A Critical Look at the Findings of Sergent (1982)

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Abstract

It is widely believed that local and global levels of visual stimuli are better processed in the left and right cerebral hemispheres, respectively. One classic explanation for this observation is the spatial frequency hypothesis proposed by Sergent (1982), which states that the left hemisphere is more efficient at processing high spatial frequencies, whereas the right hemisphere is better with low spatial frequencies. Sergent tested this by measuring RTs for laterally presented stimuli (in the left and right visual fields) composed of high and low spatial frequencies and obtained results consistent with the hypothesis. We put Sergent's findings to the test by replicating her experiment; our first experiment was a direct replication of hers, while the second used the same procedure, but with different stimuli. Our results largely corresponded with those of Sergent, and the crucial interaction between visual field and spatial frequency was obtained in Experiment 1, but was qualitatively different from Sergent's. Possible explanations are discussed.

Keywords: spatial frequency; global/local processing; hemispheric differences; hierarchical stimuli; visual hemifield paradigm.

Introduction

Neuropsychological case studies with brain-injured patients, neuroimaging studies, and experimental research with healthy participants have shown that there are certain functional asymmetries in the left and right hemispheres of the human brain. (Springer & Deutsch, 2001). When it comes to visual perception, one of the most studied phenomena in the field of hemispheric asymmetries concerns the difference between the left and right hemispheres in their ability to process (1) global vs. local aspects and (2) categorical vs. coordinate spatial relationships of visual stimuli. Studies show that the left hemisphere (LH) is better at processing the details of a visual stimulus, whereas the right hemisphere (RH) is superior for processing its overall shape, patterns formed by Gestalt principles, etc. (Han et. al., 2002; Hellige, 1996; Ivry & Robertson, 1998; Van Kleeck & Kosslyn, 1989). Similarly, research has shown a LH advantage in processing distance-independent categorical spatial tasks (e.g., "Is the dot to the left or right of the vertical line?"), and a RH advantage for spatial tasks that require relative- or absolute-distance spatial judgments (e.g., "Which dot is closer to the vertical line?"; Hellige & Michimata, 1989; Jager & Postma, 2003; Kosslyn et. al., 1989, 1994).

An early attempt to explain some of the hemispheric asymmetries was made by Sergent (1982) who proposed that the global/local effect was due to hemispheric differences in the capacity to process different spatial frequencies.[1] According to this hypothesis, the LH advantage for local stimuli emerges because the LH is better at processing high spatial frequencies (HSF), whereas the RH global advantage is due to its efficiency in processing low spatial frequencies (LSF). Attempts to verify or falsify this hypothesis have been rather controversial. Some neuroimaging and neuropsychological studies support the LH-HSF/RH-LSF asymmetry (e.g., Han et. al., 2001; Mecacci, 1993; Peyrin et. al., 2004, 2006a; Woodhead, et. al., 2011), whereas others show results partially or entirely inconsistent with it (e.g., Grabowska et. al., 1989; Fink et. al., 1997, 1999). Studies with healthy participants which use the visual hemifield paradigm yield similarly mixed results, with some research consistent (Hübner, 1998; Peyrin et. al., 2006b; Proverbio et. al., 1997; Van Kleeck & Kosslyn, 1989) and other inconsistent (Blanca & Lopez-Montiel, 2009; Evert & Kmen, 2002) with the hypothesis.

Yovel, Yovel, & Levy (2001) present a good meta-analysis of studies that used the visual hemifield paradigm with hierarchical stimuli. These are mostly Navon-type letters (large letters composed of small letters; Navon, 1977). The basic idea behind those studies is that when such a stimulus is presented in the left (LVF) or right (RVF) visual field, the response times (RT) and error rates should show a LVF advantage when the response is given based on the large letter and a RVF advantage when it is given based on the small letters.[2] Despite the theoretical predictions, Yovel et. al. found that studies confirming them are outnumbered by those that don't find a significant visual field (VF)×stimulus type interaction (i.e., more studies failed to find one or both of the LVF-LSF/RVF-HSF advantages).

[1] This hypothesis has later been used to explain the categorical/coordinate spatial relationship asymmetry as well (Ivry & Robertson, 1998).

[2] Visual input to one of the VFs is initially received and processed by the contralateral hemisphere (Beaumont, 1983).

Of the studies reviewed by Yovel et. al. which used the divided attention task, only Sergent (1982) found the significant interaction mentioned above. Another interesting observation is that, as a whole, the studies that reported significant results used fewer participants than those that didn't. Furthermore, the authors of this paper have previously employed Sergent's procedure along with an additional manipulation, but failed to obtain positive results. Sergent (1982) has been one of the most cited studies in the literature of hemispheric asymmetries for low and high spatial frequencies, yet, to our knowledge, there have been no attempts to replicate its findings. For those reasons, we decided that there is value in conducting a study with the same methodology, but significantly more participants, in order to gain more insight into the validity of the original study's results.

Sergent (1982) revisited

Sergent's study used Navon-type hierarchical letters projected to the LVF, RVF, and central visual field (CVF). The stimulus material consisted of 4 letters (for a total of 16 large-small letter combinations), 2 of which were targets and 2 non-targets. Twelve participants had to press a "yes" button if either the large or small letters were target, or a "no" button otherwise. The critical finding was that in the so-called "conflict conditions" in which a non-target large letter was composed of small target letters (L+S-), or vice versa (L-S+) a VF×stimulus type interaction was observed. That is, L+S- stimuli were responded to faster in the LVF/RH than in the RVF/LH, with the opposite result for the L-S+ condition (for the full results, see Fig. 2a). These results were interpreted in light of the spatial frequency hypothesis, i.e., that the LH is superior for HSF (small letters), whereas the RH shows an advantage for LSF (large letters).[3]

In Experiment 1, we use nearly the same procedure but with significantly more participants.

Experiment 1

Method

Participants

Forty-one volunteers and New Bulgarian University students (21 men and 20 women, aged 19-42) took part in the experiment for course credit. All were right-handed and with normal or corrected-to-normal vision. Their visual acuity was tested by presenting 4 small letters (the same as those used in the experiment) four times each in the RVF, CVF, and LVF, which they had to identify. All participants could identify most of the letters presented, deeming them fit to participate in the study.

[3] Sergent proposed that since the large and small letters are of equal complexity, they should differ only on the spatial frequency dimension.

Stimulus Material and Apparatus

The stimuli were large letters composed of small letters. The letters used were Н, С, Т и Р from the Cyrillic alphabet (analogues of the English letters N, S, T, and R), the combinations of which add up to a total of 16 stimuli. The letters were chosen to visually resemble the ones in Sergent's study, which were H, L, T and F (L was replaced with C and F was replaced with P). In our study the target letters were H and C (Fig. 1).

Large letters subtended visual angles of 2.08°×1.36° and small letters subtended angles of 0.23°×0.16°. The stimuli were black and were presented against a white background using the E-Prime software package on a 19" monitor (refresh rate of 200 Hz) of a Samsung SyncMaster 959 NF. The stimuli were presented in the LVF, CVF, and RVF. In lateral presentations, the center of the stimulus appeared 1.4° to the left or to the right of the fixation cross.

Design and Procedure

Participants were led into an experimental booth and introduced to the experiment by signing a consent form with general information about it. They were asked about handedness and tested for visual acuity. Instructions were given with emphasis on the importance of speed and accuracy of responses. Each trial began with the appearance of a fixation cross for 1500 msec, followed by a stimulus appearing for 150 msec in the LVF, CVF, or RVF, a 2000 msec response window (which terminated when participants pressed one of the response buttons), and a 2000 msec intertrial interval. Participants had to determine whether the stimulus contained either H or C or both by pressing a "yes" key if it did and a "no" key if neither level contained a target letter. The hand for response was counterbalanced across participants.

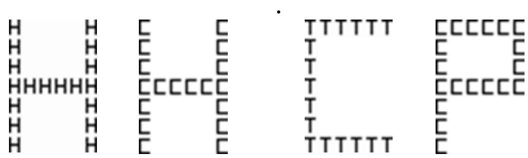
The experimental procedure began with a practice session, consisting of 36 trials with feedback on response accuracy, followed by the experimental session, consisting of five blocks of 72 trials for a total of 360 trials. The duration of the entire session was about 35 minutes, with 4 breaks in between experimental blocks, during which participants took several seconds to rest their eyes.

Both independent variables were within-subject: (1) VF (left, central, right); (2) stimulus type (6 types; see Fig. 1). An equal number of positive (containing a target at at least one level) and negative (containing only non-target letters) stimuli were randomly presented in each VF (each of the 4 negative combinations was presented 3 times as frequently as the remaining 12 combinations).

Results and Discussion

Before performing any analyses on the RTs for the different conditions, we removed all incorrect responses. The average accuracy was 97% and no participants were excluded from further analysis based on low accuracy. We also removed all data points above or below 2.5 standard deviations from the mean for each participant (excluding 2.6% of the data). There was no main effect of the between-subject factors sex,

$t(39) = 0.175$, $p = 0.862$, and hand for response, $t(39) = 0.212$, $p = 0.83$, so all further analysis was collapsed over them.



L+S+ Id. | L+S+ N. Id. | L+S- | L-S+

L-S- Id. | L-S- N. Id.

Figure 1: Sample stimuli used in Experiment 1. Top left: positive, non-conflict stimuli with identical and non-identical large and small target letters; Top right: positive, conflict stimuli with a large target letter composed of small non-target letters, and a large non-target letter composed of small target letters. Bottom: negative stimuli with identical and non-identical non-target large and small letters. The C and P in our study replaced Sergent's L and F, respectively.

Figure 2b displays the mean RTs and standard errors for each condition. A repeated measures ANOVA revealed a main effect of VF, $F(2, 39) = 15$, $p < 0.001$, with about 20 msec faster latencies in the LVF and CVF compared to the RVF. There was also a main effect of stimulus type, $F(5, 36) = 37.984$, $p < 0.001$, with the L+S+ conditions having the shortest latencies, while the L-S- conditions had the longest latencies. Similar to Sergent (1982), we also found a main effect of identicity, $F(1, 40) = 41{,}977$, $p < 0.001$. That is, it took less time to respond to identical non-conflict stimuli (i.e., large targets made up of the same small targets and large non-targets made up of the same small non-targets), compared to their non-identical counterparts.

Next, we analyzed the conflict conditions, where we found a marginally significant difference in latencies. RTs were about 17 msec faster for L+S- than for L-S+, $F(1,40) = 3.548$, $p = 0.067$. This result is consistent with findings from the psychophysical literature, according to which LSFs are available to the visual system earlier than HSFs and are therefore processed faster (Breitmeyer, 1975; Breitmayer & Ganz, 1977; Kulikowski & Tolhurst, 1973; Vassilev, Mihaylova, & Bonnet, 2001).

The conflict conditions were most interesting in regards to Sergent's hypothesis, namely, that there should be a LVH-RH advantage for the L+S- (LSF) condition and a RVF-LH advantage for the L-S+ condition (HSF). That is, when the decision is based on the large letter, there should be a RH advantage, whereas the opposite result should hold when the decision is based on the small letters. Despite the overwhelming correspondence between Sergent's and our results, as seen in Figure 2a and 2b, we only found a LVF advantage for the large letters, but, critically, no RVF advantage for the small letters. In fact, the LVF was superior for both large and small letters. Nevertheless, we did find a significant two-way interaction between left/right visual fields and the L+S-/L-S+ conditions, $F(1, 40) = 34.742$, $p < 0.001$. This is mainly due to the difference between the LVF and RVF being smaller for the L-S+ condition; when the decision was based on the small letters, participants were significantly slower to respond when the stimulus appeared in the LVF (but not slower than the RVF). However, we don't consider this observation to be good support for the hypothesis. First, the case may be that there is a ceiling effect when it comes to RVF RTs for the L-S+ stimuli. Second, it is very difficult to draw strong conclusions from RT interactions which don't involve change in sign of the slope of latency curves across conditions, given that the relationship between task complexity and RT is not always linear. In other words, the interaction could have simply been due to task difficulty (since small letters are more difficult to process) and not because of hemispheric asymmetries related to processing different spatial frequencies.

Given the discrepancy between our results and the results obtained by Sergent, we decided to analyze the data from individual participants separately. Another incentive for doing so was based on the controversial results obtained from other studies using similar procedures. We found 12 participants (from a total of 41) whose data had the pattern consistent with Sergent's results (i.e., shorter RTs in LVF than RVF for the L+S- condition, and shorter RTs for RVF than LVF for the L-S+ condition). Their results can be seen in Fig. 2d. A comparison of those and Sergent's results reveal remarkably similar patterns (coincidentally, she also used 12 participants).

Given the conflicting results of previous studies, combined with our findings, we consider the possibility that there might be a yet undiscovered dimension on which people differ. That is, there may be individual differences when it comes to hemispheric asymmetries for spatial frequency processing. Hence, it might have been the case that Sergent (1982) obtained positive results due to an unrepresentative sample of participants from the general population. We do not find this explanation to be particularly appealing, however, since it is done post-hoc, rather than based on empirical or theoretical reasoning. It is also possible, though less likely, given our larger sample size, that it is *our* sample that was unrepresentative. For those reasons, we decided to conduct a second experiment with different participants, using the same procedure, but slightly different stimuli. Instead of using hierarchical letters, we used hierarchical shapes. The purpose of this was also partly exploratory. It is possible that using verbal

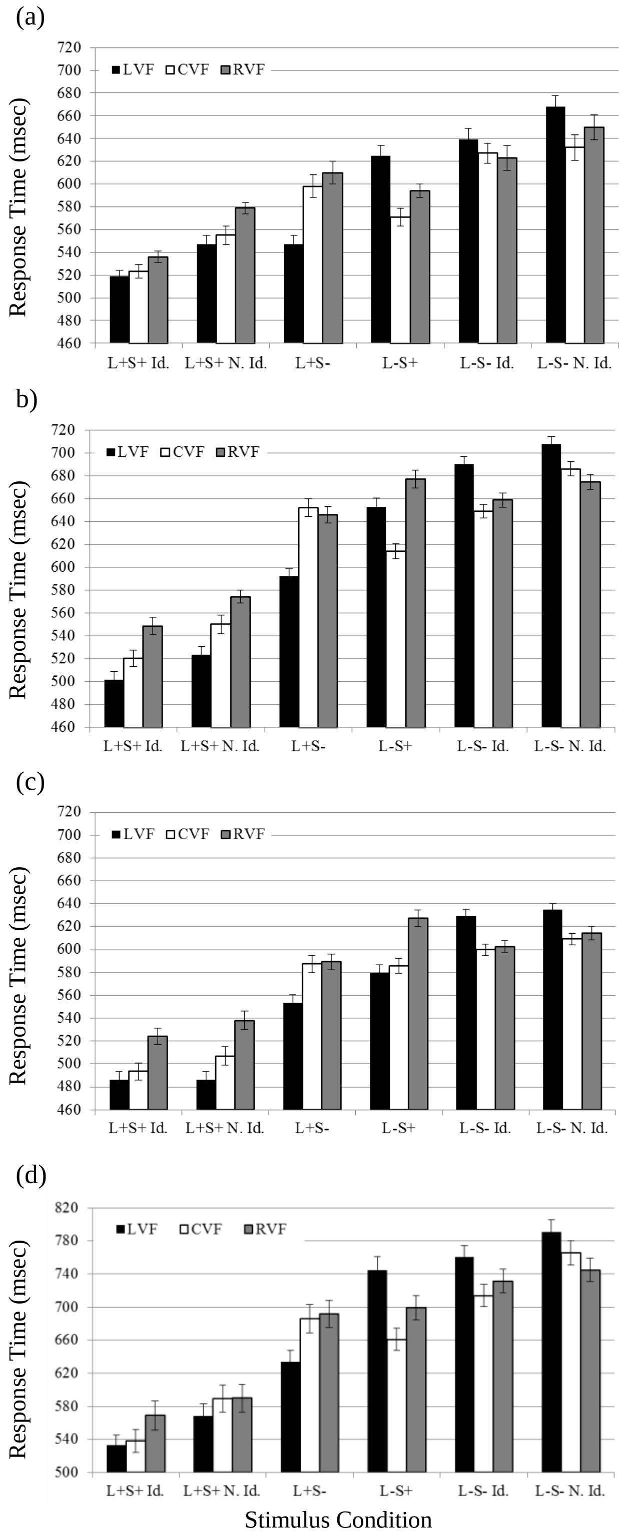


Figure 2: Mean RTs and standard errors for the six stimulus conditions for (a) Sergent (1982); (b) Experiment 1 of this study; (c) Experiment 2 of this study; (d) The data from 12 participants from Experiment 1 with results consistent with the spatial frequency hypothesis.

stimuli is a confounding factor, since it is a well-established fact that the LH plays a bigger role in language processing than does the RH (Springer & Deutsch, 2001). We wanted to see if using non-verbal stimuli would affect the results in any direction.

Experiment 2

Method

The method was identical to that of Experiment 1 with a few exceptions. Compound shapes were used, instead of compound letters (squares and triangles were target, whereas circles and crosses were non-target, see Fig. 3) and they subtended visual angles of 1.94°×1.94° for the large shapes, and 0.24°×0.24° for the small shapes. Thirty-nine right-handed volunteers and New Bulgarian University students (18 men and 21 women, aged 19-38) took part in the experiment for course credit (none of them had participated in Experiment 1).

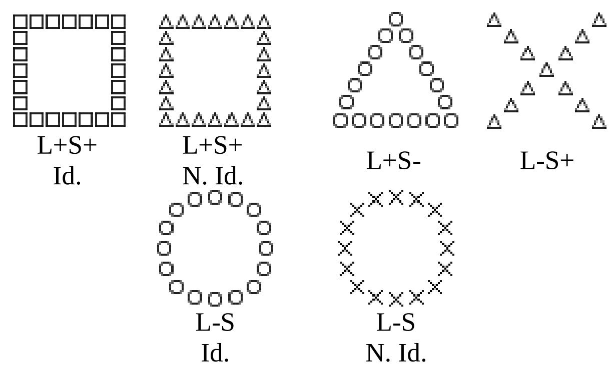


Figure 3: Sample stimuli used in Experiment 2

Results and Discussion

As in Experiment 1, we excluded all incorrect responses from further analyses. The average accuracy was 97% but one participant was excluded because of a large error rate (26%). As before, we removed all data points above or below 2.5 SD from the mean (excluding 2.8% of the data). There was no main effect of the hand for response factor, $t(36) = 1.036$, $p = .307$, but there was a marginally significant main effect of sex, $t(36) = 1.879$, $p = .068$, with men having a small average RT (by 63 msec) than women. The latter factor and the hand for response factor did not interact with any others in a theoretically meaningful or statistically significant way, so we collapsed all further analyses over them.

Figure 2c displays the mean RTs and standard errors for each condition. A repeated measures ANOVA showed a main effect of VF, $F(2, 36) = 32.054$, $p < 0.001$. As in Experiment 1, the latencies were about 20 msec faster in the LVF and CVF compared to the RVF. There was also a main effect of stimulus type, $F(5, 33) = 60.144$, $p < 0.001$, with the L+S+ conditions having the fastest latencies, while the L-S- conditions had the slowest latencies. Similar to Experiment 1, we also found a main effect of identicity, *F*(1,

37) = 9.743, $p = 0.003$, and a large letter advantage, $F(1, 37) = 16.605$, $p < 0.001$.

No significant visual field-stimulus type interaction was obtained, $F(1, 37) = 1.25$, $p < 0.269$, but we still observed a LVF-RH advantage for both large and small shapes, and no RVF-LH advantage whatsoever for small shapes. As in the previous experiment, these results run counter to Sergent's findings. Unlike in the previous experiment, in this one only two of 38 participants exhibited similar patterns to the ones Sergent reported. Our results are also inconsistent with some of the studies reporting global/local or LSF/HSF interactions with VF presentations (Gier et. al., 2010; Hübner, 1998).

General Discussion

Our experiments revealed several consistent findings. First, participants were faster as a function of both stimulus type and stimulus identity. That is, they were fastest to respond to a stimulus if both the large and small letters were target, slower when only one of the levels was target, and slowest when neither level was target; they were also faster to respond when the two levels were represented by the same letter or shape. In our interpretation, this is consistent with a model of parallel processing of the two levels where processing is facilitated when the global and local levels are composed of the same letters/shapes and when they're both either target or non-target. Therefore, when both levels are identical, it is more likely that at least one of them will evoke neural mechanisms that will lead to the proper response. Other studies have also shown evidence supporting the parallel processing of global and local levels of hierarchical stimuli (e.g., Hübner, 1997).

Another result of our experiments that is consistent with the literature is the idea that LSF are available to the visual system earlier than HSF. This phenomenon has been explained by the differences between the magnocellular and parvocellular visual pathways. They correspond to the *transient* and *sustained* channels described by Breitmeyer (1975), Breitmayer & Ganz (1977), and Kulikowski & Tolhurst (1973). The magnocellular pathway is most sensitive to LSH and high temporal frequencies (HTF), whereas the parvocellular pathway is most sensitive to HSF and low temporal frequencies (LTF). Furthermore, the magnocellular pathway is more efficient when it comes to the speed with which it propagates information to the higher cortical structures, which explains the earlier availability of LSF.

When it comes to the central hypothesis that was tested in this study, our results are inconsistent with those of Sergent (1982). We did not observe the critical interaction between spatial frequency and the visual field of stimulus presentation. At the same time, it could be argued that our results are consistent with the general trend observed in studies using the hierarchical stimulus/visual hemifield paradigms of finding mixed results. A somewhat interesting finding of our study was that 12 participants showed RT patterns for the conflict conditions that were in line with the hypothesis, but the remaining 29 participants did not. This might suggest that the conflicting results in the literature could be partially explained by individual differences on an unidentified dimension. Individual differences in processing time of the different levels (Evert & Kmen, 2002; Kimchi, 1992; Peyrin et. al., 2006b) are a possible candidate dimension. For example, Peyrin et. al. found that the classic hemispheric asymmetry for spatial frequency processing occurred only when the stimulus presentation time was 30 msec, whereas only a LVF/RH advantage emerged when the presentation time was 150 msec. Note that the latter is consistent with the results from our experiments. We propose that there may be between-subject, as well as within-subject, differences related to stimulus presentation time underlying these effects. Kimchi (1992) has done an overview of a variety of other factors that could influence the global/RH advantage in these studies, from the overall visual angle, sparcity, and number of local elements of the stimuli to goodness of form and attentional factors.

Finally, it is worth noting that some researchers argue that hierarchical stimuli are not a good way of manipulating spatial frequency (e.g., Peyrin et. al., 2003). Also, Yovel et. al. (2001) point to the salience of the hierarchical stimuli as a determining factor for obtaining the critical interaction. They observed a RH advantage for both global and local levels when stimuli were globally salient, as opposed to equally salient, in which case they observed a RH advantage for global letters and a LH advantage for local letters. The stimuli used in Sergent's and our study are of the globally salient type.

We conclude that, despite the large number of studies, there is still a significant amount of uncertainty surrounding the nature of hemispheric asymmetries for low and high spatial frequency processing. Further studies are needed to explore the underlying mechanisms, the different stimulus and procedural factors involved, as well as possible individual differences that are at play.

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References

Beaumont, J. G. (1983). Methods for studying cerebral hemispheric function. In A. W. Young (Ed.), Functions of the right cerebral hemisphere. *London: Academic Press*.

Blanca, M.J., & López-Montiel, G. (2009). Hemispheric Differences for Global and Local Processing: Effect of Stimulus Size and Sparsity. *The Spanish Journal of Psychology*, 12 (1), 21-31.

Breitmeyer, B. (1975). Simple reaction time as a measure of the temporal response properties of the transient and sustained channels. *Vision Research*, 15, 1411-1412.

Breitmeyer, B., & Ganz, L. (1977). Temporal studies with flashed gratings: Inferences about human transient and sustained channels. *Vision Research*, 17, 861-865.

Evert, D. L., & Kmen, M. (2003). Hemispheric asymmetries for global and local processing as a function of stimulus exposure duration. *Brain and Cognition*, 51, 115–142.

Fink, G. R., Marshall, J. C., Halligan, P. W., Frith, C. D., Frackowiak, R. S., & Dolan, R. J. (1997). Hemispheric specialization for global and local processing: the effect of stimulus category. *Proceedings of the Royal Society of London B*: Biological Sciences, 264(1381), 487–494.

Fink, G. R., Marshall, J. C., Halligan, P. W., & Dolan, R. J. (1999). Hemispheric asymmetries in global/local processing are modulated by perceptual salience. *Neuropsychologia*, 37, 31-40.

Grabowska, A., Semenza, C., Denes, G., & Testa, S. (1989). Impaired grating discrimination following right hemisphere damage. *Neuropsychologia*, 27, 259-263.

Gier, V., Kreiner, D., Solso, R., & Cox, S. L. (2010). The Hemispheric Lateralization for Processing Geometric Word/Shape Combinations: The Stroop-Shape Effect. The *Journal of General Psychology*, 137(1), 1–19.

Han, S., Waver, J. A, Murray, S. O, Kang, X., Yund, E. W., & Woods, D. L. (2002). Hemispheric asymmetry in global/local processing: effects of stimulus position and spatial frequency. *Neuroimage*, 17(3), 1290-9.

Hellige, J.B. (1996). Hemispheric asymmetry for visual information processing. *Acta Neurobiologiae Experimentalis*, 56, 485-497.

Hellige, J.B., & Michimata, C. (1989). Categorization versus distance: Hemispheric differences for processing spatial information. *Memory and Cognition*, 17, 770-776.

Hübner, R., (1997). The effect of spatial frequency on global precedence and hemispheric differences. *Perception & Psychophysics*, 59 (2), 187-201.

Hübner, R., (1998). Hemispheric Differences in Global/Local Processing Revealed by Same–Different Judgements. *Visual Cognition*, 5 (4), 457–478.

Ivry, R .B., & Robertson, L.C. (1998). The two sides of perception. *Cambridge, MA: The MIT Press.*

Jager, G., & Postma, A. (2003). On the hemispheric specialization of categorical and coordinate spatial relations: A review of the current evidence. *Neuropsychologia*, 41, 504-515.

Kimchi, R. (1992). Primacy of wholistic processing and global/local paradigm: A critical review. *Psychological Bulletin*, 2(1), 24-38.

Kosslyn, S. M., Koenig, O., Barrett, A., Cave, C. B., Tang, J., & Gabrieli, J. D. E. (1989). Evidence for two types of spatial representations: Hemispheric specialization for categorical and coordinate relations. *Journal of Experimental Psychology: Human Perception & Performance*, 15, 723-735.

Kosslyn, M. S., Anderson, A. K., Hillger, L. A., & Hamilton, S. E. (1994). Hemispheric differences in sizes of receptive fields or attentional biases? *Neuropsychology*, 8(2), 139-147.

Kulikowski, J. J. & Tolhurst, D. J. (1973). Psychophysical evidence for austained and transient detectors in human vision. *Journal of Physiology*, 232, 149-162.

Mecacci, L. (1993). On spatial frequencies and cerebral hemispheres: some remarks from the electrophysiological and neuropsychological points of view. *Brain and Cognition*, 22(2), 199-212.

Navon, D. (1977). Forest before trees: the precedence of global features in visual perception. *Cognitive. Psychology*. 9, 353– 383.

Peyrin, C., Chauvin, A., Chokron, S., & Marendaz, C. (2003). Hemispheric specialization for spatial frequency processing in the analysis of natural scenes. *Brain and Cognition*, 53, 278–282.

Peyrin, C. Baciu, M., Segebarth, C., Marendaz, C. (2004). Cerebral regions and hemispheric specialization for processing spatial frequencies during natural scene recognition. An event-related fMRI study. *Neuroimage*, 23, 698-707.

Peyrin, C., Chokron, S., Guyader, N., Gout, O., Moret, J., & Marendaz, C. (2006a). Neural correlates of spatial frequency processing: A neuropsychological approach. *Brain Research*, 1073, 1-10.

Peyrin, C., Mermillod, M., Chokron, S., & Marendaz, C. (2006b). Effect of temporal constraints on hemispheric asymmetries during spatial frequency processing. Brain Cognition, 62(3), 214-20.

Proverbio, A. M., Zani, A., & Avella, C. (1997). Hemispheric Asymmetries for Spatial Frequency Discrimination in a Selective Attention Task. *Brain and Cognition*, 34, 311-20.

Sergent, J. (1982). The cerebral balance of power: Confrontation or cooperation? *Journal of Experimental Psychology: Human Perception and Performance*, 8, 253–272.

Springer, S. P., & Deutsch, G. (2001). Left brain, right brain: Perspectives from cognitive science. *NY: W. H. Freeman and Company Worth Publishers.*

Van Kleeck, M., & Kosslyn, S. M. (1989). Gestalt laws of perceptual organization in an embedded figures task. *Neuropsychologia*, 27(9), 1179-1186.

Vassilev, A., Mihaylova, M., & Bonnet, Claude (2001). On the delay in processing high spatial frequency visual information: reaction time and VEP latency study of the effect of local intensity of stimulation. *Vision Research*, 42, 851–864.

Woodhead, Z. V., Wise, R. J., Sereno, M., & Leech, R. (2011). Dissociation of sensitivity to spatial frequency in word and face preferential areas of the fusiform gyrus. *Cerebral Cortex*, 21, 2307-2312.

Yovel, G., Yovel, I., & Levy, J. (2001). Hemispheric asymmetries for global and local visual perception: Effects of stimulus and task factors. Journal of Experimental Psychology: *Human Perception and Performance*, 27, 1369–1385.