Hemispheric asymmetry for visual information processing

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Abstract. The left and right hemispheres of humans do not handle all aspects of visual information processing with equal ability. This is illustrated by a review of research concerning the processing of global *versus* local stimulus properties, low *versus* high spatial frequencies, and coordinate *versus* categorical spatial relationships. In general, the right hemisphere is dominant for processing global aspects of visual stimuli that are carried by low spatial frequencies, for the processing of coordinate spatial relationships and, perhaps, for extracting information from the magnocellular visual pathway. In something of a complementary manner, the left hemisphere is dominant for processing local aspects of visual stimuli that are carried by high spatial frequencies and, perhaps, for processing categorical spatial relationships and for extracting information from the parvocellular visual pathway. Consideration is given to developmental mechanisms that may underlie the emergence of hemispheric asymmetry for these interrelated aspects of visual information processing.

INTRODUCTION

The right and left cerebral hemispheres of humans do not handle all aspects of visual information processing with equal ability. Instead, the two hemispheres make complementary contributions to the identification of visual stimuli and to the localization of visual stimuli in space. Examples of this can be seen in the processing of global *versus* local aspects of visual stimuli, in the processing of low *versus* high visuospatial frequencies and in the processing of what have been referred to as coordinate *versus* categorical spatial relationships among visual stimuli. In the present article, I review research that illustrates hemispheric asymmetry for these various aspects of visual processing. I also consider the possibility that hemispheric asymmetry for these different aspects of processing are different manifestations of the same underlying hemispheric asymmetry, which may involve differences in the efficiency with which the two hemispheres can process information along the magnocellular and parvocellular visual pathways. The article concludes with a brief consideration of developmental mechanisms that may contribute to these hemispheric asymmetries in visual information processing.

HEMISPHERIC ASYMMETRY FOR PROCESSING GLOBAL VERSUS LOCAL ASPECTS OF VISUAL STIMULI

Visual stimuli can contain many levels of embedded structure, with smaller local patterns or parts contained within larger global patterns. This is illustrated in Fig. 1, which shows small letter *J*s (the local elements) arranged in the shape of a large letter *H* (the global pattern). According to various theories, internal representations of visual information preserve this hierarchical structure (e.g., Palmer 1977, Robertson 1986, Lamb et al. 1990, Robertson 1995). In this section, I review evidence indicating that the right hemisphere is superior to the left for the processing of global levels of visual information
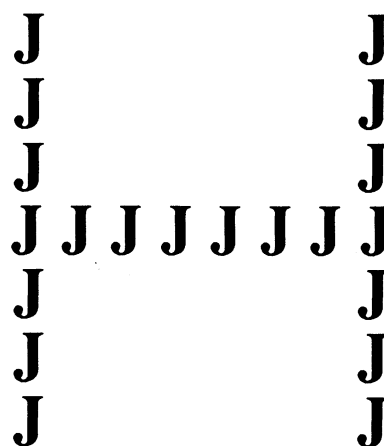

Fig. 1. Example of an hierarchical visual pattern composed of small letters (the local level) arranged into the shape of a large letter (the global level).

whereas the left hemisphere is superior to the right for the processing of local levels.

The clearest evidence of hemispheric asymmetry for processing global *versus* local levels of visual information comes from studies that present stimuli such as those shown in Fig. 1 to brain-injured patients and to neurologically intact individuals. For example, Delis et al. (1986) presented patients with a pattern of the sort shown in Fig. 1 and asked them to draw the pattern from memory after performing a distractor task for 15 s. Patients with unilateral right hemisphere injury typically drew the correct local information (e.g., several small *J*s), but did not arrange the elements in the correct global pattern. By way of contrast, patients with unilateral left hemisphere injury typically drew the correct global pattern (e.g., a large *H*), but omitted the local elements. This pattern of effects is not restricted to tasks that require drawing, as conceptually similar results have been reported in studies of recognition memory for the type of stimulus shown in Fig. 1 (e.g., Delis et al.1986) and in studies that required patients to identify as quickly as possible the letter that appears at either the global level or the local level (e.g., Robertson et al. 1988, Lamb et al. 1989, 1990, Robertson et al. 1991, Robertson 1995). Based on the entire pattern of results from these various studies, Lamb et al. (1990) conclude that normal processing of global aspects depends on the

integrity of the posterior superior temporal lobe of the right hemisphere, whereas normal processing of local aspects depends on the integrity of the posterior superior temporal lobe of the left hemisphere. They also provide evidence that the relative speed with which global and local aspects of a stimulus can be processed is modulated by an attention mechanism that involves the rostral inferior parietal lobe (see also Robertson 1995).

Hemispheric asymmetry for processing global *versus* local aspects of visual stimuli has also been examined in a number of visual half-field studies with neurologically intact individuals. Visual half-field studies take advantage of the fact that, in humans, visual information from each side of an individual's fixation point (each visual half-field) projects directly to the contralateral visual cortex. Thus, a stimulus presented to the right visual field (RVF) projects directly to the left hemisphere (LH) and a stimulus presented to the left visual field (LVF) projects directly to the right hemisphere (RH). In a typical visual half-field study, a stimulus is flashed very briefly to either the RVF/LH or LVF/RH on each trial and performance (e.g., error rate or reaction time) is examined as a function of which half-field (and hemisphere) was stimulated. Of course, there is a great deal of communication between the two hemispheres in the intact brain. Despite this, it is possible to obtain reliable visual field differences that change in theoretically interesting ways as a function of task demands. Furthermore, it is clear that under appropriate experimental conditions these visual field differences reflect hemispheric asymmetry (for discussion of the visual half-field technique, see Hellige and Sergent 1986, Sergent and Hellige 1986, Hellige 1993, 1995a).

A number of visual half-field studies have used stimuli similar to those shown in Fig. 1 and found a LVF/RH advantage for identification of the large letter and a RVF/LH advantage for identification of the small letter – though the individual effects have not always been statistically significant (e.g., Martin 1979, Alivisatos and Wilding 1982, Alwit 1982, Sergent 1982a, Boles 1984). Based on a statistical meta-analysis of the results from these studies and

others, van Kleeck (1989) concludes that there is a global/local by visual field interaction in neurologically intact individuals. In addition, using very clever operant conditioning and stimulus viewing paradigms, Deruelle and de Schonen (1991) have found similar hemispheric asymmetries in infants aged 4-10 months. When these results are taken together with those from studies using patients with unilateral brain injury, there can be little doubt about hemispheric asymmetry for processing global *versus* local levels of visual information.

HEMISPHERIC ASYMMETRY FOR PROCESSING LOW *VERSUS* HIGH VISUOSPATIAL FREQUENCY

Contemporary theories of visual information processing note that each point in the visual field is multiply encoded in the brain by size-tuned filters corresponding to overlapping receptive fields. It has been proposed that these different scales of resolution are determined by outputs from neurones that are tuned to intensity variations over spatial intervals of different sizes; that is, tuned to different spatial frequencies (e.g., De Valois and De Valois 1980). A single spatial frequency consists of a regular sinusoidal variation of luminance across space and looks somewhat like alternating dark and light bars with fuzzy borders. Spatial frequency refers to the number of dark-light cycles per unit of space – the more cycles per unit of space, the higher the spatial frequency. The concept of spatial frequency has generated considerable interest because it is possible, in principle, to represent any complex image as a set of spatial frequencies in specific orientations, phase relationships and so forth (e.g. Campbell and Robson 1968, Thomas 1986).

There is a clear relationship between global and local aspects of a visual stimulus and low *versus* high spatial frequency. That is, information about the larger, global aspects of a stimulus (e.g., the *H* in Fig. 1) is carried by a lower range of spatial frequencies than is information about the smaller, local

aspects of the same stimulus (e.g., the *J*s in Fig. 1). This being the case, in the present section I consider the hypothesis that, at some level of processing beyond the sensory cortex, the right and left hemispheres are biased toward efficient use of lower and higher spatial frequencies, respectively (e.g., Sergent 1982a,b, 1983, Sergent and Hellige 1986, Sergent 1987a,b).

The spatial frequency hypothesis about hemispheric asymmetry was proposed initially as an attempt to explain the effects of various input variables on visual half-field asymmetry (e.g., Sergent 1982a, 1983, Sergent and Hellige 1986). In particular, various forms of perceptual degradation (e.g., overlay masks of line and dots, blurring) have been shown to interfere with processing more when stimuli are presented to the RVF/LH than when stimuli are presented to the LVF/RH. In view of the fact that many of these manipulations would tend to interfere primarily with processing of information carried by higher spatial-frequency channels, the results are at least consistent with the spatial frequency hypothesis. In recent years, there have been a great many experiments and literature reviews considering various aspects of the spatial frequency hypothesis. In general, this work illustrates that spatial frequency is, indeed, an important determinant of hemispheric asymmetry for processing visual information. At the same time, the accumulated studies also point to important limitations and modifications of the original spatial frequency hypothesis. While many studies have provided at least indirect tests of the spatial frequency hypothesis using complex visual stimuli such as faces, letters and numbers, a review of those studies is beyond the scope of the present article. However, detailed reviews of this work can be found in Christman (1989, 1990), Hellige (1993, 1995b) and Kitterle et al. (1995). Here, I focus on recent studies using sine-wave gratings.

Kitterle et al. (1990) reported a series of experiments using sine-wave gratings of either 1 cycle/degree of visual angle (low-frequency) or 9 cycles/degree of visual angle (high frequency) presented to the LVF/RH or RVF/LH of neurologically intact observers. In some experiments, the observer merely indicated on each trial whether or not a grating

stimulus had been presented (without regard to its frequency). In these stimulus detection experiments, there was no interaction of hemisphere and spatial frequency. Thus, the two hemispheres are equally sensitive to low and high spatial frequencies when the computational demands are minimal. This suggests that, if the hemispheres do differ in the processing of information carried by low *versus* high spatial frequency channels, the differences result from processing beyond the sensory level (e.g., Sergent 1983, Hellige and Sergent 1986).

For other experiments, Kitterle et al. (1990) required observers to indicate whether the grating shown on a trial was the "wide" (low frequency) stimulus or the "narrow" (high frequency) stimulus. As shown in Fig. 2, in these stimulus identification experiments there was a LVF/RH advantage for responding to the low frequency stimulus and a RVF/LH advantage for responding to the high frequency stimulus. This same type of hemisphere by spatial frequency interaction extends to complex gratings that are either made up of two low frequency gratings that are superimposed or of two high frequency gratings that are superimposed (Christman et al. 1991) and to a variety of stimulus discrimination tasks (e.g., Kitterle and Selig 1991, Kitterle et al. 1993, 1995). These results indicate that the spatial frequency contained in a stimulus is an important determinant of visual half-field asymmetry, but only when observers must use information about spatial frequency or stimulus identity.

An experiment reported by Kitterle et al. (1992) indicates that hemispheric asymmetry for slightly more complex stimuli also depends on which of the spatial frequencies contained in a stimulus are relevant for performing the task that is required. In this experiment, observers performed two different tasks using the same four stimuli. As diagrammed in Fig. 3, two of the stimuli were sine wave gratings of different spatial frequencies (1 or 3 cycles/degree of visual angle). The other two stimuli were square wave gratings that had fundamental frequencies of 1 or 3 cycles/degree of visual angle. A square wave grating consists of alternating dark and light stripes with sharp edges, whereas the edges in a sine wave
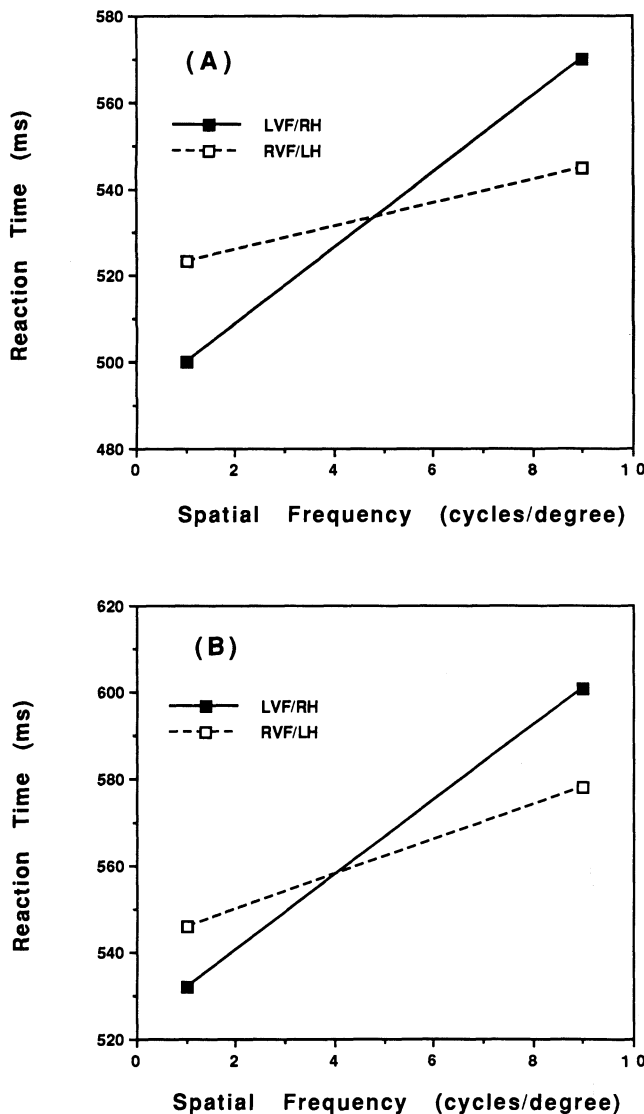
Stimulus Conditions

	Wide	**Narrow**
Fuzzy	1 cpd, sine	3 cpd, sine
Sharp	1 cpd, square	3 cpd, square

Fig. 3. Stimulus conditions used by Kitterle et al. (1992). Wide stimuli were gratings of 1 cycle per degree of visual angle (cpd) and narrow stimuli were gratings of 3 cpd. Fuzzy stimuli were sine wave gratings (sine) and sharp stimuli were square wave gratings (square).

frequencies; specifically, the odd higher harmonics of the fundamental frequency. These properties of square wave gratings allow observers attention to be directed to either relatively low or high spatial frequencies for different tasks.

As illustrated in Fig. 3, one task used by Kitterle et al. (1992) required observers to indicate as quickly as possible whether the single stimulus presented on a trial was one of the two wide gratings (1 cycle per degree) or one of the two narrow gratings (3 cycles per degree), ignoring whether the stimulus contained

Fig. 2. Reaction time to identify vertical sine wave gratings of 1 and 9 cycles/degree of visual angle when the gratings were flashed briefly to either the LVF/RH or RVF/LH. The top panel (A) shows results from Experiment 4 reported by Kitterle et al. (1990) with the results averaged across three levels of stimulus contrast. The bottom panel (B) shows results from their Experiment 5, with the results averaged across three levels of stimulus duration.

grating appear to be very fuzzy. It is important to note that a square wave grating consists of several well-defined spatial frequencies. The lowest frequency is the fundamental frequency and corresponds to the width of the bars. Information about the sharp edge is conveyed by much higher spatial
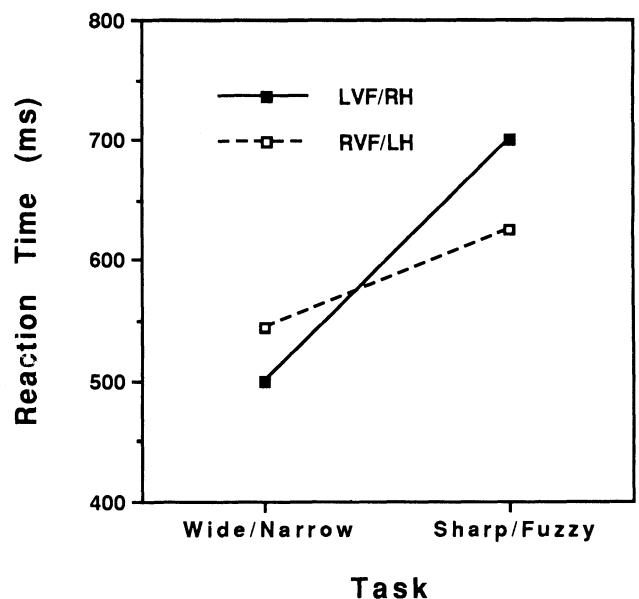

Fig. 4. Reaction time to respond to square wave stimuli for the wide/narrow task and for the sharp/fuzzy task when stimuli were flashed briefly to the LVF/RH or RVF/LH. After Kitterle et al. 1992.

fuzzy or sharp edges. Note that this "wide/narrow" task requires observers to attend to the relatively low fundamental frequencies. The other task re-quired observers to indicate as quickly as possible whether the stimulus contained fuzzy edges (the sine wave stimuli) or sharp edges (the square wave stimuli), ignoring the width of the bars. Note that this "sharp/fuzzy" task requires observers to attend to the relatively high harmonic frequencies. The critical results from this experiment concern the vis-ual half-field asymmetries for processing the square wave stimuli (which contain a wide range of fre-quencies) during each of the two tasks. As shown in Fig. 4, when the task required observers to attend to the low frequencies (the wide/narrow task) there was a LVF/RH advantage. However, when the task required observers to attend to the high frequencies (the sharp/fuzzy task) there was a RVF/LH advant-age. Exactly the same stimuli were used for both tasks, so that these results cannot be attributed to the range of spatial frequencies contained in the stimuli. What is important is whether the range of task-rele-vant frequencies is relatively high or relatively low. In view of these attentional effects, it is interesting to note that Brown and Kosslyn (1995) have recent-ly reported that attentional manipulations also moderate hemispheric asymmetry for processing glo-bal *versus* local information from visual displays.

It is also the case that hemispheric advantages for processing a particular spatial frequency depend on the context in which that frequency occurs. For example, Christman et al. (1991) found that a sine wave grating of 2 cycles/degree of visual angle was processed more efficiently on LVF/RH trials when it was the lowest of three frequencies in a complex stimulus but was processed more efficiently on RVF/LH trials when it was the highest of three fre-quencies in a complex stimulus. Thus, it seems to make a difference whether the spatial frequency that is critical for performing the task that is re-quired is high or low relative to other frequencies contained in the complex stimulus. This is interes-ting in view of the fact that whether a stimulus is global or local also depends on the context in which it is presented (e.g., Robertson 1995). From this per-

spective, it is also interesting that Grabowska et al. (1989) found that right-hemisphere brain lesions were more detrimental than left-hemisphere brain lesions to the discrimination of square wave grat-ings, regardless of whether the two gratings on a trial were low, medium or high spatial frequency. Note that, in order to tell whether two square wave gratings are identical in frequency, observers need attend only to the fundamental frequency of the gratings – which, in relative terms, are always the lowest frequencies contained in the square wave stimuli (see also Szeląg et al. 1987).

The type of results reviewed here suggest the fol-lowing conclusions about the spatial frequency hy-pothesis. At least three aspects of spatial frequency influence hemispheric asymmetry for processing a visual stimulus: (1) the absolute range of spatial fre-quencies contained in the stimulus, (2) the range of spatial frequencies that is relevant for the task being performed (or the range attended to by the observer) and (3) whether the relevant (and attended) frequen-cies are high or low relative to other frequencies contained in the stimulus. In view of this, it is not surprising that hemispheric differences for the identification of more complex stimuli (e.g., faces) can also be influenced by manipulations of spatial frequency. At the same time, pattern recognition with complex stimuli depends not only on which spatial frequencies are present but also on the orien-tation of those frequencies, phase relationships among the frequencies and so forth. Thus, the con-tributions of spatial frequency must eventually be considered in view of possible hemispheric asym-metry for other components that are necessary for visual pattern recognition.

HEMISPHERIC ASYMMETRY FOR PROCESSING COORDINATE *VERSUS* CATEGORICAL SPATIAL RELATIONSHIPS

The studies reviewed so far have all had to do with processing information about the identity of a visual stimulus. In the present section, I review re-

cent findings that suggest the two hemispheres also make complementary contributions in processing information about the location of a visual stimulus and consider whether the same mechanisms might contribute to asymmetries of both sorts.

It has been hypothesized that the brain computes at least two kinds of spatial relation representations. One type of representation ("categorical") is used to assign a spatial relation to a category such as "connected to" or "above" whereas the other type of representation ("coordinate") is used to represent precise distances and locations in a metric coordinate system (e.g, Kosslyn 1987). Recent experiments suggest that the right hemisphere makes more effective use of coordinate or metric distance information about spatial relationships whereas there is either no hemispheric asymmetry or a left--hemisphere advantage for processing information about categorical spatial relationships (for reviews, see Kosslyn et al. 1989, Kosslyn and Koenig, 1992, Hellige 1993a, 1995).

Several visual half-field experiments from a number of different laboratories have produced results consistent with the hypotheses just outlined. For example, a LVF/RH advantage has been reported consistently for tasks that require subjects to indicate whether or not two stimuli (e.g., a line and a dot) are within a certain distance of each other (e.g., nearer than 3 cm to each other or farther than 3 cm from each other). By way of contrast, when subjects are required to make a categorical spatial judgment about the same stimuli (e.g., is a dot above or below a line), there is typically a trend toward a RVF/LH advantage (with the RVF/LH advantage sometimes being statistically significant and sometimes not). (See Fig. 5) In addition, in some studies, this task by visual field interaction disappears with practice, possibly because subjects learn to perform the distance judgment task in a more categorical way (for examples of this task by visual field interaction see Kosslyn 1987, Hellige and Michimata 1989, Kosslyn et al. 1989, Koenig et al. 1990, Rybash and Hoyer 1992, Cowin and Hellige 1994, Hellige 1995a).

Based on a set of neural-network computer simulations, Kosslyn et al. (1992) showed that networks
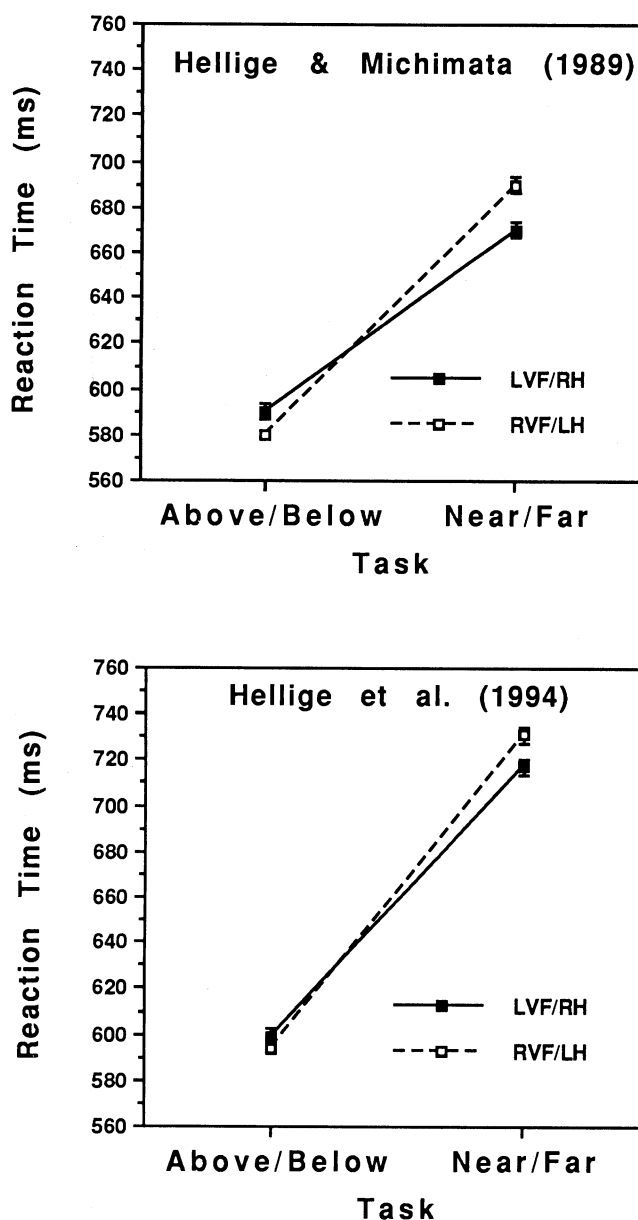

Fig. 5. Reaction time for a categorical spatial task (above/below) and for a coordinate spatial task (near/far) for LVF/RH and RVF/LH trials. Results in the upper panel come from Hellige and Michimata (1989) and results in the lower panel come from Hellige et al. (1994).

that received input that had been filtered through units with relatively large, overlapping "receptive fields" compute coordinate spatial information better than networks that received input that had been filtered through units with relatively small, non-overlapping "receptive fields." Exactly the reverse was found for the computation of categorical spatial

information (for additional discussion about the use of these neural network simulations see Cook et al. 1995 and Kosslyn et al. 1995). To account for the hemispheric differences in categorical *versus* coordinate spatial processing, Kosslyn and his colleagues hypothesize that the left hemisphere is predisposed toward efficient use of information from visual channels with small, nonoverlapping receptive fields whereas the right hemisphere is predisposed toward efficient use of information from visual channels with large, overlapping receptive fields. Kosslyn et al. (1992) note the similarity between low spatial frequency and visual channels with large receptive fields and high spatial frequency and visual channels with small receptive fields. In this sense, the hypothesis advanced by Kosslyn et al. is consistent with the spatial frequency studies reviewed earlier. In further support of their hypothesis, Kosslyn et al. (1992) suggest that magnocellular ganglia (which are known to have relatively large receptive fields) may project preferentially to the right hemisphere.

Portions of the foregoing hypotheses receive support from research reported recently by Cowin and Hellige (1994), which examined the effects of dioptric blurring on categorical *versus* coordinate spatial processing. Dioptric blurring selectively impairs processing of relatively high visual spatial frequencies and, according to the above hypothesis, such blurring should be particularly disruptive of categorical spatial processing. In fact, Cowin and Hellige found that dioptric blurring consistently increased reaction time and error rate for a categorical task that required subjects to indicate whether a dot was above or below a line. By way of contrast, dioptric blurring had no consistent effect on either reaction time or error rate for a coordinate task that required subjects to indicate whether a dot was within 3 mm of a line. (see Fig. 6). On an initial block of trials, however, there were significantly fewer errors on LVF/RH than on RVF/LH trials for the coordinate processing task and this LVF/RH advantage was independent of whether the stimuli were clear or blurred.

CONTRIBUTIONS OF THE MAGNOCELLULAR AND PARVOCELLULAR VISUAL PATHWAYS

It has been hypothesized that the processing of visual information in primates is accomplished by two parallel visual pathways with different spatial and temporal characteristics. In general, the magnocellular system is most sensitive to low spatial frequencies, has high temporal resolution and responds quickly and transiently to moving targets. This system is thought to be involved in such things as brightness discrimination, the perception of motion and depth, the localization of visual stimuli in space and in the global analysis of visual scenes. By way of contrast, the parvocellular system is most sensitive to high spatial frequencies, has a long response persistence and responds in a sustained fashion to stationary targets. This system is thought to be involved in such things as the identification of visual patterns, especially small local details and in colour perception. (For discussion of the characteristics of the magnocellular and parvocellular visual sys-
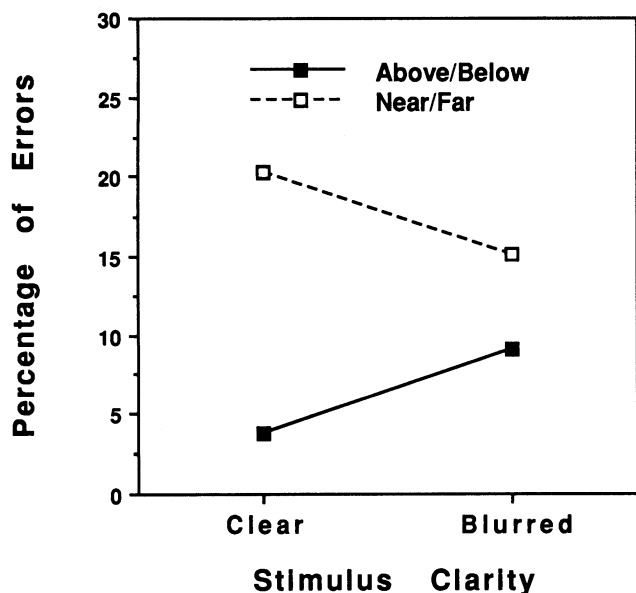

Fig. 6. Percentage of errors on the first 24-trial block for a categorical spatial task (above/below) and for a coordinate spatial task (near/far) for clear stimuli and blurred stimuli. After Cowin and Hellige (1994).

tems, see Schiller and Malpeli 1978, Livingstone and Hubel 1984, 1987, 1988, Van Essen 1985, Breitmeyer and Williams 1990, Breitmeyer et al. 1991, Shapley 1994). In this section, I consider the possibility that the two hemispheres differ in their ability to process visual information carried by these two visual systems.

A dioptric blurring manipulation like that used by Cowin and Hellige (1994) might be expected to attenuate processing primarily along the parvocellular visual pathway. This being the case, their results suggest that processing along this pathway is more critical for categorical than for coordinate spatial processing and that the right-hemisphere advantage for coordinate spatial processing may not depend on processing along the parvocellular pathway. In very recent experiments, we (e.g., Cowin and Hellige 1995) have begun to examine categorical and coordinate spatial processing for stimulus conditions that more directly attenuate processing along the magnocellular visual pathway. In this experiment, the stimuli on each trial consisted of a horizontal line and two dots, with the dots being on the same horizontal level as each other. The line varied in length from trial to trial as did the horizontal distance between the two dots. The categorical task required subjects to indicate whether the dots were above or below the line. The coordinate task required subjects to indicate whether or not the line on that trial could fit in the space between the two dots (after Rybash and Hoyer 1992).

In order to manipulate how efficiently information could be processed along the magnocellular visual pathway, we used red stimuli on a green background or green stimuli on a red background, with the specific red and green stimuli chosen for each subject to be isoluminant using the method of heterochromatic flicker photometry. We chose this manipulation of stimulus colour for the following reasons. Psychophysical and physiological data indicate that the relative contribution of magnocellular and parvocellular visual channels to the processing of a stimulus can be affected by colour or wavelength. Specifically, a steady red background light has been found to attenuate the re-

sponse of the magnocellular system in both nonhumans (e.g, Dreher et al. 1976, Schiller and Malpeli 1978, Livingstone and Hubel 1984, Van Essen 1985) and in humans (e.g., Breitmeyer and Williams 1990, Breitmeyer et al. 1991, Williams et al. 1991). For example, a form of metacontrast masking that is known to be mediated by the magnocellular system is considerably weaker when the target is green and the surrounding mask is red than *vice versa* (e.g., Breitmeyer et al. 1991). Thus, we reasoned that the use of green stimuli on a red background would attenuate magnocellular processing relative to the opposite condition. With this in mind, it is interesting that there was a very robust task by color condition interaction. As shown in Fig. 7, for the coordinate task, reaction time was significantly longer in the red background condition than in the green background condition. For the categorical task, exactly the opposite was found. Note that this interaction is consistent with the hypothesis that the coordinate task is more dependent on magnocellular processing than is the categorical task. On the first block of trials, when visual field differences in these tasks have been most prominent, there was also a
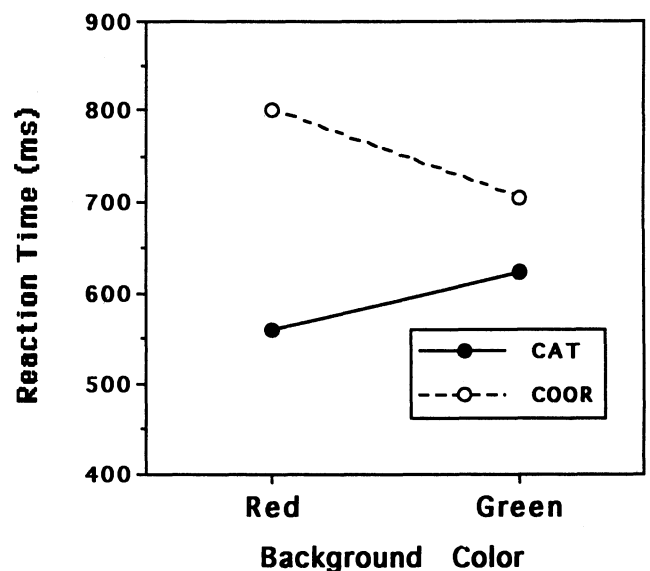

Fig. 7. Reaction time for a categorical spatial task (CAT) and for a coordinate spatial task (COOR) in a red background condition and in a green background condition. From Cowin and Hellige (1995).
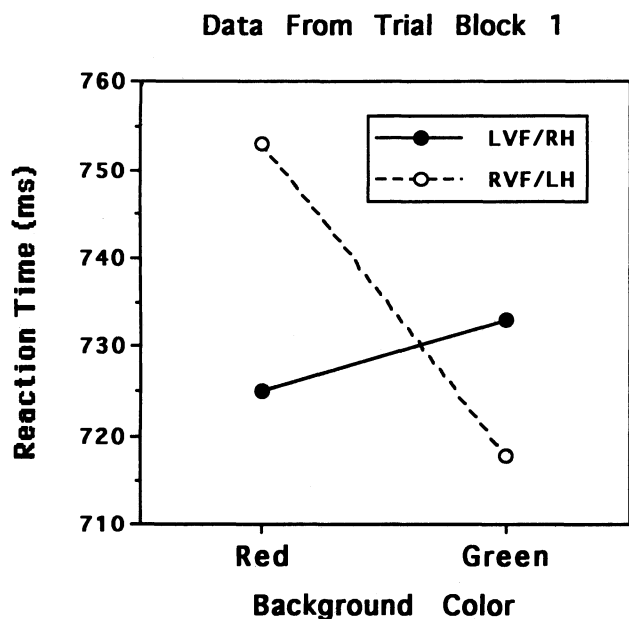
Data From Trial Block 1

Fig. 8. Reaction time on LVF/RH and RVF/LH trials as a function of background colour on an initial 24-trial block. From Cowin and Hellige (1995).

visual field by colour condition interaction. As shown in Fig. 8, on RVF/LH trials, reaction time was significantly longer in the red background condition than in the green background condition. On LVF/RH trials, there was no effect of background colour. One interpretation of this interaction is that attenuation of magnocellular processing is more disruptive on left-hemisphere trials because the left hemisphere does not process information from that pathway very efficiently to begin with. In this sense, the use of a red background produces results that are similar to the effects of several other forms of perceptual degradation (for review, see Hellige 1993, 1995a).

The robust nature of these interactions involving colour condition suggests that the manipulation of colour is a potentially powerful tool to investigate the extent to which processing of information carried by the magnocellular pathway contributes to the performance of different tasks and to hemispheric asymmetry in the visual modality. Thus, it will be interesting to determine the effect of background colour on the type of stimulus identification tasks described earlier in the present article. Such

studies would be particularly interesting in view of recent hypotheses that certain asymmetries for stimulus identification arise because the two hemispheres differ in their ability to monitor outputs from visual neurones that have different size receptive fields (e.g., Jacobs and Kosslyn 1994, Brown and Kosslyn 1995).

DEVELOPMENTAL EMERGENCE OF HEMISPHERIC ASYMMETRY FOR VISUAL PROCESSING

There is growing evidence that the hemispheric asymmetry we see in adults is the result of a complex interplay of biological and environmental factors, beginning *in utero* and continuing into old age (for discussion and review, see Hellige 1993). In view of this, it is worthwhile to consider how asymmetry for visual information processing may arise developmentally. Although a detailed discussion of the developmental possibilities is beyond the scope of the present article, it may be instructive to note briefly a developmental scenario that I have presented in more detail elsewhere (e.g., Hellige 1993, 1995b) and that I believe merits additional investigation. The scenario is based on the following observations.

There is evidence that the development of various brain areas is somewhat more advanced in the right hemisphere than in the left hemisphere at the time of birth and, perhaps, for at least a short time thereafter (e.g., Geschwind and Galaburda 1987, Sergent 1987b, Turkewitz 1988, de Schonen and Mathivet 1989, Corballis 1991, Hellige 1993). This leads to the possibility that a sort of critical period for being modified by incoming visual input occurs somewhat earlier for the right hemisphere than for the left hemisphere – at a time when the sensory system of the newborn provides the brain with visual input that is highly degraded. In fact, the visual sensory system of newborns is especially limited in its ability to transmit information carried by high spatial frequencies (for review, see Banks and Dannemiller 1987, de Schonen and Mathivet 1989). This being

the case, early modification of the right hemisphere may predispose that hemisphere to become dominant for processing such things as the low spatial frequencies that are relatively better preserved in the visual world of the newborn and that would seem to be associated with visual channels with large receptive fields. Furthermore, once the right hemisphere has been modified by degraded visual input, it may be less able than the left hemisphere to take full advantage of such things as higher frequencies when they finally are transmitted by the visual sensory system. Although this scenario is admittedly speculative, it should be noted that any hemispheric differences that emerge in this way would influence asymmetry for a wide variety of visual information processing tasks, regardless of whether the task requires stimulus identification, stimulus localization or both.

CONCLUDING COMMENTS

With respect to hemispheric asymmetry for visual information processing, the following conclusions seem justified. Neither hemisphere is uniformly superior for visual processing. Instead, the two hemispheres make complementary contributions to the identification of visual stimuli and to the localization of visual stimuli in space. This has been illustrated by examining hemispheric asymmetry for the processing of global *versus* local aspects of visual patterns, low *versus* high spatial frequencies and coordinate *versus* categorical aspects of spatial relationships. However, rather than view these as conceptually distinct aspects of hemispheric asymmetry, it seems more appropriate to regard them as different manifestations of the same underlying mechanisms. Additional research is clearly needed to understand those mechanisms. Nevertheless, recent research suggests that they may involve hemispheric differences in the ability to process information transmitted by magnocellular *versus* parvocellular visual pathways and that these differences emerge from the complex interplay of biological and environmental factors during the course of ontogenetic development.

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