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Behavioral and physiological findings of gender differences in global-local visual processing

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Abstract

Hemispheric asymmetries in global-local visual processing are well-established, as are gender differences in cognition. Although hemispheric asymmetry presumably underlies gender differences in cognition, the literature on gender differences in global-local processing is sparse. We employed event related brain potential (ERP) recordings during performance of a global-local reaction time task to compare hemispheric asymmetries and processing biases in adult men ($n = 15$) and women ($n = 15$). Women responded more quickly to local targets while men did not differentially respond to hierarchical stimuli. ERP data indicated that women had P100 responses that were selectively lateralized to the left hemisphere in response to local targets and N150 responses that were smaller for global targets. They also had P300 responses that were greater following local stimuli. The physiological data demonstrate that male-female performance differences arise from biologically based differences in hemispheric asymmetry. Findings are discussed in the context of existing literature regarding gender differences, hemispheric specialization, and the role of stimulus characteristics.
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1. Introduction

Gender differences in cognition are now well established. Men typically perform better on tests of quantitative problem solving and spatial ability than women, while women tend to perform better on verbal tasks (Halpern, 1992; Herlitz, Nilsson, & Backman, 1997). In particular, women excel at verbal memory (Basso, Harrington, Matson, & Lowery, 2000; Kramer, Delis, Kaplan, O'Donnell, & Prifitera, 1997), verbal problem-solving, articulation speed, word list generation, grammar, and color-naming (Kimura, 1992) tasks. Men typically demonstrate a distinct advantage on a broad range of visual tasks, including visual–spatial orientation (Basso & Lowery, 2004).

While gender differences in verbal vs. visual spatial ability may reflect culturally instilled sex role preferences, they also suggest specific differences in those cognitive functions that are theoretically influenced by hemispheric asymmetries. The emergence of advanced electrophysiological and brain imaging methods has provided increasing evidence that functional differences in brain activity may underlie gender differences in cognitive performance. For example, on a visual orientation task in which men outperformed women, Gur et al. (2000) found that women had less lateralized right hemisphere activation than men. This association between increased right hemisphere activation and better visual–spatial processing raises the possibility that sex differences in higher order cognitive functioning are founded on differences at earlier stages of visual information processing. Early obligate responses carry no sex role stereotypes since they involve little conscious awareness, making behavioral and physiological measures ideal for ascertaining potential gender differences.

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A fundamental question of visual attention and perception is whether an entire visual scene is decomposed into or constructed by its parts. By presenting hierarchically constructed stimuli involving an overall configuration (global level) comprised of elemental details (local level), Navon (1977) concluded that global aspects of a stimulus are analyzed before its local features. Specifically, Navon demonstrated faster reaction time (RT) to global rather than local targets, concluding that perceptual processing is organized in a temporal manner, progressing from a global to a local level. Such a "global precedence" has been supported by subsequent research (Proverbio, Minniti, & Zani, 1998; Shedden & Reid, 2001; Tanaka & Fujita, 2000). Taken together, neuropsychological (Delis, Kiefner, & Fridlund, 1988; Lamb & Robertson, 1988; Lamb, Robertson, & Knight, 1989; Robertson, Lamb, & Knight, 1988) and imaging (Fink et al., 1997a; Heinze, Hinrichs, Scholz, Burchert, & Mangun, 1998; Lamb & Robertson, 1988; Martinez et al., 1997; Proverbio et al., 1998; Weber, Schwarz, Kneifel, Treyer, & Buck, 2000) data suggests that the right and left hemispheres more efficiently process global and local stimuli, respectively.

The global-local paradigm is a useful tool for assessing hemispheric asymmetry, with applications across a range of psychological phenomena including spatial perception (Delis et al., 1992; Kramer, Kaplan, Blusewicz, & Preston, 1991), spatial orientation (Basso & Lowery, 2004), emotion (Basso, Schefft, Ris, & Dember, 1996), and neuropsychiatric disorders (Granholm, Cadenhead, Shafer, & Filotero, 2002; Granholm, Perry, Filotero, & Braff, 1999). The global-local paradigm may, therefore, be useful in the study of gender differences, since hemispheric asymmetry is one factor that theoretically underlies the differential cognitive strengths of men and women. For example, as the brains of men are typically more lateralized than those of women (Kolb & Wishaw, 1996), women should theoretically demonstrate more symmetrical processing of global-local hierarchical stimuli relative to men (Kramer, Ellenberg, Leonard, & Share, 1996). Nonetheless, relative global and local processing biases would be expected in men and women, respectively, consistent with their differential performances on respective right (visual–spatial) and left (verbal) hemisphere tasks.

To our knowledge, only one study has employed a global-local paradigm to directly examine visual processing differences between the sexes (Kramer et al., 1996), and this study was conducted in a pediatric population. In Kramer et al.'s (1996) study, boys demonstrated a relative global processing bias while a relative local processing bias was apparent in girls. A less direct assessment of processing biases in children revealed that males tend to approach visual-construction tasks from a configural (global) perspective while females typically employ an elemental (local) approach (Waber, 1977). Taken together, it appears that global-local processing biases are associated with hemispheric asymmetries early in human life. In an indirect study of gender and global-local biases in adults, men outperformed women on a spatial orientation task, and

increased scores on this task were associated with a relative global processing bias (Basso & Lowery, 2004). To clarify the relationship between global-local processing biases and gender, a direct examination is warranted in an adult population.

The use of event related brain potential (ERP) recordings to examine global-local perception provides "online" measurement of the processing of hierarchical information (Johannes, Wieringa, Matzke, & Münte, 1996), potentially elucidating the relationship between global-local processing and spatial–temporal brain activation. A growing literature has conjointly employed ERP technology and the global-local paradigm to study hemispheric asymmetries (Evans, Shedden, Hevenor, & Hahn, 2000; Han et al., 1999; Han, Fan, Chen., & Zhuo, 1999; Heinze and Munte, 1993; Johannes et al., 1996; Yamaguchi, Yamagata, & Kobayashi, 2000), supporting both global precedence (e.g., Proverbio et al., 1998) and parallel processing (e.g., Evans et al., 2000) models of hierarchical perception. While some studies support a right-hemisphere advantage for processing global configurations and a left-hemisphere preference for processing local details (e.g., Evans et al., 2000; Yamaguchi et al., 2000), others have not (e.g., Johannes et al., 1996). In particular, Johannes et al., supported a left hemisphere bias for processing both global and local aspects of a stimulus, and they suggest that their findings reflect the complex interaction between multiple brain structures.

Prior studies of visual processing biases have employed selective attention tasks in which participants' attention is directed towards a specific hierarchical level (e.g., Weissman, Mangun, & Woldorff, 2002). In contrast, our goal was to investigate potential sex differences in electrophysiological responses using a divided-attention global-local paradigm, which is a more naturalistic design. Specifically, participants were instructed to respond to a single target letter, regardless of its global or local position. This paradigm permitted us to measure ERPs in addition to reaction times (RTs). This multi-method approach yields intermethod reliability data, and the inclusion of ERPs provides more valid information regarding the temporal nature of global-local processing than RT data alone (Heinze & Munte, 1993). The current study is the first to directly examine gender differences in global-local processing in an adult sample. The study's conjoint employment of ERP technology and a global-local paradigm permits examination of temporal and hemispheric characteristics that theoretically underlie gender differences in visual processing biases. We anticipated that women would demonstrate a local processing bias with greater response to local targets, with a converse relationship expected for men.

2. Method

2.1. Participants

Thirty healthy adults (15 men, 15 women) from the University of Pennsylvania's Schizophrenia Research Center

comprised the sample. All participants underwent comprehensive assessment including medical, neurological, and psychiatric evaluations (Structured Clinical Interview for DSM-IV, Non-Patient Edition; First et al., 1996). Participants with a history of neurological disorder, substance abuse, medical condition affecting brain functioning, or any history of Axis I or II diagnosis were excluded from the study. Men and women did not differ with respect to age ($t(28) = -.47$, $p > .10$; men mean = 29.80, $SD = 12.12$; women mean = 31.93, $SD = 12.52$), educational attainment ($t(28) = -.64$, $p > .10$; men mean = 16.50, $SD = 1.99$; women mean = 16.87, $SD = 1.99$), or handedness ($\chi^2(2) = .67$, $p > .10$). The majority of men and women were right handed (80%). Of the men, two were left-handed (13.6%) and one was ambidextrous (6.7%). Of the women, one was left-handed (6.7%) and two were ambidextrous (13.3%). Prior to their participation, subjects were provided with a description of the study and informed consent was obtained.

2.2. Materials

2.2.1. Global-local stimuli

Letters 'E,' 'T,' 'H,' and 'U' comprised the visual stimuli (see Fig. 1). White letters were displayed against a blue background. Large letters (global stimuli) composed of smaller letters (local stimuli) appeared in the center of the screen one at a time for a duration of 500 ms. The global letters were 14.61×9.53 cm, and the local letters measured 3.02×1.27 cm. Distance to the screen was 150 cm. Maximum visual angle subtended by any stimulus was thus 5.5°. This stimulus size was designed to avoid selective global or local attention biases. Faster responses to local targets have been associated with maximum visual angles greater than 6° (Lamb & Robertson, 1989), and global response biases have been associated with visual angles of 2 or fewer degrees (Heinze & Munte, 1993). To counter expectancy effects, the inter-stimulus interval varied between 3 and 4 s.

2.3. Procedure

2.3.1. Global-local task

The procedure was administered individually. Participants were seated comfortably in front of a computer monitor and directed to fixate on the center of the screen.

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E    E    HHHHH    UUUUU
E    E    H            U
E E E E    HHHH        U
E    E    H            U
E    E    HHHHH        U

GLOBAL 'H'    LOCAL 'H'    DISTRACTER
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Fig. 1. Illustration of visual stimuli, showing examples of a global target, a local target and a distracter.

They were instructed to minimize eye movement to avoid excessive eye artifact. Stimulus presentation was controlled by Stim Software (Neuroscan, El Paso, TX, now known as Compumedics USA). Participants were informed that letters would be presented on the screen, and they were instructed to respond by pressing a response button with the right index finger every time an 'H' was perceived. The target letter 'H' appeared either at the global or local level but never appeared at both levels simultaneously. A total of 240 stimuli were presented in random order including 60 global targets, 60 local targets, and 120 distracters in which the 'H' did not appear. To familiarize the subjects with the task, five practice trials were provided. Behavioral responses and reaction time to targets were collected. Subjects were not instructed to attend preferentially to the global or the local stimuli. Rather, a naturalistic design was employed, in which subjects were presented with task salient information on either the global or the local level.

2.3.2. ERP recording

Scalp potentials were collected using a 64 channel tin cup ECI Electro-Cap Electrode System (Electro-Cap International, Eaton, OH). Standard electrode sites followed the International 10–20 System nomenclature (Jasper, 1958), and the left earlobe (A1) served as reference. An electrode site above Fpz and between F3a and F4a was used as ground. Electrodes placed above and below the left eye monitored vertical eye movements. Electrodes lateral to the outer canthi of the left and right eye measured horizontal eye movements. Impedances were below 5 kΩ at all electrode sites. Event-related potentials (ERPs) were recorded using two 32-channel SynAmp (Neuroscan, El Paso, TX, now known as Compumedics USA) amplifiers (gain: 1000; range 5.5 mV; bandpass filter settings 0.1–50 Hz). The ERP waveforms were continuously digitally sampled at 250 Hz, and were written to disk for offline post-processing.

2.3.3. ERP data processing

Eye movement artifact reduction was performed using an automated correction algorithm (Semlitsch, Anderer, Schuster, & Presslich, 1986). The time series data were then separated into individual trial epochs beginning at 200 ms prestimulus and extending to 800 ms post-stimulus. The resulting individual trial waveforms were then averaged separately for global target, local target, and distracter stimuli. All averaged waveforms were baseline corrected relative to the 200 ms prestimulus interval. Fig. 2 illustrates the grand average waveforms for men and women across multiple electrode sites.

The multi-channel averaged ERP data were reduced to single component waveforms by applying singular value decomposition (SVD) to specified time intervals centered around each subject's peak component activity. In contrast to typical peak detection methods that compare measures at a specified channel, SVD does not assume that the scalp topography of a given component is uniform across subjects

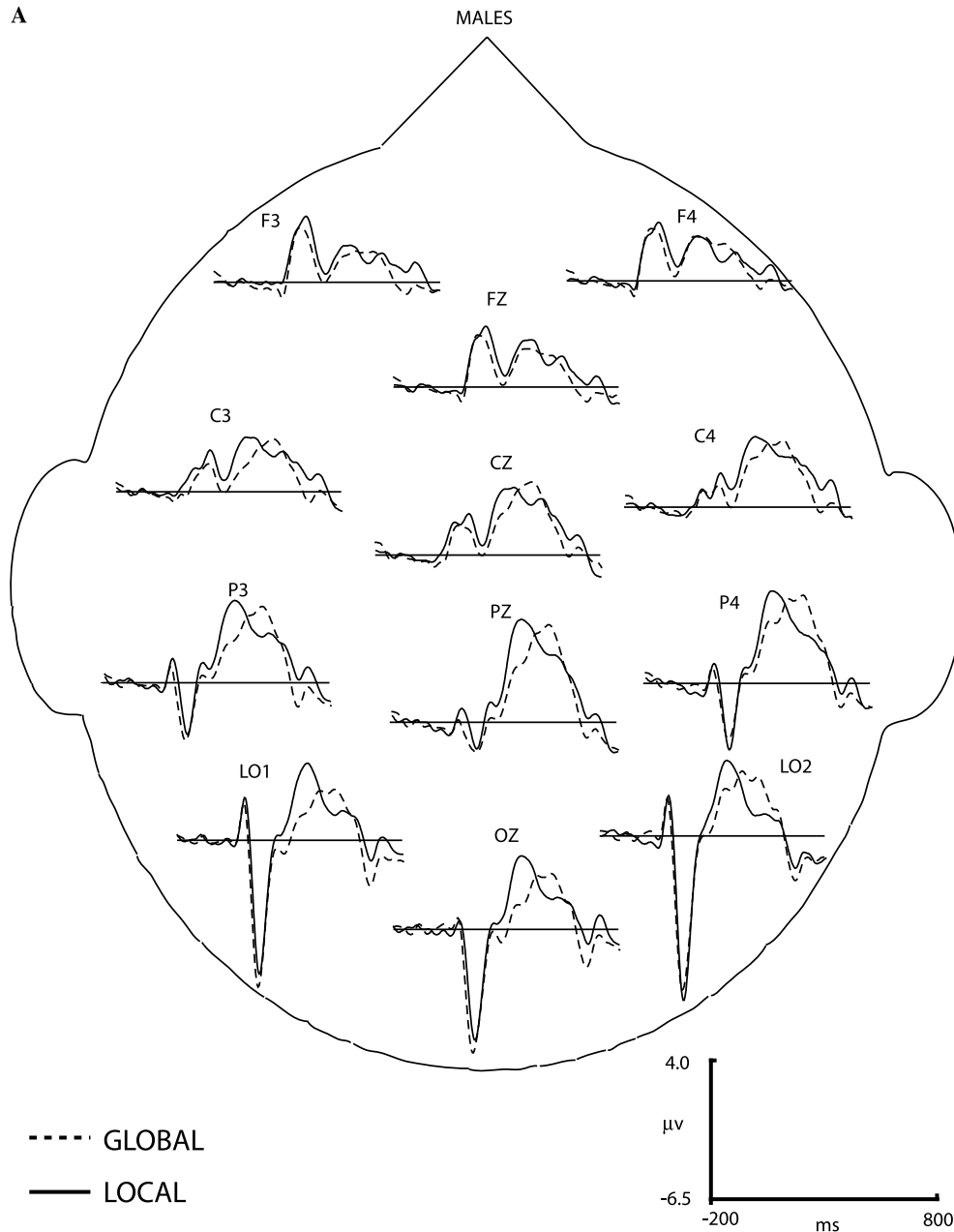**A**

MALES

- - - - GLOBAL

——— LOCAL

Fig. 2. Grand average waveforms at multiple scalp electrode sites. Waveforms are presented separately for men (A) and women (B) for the local (solid) and global (dashed) target conditions.

and conditions. It also takes advantage of the correlation of evoked activity across electrodes to more effectively separate signal from noise (Cardenas, Yingling, Jewett, & Fein, 1995). Separate waveforms were extracted for the P100 and N150 components of early visual processing, and for the endogenous P300 component indexing subsequent cognitive processing. Peak latencies and amplitudes were then determined from these component waveforms, separately for each subject and experimental condition. For each of the three ERP components of interest, the mean fractional variance explained by a single SVD component, across all subjects, was as follows: $P100 = 0.91 \pm 0.08$; $N150 = 0.94 \pm 0.06$; $P300 = 0.98 \pm 0.02$. These values, which indicate

that an individual component could explain over 90% of the multi-channel activity within each time interval, validate the use of the SVD as a decomposition method.

In addition to a component waveform, the SVD analysis outputs a standardized weight for each electrode on the scalp, indicating the contribution of that electrode to the extracted single component waveform. The electrode weights associated with each component thus represent a normalized topographic map, which provides a visual representation of the scalp distribution of the electrical activity of the component for each subject. These electrode weights can be used to test for topographic differences in ERP responses across subject groups or experimental conditions.
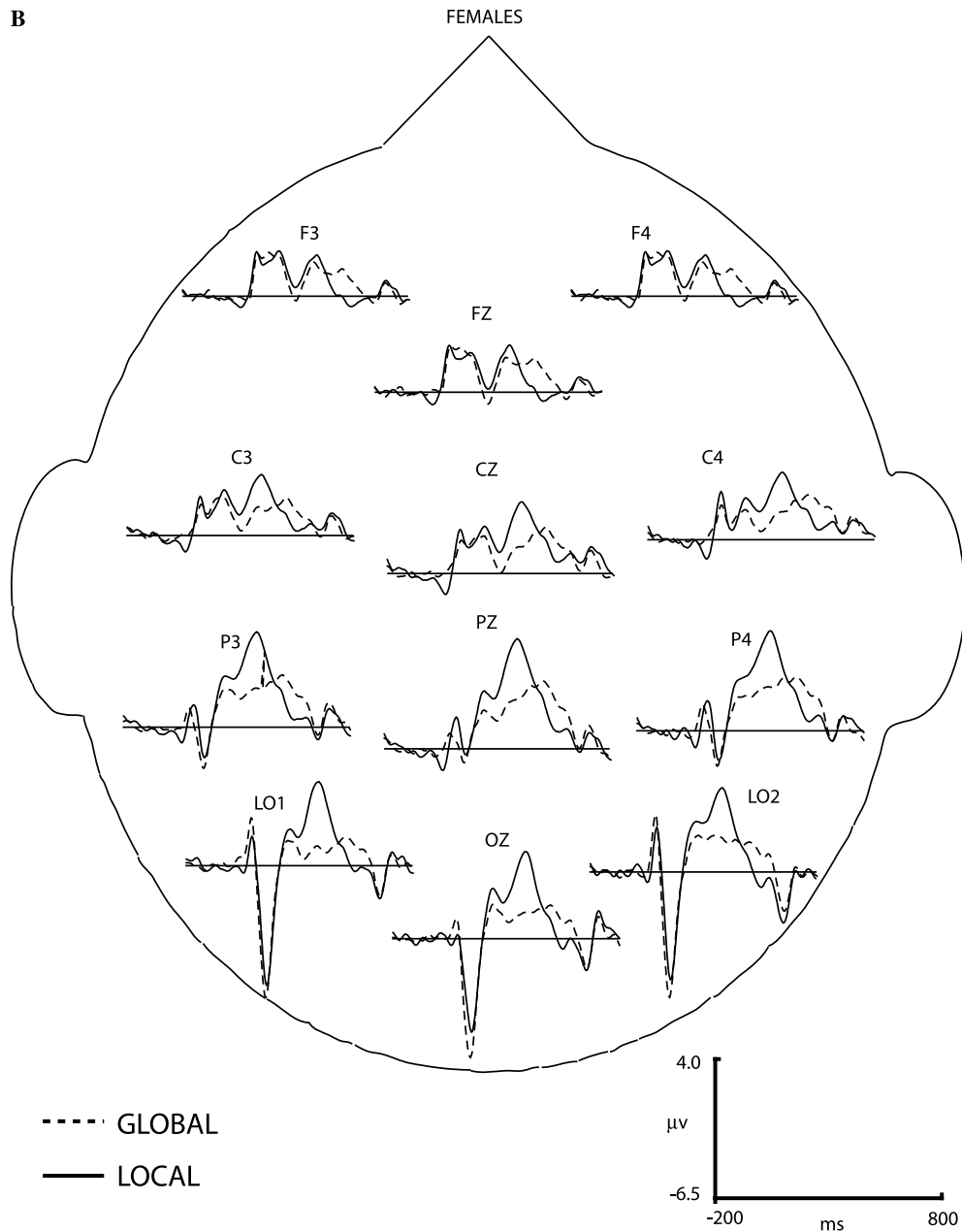
Fig. 2. (*continued*)

2.3.4. Statistical analysis

Measures of performance speed (median reaction time) and accuracy (total number of correct responses) were analyzed using repeated measures multivariate analysis of covariance (MANCOVA), with gender as a between-subjects factor and condition (global vs. local) as a within-subjects factor. Age served as a covariate, as reaction time is potentially affected by age (e.g., Oken, Kishiyama, Kaye, & Jones, 1999; Roux & Ceccaldi, 2001). Because of the nearly complete absence of false positive responses by all participants, distracters were excluded from the performance analyses. ERP measures were analyzed similarly, with gender as a between-subjects factor and condition (global, local, or distracter) as a within-subjects factor. As age

potentially affects ERP interpretation, and given that Pearson product moment correlations revealed significant associations between age and ERP measures, age served as a covariate. Separate analyses were conducted for the amplitude and latency of each of the three ERP components (P1, N150, and P300).

Topographic differences in component activity were evaluated by MANCOVA with the normalized electrode weights as the dependent measures, gender as a between-subjects factor, and condition (global, local, or distracter) and electrode site as within-subjects factors. Gender differences in response topography, in this case, were indicated by significant group $\times$ electrode or group $\times$ condition $\times$ electrode interactions.

All analyses were conducted for both the entire sample ($N = 30$) and for right-handed subjects only ($N = 24$). There were no differences in significant outcome measures between these two data sets and results are reported only for the entire sample ($N = 30$). Statistical significance was expressed at the $p < .05$ level.

3. Results

3.1. Performance data

The analysis of reaction time revealed a significant effect of stimulus condition [$F(1,27) = 18.66$, $p < .001$]. Overall, local targets were responded to more quickly than global targets. There was also a condition × gender interaction [$F(1,27) = 13.10$, $p < .01$]. Men responded in a similar manner to both global and local targets, and exhibited no significant differences across the two conditions (global reaction time mean = 643 ms, $SD = 125$; local reaction time mean = 650 ms, $SD = 121$; $F(1,27) = 0.80$, $p = .38$). Women, in contrast, had significantly faster responses to local targets (global reaction time mean = 702 ms, $SD = 99$; local reaction time mean = 663, $SD = 104$; $F(1,27) = 17.92$, $p < .001$). Finally, there was a condition × age interaction [$F(1,27) = 13.82$, $p < .001$], with reaction times to local targets increasing more than reaction times to global targets. There were no significant gender, condition, or age effects for response accuracy. Table 1 summarizes median global-local reaction time and mean performance accuracy by group.

Table 1
Behavioral performance measures (mean ± SD)

	Male	Female
Median reaction time (ms)		
Global target	643 ± 125	702 ± 99*
Local target	650 ± 121	663 ± 104*
# Correct responses		
Global target	58.1 ± 2.8	56.6 ± 4.1
Local target	58.9 ± 1.6	55.8 ± 4.9

* Female global vs. local, $p < .001$.

3.2. Event-related potentials

Mean amplitudes and latencies of the individual ERP components, for each experimental condition, are presented separately for men and women in Table 2.

3.2.1. Visual P1

There were no significant main or interaction effects of gender, age, or condition on either P100 latency or amplitude. There was, however, a significant gender × electrode interaction, indicating a gender-related difference in the topography of the P100 response [$F(59,1416) = 1.39$, $p < .05$]. There was also a significant gender × electrode × condition interaction [$F(118,2832) = 1.26$, $p < .05$], indicating that gender differences in topography were condition dependent. In individual contrasts, there was a significant gender × electrode interaction for the local target [$F(59, 1475) = 2.45$, $p < .000001$], but not for either the global target [$F(59,1475) = 0.52$, $p = 1.00$] or the distracter [$F(59, 1475) = 0.97$, $p = .54$] condition. As illustrated in Fig. 3, women exhibited reduced left occipital activity in response to the local target stimulus. The mean standardized weights at the LO1 electrode site were $0.21 ± .12$ for men and $0.07 ± .17$ for women [$t(28) = 2.61$, $p < .05$]. Comparable values at the right hemisphere RO1 site were $0.20 ± .15$ for men and $0.17 ± .16$ for women [$t(28) = 0.61$, $p = .55$].

3.2.2. Visual N150

There were no main effects of gender, age, or condition on N150 amplitude. However, there was a significant gender × condition interaction [$F(2,54) = 3.24$, $p < .05$]. In individual contrasts, men and women differed significantly only in the amplitude of their responses to global targets (men > women) [$F(1,27) = 4.97$, $p < .05$]. Although there was a similar trend effect for local targets, this did not reach the threshold for significance [$F(1,27) = 3.26$, $p = .08$]. There were no group differences for distracters [$F(1,27) = 0.01$, $p = .92$]. For N150 latency, there was only an insignificant trend effect of gender [$F(1,27) = 3.32$, $p = .08$]; mean latency

Table 2
ERP component measures (mean ± SD)

	Amplitude					
	P100		N150		P300	
	Male	Female	Male	Female	Male	Female
Global target	15.24 ± 13.15	24.65 ± 17.22	52.02 ± 13.17[a]	36.52 ± 23.40[a]	45.48 ± 16.52	36.00 ± 10.29[b]
Local target	16.08 ± 12.81	20.81 ± 20.76	47.06 ± 15.11	34.21 ± 23.21	52.09 ± 22.48	55.58 ± 14.71[b]
Distracter	17.16 ± 7.50	21.10 ± 20.79	37.89 ± 26.55	37.43 ± 20.71	42.44 ± 19.77	33.02 ± 11.69[b]
	Latency					
	P100		N150		P300	
	Male	Female	Male	Female	Male	Female
Global target	94.4 ± 17.5	99.5 ± 18.4	160.5 ± 28.6	172.0 ± 29.1	405.9 ± 87.8	399.2 ± 97.8
Local target	97.1 ± 16.2	100.5 ± 16.7	164.8 ± 34.5	171.2 ± 31.1	394.7 ± 92.4	379.7 ± 62.4
Distracter	101.1 ± 15.6	100.0 ± 19.8	162.4 ± 36.7	170.9 ± 31.4	350.9 ± 54.2	357.1 ± 61.1

[a] Global N150, male vs. female, $p < .05$.
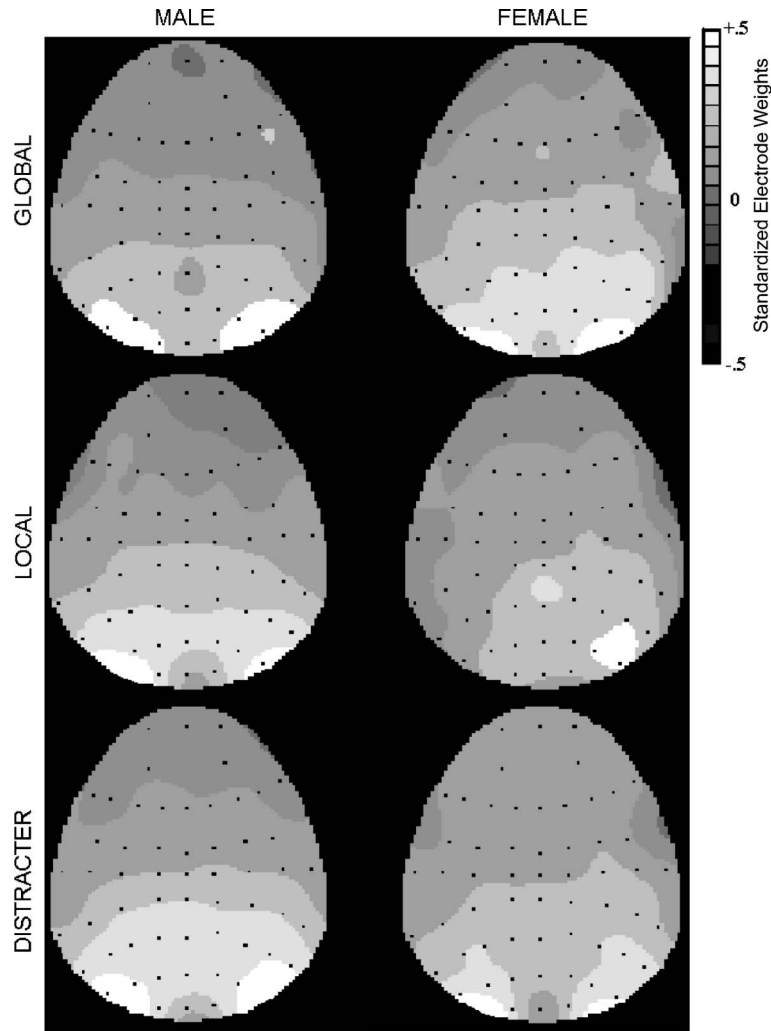[b] Female P300, global vs. local vs. distracter, $p < .00001$.

Fig. 3. Topography of the P100 response for men and women for the three different stimulus conditions. The response is maximum over occipital electrode sites and is bilateral, except for the female response to the local target, which is limited to the right side of the scalp.

was slightly faster for women. However, there were no latency differences across experimental conditions, and no gender or condition differences in scalp topography.

3.2.3. Visual P300

There was a significant main effect of condition on P300 amplitude $[F(2,54) = 8.79, p < .001]$. This reflected an overall greater response to local stimuli compared to either global $[F(1,27) = 23.72, p < .0001]$ or distracter $[F(1,27) = 35.76, p < .00001]$ stimuli. Global targets and distracters did not differ $[F(1,27) = 1.64, p = .21]$. There was also a trend towards a condition × age interaction $[F(2,54) = 2.73, p < .07]$. This reflected the fact that the response to local targets was more sensitive to increasing age $(r = -.31, p = .10)$ than was the response to either global targets $(r = -.24, p = .21)$ or distracters $(r = -.02, p = .91)$.

There was also a significant condition × gender interaction $[F(2,54) = 4.67, p < .01]$. In separate group analyses, there were no significant differences across experimental conditions for men $[F(2,26) = 2.94, p = .07]$, but a very strong condition effect for women $[F(2,26) = 19.13,$

$p < .00001]$. The amplitude of the P300 elicited by local targets greatly exceeded the amplitudes of the responses to either global targets or distracters. This can be readily seen, for local vs. global targets, in the raw ERP waveforms depicted in Fig. 2. The local response amplitude is much larger across all posterior electrode sites. Analysis of P300 latency showed a nearly significant main effect of condition $[F(2,54) = 2.95, p < .06]$. In paired contrasts, the latency of the global target response was delayed relative to either the local target $[F(1,27) = 7.63, p < .01]$ or the distracter $[F(1,27) = 23.03, p < .0001]$. However, there were no main or interaction effects of gender on P300 latency, and no gender or condition effects on scalp topography.

4. Discussion

The findings revealed that men and women perform differentially across behavioral and physiological measures of global vs. local processing. Specifically, reaction time data showed a delayed response to global targets in women. Since women typically excel at left-hemisphere tasks relative to

men (Halpern, 1992; Herlitz et al., 1997) and the left hemisphere is thought to be more efficient in processing the local level of hierarchical information (Kimchi, 1992; Van Kleeck, 1989), we anticipated that women would respond more quickly to local targets than global. While reaction time for men was slightly faster for global targets, they were actually more similar across the two conditions than women, an unexpected finding given that men typically demonstrate greater cerebral lateralization than women (Davidson, Cave, & Sellner, 2000; Gur et al., 2000; Kolb & Wishaw, 1996).

The P300 ERP data revealed gender differences that mirrored the behavioral findings. Although both men and women had greater P300 responses to the local targets, men had statistically similar responses across experimental conditions. Women, in contrast, exhibited a significantly greater response to the local targets than to the other types of stimuli. P300 amplitude is determined primarily by stimulus probability (which in this experiment was the same across all conditions), by controlled attentional processes, and by task salience (Johnson, 1984). These findings, therefore, suggest that women allocated greater attentional resources towards, and/or attributed greater task salience to local, as opposed to global, stimuli.

The etiology of this gender difference actually appears to originate earlier in the information processing stream than the level of stimulus evaluation indexed by the P300. Differential gender × condition effects were also observed at the time of both the P100 and N150 ERP components, which are obligate evoked perceptual responses that precede stimulus evaluation and discrimination. In particular, at the earliest level of a measurable response, the P100, women showed a strongly lateralized response to local stimuli that was not evident in men, or in response to other classes of stimuli. The topography of this response, with increased activity over the right hemisphere appears, at first glance, to be contrary to the expected left hemisphere lateralization for local stimuli. However, it is incorrect to assume that data recorded at a particular scalp location necessarily reflects activity of the underlying brain parenchyma. It has, in fact, been shown that the P100 response to visual hemifield stimulation is manifest on the scalp area contralateral to the stimulated hemisphere, rather than directly over the activated visual cortex. This reflects the spatial orientation of the underlying neural generators, which point towards the opposite occipital scalp surface (Celesia et al., 1982). So, we may understand our finding as indicating a strongly lateralized left hemisphere P100 response, in women, especially to local stimuli, as compared to a bilateral response in men. We would suggest that this reflects an overall left hemisphere bias in women, which is accentuated by a stimulus condition that preferentially entails left hemisphere processing. This underlying left hemisphere bias might be expected to interfere with global stimulus processing, which preferentially entails the right hemisphere. The fact that women had smaller N150 amplitudes for global stimuli is consistent with this underlying left hemisphere bias during early stimulus processing. This early bias is presumably the basis for the subsequent behavioral and cognitive ERP differences that we observed.

The observation of a differential response to global and local stimuli within the first 100 ms, in a divided attention task, is a new finding. Previous studies have reported global/local differences, during divided attention, for the N250 ERP component but not for the P100 (Heinze et al., 1998; Heinze & Munte, 1993). Although a differential P100 response was seen when attention was directed to either global or local stimuli (Heinze et al., 1998), this was attributed to differences in the size of the attended spatial region in the two conditions, not to differences in the actual response to global or local targets. The complex visual analysis required for such stimulus classification was thought to only occur later in the stream of visual processing.

This idea, that higher order visual processing cannot occur in the first 100 ms, has been challenged, recently, by a number of published reports. Two studies looking at facial recognition have demonstrated both that faces can be distinguished from other classes of stimuli within the first 100 ms (Liu, Harris, & Kanwisher, 2002), and that novel faces can be distinguished from previously seen faces as early as 50 ms post-stimulus (Seeck et al., 1997). Similarly, ERP responses to visually matched linguistic and nonlinguistic images (Schendan, Ganis, & Kutas, 1998), to solid color and hatched geometrical shapes (Mouchetant-Rostaing, Giard, Delpuech, Echallier, & Pernier, 2000) were found to diverge within the first 100 ms. Collectively, these findings demonstrate that differential responses to different classes of stimuli can be seen quite early in the visual processing stream and that our results for the P100 component are not unreasonable. It should be noted, in this regard, that we observed a differential P100 response only within our female subsample, while studies reporting the absence of this effect (e.g., Heinze et al., 1998) were conducted on predominantly male samples and did not separately examine the female subjects.

The P300 amplitude data also indicated that there was a greater response to local stimuli, independent of gender. While many studies have demonstrated a relative global processing bias for visual information (e.g., Navon, 1977; Proverbio et al., 1998), there are an array of factors that can potentially facilitate a local processing bias (Kimchi, 1992). In the current study, the apparent local processing bias might be attributable to design issues, stimulus characteristics, or both. For example, our experimental stimuli subtended 5.5° on the retina, which, while still below the 6° threshold, is approaching a size beyond which a local processing bias can be seen (Lamb & Robertson, 1989). Additionally, others (Grice Canham, & Boroughs, 1983; Pomerantz, 1983) have observed that a global processing bias tends to emerge with increased distance of visual stimuli from the fovea. That is, a global bias becomes more likely with peripheral stimulus presentation, and is less likely when stimuli are presented centrally, as in our design (Kimchi, 1992).

The observed overall local processing bias might also be attributable to the relatively sparse number of local elements comprising our global configurations. Spatial frequency has been observed to affect visual processing biases, with perceptual salience and low spatial frequency being associated with a local processing bias (Fink, Marshall, Halligan, & Dolan, 1998; Kimchi, 1992). Also, global precedence typically decreases as stimulus size increases (Lamb & Robertson, 1990; Lawson et al., 2002). In the current study, our local elements were relatively large relative to the global configuration, possibly increasing the salience of local elements. Another factor that warrants consideration is the verbal nature of our stimuli. The observed local processing bias might reflect the linguistic quality of the hierarchical configurations, especially as the left hemisphere is relatively more efficient in processing both language and elemental (local) information. Fink, Halligan, Frith, Frackowiak, and Dolan (1997b) observed a reversal of hemispheric asymmetry when letters versus other stimuli were used, with the left hemisphere preferentially processing letters and the right hemisphere specializing in other meaningful stimuli.

Another factor that must be considered is the difference between our relatively naturalistic divided attention design and the directed attention design employed in some previous studies. In our task, subjects were not instructed to attend preferentially to global or local stimuli. Rather, they looked for targets in both domains. The advantage of such a design is that the natural tendencies of the subjects are not modified by differences in task demands or instruction set. The disadvantage, relative to experimental designs in which subjects are instructed to pay attention only to global or local targets, is that global and local targets are not physically identical. The global bias typically observed in directed attention studies may, in part, reflect the differential advantage provided by having one's attention directed exclusively to the global features of a stimulus. It may be easier to ignore the local attributes while attending to global stimulus features, than it is to ignore global features while attending to local attributes.

It is not clear how the overall local bias of our experiment might have affected the gender differences that were the focus of this investigation. It may have attenuated the observed gender difference, by facilitating local processing in men. Alternatively, it may have preferentially facilitated the underlying tendency, in women, to focus on local stimulus aspects, thus increasing the difference across genders. While we cannot distinguish between these two possibilities, this does not mitigate the strength of our basic finding; women responded to local targets above and beyond whatever local bias was inherent in the experimental design.

There is one additional caveat that must be noted concerning our study design and results. Our global target, local target and distracter stimuli were not physically identical to each other. We cannot, therefore, entirely rule out the possibility that some of the differences we observed reflected physical differences in the stimuli, rather than stimulus classification differences. In retrospect, this problem could have been avoided by rotating the target letters in different experimental blocks. It is unlikely, though, that physical differences between stimuli had a substantial impact on the ERP response. Although global and local targets were physically distinct, they were equivalent with respect to brightness, contrast and the visual fields subtended by the global and local elements of each figure. Response differences due to other physical distinctions would necessarily be very subtle. In any case, such physical differences would only affect the earliest component of the ERP response, the P100. We would not expect either the N150 or the P300 to be affected, and both of these components exhibited robust interactions between gender and the global vs. local target distinction. The same is true for reaction time, which exhibited a similarly robust interaction between gender and condition. We would argue, therefore, that the gender differences we have reported cannot be attributed simply to differences in the physical attributes of the global and local targets.

To our knowledge, the current study is the first to directly examine gender differences in global-local processing in an adult population. It extends prior research conducted in children (Kramer et al., 1996) and suggests that gender differences in global-local processing persist into adulthood. Moreover, we provide behavioral (RT) and physiological (ERP) data that concurrently support a local processing bias in women, increasing the validity of this finding. Physiological findings also suggest that gender differences in global-local processing reflect differences in early lateralized visual stimulus processing between men and women. Collectively, the findings support and provide a biological basis for differential hemispheric asymmetries between men and women, which was previously suggested by neuropsychological findings.

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