol: _______

Years of Education: _______

Medication List: ______________________________

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Current or Recent Health Issues:

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