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Hemispheric differences in global/local processing: The effects of attentional allocation.

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HEMISPHERIC DIFFERENCES IN GLOBAL/LOCAL PROCESSING: THE EFFECTS OF ATTENTIONAL ALLOCATION

by

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Abstract

This study employed global/local stimuli to investigate RT performance of normal controls on divided and directed attention tasks. The purpose of the present study was two-fold: (1) to examine the role of attentional factors in global versus local processing, and (2) to investigate hemispheric differences in hierarchical visual processing. The results indicated that response times were significantly faster under the directed attention condition compared to the divided attention condition. The data, however, failed to support the hypothesized left hemisphere/analytic and right hemisphere/holistic dichotomy that predicts hemispheric superiority in local versus global processing. Evidence from the present investigation is consistent with the claim that global/local processing is mediated by attentional mechanisms and not solely dependent on lower-level sensory processes. Furthermore, the data suggest that attentional mechanisms involved in global/local analysis are not lateralized and that both hemispheres are equally proficient at allocating attentional resources to global and local levels.

Dedication

This thesis is dedicated in the loving memory of my father, Roshanally Murji.

Acknowledgements

Completing my M.A. thesis was very much like running an obstacle course for the first time. Not only was I unsure as to what challenges lay ahead, but I was also uncertain about whether or not I would make it in "good time". Having completed this arduous task, I am grateful to those who have helped me along the way. First and foremost, I would like to thank my committee members: Dr. D. Shore, Dr. G. Namikas, and Dr. P. Weir. Their guidance and constructive comments were greatly appreciated. I would also like to thank Renee Cormier (University of Windsor) and Malcolm Binns (Rotman Research Institute) for their much needed help in the area of statistics. Finally, I would like to thank my family and my boyfriend Shamir who have always been there - cheering me on to the finish.

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Introduction

The perceptual relationship between wholes and their parts has been subjected to a longstanding debate in psychology. The controversy centers around the issue of whether perception of the whole or overall configuration precedes and facilitates the perception of its component parts, or vice versa. For example, is a face recognized by the identification of facial features, such as eyes, nose, lips, or by perceiving the overall shape first? Similarly, does perception of a visual scene occur by extracting details and integrating them into the whole picture, or does perception of the whole scene precede the percept of its elements? These questions have permeated several subdisciplines of psychology, including the psychology of perception, cognitive psychology, and neuropsychology.

One of the ways in which the issue of part/whole relations has been investigated is through hierarchically organized stimuli. These are patterns in which a large (global) structure is constructed from smaller (local) elements (see Appendix A). Letters, numbers, or shapes may be used to construct the hierarchical stimuli. In a typical experiment, each hierarchically organized pattern contains a target at either the global or local level, or both. The stimuli are briefly presented on the screen[1] and subjects are required to make a key press in response to the target. The main dependent variables are reaction time (RT) and errors.

[1] Older studies utilized oscilloscopes and tachistoscopes to present stimuli whereas more recent studies employ computers.

This so-called global/local paradigm is regarded as a useful and elegant method for studying visual processing [2]. In particular, it has become an extremely important tool for investigating hemispheric specialization, especially with regard to the analytic/holistic dichotomy. According to this hypothesized dichotomy, the right hemisphere is more specialized in holistic, global, Gestalt-like mode of processing, while the left hemisphere is more specialized in analytic mode of processing. (See Bradshaw and Nettleton [1981] for a comprehensive review.) Given the assumption that stimuli presented to the right visual field (RVF) are initially processed by the left hemisphere and stimuli presented to the left visual field (LVF) are initially processed by the right hemisphere, global/local stimuli are used to infer functional hemispheric asymmetry by the very nature of these stimuli. That is, a differential hemispheric sensitivity in global/local analysis is predicted in which the left hemisphere is more efficient in local analysis and the right hemisphere is more efficient in global analysis.

What makes the global/local paradigm so useful in studying hemispheric differences? In particular, the use of dual-level letters is advantageous since it is possible to construct letters in which both levels are equally complex and familiar. In other words, stimuli can be designed in such a way that one level does not predict the other. This eliminates potential biases in which subjects may be influenced to respond to one level over another. These global/local stimuli are also useful for generating a Stroop type or interference effect. Interference is measured by comparing RTs for a given level when the letters at the two levels

[2] The reader should note that the term processing, though loosely defined, is used to refer to the way in which information is identified or analyzed.

are different (e.g., local "H"s forming a global "S") to RTs when the two levels are the same (e.g., local "H"s forming a global "H"). Therefore a Stroop type effect is observed when the global and local levels of these letters are in conflict.

Navon (1977) was the first to use the global/local paradigm to address the issue of whether the whole is perceived before its parts, or vice versa. He predicted that the perceptual system operates in a global to local fashion, that is, the whole is recognized before its parts. In the first two experiments, subjects were required to respond to a letter presented auditorily while looking at a hierarchical letter. Navon found that the subjects' auditory discrimination responses were affected only by the large letter. That is, processing of the global level, not the local level, interfered with the subjects' ability to respond to auditorily presented letters. In another experiment (Experiment 3), Navon presented the hierarchical visual stimuli without any auditory stimuli. Stimuli were presented under two conditions: global-directed, in which subjects were to indicate whether the global letter was H or S, and local-directed, in which subjects were to indicate whether the local letter was H or S. If both global and local letters were the same, they were said to be consistent. If global and local letters were different, they were said to be conflicting. The results showed that RTs were faster for global than local letters. In addition, Navon showed that by directing subjects' attention to local letters, response times were slowed if global letters were conflicting (i.e., Stroop type interference in which the global letter interfered with the perception of the local letters). However, if attention was directed toward the global letter, no interference was detected from the conflicting local letters. Altogether, these findings led Navon to conclude that global analysis precedes local analysis in visual processing. In his words, Navon stated that "perceptual processes are temporally organized so that they proceed from global structuring towards more and more fine-grained analysis. In other words, a scene is decomposed rather than built up" (Navon, 1977, p.354).

This notion that global processing occurs prior to local analysis has been termed global precedence [3]. According to the global precedence hypothesis, identification of the global aspect is always completed first and constitutes a mandatory stage of perception, whereas identification of the local aspect is optional and occurs after identification of the global aspect. The hypothesis, therefore, predicts unidirectional interference, that is, from the global to local level.

Subsequent research has been generated by Navon's global precedence hypothesis. Investigators have used similar hierarchical stimuli and experimental designs to study differences in global versus local processing. The global precedence effect has been replicated, wholly or in part, by several investigations (e.g., Grice, Canham, & Boroughs, 1983; Hughes, Layton, Baird, & Lester, 1984; Navon & Norman, 1983; Paquet & Merikle, 1988; Pomerantz, 1983).

[3] Global precedence includes two components : 1) response times are faster for global than local letters, and 2) interference is unidirectional - from global to local.

However, other researchers, using slight variations of Navon's global/local paradigm[4], have failed to reproduce the global precedence effect. These studies have demonstrated that certain variables can affect global versus local superiority. These include the overall stimulus size (Kinchla & Wolfe, 1979; Lamb & Robertson, 1990; McLean, 1979), retinal location of the stimulus (i.e., central vs. peripheral) (Grice et al., 1983; Lamb & Robertson, 1988; Pomerantz, 1983), location uncertainty of the stimulus (Kimchi & Merhav, 1991; Lamb & Robertson, 1988), stimulus exposure duration (Paquet & Merikle, 1984), the number of local elements comprising the global form (Kimchi, 1988; Kimchi & Merhav, 1991; Martin, M., 1979b), spatial frequency (Badcock, Whitworth, Badcock, & Lovegrove, 1990; Lamb & Yund, 1993; Sergent, 1982), and the quality of information or "goodness" of form (Hoffman, 1980). Clearly, global precedence as Navon had intended, does not appear to be a robust phenomenon.

Although Navon did not intend to measure differences between the right and left hemisphere in visual processing, the global/local paradigm has become an important tool for this purpose. By presenting the hierarchically organized patterns to each visual field, it is possible to infer differential processing of the hemispheres. The next section will provide a detailed review of studies employing this paradigm to investigate hemispheric differences in global/local processing. Following this, the role of attentional mechanisms in global/local analysis will be explored. As we will see, the literature suggests that hierarchical analysis is not solely determined by "bottom-up" perceptual processes, but that "top-down" attentional

[4] For a critical review of the global/local paradigm, the reader is referred to Kimchi (1992).

mechanisms can also affect the speed at which global and local information is processed. More recent evidence from neuropsychology has further enhanced our understanding of differential hemispheric processing of global/local information. Hence, studies using the global/local paradigm with brain-damaged populations will be discussed as they relate to the above mentioned sections. The review concludes with a summary, followed by a discussion of the specific research question, purpose and hypotheses.

Hemispheric Differences in Global/Local Processing [5]

Using a paradigm similar to Navon (Experiment 3), Martin, M. (1979a) addressed the issue of hemispheric differences in the processing of global and local features. She presented hierarchical letters to the right and left visual fields by using peripheral presentations. Subjects were instructed beforehand to attempt to recall either the global or the local letter and to make a vocal response ("H" or "S") as quickly and accurately as possible. In agreement with Navon's results, Martin also found that subjects responded faster to global than local letters. More interestingly, she found a RVF advantage for local letters and a nonsignificant trend for a LVF advantage in recognizing global letters. Martin interpreted her findings by suggesting that the left hemisphere is more efficient for local processing while global processing is not strongly lateralized.

However, Martin's findings may be limited due to the fact that she instructed subjects to make a vocal response to the target. This is somewhat problematic since a vocal response is

[5] These studies, including Navon's (1977) and the present study are summarized in Appendix B.

likely to favor left hemisphere processing due to its involvement in language. Later studies employing the global/local paradigm have utilized manual (i.e., key press) responses in order to avoid this possible confound.

Sergent (1982) also reported hemispheric asymmetries in the direction of left hemisphere/local and right hemisphere/global processing. In this experiment, Sergent considered the spatial frequency of the hierarchical stimulus as a critical variable. She found that large letters, composed of lower frequencies were processed faster when presented to the LVF, whereas small letters, made of higher frequencies, were processed more rapidly in RVF presentations. She interpreted these findings in terms of a differential sensitivity of the hemispheres: the right hemisphere being more sensitive to "early-available" low frequencies and the left hemisphere more skillful at processing "later-available" high frequencies. Interestingly, Sergent's interpretations nicely explain Navon's (1977) global precedence effect.

In contrast to Martin (1979a) and Sergent (1982), other investigators were unable to obtain hemispheric differences in global/local processing (Alivisatos & Wilding, 1982; Boles, 1984). Boles (1984) used a tachistoscope to present hierarchically organized letters to each visual field. Subjects were instructed beforehand to respond to either the global or local letters. The results did not reveal any visual field asymmetries, although there was a tendency towards a left hemisphere advantage for identifying local letters and a right hemisphere advantage in recognizing global letters. In a second experiment, Boles increased the number of trials (from 192 to 768) per subject by using a computer to present the stimuli. Once again, the data did not indicate any hemispheric differences in global versus local processing. It should be noted however, that both experiments did yield faster RTs to global as opposed to local targets, thus partially replicating Navon's global precedence hypothesis.

Using a slight variation of the global/local task, Alivisatos and Wilding (1982) also failed to find hemispheric differences in processing hierarchical stimuli. Subjects were first presented with a hierarchical letter in the center of the screen for one second. Then a target letter was flashed in either the RVF or LVF for 100 ms. The subjects' task was to match the two letters on the basis of either the global level (Experiment 1) or the local level (Experiment 2). A manual "same/different" response was required. Overall, the global matching task was significantly faster than the local matching one. Also, when global and local letters were conflicting, RTs were significantly slower in the local matching task, suggesting that the global level was interfering with recognition of the local level. Although these results are consistent with the global precedence hypothesis, no overall hemispheric differences were noted on the matching tasks. The authors concluded that both hemispheres are capable of analytic and holistic processing.

In a series of experiments, Lamb and Robertson (1988) demonstrated that spatial or locational uncertainty can influence the processing of hierarchical stimuli. For example, they found that response times for fixed stimulus presentations (i.e., only central presentations) were faster compared with random stimulus presentations (i.e., LVF, RVF, central). An alternate explanation, however, is that centrally presented stimuli are processed faster because of increased visual acuity. To control for the possible effects of size, a single small letter was also presented. It was found that central presentations yielded faster RTs for local letters but not single letters. Thus small letters were identified faster if they appeared in a hierarchical letter but not if they appeared alone. The authors also ruled out the possibility that eye movements may have accounted for the differences between central and peripheral presentations by the use of an eye-movement monitor. The authors interpreted these findings in terms of an attentional "spotlight" in which processing capacity is enhanced as attention is restricted to a small area. Conversely, processing efficiency decreases as the size of the attended area increases. The findings from this study may be limited, however, since the authors make comparisons between experiments [6]. In addition, since half of the subjects in Experiment 1 also participated in Experiment 2, they may have benefited from practice effects.

Christman (1993) found evidence to support the hypothesis that the upper versus lower visual fields are functionally specialized for the processing of local versus global information, respectively. In the analysis of left versus right visual field differences, the results indicated only a LVF advantage for global processing and no significant visual field effect for local processing. However, these results may be confounded by the spatial uncertainty of the stimuli; whereas most studies use two or three stimulus locations, the present study employed four and eight locations. In terms of the attentional "spotlight" theory

[6] Experiment 1 - spatial uncertainty (random presentations); Experiment 2 - spatial certainty (fixed presentations)

mentioned above, using many different stimulus locations would force the subjects to attend to a much larger area, thereby influencing the RT data.

Van Kleeck (1989), using a paradigm similar to Martin's (1979a) also found evidence for global precedence but no significant visual field differences. Therefore, it appears that studies using similar paradigms to investigate lateralization effects in global versus local processing have yielded mixed results. However, using meta-analytic techniques, Van Kleeck (1989) found evidence to support the hypothesis that the left hemisphere is specialized for local, analytic processing whereas the right hemisphere is specialized for global, holistic processing.

Hemispheric Differences in Global/Local Analysis: Evidence from Neuropsychology

The issue of how wholes and their parts are processed has also been addressed in neuropsychology - mainly by studies of hemispheric laterality. Perhaps the most significant contribution in this realm has come from studying patients with unilateral brain damage. In particular, it has been demonstrated that individuals with left hemisphere lesions are impaired in processing details or local aspects of visual information, whereas those with right hemisphere damage exhibit difficulty with the whole or global aspects (e.g., Delis, Robertson, & Efron, 1986). This distinction between left and right brain has led to various theories of functional hemispheric asymmetry, most notably that the left hemisphere is specialized for analytic processing and the right hemisphere is proficient at holistic processing (Bradshaw & Nettleton, 1981).

Much of the research involving global/local processing in brain-damaged individuals has been conducted by Delis and his colleagues. In particular, these investigators have demonstrated that functional hemispheric asymmetry is evident in patients with focal lesions (e.g., CVAs) as well as those with more diffuse injury (e.g., Alzheimer's disease). These studies are described next.

Delis et al., (1986) utilized a forced-choice recognition task to assess memory for hierarchical stimuli in both control and unilateral brain-damaged subjects. The experimental trials consisted of a central presentation of the target stimulus followed by a 15-second distracter task. Immediately after the distracter task, four alternative hierarchical stimuli were presented in the four quadrants of the screen. The four alternatives always contained (a) both large and small forms correct (the original target); (b) only the large form correct; (c) only the small form correct; and (d) neither form correct. The subject's task was to choose the alternative that matched the target stimulus on the basis of both the large and small forms. Linguistic and nonlinguistic hierarchical stimuli were alternatively presented. The results indicated that, relative to controls, the left hemisphere damaged (LHD) patients made more errors in recalling the local forms, while the right hemisphere damaged (RHD) patients made more errors in recalling the global forms. This occurred for both linguistic and nonlinguistic stimuli. Interestingly, this study demonstrates that LHD and RHD patients do not necessarily differ with respect to verbal versus nonverbal processing per se, but instead in their ability to remember global versus local levels of hierarchical stimuli.

Given the hemispheric asymmetry found in patients with focal brain damage, Delis et al., (1992) examined whether global/local differences would also be evident in patients with more diffuse brain injury such as Alzheimer disease (AD). Using scores from the Boston Naming Test (BNT) and the WISC-R Block Design subtest (BD), the AD patients were divided into three subgroups: high-verbal (patients with better naming than block construction); high-spatial (patients with better block construction than naming); and equal (patients with similar scores on the BNT and BD). Global/local stimuli, composed of either letters or shapes, were presented centrally for 10 seconds. Simple large and small figures were also presented. The subjects' task was to recall and copy the stimuli. These were scored on a 5-point accuracy scale. The results showed a dissociation in global/local analysis between the AD subgroups. The high-verbal AD patients demonstrated difficulty in recalling the global forms relative to high-spatial AD patients and normal controls. In contrast, the high-spatial AD patients showed deficits in recalling the local forms relative to high-verbal AD patients and controls. It is important to note that these differences between subgroups occurred regardless of whether the stimuli were letters (verbal) or shapes (nonverbal). This suggests that grouping AD patients into those with strong spatial skills versus those with strong verbal skills may prove misleading. Rather, differentiating patients on the basis of their ability to analyze the local and global features of complex stimuli may be more accurate. [7]

[7] Although the results of this study seem to fit the hypothesized left hemisphere/verbal/local and right hemisphere/spatial/global dichotomies, it seems that a diffuse disease process such as AD may affect many cognitive functions - e.g., attention, perception, memory, motor, etc. Therefore, before making firm conclusions regarding visual processing of hierarchical stimuli in AD patients, it is necessary to control for these various factors.

In a subsequent study, Delis and his colleagues (Massman et al., 1993) attempted to control for any constructional impairments of AD subjects by employing a directed attention RT procedure. (Recall in the previous study, subjects were required to *draw* the stimuli - a task with a definite constructional component.) Similar to their previous investigation (Delis et al., 1992), AD patients were separated into high-verbal, high-spatial, and equal subgroups on the basis of BNT and BD scores. Hierarchical stimuli as well as simple large and small stimuli were centrally presented and remained on the screen until the subject responded. Subjects were directed to attend to either the global (large) numbers or local (small) numbers. RT data revealed that high-verbal AD patients were more accurate in identifying local than global forms, whereas high-spatial AD patients were more accurate in identifying global than local forms. These findings are consistent with those of their previous study (Delis et al., 1992). Furthermore, the AD subgroups did not differ with respect to processing of simple stimuli, suggesting that it is the hierarchical relationship of the global and local forms, not their absolute size, that resulted in the observed pattern of global/local performance in the AD subgroups.

Further evidence for hemispheric differences in global/local analysis has been obtained by studying commissurotomized patients. Delis, Kramer, and Kiefner (1988) reported a case study in which drawing and recognition memory for visual hierarchical stimuli were assessed before and after commissurotomy. Before surgery, the patient was able to draw both global and local levels of hierarchical stimuli with either hand. After surgery, the patient was more accurate in drawing and recognizing global forms relative to local forms when responding with his left hand (and right hemisphere). When responding with his right hand (and left hemisphere), he was more accurate in drawing and recognizing local forms relative to global forms. These results are consistent not only with findings from unilateral brain-damaged subjects but also with reports from normal subjects where hierarchical stimuli are presented to each visual field.

Robertson, Lamb, and Zaidel (1993) presented hierarchical stimuli to three commissurotomized subjects. Unlike controls, commissurotomized subjects did not show evidence of global interference (i.e., RTs to locally-directed targets were not slowed by the conflicting global form). Based on these findings and those from previous investigations, the authors suggested that transfer via the corpus callosum is necessary in order to produce "normal global interference". In addition, the authors also suggested that communication between the two hemispheres is necessary in order for integration of information at global and local levels to occur.

In a review, Robertson and Lamb (1991) examined the neuropsychological evidence for hierarchical visual processing. Based on previous findings, they proposed that separate mechanisms associated with each hemisphere are responsible for differential processing of global and local forms. In other words, left hemisphere mechanisms are associated with more rapid local analysis whereas right hemisphere mechanisms are associated with more rapid global analysis. Thus while both hemispheres are capable of analyzing global and local information, each has its own area of specialization.

These converging findings from both brain-injured patients and normal controls[*] strongly support the notion of hemispheric specialization for differential hierarchical processing. Although the above mentioned studies seem to focus on lower-level or "bottom-up" (sensory) processes in the analysis of complex stimuli, it should be noted that the literature is also suggestive of higher-level or "top-down" processes in global/local analysis. For example, several investigations have demonstrated that attentional manipulations can influence the speed at which global and local information is processed. These are discussed in the following section.

Attentional Processes in Global/Local Analysis

Several experiments using normal controls have provided evidence for an attentional component in the processing of hierarchically organized stimuli. Specifically, most investigations have examined the effects of attentional allocation, (i.e., directing subjects' attention to a particular level) on the relative speed of processing. In the more common focused or directed attention task, the subject is instructed beforehand to respond to one level (e.g., global) while ignoring the other level (e.g., local). In a divided attention task, the subject is not told which level to attend to but instead must detect targets at either level, hence *dividing* their attention over both levels.

Earlier studies examined whether introducing an attentional component to the global/local task would affect Navon's global precedence effect. Navon and Norman (1983)

[*] The reader is reminded that divided visual field studies of normal controls, though supporting a trend in the predicted direction of left hemisphere/local and right hemisphere/global, are highly variable.

failed to find evidence to suggest that the global advantage had an attentional component. They used two attention conditions: focused and divided attention. In the former, subjects were presented with large Cs made up of small circles (global block) or large circles made up of small Cs (local block). In divided attention, both types of stimuli were presented. Under both conditions, the subjects' were required to indicate the direction of an opening of the C. The results showed that the global advantage did not depend on attentional allocation. That is, no significant differences in global advantage were observed between focused and divided attention conditions.[9]

Contrary to Navon and Norman (1983), Hoffman (1980) showed that global precedence did not hold under conditions of focused and divided attention. In divided attention, subjects were equally fast in detecting targets at either the global or local level. In focused attention, both the global and local levels were capable of producing interference. Overall, RTs were slower for divided attention than focused attention conditions. This appears to be consistent with Lamb and Robertson's (1988) attentional "spotlight" theory.

Major procedural differences between these two studies make it difficult to directly compare and contrast these findings. For example, Hoffman used an oscilloscope to present stimuli to six subjects. In addition, his study modified the basic RT paradigm to include a memory component in which subjects were required to match letters. Navon and Norman, on

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[9] Navon and Norman constructed these stimuli in order to control for eccentricity - i.e., the distance from the fovea. The main purpose of their experiment was to examine the effects of stimulus size on global precedence, while keeping eccentricity constant. A second aim of their study was to test the hypothesis that the global advantage is partly mediated by attentional mechanisms.

the other hand, used a carousel slide projector to present both small (2°) and large (17.25°) stimuli to 24 subjects. Not only were the stimuli drastically different in these studies, but the task demands also differed considerably.

Paquet and Merikle (1988) investigated whether global precedence would hold true for nonattended hierarchical patterns, that is, whether the global form of a nonattended pattern would receive priority in perceptual processing. [10] Pairs of hierarchical patterns were presented, with the attended pattern defined as being enclosed in a square or circle. Subjects were told to attend to either the global level or the local level located within the square or circle while ignoring all other letters. The results indicated that for attended patterns, the global aspect was identified faster and was more difficult to ignore than the local aspect (i.e., global precedence). The results also indicated that the direction of attention to the global or local level of the attended pattern determined which level of the nonattended pattern was identified. When attention was directed toward the global level of an attended pattern, it was harder to ignore the identity of the global than the local level of the nonattended pattern, whereas the reverse was found when attention was directed toward the local level of an attended pattern.

Ward (1982) demonstrated that prior allocation of attention to either global or local levels can influence the speed with which a current stimulus is processed. He proposed a level-readiness effect, whereby RTs are faster for a given level, global or local, if previous

[10] Note: Navon's global precedence only applies to attended objects.

processing occurred for that same level. Kinchla, Solis-Macias and Hoffman (1983) also found faster RTs under directed attention conditions. However, in their interpretation, they suggested that directing attention to a particular level of a hierarchical structure is likely to result in more rapid use of information from that level at a cost of slower use of information from other levels. Moreover, they suggested that the observer, when viewing a stimulus, chooses one of two alternative attentional strategies in which each strategy is optimal for extracting information from one structural level, but less than optimal for the other. Whether this equates to Ward's level-readiness effect is uncertain. What seems to be the case, however, is that allocating attentional resources to a particular level affects the speed with which *that* level is processed. It may be that prompting or cueing subjects beforehand as to which level to respond to, results in an expectancy or type of hemispheric readiness for a specific type of processing, whether analytic or holistic, global or local, whole or part, etc.

The Role of Attentional Mechanisms in Global/Local Processing: Evidence from Neuropsychology

Recent evidence from neuropsychology has illustrated the importance of attentional mechanism in hierarchical visual processing. Various patient populations have been studied, including those with focal brain damage (e.g., CVAs) and those with more widespread damage (e.g., AD, HIV+). These investigations have primarily demonstrated that the nature of the attentional deficit is dependent on the type of injury. However, at present, only a small number of investigations have been conducted concerning the role of attentional mechanisms in the analysis of global/local information. Clearly, more research is needed in this area before any firm conclusions can be drawn. The following section discusses the existing literature in this domain.

Filoteo et al. (1994) administered a divided attention task to patients with Parkinson's disease (PD) and normal controls. These researchers were interested in whether PD patients would exhibit impairment in maintaining covert attention. Shifts in covert attention were examined by comparing performance across consecutive trials in which the target remained at the same hierarchical level (e.g., global to global) or changed levels (e.g., global to local). Hierarchical stimuli composed of numbers (e.g., a large 1 composed of smaller 3s) were used. Subjects were told to press one key if they observed one target at either level and to press another key if they observed the second target at either level. The results showed that when the target remained at the same level across two consecutive trials, PD patients responded slower to the second stimulus compared to controls. When the target changed levels across consecutive trials, the PD patients responded faster to the second stimulus than did control subjects. The authors suggested that PD patients show abnormally rapid shifts in attention and therefore are impaired in maintaining covert attention. One methodological shortcoming of this study is that PD patients were not tested for visual acuity. Since deficits in visual perception are not uncommon in PD, the results of this study may be misleading as deficits in visual functions may be incorrectly interpreted as attentional deficits.

Filoteo and his group (Filoteo et al., 1992) also investigated attentional impairments in a group of AD patients using the same experimental paradigm. An opposite pattern of results was obtained. AD patients were faster to respond than controls when the target remained at the same level across consecutive trials. In contrast, when the target level was different across consecutive trials, AD patients were slower to respond compared to controls. The results imply that AD patients have difficulty disengaging their attention from one hierarchical level and shifting to another level. Thus unlike PD patients who are abnormally rapid in disengaging attention, AD patients are abnormally slow in disengaging and shifting their covert attention to different global/local levels. The authors suggested that these differences in attentional impairments may be related to the different neuropathological changes associated with PD and AD.

In addition, the authors compared performance on both directed and divided attention tasks. In the directed attention task, subjects were required to focus their attention on either the global or local level. In the divided attention task, subjects were required to divide their attention across both hierarchical levels. Consistent with their hypothesis, AD patients were significantly slower on the divided attention task than on the directed attention task relative to controls. Although controls also exhibited slower RTs on the divided attention task, this difference was not as pronounced as that seen with AD patients on the two attention tasks. Thus, AD patients exhibited disproportionately greater deficits on the divided attention task than on the directed attention task.

Robertson and her colleagues have conducted several investigations regarding perceptual and attentional mechanisms involved in global/local processing. They have employed various patient populations in their quest, including persons with focal cortical lesions (Lamb, Robertson, & Knight, 1989; Robertson & Delis, 1986; Robertson & Lamb, 1991; Robertson, Lamb, & Knight, 1988, 1991) as well as commissurotomized patients (Robertson et al., 1993). These studies have primarily demonstrated that RT performance [11] tends to vary as a function of lesion location. For example, they found that patients with inferior parietal lobe lesions exhibit abnormal RT tradeoffs [12], suggesting an impairment in allocation of attention under divided attention. In contrast, patients with superior temporal gyrus lesions show normal RT tradeoffs but have difficulty with the automatic component of the global/local task (Robertson et al., 1988). Unlike these groups, persons with dorsolateral frontal lobe lesions do not show deficits in either component of the task (Robertson et al., 1991). Altogether, these findings from brain-damaged patients are consistent with their position that the posterior association cortex is crucial in global/local analysis (Lamb et al., 1989; Robertson et al., 1988, 1991).

Recently, the nature of attentional deficits in a large group of HIV-seropositive (HIV+) individuals was investigated by Martin, E. et al., (1995). The global/local task was

[11] RT performance is thought to be influenced by two components of attention: automatic and controlled attentional processes. When targets appear at either level with equal probability, RTs are thought to be influenced mainly by automatic processes. When the probability is varied such that the subject is biased to respond to one level over another, controlled attentional processes are engaged (Robertson et al., 1988; Martin, E. et al.,1995).

[12] Normal individuals show a "tradeoff" in RTs, with a benefit (i.e., decreased RTs to targets appearing at the more probable level) and a cost (i.e., increased RTs to targets appearing at the less probable level) compared to RTs in an equal (50/50) probability condition (Robertson et al., 1988; Martin, E. et al., 1995).

designed in order to assess automatic and controlled attentional processes. Subjects were run under three divided attention conditions: a global bias condition, with 75% of targets appearing at the global level; a local bias condition, with 75% of targets appearing at the local level; and a no-bias condition, with targets appearing with equal probability at the global or local level. There was no significant differences in performance between the experimental and control groups in the no-bias condition. This finding supported the authors' prediction that HIV+ individuals would show no evidence of impairment on the automatic component of the task. In the biased conditions, both groups showed faster RTs for more probable targets and slower RTs for less probable targets. However, HIV+ subjects showed significantly greater costs relative to controls. That is, the increase in RT to the less probable target compared with neutral baseline (cost) was greater for the HIV+ group compared to controls. The decrease in RT to the more probable target level compared with neutral baseline (benefit) did not differ between the two groups. In other words, the HIV+ group showed normal benefits but much greater costs compared to controls. The authors suggested that controlled attentional processing deficits may be evident early in the course of the disease and that RT tasks may prove as useful alternatives to standard clinical tests in the study of HIV-related mental slowing.

Summary

The issue of whole/part processing has generated much controversy in the psychology of perception. The global/local paradigm is a simple, yet elegant method for investigating visual processing of global and local forms. Navon (1977) used this paradigm to investigate global/local processing of visual information and found a pattern of results that he termed global precedence. Navon originally explained the phenomenon of global precedence by stating that the global level of the hierarchical pattern is identified before the local level. Thus, in perceptual processing, the local aspect of the stimulus is only identified after the global aspect and hence the latter dominates early perceptual processing. However, Navon's interpretation of global precedence may not be entirely accurate as subsequent investigations have shown that many factors (e.g., stimulus size, exposure duration, spatial frequency) can influence the speed with which global and local levels are processed.

Since it was first used by Navon, many researchers have used similar or modified versions of this task in an attempt to study hemispheric differences in global/local processing. Although these investigations have produced inconsistent findings with regard to hemispheric differences in visual processing, meta-analytic techniques have provided support for the left hemisphere/local and right hemisphere/global dichotomy (Van Kleeck, 1989). Data from brain-damaged patients have been more consistent. Neuropsychological investigations have provided further evidence for the analytic/holistic dichotomy by demonstrating that the left hemisphere is more adept at analyzing the local forms of hierarchical patterns, while the right hemisphere is more efficient in processing the global forms.

The accumulation of evidence from studies using the global/local paradigm with normals and brain-injured patients suggests that both perceptual and attentional processes are involved in global/local analysis. However, the relationship between these lower-level sensory mechanisms and higher-level attentional mechanisms has not been clearly delineated. Recent neuropsychological evidence suggests that processing of global and local information occurs by separate mechanisms. In particular, Robertson and colleagues propose that there are separate neural subsystems involved in these processes as damage to different regions can independently affect attentional or perceptual mechanisms (see Robertson & Lamb, 1991). Furthermore, neuropsychological studies have demonstrated that different aspects of attention may be impaired, depending on the nature of the brain injury.

Although there is consensus in the literature that attentional mechanisms play a role in the perception of wholes and their parts, relatively few systematic investigations have been conducted in this area. Most studies have employed directed attention tasks, in which the subjects are told to attend to a particular level. Fewer studies have employed divided attention tasks, whereby both levels are relevant to the subject. However, these attention conditions have simply been part of the experimental design, not variables selected for study. Very few investigations have directly examined the effects of attentional allocation. The evidence, thus far, tends to support the notion that processing is faster under directed attention conditions than under divided attention conditions. This is consistent with Lamb and Robertson's (1988) attentional "spotlight" theory which states that processing is more efficient (i.e., faster) as the size of the attended area decreases.

There have only been three studies that have directly compared directed and divided attention conditions. Hoffman (1980), using a memory-scanning task, found that subjects were faster to respond to targets when told to attend to a particular level. However, many procedural differences date this study. Navon and Norman (1983) used hierarchical letters in which the elements were located along the perimeter. Using centrally presented stimuli, these investigators also found faster RTs under directed than divided attention conditions. However, they failed to find any effects of attentional allocation on global advantage. Filoteo et al., (1992) compared focused and divided attention conditions using both AD patients and normal controls. However, their stimuli consisted of hierarchical numbers, not letters. It is important to note that in all of these studies, the stimuli were presented centrally and therefore, hemispheric differences were not examined.

In sum, a controlled study of the effects of attentional allocation would likely enhance our understanding of the relative contribution of attentional strategies in global/local processing. By comparing directed and divided attention, it may be possible to detect differences between a more "natural" attentional mechanism and one that is used as a result of prompting or cueing [13]. Furthermore, using visual field presentations may permit a closer inspection of the interaction between attentional cueing and hemispheric processing.

Statement of Purpose and Hypotheses

As mentioned above, the literature is lacking in the study of the effects of attentional allocation on hemispheric differences in global/local analysis. If global/local processing is

[13] The assumption here is that, in divided attention where task demands are vague, the participant is not influenced or biased in any way to allocate attentional resources. In contrast, in directed attention, task demands are specific and the participant is biased or cued beforehand to direct his/her attention to a particular hierarchical level.

indeed mediated by attentional mechanisms, then it should be possible to detect differences in hemispheric processing under both directed and divided attention conditions. This study attempts to determine if global/local processing is influenced by lateralized attentional mechanisms. In other words, one could pose the question: Are there attentional asymmetries that favor processing of global over local information, or vice versa?

The purpose of the present study is two-fold: (1) to investigate the role of attentional allocation in global versus local processing, and (2) to investigate hemispheric differences in hierarchical visual processing. The following hypotheses are made in this study:

(1) It is hypothesized that the directed attention condition will yield faster response times to target stimuli than the divided attention condition.

(2) In accordance with the left hemisphere/analytic and right hemisphere/holistic dichotomy, it is predicted that RTs to local letters will be faster in RVF (left hemisphere) presentations compared to that of global letters. Similarly, RTs to global letters will be faster in LVF (right hemisphere) presentations than those of local letters.

(3) Furthermore, it is predicted that this difference in hemispheric processing will be more pronounced under divided attention conditions than under directed attention conditions.

Method

Subjects

Sixteen right-handed undergraduate students from the University of Windsor served as subjects. An equal number of males and females participated in the study and all received class credit for their participation. All subjects had normal or corrected-to-normal vision.

Stimuli and Apparatus

The stimuli consisted of eight different hierarchical patterns, similar to those used by Martin (1979a). As shown in Appendix A, each stimulus consisted of a global letter shape ("H", "S" or "O") made up of local elements (again "H", "S" or "O"). The stimuli were classified according to three consistency conditions: consistent, neutral, and conflicting.

The sequence of presentation was controlled using Psychlab software (Bub & Gum, 1988) on a Macintosh Classic computer with a 12-inch monitor. For each pattern, the global size was 3.5 x 1.9 cm and the local size 0.3 x 0.2 cm. At a viewing distance of 42 cm, the global and local shape subtended approximately 4.8 x 2.6 ° and 0.4 x 0.3 ° of visual angle, respectively. Subjects were positioned in a chin rest, ensuring that the viewing distance would be constant for all subjects. Also, the chin rest was employed to keep head movements at a minimum.

Procedure

On each trial, a black fixation point appeared centrally on a white computer screen for 1 s followed by a 100 ms delay. Following the fixation, the stimulus was presented for 100 ms, with the inner edge of the letter 1.8 cm (2.5 °) to the left or right of fixation. Subjects were instructed to maintain fixation throughout the trial.

The experiment consisted of two attention conditions: directed and divided attention. In the directed attention task, subjects were instructed beforehand to respond to either the large or small letters and to ignore the irrelevant dimension. Eight blocks of 36 trials each were administered. For four of the blocks the subjects were required to classify the global shape as an "H" or an "S". Similarly, for the other four blocks, they were instructed to classify the local elements. For the global attention trials, only the six stimuli whose global shape was an "H" or an "S" were used; similarly, for local attention trials, only the six stimuli whose local shape was an "H" or an "S" were used. Each block consisted of an equal number of LVF and RVF trials, which were divided equally between the three categories of stimulus consistency (i.e., consistent, neutral, conflicting).

The procedures for the divided attention condition were identical to those of the directed attention conditions with a couple of exceptions: (1) Subjects were told to press one key if they observe an "H" at *either* the global or the local level, and to press another key if they observe an "S" at *either* level. (2) All eight stimuli were used. For this task, four blocks of 32 trials each were administered. Therefore, the experiment consisted of a total of 416 trials per subject.

Half of the subjects began with the directed attention condition and half began with the divided attention condition. Within the directed attention condition, the order of global and local attention blocks was also counterbalanced. Subjects were given both instructions and 12 to 16 practice trials (depending on attention task) with feedback prior to the presentation of the experimental trials. Experimental trials were not administered until it was clear that subjects understood the task. Responses were made by pressing either the "M" key (labeled "H") or the "N" key (labeled "S") on the keyboard with the index finger of each hand. The key/hand assignment was balanced over subjects. Subjects were instructed to respond as quickly and accurately as possible.

Results

Divided vs. Directed Attention

Error rates were calculated for both directed and divided attention tasks. The mean error rate for the directed attention condition was 1.0 % (SD = 3.08), whereas that for the divided attention condition was 1.8 % (SD = 5.74). Subjects made significantly more errors in the latter condition [$F(1,46) = 6.58$, $p < .01$]. Incorrect responses were discarded [14] and median RTs for correct responses were calculated for each subject.

The RT data were subjected to a 2 X 3 X 2 repeated measures ANOVA, with Attention (divided vs. directed), Consistency (consistent vs. conflicting vs. neutral), and Visual Field (LVF vs. RVF) as the within-subject factors. The ANOVA revealed a significant main effect for Attention, $F(1,15) = 18.60$, $p < .001$. As predicted, response times were slower in the divided attention task than in the directed attention task. The main effect of Consistency was also significant [$F(2,30) = 24.92$, $p < .001$]; consistent stimuli yielded the fastest responses (586.3 ms), followed by neutral stimuli (624.1 ms) and conflicting stimuli (634 ms).

The Attention X Consistency interaction also reached statistical significance [$F(2,30) = 5.43$, $p < .01$]. This interaction is illustrated in Figure 1.

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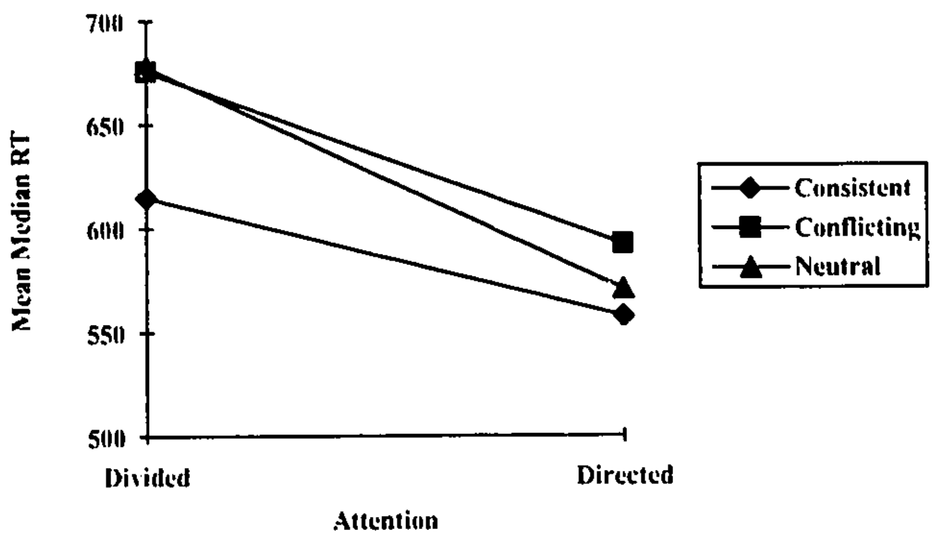
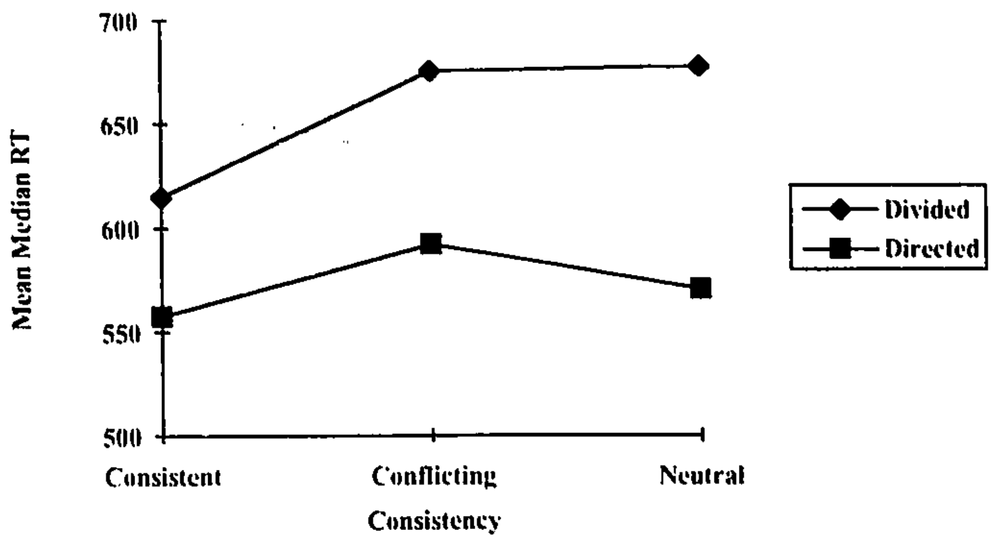
[14] Responses due to technical errors (e.g., the key was not pressed hard enough for a response) were also discarded. In this manner, responses greater than 1300 ms were discarded.

Figure 1. The effect of stimulus consistency on RT for divided and directed attention tasks.



As shown in Figure 1, the effect of consistency is more pronounced under divided attention conditions than under directed attention conditions. Examination of the means using a Tukey Test revealed that for divided attention, RTs to consistent stimuli were significantly faster than RTs to conflicting ($p < .01$) and neutral ($p < .01$) stimuli. For the directed attention condition, responses to consistent stimuli were significantly faster than responses to conflicting stimuli ($p < .01$). Responses to neutral stimuli were not significantly different than responses to consistent or conflicting stimuli. Further analysis of the means indicated that response times under divided attention conditions were significantly slower than those under directed attention conditions at all three levels of consistency (i.e., consistent, $p < .05$; conflicting, $p < .01$; neutral, $p < .01$). See Figure 2.

Figure 2. Response times for divided and directed attention tasks across varying levels of consistency.



A main effect for Visual Field was significant [$F(1,15) = 5.03$, $p < .04$]; latencies were shorter in RVF than in LVF presentations (609.5 vs. 620.1 ms). However, the data do not support the notion that global/local processing is influenced by any lateralized attentional mechanism(s), as evidenced by a nonsignificant Attention X Visual Field interaction [$F(1,15) = .0$, $p > .50$].

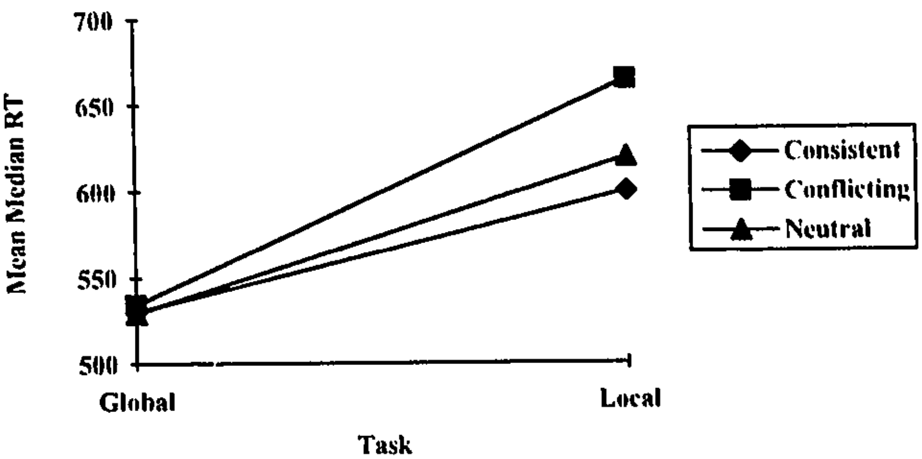
Directed Attention : Global vs. Local Processing

Data from the directed attention task were analyzed further in order to determine the influence of hierarchical processing on RT performance. As mentioned above, the mean error rate for the directed attention condition was 1.0 % (SD = 3.08). Error rates were also calculated for global and local attention trials. The mean error rate for global attention was 0.7% (SD = 2.11) and that for local attention was 1.2% (SD = 3.60). These error rates did not differ significantly.

Median RTs for correct responses were subjected to a 2 X 3 X 2 repeated measures ANOVA, with Level (global vs. local), Consistency (consistent vs. conflicting vs. neutral), and Visual Field (LVF vs. RVF) as the within-subject factors. The analysis revealed a main effect for Level [$F(1,15) = 52.36$, $p < .001$], with faster responses when attention was directed globally (531.2 ms) than when attention was directed locally (628.2 ms). In addition, the main effect for Consistency was also significant [$F(2,30) = 47.09$, $p < .001$]; consistent stimuli yielded the fastest responses (565.3 ms), followed by neutral stimuli (574.4 ms) and conflicting stimuli (599.5). This pattern is consistent with the expected level of difficulty of the three classes of stimuli.

The effect of consistency was greater when subjects were directed locally than when they were directed globally, as reflected by a significant Level X Consistency interaction [$F(2, 30) = 26.86$, $p < .001$]. Figure 3 illustrates this interaction.

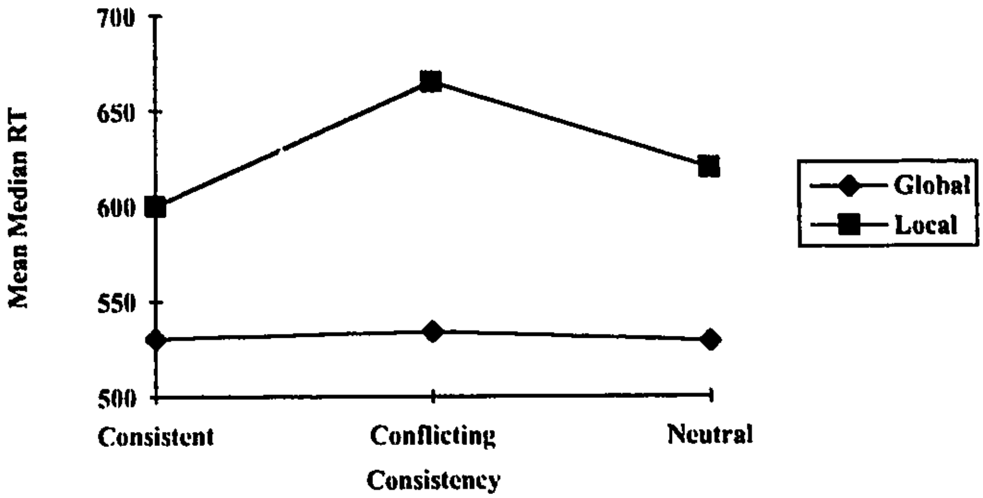
Figure 3. The effect of stimulus consistency on RT for global and local attention tasks.



Examination of the means using a Tukey Test revealed that for local attention, all three levels of stimuli consistency differed significantly with each other ($p < .01$). No significant differences were found in stimulus consistency for global attention.

Further analysis of the means indicated that response times under global attention were significantly faster than those under local attention at all three levels of consistency (i.e., consistent, $p < .01$; conflicting, $p < .01$; neutral, $p < .01$). See Figure 4.

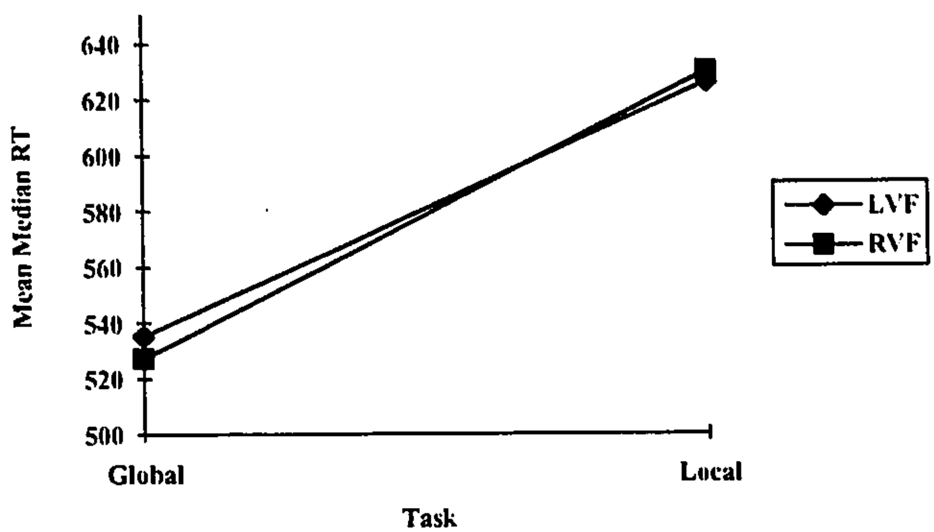
Figure 4. Response times for global and local attention tasks across varying levels of consistency.



In agreement with previous visual half field studies, the global precedence effect was also generated by the present data. This global advantage in visual processing was demonstrated in two ways. First, RTs to global letters were faster than RTs to local letters (531.2 vs. 628.2 ms). Second, interference (defined as the increase in the mean RT for conflicting stimuli relative to the mean RT for consistent stimuli) was unidirectional; the global level of the hierarchical stimulus interfered with local judgements more than the local level interfered with global judgements. In other words, response times were considerably slower to conflicting stimuli only when subjects were directed locally and not globally (increases of 64.8 vs. 3.7 ms).

Although the findings replicated the standard global precedence effect, there were no effects for visual field. More importantly, the critical Level X Visual Field interaction was not significant [$F(1,15) = 2.10$, $p > .15$]. Thus, the hypothesized left hemisphere/analytic and right hemisphere/holistic dichotomy that predicts hemispheric superiority in local versus global processing was not supported by the data. These results are illustrated in Figure 5.

Figure 5. Response times to global and local targets in the left and right visual fields.



As shown in Figure 5, response times to global and local targets are very similar in both visual fields. In fact, there does not even appear to be a trend in the RVF/local and LVF/global direction [15].

[15] A power of approximately 6% was calculated for this interaction, suggesting that a greater number of subjects would increase the ability to detect an effect, if there is one. However, the data indicate that the interaction effect, even if detected, is very small.

Discussion

Two major hypotheses were examined by the present experiment. First, the effects of attentional allocation on global/local analysis was explored. Specifically, it was predicted that RT performance would differ under divided and directed attention conditions. Second, hemispheric differences in processing global versus local stimuli were investigated. In accordance with the left hemisphere/analytic and right hemisphere/holistic dichotomy, a RVF (and left hemisphere) advantage was predicted for local targets and a LVF (and right hemisphere) advantage was predicted for global targets. The findings relating to each of these hypotheses will be discussed in turn.

As predicted, response times were slowed on the divided attention task relative to the directed attention task. This finding is consistent with previous studies that also directly compared directed and divided attention (Hoffman, 1980; Filoteo et al., 1992; Navon & Norman, 1983). It is possible to interpret this finding according to the attentional "spotlight" theory (Lamb & Robertson, 1988) which states that processing efficiency increases as the size of the attended area decreases. Therefore, under the divided attention condition, subjects were required to attend to a larger area (i.e., both hierarchical levels) compared to the directed attention condition in which the attended area was smaller (i.e., one level only). Furthermore, in the divided attention task, subjects were uncertain as to which level the target would appear, whereas this uncertainty was removed in the directed attention task. Thus, it seems that advance information regarding the level at which the target will appear influences the speed of processing, not only by narrowing attention to a particular level, but also by eliminating any uncertainty as to which level the target will appear.

A limitation of this study is that it failed to determine the effects of level for divided attention. Recall that under divided attention conditions, targets could appear at both levels simultaneously and there was no way of determining whether subjects were responding to the local or global level.

For both attention conditions, RT performance was affected by the three categories of stimulus consistency (i.e., consistent, conflicting, neutral). For divided attention, responses to consistent stimuli were significantly faster than responses to conflicting or neutral stimuli. Response times to neutral and conflicting stimuli did not differ significantly, indicating that both levels were relevant to the subjects. For directed attention, stimulus consistency depended on task requirements. While there was no effect of stimulus consistency when subjects were directed globally, there was an effect of stimulus consistency on the local task. Together, these findings imply that under directed attention conditions, interference tends to be unidirectional (i.e., global interference), whereas bidirectional interference occurs under divided attention conditions. This would also tend to explain the overall longer response times for divided attention relative to directed attention.

Although the data indicated that latencies were slightly faster in RVF than in LVF presentations across attention, the critical interaction of visual field, namely attention x visual field, failed to reach significance. This argues against the notion of lateralized attentional mechanisms in which one favors processing of global over local information and the other favors processing of local over global information. Rather, the data suggest that both hemispheres are equally proficient at allocating attention to global and local levels.

Neuropsychological studies have suggested that attention is an important determiner in global/local analysis. In particular, it has been shown that right-hemisphere patients exhibit impairment in attending to global information whereas left-hemisphere patients attend poorly to local information (Robertson et al., 1988). Robertson and Lamb (1991) have suggested that the normal distribution of attention may be disrupted in different ways, depending on the site of injury. Evidence from neuropsychology also suggests that diffuse brain injury impairs the ability to divide attention on global/local tasks. For example, Filoteo et al., (1992) demonstrated that AD patients exhibited a marked impairment under divided attention conditions relative to directed attention conditions. Martin, E. et al., (1995) found that HIV+ individuals are impaired on tasks involving controlled attentional processes, in which the subject is biased to allocate more attention to one level of the hierarchical stimulus than to the other.

Neuropsychological studies also tend to support perceptual contributions to global/local analysis by demonstrating differences in visuospatial processing among unilateral brain-damaged patients (e.g., Delis et al., 1986). It appears that neuropsychological evidence is more consistent in demonstrating hemispheric functional asymmetries than studies employing normal controls. It may be that each hemisphere functions differently in an intact brain than in an injured brain. Following injury, the role of the uninjured hemisphere may become more specialized, thus yielding differences in hemispheric functioning that are more apparent than those seen by studying normal control subjects.

Regarding the second hypothesis, the findings from this study do not support the claim that the left hemisphere is more adept at local processing and the right hemisphere is more efficient at global analysis. Unlike previous investigations (Christman, 1993; Martin 1979a; Sergent, 1982), no significant differences were found between visual fields. In fact, response times were very similar in both visual fields and even a trend in the RVF/local and LVF/global direction was not detected. However, these results are in accordance with other previous investigations using the global/local paradigm to infer hemispheric differences (Alivisatos & Wilding, 1982; Boles, 1984; Van Kleeck, 1989). Methodological differences may account for some differences between these studies. For example, all of the studies except Sergent's (1982) used directed attention tasks in which subjects were explicitly told to attend to a particular level. Sergent employed a divided attention task in which both levels were relevant to the subject. Interestingly, Sergent's results imply that differences between the hemispheres are more pronounced when subjects are required to use more "natural" attentional strategies. Although Martin (1979a) found a left hemisphere advantage for local processing using a directed attention task, her results may be confounded since she asked subjects to name their responses, a task which may bias faster left hemisphere processing.

Christman's (1993) results may be confounded by spatial uncertainty as many different stimulus locations were used.

With regard to the global precedence effect, the findings from the present experiment extend those of previous investigations (Alivisatos & Wilding, 1982; Boles, 1984; Martin, 1979a; Navon, 1977; Van Kleeck, 1989). Both aspects of global precedence were replicated: global targets were identified faster than local targets and identification of the global level interfered with identification of the local level, but not vice versa. These findings appear to be more robust than those regarding visual field/hemisphere differences.

The notion that stimuli in the LVF are presented to the right hemisphere and RVF stimuli are presented to the left hemisphere is the basis for visual hemifield studies. Accordingly, the rationale for using peripheral presentations is to ensure that information is directly received by only one hemisphere. However, this rationale is rarely made explicit. There is some suggestion that although cortical connections from nasal and temporal hemiretinae may overlap anatomically, they are dissociable functionally. Furthermore, it has been demonstrated that both foveal and extra-foveal inputs can result in functional separation of the hemispheres (Haun, 1978).

However, interpreting cerebral functional asymmetries with the global/local paradigm is somewhat more complex. In particular, it is difficult to ascertain the magnitude of the laterality effect because stimulus eccentricity tends to be confounded with visual acuity. Since visual acuity decreases with increasing distance from fixation (Young, 1982), it may be more difficult to discriminate the local (smaller) letters. In fact, some investigators have argued that peripheral presentations tend to favor global over local processing (Grice et al., 1983; Pomerantz, 1983). However, other investigations do not support this claim. Lamb and Robertson (1990) demonstrated that absolute size of the stimulus did not affect the speed with which global and local information were identified. In an earlier study, Lamb and Robertson (1988) showed that small letters were identified faster in the center than in the periphery only if they appeared in a hierarchical pattern but not if they appeared alone. The present experiment did not control for stimulus size and hence cannot rule out the possibility that global targets were identified faster because they were easier to see.

Although it may be possible to construct global/local stimuli that are equally complex, familiar and predictable, it is more difficult to equate these stimuli in terms of visual discriminability. Thus, because local letters are smaller than global letters, they may be more difficult to detect, especially the further they are presented in the periphery. This tends to be a problem inherent in global/local stimuli. Ironically, it is because of the simple, dual-level organization of these stimuli that the global/local paradigm is regarded as an elegant means of inferring hemispheric differences. Clearly, the issue of discriminability needs to be resolved before inferences about hemispheric differences can be made.

It is difficult to explain why both Martin (1979a) and Sergent (1982) found hemispheric differences in processing global/local stimuli simply on the basis of stimulus eccentricities. Whereas Sergent presented stimuli very close to center (1.4 °), Martin presented stimuli that were farther (2.8 °) away from fixation. Those studies that did not report any significant visual field differences, including the present study, employed stimulus presentations ranging from 1.65 ° to 3.3 ° from central fixation (Alivisatos & Wilding, 1982; Boles, 1984; Martin, 1979a; Van Kleeck, 1989). These discrepancies tend to support the claim that global/local processing is not solely dependent on lower-level sensory processes.

Several investigators have suggested that the analysis of hierarchically organized patterns is dependent on the differences in spatial frequency between global and local forms (Badcock et al., 1990; Kitterle, Christman, & Hellige, 1990; Kitterle, Christman, & Conesa, 1993; Lamb & Yund, 1993; Sergent, 1982; Shulman & Wilson, 1987). Specifically, it has been hypothesized that low spatial frequency channels are involved in the analysis of global forms whereas high spatial frequency channels are thought to analyze small, local forms. Therefore, the differences in global versus local processing may, in part, stem from differences in information processing by low versus high frequency channels.

In the present experiment, it could be that subjects attended to lower spatial frequencies of global letters more than the higher spatial frequencies of local letters, thereby facilitating global processing relative to local processing. Furthermore, as suggested by Sergent (1982), since the fovea is equipped with "high-acuity receptors" that are capable of transmitting information from high frequency channels, local letters may be processed faster if projected on the fovea. The present study used non-foveal presentations (i.e., 2.5 ° from fixation) which may explain the overall slower response times to local targets.

Conclusion

The role of attentional allocation in global/local analysis was explored in this experiment. While evidence supports the notion that global/local processing is mediated by attentional mechanisms, the present data do not support the claim that attentional mechanisms are lateralized. In other words, the data refute the possibility of attentional asymmetries in which one hemisphere favors global processing, while the other favors local processing. What the data do suggest, however, is that attentional mechanisms tend to favor global over local processing - in both hemispheres. Since attention is a complex phenomenon that cannot be reduced to a single neural substrate, it seems likely that attentional strategies are more widespread and involve both cerebral hemispheres.

The results from the present investigation did not yield any visual field differences, thus failing to support the left hemisphere/analytic and right hemisphere/holistic dichotomy. Whether differential hierarchical processing of global versus local information occurs may be obscured by the very nature of the global/local stimuli. Because visual acuity decreases with increasing distance from central fixation, local processing is affected more than global processing. This may explain the faster response times to global targets for both attention tasks. Furthermore, differences in spatial frequencies of global/local stimuli may account for the findings. This avenue of research should be further explored.

Evidence from neuropsychology has been more consistent than that from normal controls in supporting the analytic/holistic theory of hemispheric specialization. In general, studies of brain-injured patients have demonstrated that left-hemisphere patients are impaired in processing the local aspects of visual stimuli whereas right-hemisphere patients have difficulty with the global or overall configuration of visual stimuli. Current research tends to support the view that both attentional and perceptual processes contribute to global/local analysis as damage to different cortical areas may independently affect either of these processes. Future investigations should attempt to delineate the relative importance of perceptual and attention mechanisms in global/local processing, using normals and brain-injured individuals.

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APPENDIX A: Hierarchical Letters Used in this Experiment

In the directed attention condition, local attention trials included only the six stimuli whose local forms are "H" or "S". Global attention trials included only the six stimuli whose global shape is "H" or "S". All eight stimuli were used in the divided attention condition.

<u>consistent</u>

```
H    H  SSSSS
H    H  S
H    H  S
HHHHH   SSSSS
H    H      S
H    H      S
H    H  SSSSS
```

<u>conflicting</u>

```
S    S  HHHHH
S    S  H
S    S  H
SSSSS   HHHHH
S    S      H
S    S      H
S    S  HHHHH
```

<u>neutral: local</u>

```
HHHHH   SSSSS
H    H  S    S
H    H  S    S
H    H  S    S
H    H  S    S
H    H  S    S
HHHHH   SSSSS
```

<u>neutral: global</u>

```
O    O  OOOOO
O    O  O
O    O  O
OOOOO   OOOOO
O    O      O
O    O      O
O    O  OOOOO
```

APPENDIX B: Divided visual field studies employing global/local stimuli to infer functional hemispheric asymmetries [*]

Study	n	Apparatus	Stimuli	Stimulus Angle	Stimulus Present"	No. of Trials	Viewing Distance	Outcome
Navon (1977)	14	oscillo-scope	H, S, O	2.8 °	40 ms	288	50 cm	global precedence
Martin (1979a)	16	tachisto-scope	H, S, O	2.8 °	100 ms	144	50.8 cm	• RVF (LH) advantage for local letters - global precedence
Sergent (1982)	12	tachisto-scope	F, H, L, T	1.4 °	150 ms	270	?	• LVF advant for global (low freq), RVF advant for local (high freq) letter
Alivasatos & Wilding (1982)	40	tachisto-scope	varied	2.2 °	100 ms	48	52 cm	no VF effect - global precedence
Boles (1984)	16	tachisto-scope	A, H, I, T	2.2 °	150 ms	192	84 cm	no VF effect - global precedence
Exp. 2	16	computer	same	2.7 °	150 ms	768	50 cm	no VF effect
Lamb & Robertson (1988)	16	computer	H, S	2.7 °	100 ms	324	54 cm	faster RTs to central presentations
Exp. 2	16	computer	H, S	only central present"	100 ms	324	54 cm	faster RTs when locally directed
Exp. 3	16	computer	H, S	2.7 °	100 ms	324	54 cm	no effects of eye movements or mask
Van Kleeck (1989)	24	computer	H, S, O	1.65 °	100 ms	144	38 cm	no VF effect - global precedence
Christman (1993)	16	computer	E, H	1.6 °	100 ms	432	70 cm	• LVF advant for global letters
Present Study (1995)	**16**	**computer**	**H, S, O**	**2.5 °**	**100 ms**	**416**	**42 cm**	**no VF effect - global precedence**

• Studies that found a level x visual field interaction effect.

[*] Note: Navon (1977) and Lamb & Robertson (1988) did not intend to investigate hemispheric differences.

APPENDIX C: Characteristics of the Subject Sample

SUBJECT	SEX	AGE	EDUCATION	HAND	FAMILIAL LH	VISUAL ACUITY
1. C.M.	M	29	13	R	y - brother	ok
2. J.K.	F	26	14	R	no	ok - glasses
3. P.K.	M	29	20	R	no	ok - glasses
4. A.E.	M	40	16	R	no	ok
5. J.N.	M	23	14	R	no	ok - glasses
6. A.W.	F	21	15	R	no	ok
7. M.C.	F	19	14	R	no	ok - contacts
8. M.K.	F	23	17	R	no	ok - contacts
9. M.M.	M	27	15	R	no	ok
10. T.Y.	F	21	15	R	no	ok
11. J.M.	M	21	15	R	y - sister	ok
12. K.M.	F	34	16	R	y - father	ok
13. R.S.	F	22	17	R	y - mother	ok
14. W.K.	M	23	15	R	no	ok - glasses
15. L.M.	M	23	15	R	no	ok - glasses
16. S.L.	F	21	14	R	y - sister	ok - glasses

VITA AUCTORIS

Shemira Murji was born on July 25, 1969 in Mwanza, Tanzania. At the age of 7, she immigrated to Canada. In 1987, she graduated from Crescent Heights High School in Calgary, Alberta. Thereafter, she attended the University of Toronto where she obtained a B.Sc. degree in Neuroscience in 1992. Following this, she was employed as a research assistant at the Rotman Research Institute - a place which fostered her interests in neuropsychology. In 1993, she began her postgraduate studies in psychology at the University of Windsor. Currently, she is a candidate for a Master's degree in Clinical Neuropsychology. She also hopes to complete her doctoral degree in neuropsychology at the University of Windsor.