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Running Header: GESTALT HEMISPHERIC DIFFERENCES

Are there hemispheric differences in visual processes that utilize Gestalt principles?

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Abstract

Hemispheric differences in the visual system have been well-established, although their exact nature remains under study (Hellige 1990). Thus far, research has focused on the perception of whole objects or scenes. Van Kleeck and Kosslyn (1989) investigated the possibility of lateralization for Gestalt principles using an embedded figures task. They found an effect of lateralization, that parts of figures fitting Gestalt breaks were more quickly identified by the right than the left hemisphere. They concluded that Gestalt processing is lateralized to the right hemisphere. In this study, two experiments were conducted to more closely investigate this claim. The first experiment focused on the Gestalt principle of grouping by proximity using dot lattices. No effects of lateralization were found. In the second experiment, concentric circles of Gabor patches were used to test grouping by orientation. This did not result in any main effects of hemisphere, but in reaction time, those stimuli with the probe located in central vision created a large decrease in reaction time for the right hemisphere, while probes in the periphery caused a greater increase for the right hemisphere than the left. This seems to indicate that not all Gestalt principles are processed preferentially in the right hemisphere, but some Gestalt principles do show the same lateralization as found by Van Kleeck and Kosslyn.

Are there hemispheric differences in visual processes that utilize Gestalt principles?

One of the early discoveries about how the brain functions was that the two hemispheres of the brain do not play identical roles. Broca and Wernicke both discovered language centers of the brain which were located in the left hemisphere, while damage to the analogous area in the right hemisphere did not affect language. The brain has several physical and functional hemispheric differences. One of the important physical divisions is the two visual fields that provide information to visual system. Each visual field is seen mostly by the eye on that side, so most of the right visual field (RVF) is processed by the right eye, and the majority of the left visual field (LVF) is processed by the left eye. When the information obtained in these visual fields transfers from the retina to the visual cortex, the information of each visual field crosses over to be used by the contralateral hemisphere. In other words, information from the RVF travels to the left hemisphere (LH) and information from the LVF is processed by the right hemisphere (RH). At first this may not seem significant, since the visual cortex is generally held to be nearly identical in both hemispheres. However, damage to one of the hemispheres will only affect the processing of the corresponding visual field. For example, some people have problems in or lesions to area V4 of the brain which results in achromatopsia (color-blindness). Usually a problem such as color-blindness affects the entire visual system, but when a person only has damage on one side, only one visual field appears without color (Gazzaniga 2000).

There are also functional division in vision, as well as throughout the two hemispheres. Most current dichotomies have grown out of the suggestion that the LH processes information analytically and the RH processes information holistically. As researchers like Robertson (referenced in Hellige 1990) have pointed out, analytic versus holistic processing is very ill-defined. Because of these ambiguous descriptions, many results have been argued to both

support and refute this dichotomy. In order to provide more specific terms, two possible dichotomies have arisen: local versus global processing and categorical versus coordinate processing. The first dichotomy stems from research done by Navon where he used stimuli that contained a global letter shape formed by several of a different letter, for example a 'H' made of small 's's (referenced in Hubner 1997). In this dichotomy, the RH plays a larger role in processing global stimuli, such as the larger letter being formed, and the LH plays a primary role in processing local stimuli, such as the smaller letters in the stimuli. The other dichotomy has been suggested by Kosslyn and colleagues (i.e. Van Kleeck & Kosslyn 1989). Kosslyn proposes that instead of processing local information, the LH hemisphere has superior processing for categorical information like defining whether a specific dot is above or below or near to or far from a specific line. The role of the RH is processing coordinate information, such as how near the line, in millimeters, the dot is (i.e. the metric information).

These explanations, while more concrete than the original, still lack full definitions that can easily be tested. In an attempt to both unite these theories and provide a physical description to use in creating stimuli, Robertson and Ivry (2000) have proposed a theory they refer to as Double Filtering by Frequency (DFF). This theory suggests that both global and coordinate distinctions are referring to lower spatial frequencies. In this way, the RH is faster to process the low spatial frequencies presented to the visual system and the LH is faster at processing high spatial frequencies. In this theory, the low versus high is still relative to each stimulus, creating a continuum, but it at least provides a measurable dimension.

The majority of research in hemispheric differences up to this point has used complete objects or scenes as stimuli. Processing objects, however, is a complicated task for the visual system. While the hemispheric differences are often found with this higher level of processing,

relatively little research has looked at the aspects involved in lower levels to create this object representation. One important step in creating a representation of an object or a scene is to group the information according to various rules. These grouping principles, usually referred to as Gestalt principles, include grouping by color, shape, orientation, and proximity. While using these principles to create object representations can seem elementary, Bronson, Scott, Fox, and Pye (2004) found that not all people are able to make these representations naturally. They found that autistic children are much less likely to utilize these grouping principles than controls of the same mental age. Since this is an important step of visual processing, and is not something already embedded in the information, it is possible that this processing could play different roles in the two hemispheres. Gestalt plays an important role in the global understanding of an object or scene, and the autistic children had difficulty identifying possible and impossible shapes. To investigate the possibility of hemispheric differences, Van Kleeck and Kosslyn (1989) used an embedded figures task to test accuracy and reaction time for identifying whether a piece of a figure had been part of a figure that had previously been presented to the participant. They expected and found that the RH was faster at identifying embedded figures that followed important Gestalt rules of the larger object. For incorrect embedded figures, the LH was faster, suggesting that either local processing was required, and the breaking of the Gestalt rules made figure more difficult for the RH to process.

This study, however, still uses objects to establish hemispheric differences. Research has well established that there are some hemispheric differences at higher levels of processing. Research has also shown that the processing in primary visual cortex, the first part of visual processing by the brain, appears to function identically in both hemispheres. The question arises as to when the hemispheres begin to process visual information differently. Based on the

findings by Van Kleeck and Kosslyn, hemispheric differences should appear as soon as Gestalt principles are utilized in making judgments about stimuli.

Experiment 1

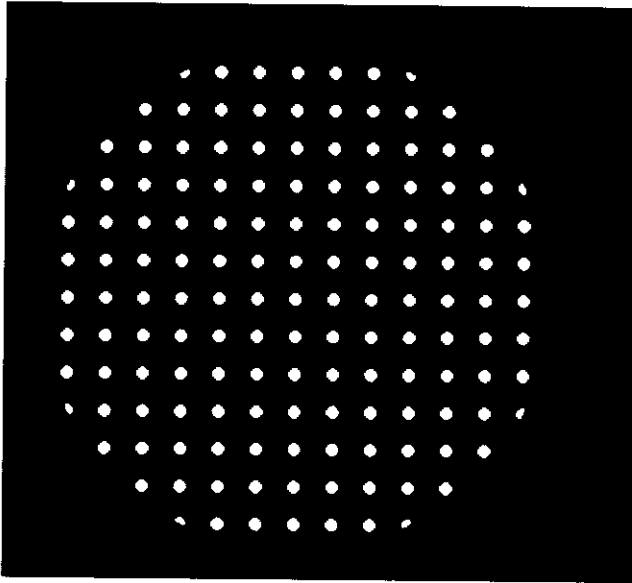
Methods

Participants. All subjects were Carnegie Mellon University introductory psychology students who received credit toward a class requirement. There were 16 subjects (7 males; 9 females) between the ages of 18 and 25 (mean age = 20). All subjects scored between 89.5 and 100 on the Edinburgh Handedness Survey. All subjects had normal or corrected-to-normal vision and gave informed consent to participate in this experiment.

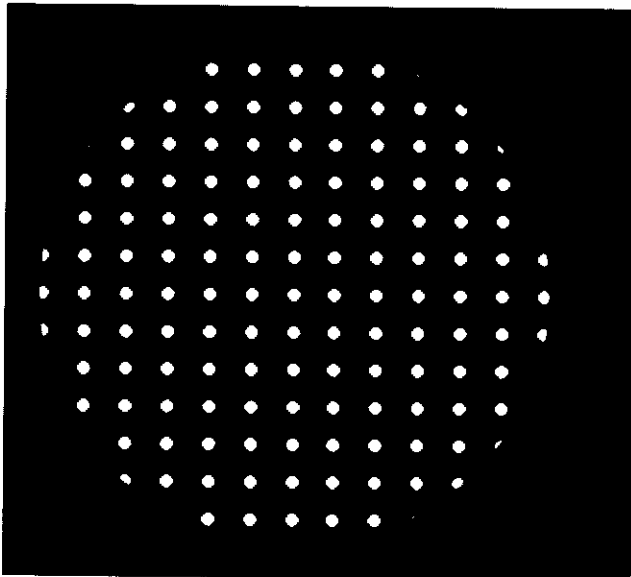
Apparatus. The experiment was run using E-Prime™ on two PCs running Microsoft XP Professional™. The first was a desktop computer with a 15-inch monitor and the second was an IBM ThinkPad T30 laptop. All subjects used a chin rest to ensure the same viewing distance.

Stimuli. The stimuli were dot lattices similar to the ones used in previous studies by Kubovy (i.e. Strother & Kubovy, in press). As shown in Figure 1, the distance between the dots differed in either the horizontal or vertical direction, creating 5 aspect ratios from 0 (distances equal) to 4. A higher aspect ratio would give rise to the visual grouping of the dots into either columns or rows to be stronger. If the distance between two dots horizontally next to each other was increased, they appeared to be in vertical columns and vice versa.

a.

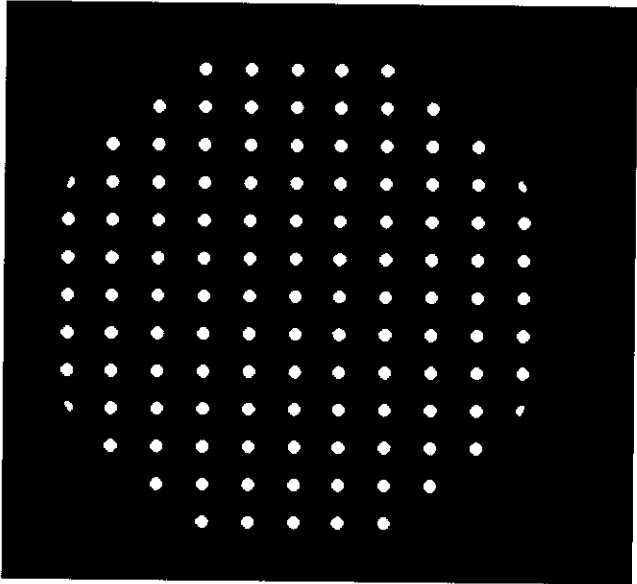


b.

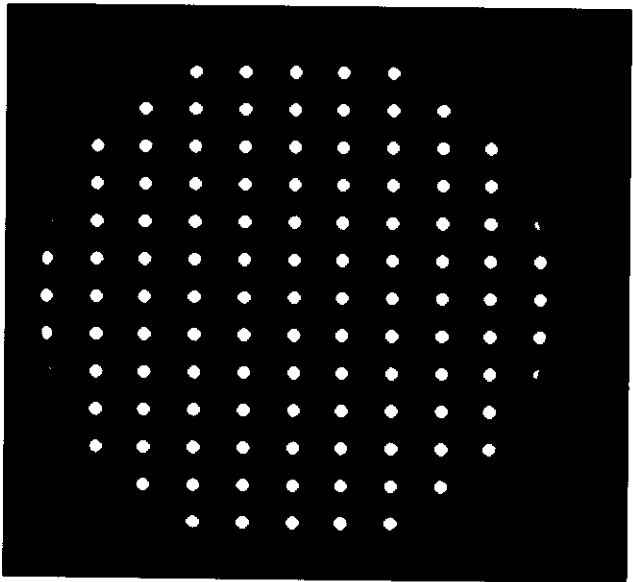


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c.



d.



e.

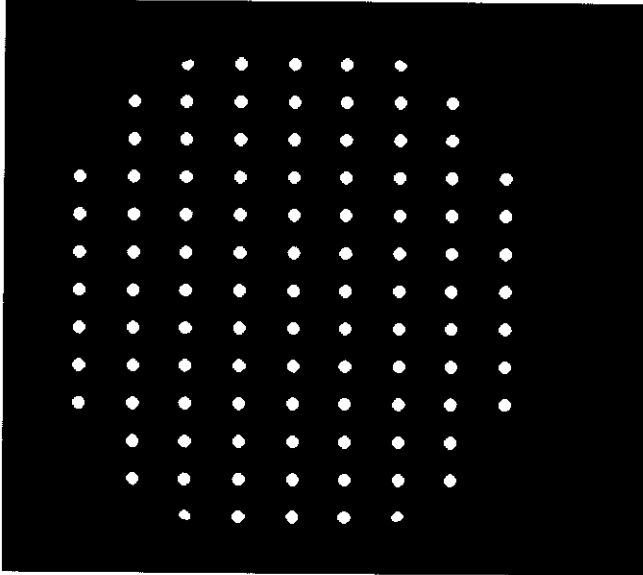


Figure 1. Examples of dot lattice stimuli with aspect ratios (a) 0, (b) 1, (c) 2, (d) 3, and (e) 4 that were grouped as vertical.

Design. This experiment used a $5 \times 2 \times 2$ (aspect ratio \times vertical/horizontal \times presentation side) factorial design. There were a total of 20 stimuli for the vertical and horizontal conditions with aspect ratios 0 and 4. There were 100 stimuli for aspect ratios 1, 2, and 3 for both vertical and horizontal conditions. Half of all possible stimuli were presented to the right side of the screen (in the subjects' right visual field - RVF) and half were displayed to the left. Presentation and side order was randomized and these stimuli were distributed across two blocks. These two blocks contained exactly the same stimuli (10 with aspect ratios 0 and 4; 50 for 1, 2, and 3), and were created to give the subject a brief rest.

Procedure. First, each subject completed the Edinburgh Handedness Survey to ensure that they were right hand dominant. The survey was online and calculated scores immediately. Then subjects took up a position in a chin rest 3 feet away from the screen. They were instructed to focus on a fixation cross in the center of the screen which appeared for one second before the

stimulus and disappeared with the stimulus. Stimuli were flashed for 150ms to either the left or the right side of the screen. Stimuli appeared with equal probability in each visual field and the order of the visual field was random. Subjects responded using key presses to indicate whether the dots were aligned vertically (in columns) or horizontally (in rows). Half of the subjects were asked to respond with their left hand and half with their right. The experiment was run in two identical blocks with a short break in between the blocks.

Results

Using multivariate ANOVAs, mean accuracy, log of the mean, and reaction time were all analyzed. Aspect ratio did not significantly effect reaction time ($p = 0.468$), but did have an effect on accuracy ($p < 0.0005$), as expected. This indicates that the greater the distance, the more clearly the dots are grouped into rows or columns. None of the other results reached a significant level ($p = 0.05$). There were also no significant interactions. The presentation side, whether the stimuli appeared to the LVF or RVF did not approach significance in accuracy (mean $p = 0.945$; $\log(\text{mean}) p = 0.615$). Controlling for the fact that reaction time has a non-normal distribution, reaction times were limited to those slower than 200ms and faster than 2000ms. To study the effects of reaction time, a univariate ANOVA was run on both reaction time and speed ($1/\text{reaction time}$). As illustrated in Figure 2, neither reaction time nor speed showed a significant effect for presentation side ($p = 0.980, 0.197$, respectively).

Reaction Time for Dot Orientation x Presentation Side

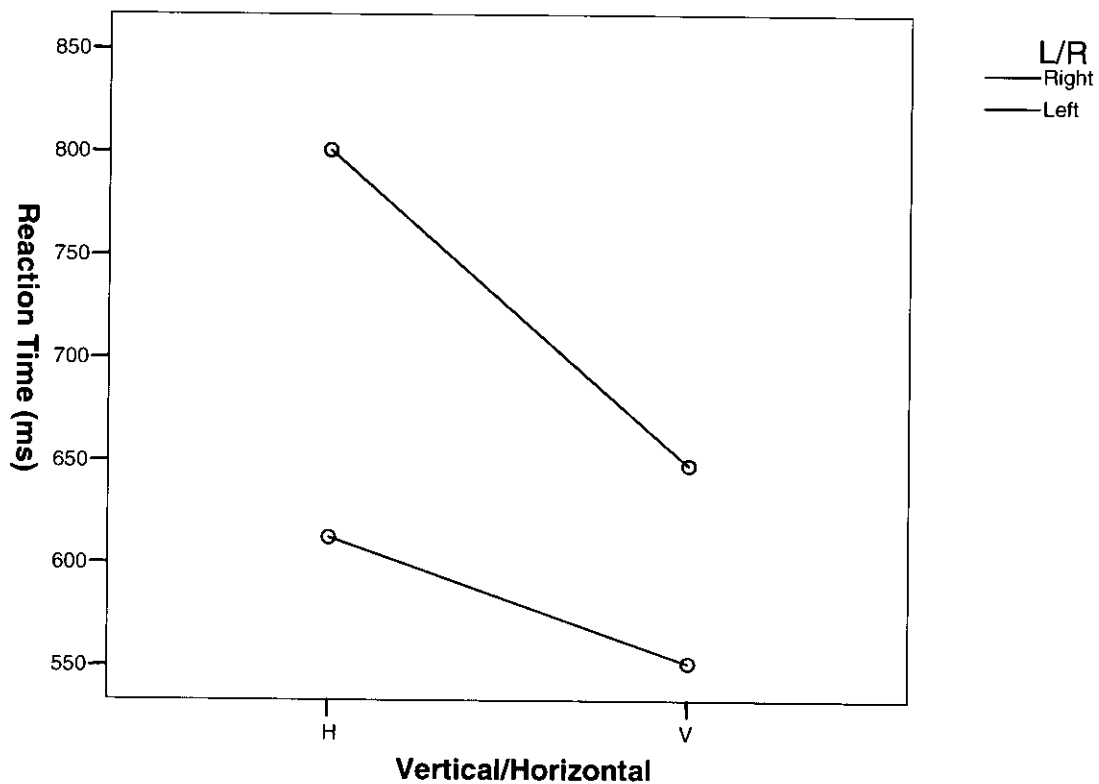


Figure 2. Presentation side did show a trend toward faster reaction times for vertically grouped stimuli, but neither the main effect nor interaction was significant.

At first there appeared to be a trend toward significance for reaction time as a function of dot orientation ($F(1,15) = 4.084$, $p = 0.061$), however this trend did not hold for speed ($p = 0.648$). Accuracy had a trend toward significance (mean $F(1,15) = 3.240$, $p = 0.073$; $\log(\text{mean})$ $F(1,15) = 16.648$, $p = 0.062$). Figure 3 suggests that participants were slightly more accurate for vertically aligned arrays and showed a slight vertical bias overall.

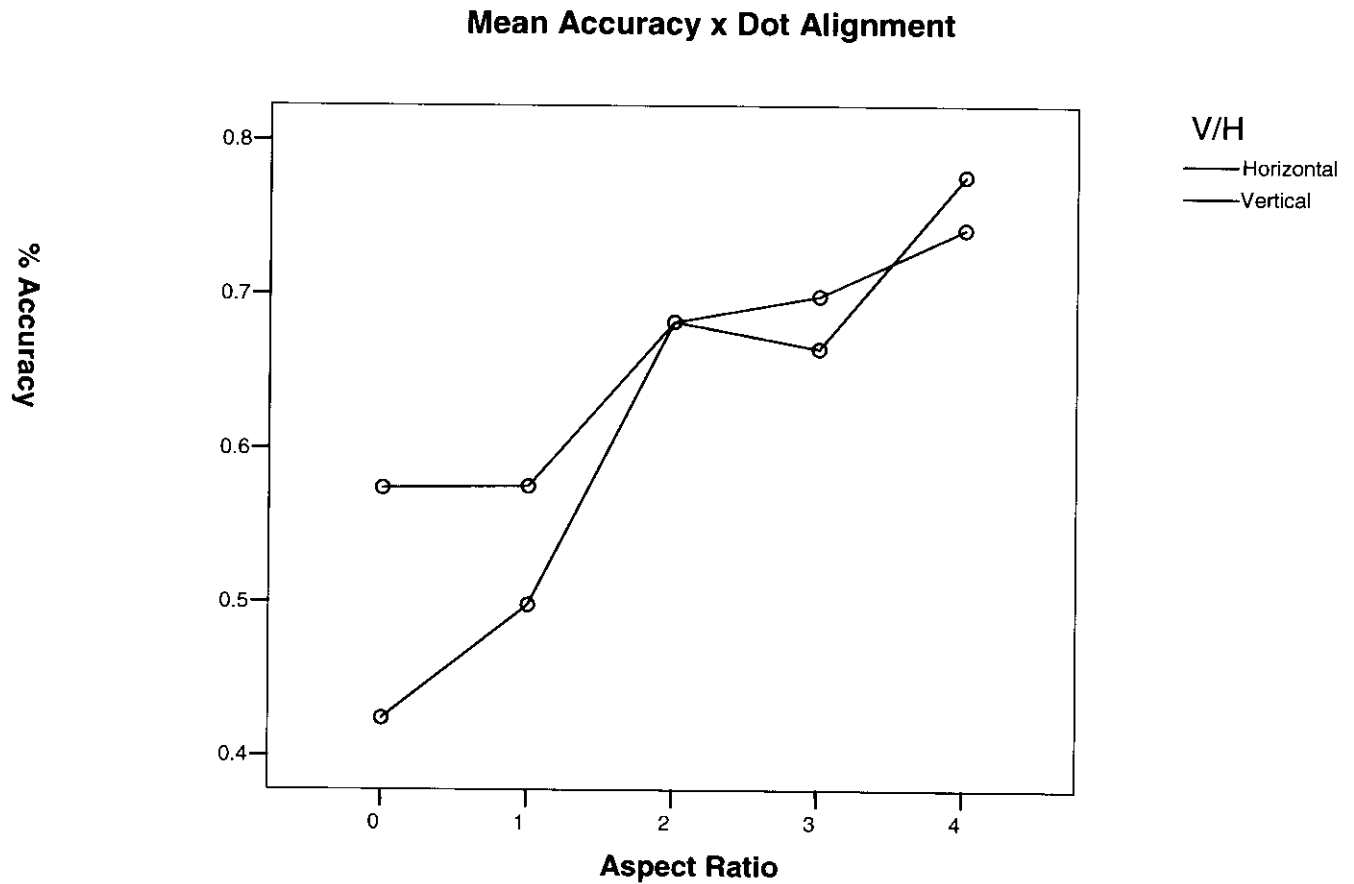


Figure 3. As aspect ratio (distance in one dimension) increased, so did the participants' ability to consistently identify the stimuli with the same group.

Experiment 2

Since Experiment 1 did not lead to any statistically significant results, Experiment 2 was designed to investigate whether this was a trend across multiple Gestalt principles. Experiment 2 was meant to determine whether Gestalt principles were not lateralized, or if specifically grouping by proximity did not show lateralization effects, while other principles would.

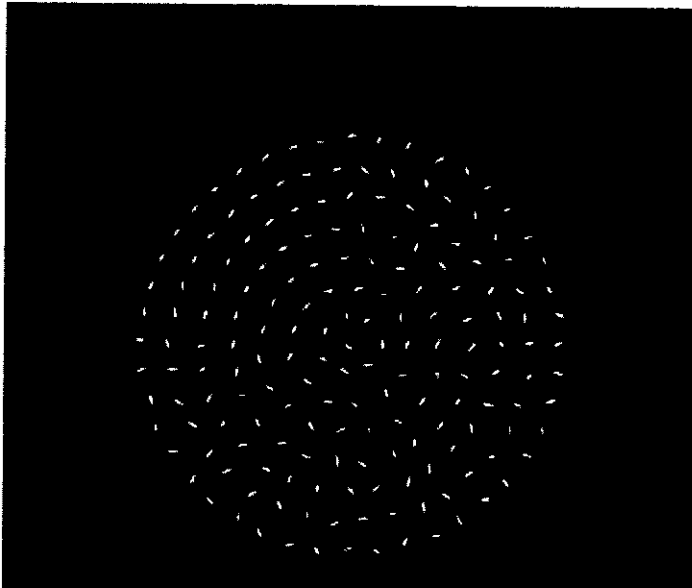
Method

Participants. There were 16 participants (7 males; 9 females) between the ages of 18 and 23 (mean age = 20). All participants were Carnegie Mellon University psychology students with

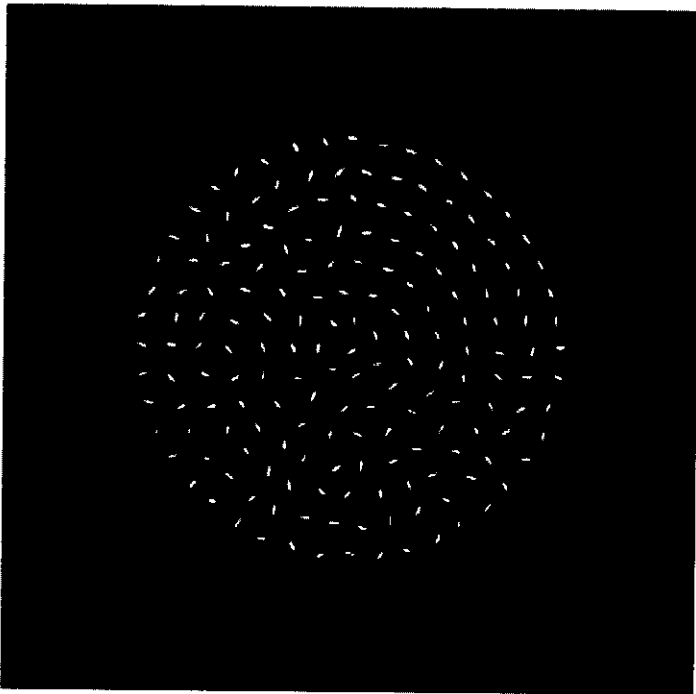
normal or corrected to normal vision. All but one of the subjects were right-handed. Subjects received credit toward their psychology course for participation.

Stimuli. The stimuli consisted of Gabor patches with centers aligned in concentric circles. The orientation of these patches could be manipulated to make them seem more ordered (aligned in concentric circles) or more chaotic (random orientation). Each stimulus had one wedge (quadrant) of the circle that had a different degree of order than the rest of the shape, which was uniform. The degree of difference between the one quadrant and the rest of the shape varied from indistinguishable to the eye to very clear (chaotic wedge, ordered shape or ordered wedge, chaotic shape). The wedge could appear in any of the four quadrants and there were two sets of every quadrant location x degree of contrast. Examples of the stimuli can be found in Figure 4.

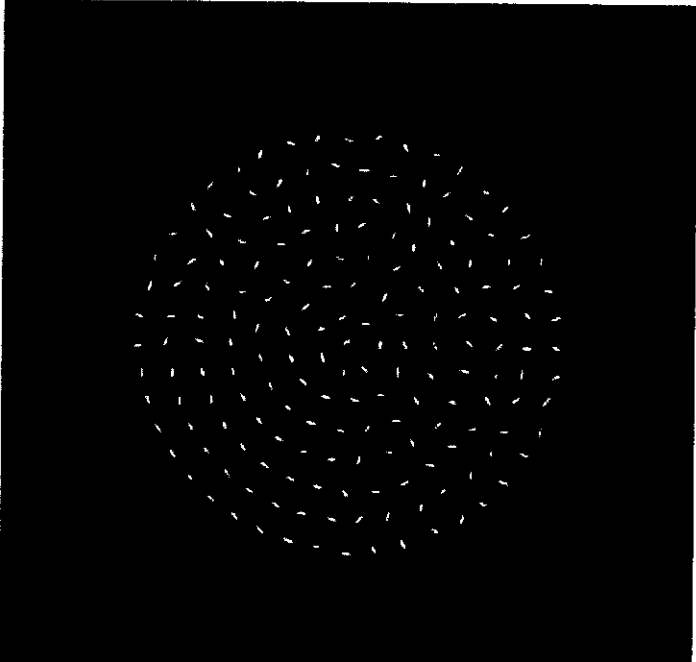
a.



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c.



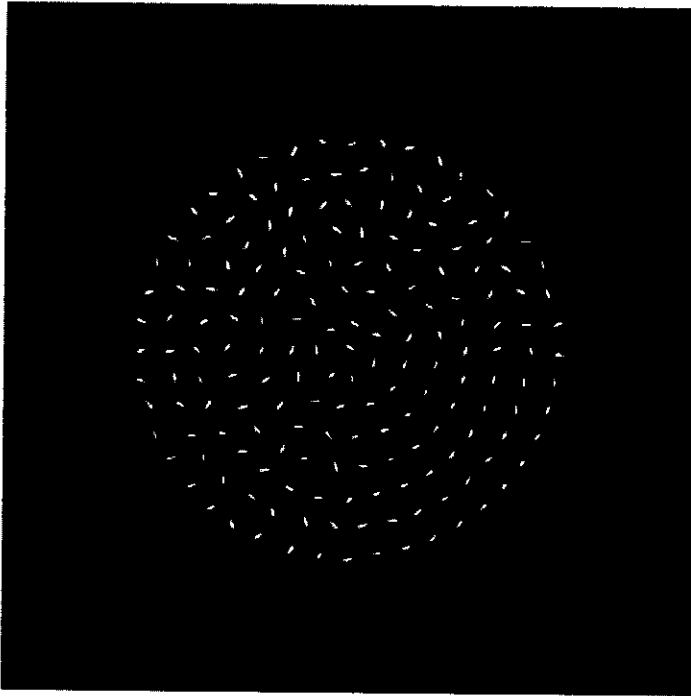


Figure 4. Examples of stimuli made of Gabor patches with the wedge in each quadrant with the highest degree of difference. The correct responses would be (a) 1, (b) 2, (c) 0, (d) 9.

Design. This experiment used a 2 x 16 x 4 (presentation side x degree of contrast x wedge location) factorial design. There were a total of 256 stimuli. There were two blocks of trials and each was preceded with a short practice session of 20 trials. For each presentation, a fixation cross appeared for one second before the stimulus. In the first block, each stimulus was displayed in the center of the screen for 150ms, so the fixation cross disappeared when the stimulus was displayed. In the second block, each stimulus was shown once to each visual field and the fixation cross remained for the 150ms that the stimulus was displayed. Presentation and side order were random with an equal number of stimuli in center, left, and right.

Procedure. After giving informed consent, each participant was shown examples of the stimuli (shown in Figure 4). Then the participant began the practice trials for the centrally located stimuli. They were told to keep their eyes fixated on the cross that would appear in the center of the screen and to respond using key presses as to which quadrant was different (starting from top

left, in clockwise order, first = '1', second = '2', third = '0', fourth = '9'). After the 20 practice trials, they completed the first experimental block. The second block also began with 20 practice trials before the actual experimental trials. Participants were once again asked to fixate on the cross in the center of the screen and to respond with the same key presses which quadrant was different. In the second block they were informed that the stimuli would appear to the right or left of the screen, but they were still instructed to maintain central focus. All stimuli were presented and the experiment was run using E-Prime™ on an IBM ThinkPad T30.

Results

The first block of the experiment, with stimulus presentation in the center, was to allow for practice and to act as a baseline to compare with any significant results of the half-field presentation. For accuracy, both the degree of difference and quadrant showed significant differences ($F(7,15) = 64.251, p < 0.0005$; $F(3,15) = 5.966, p = 0.002$, respectively), but there was not a significant interaction ($p = 0.385$). The reaction times also showed a significant effect on both degree of difference and quadrant ($F(7,15) = 9.598, p < 0.0005$; $F(3,15) = 5.021, p = 0.004$).

The accuracy data were fit to a logarithmic function to create linearity, but it did not result in a significant effect of presentation side ($F(1,15) = 0.001, p = 0.974$). There was an effect of quadrant ($F(3,15) = 8.574, p < 0.0005$), and as can be seen in Figure 5, for presentation to the LVF, quadrants 2 and 4 were better than quadrants 1 and 3. Alternately, for presentation in the RVF, quadrants 1 and 3 were better than 2 and 4. This seems to be due to the better quadrants located in the center of the display and the worse ones being in the periphery. The

interaction between presentation side and quadrant was significant ($F(1,3) = 14.452, p < 0.0005$) and presentation to the LVF seem to have greater variability based on quadrant.

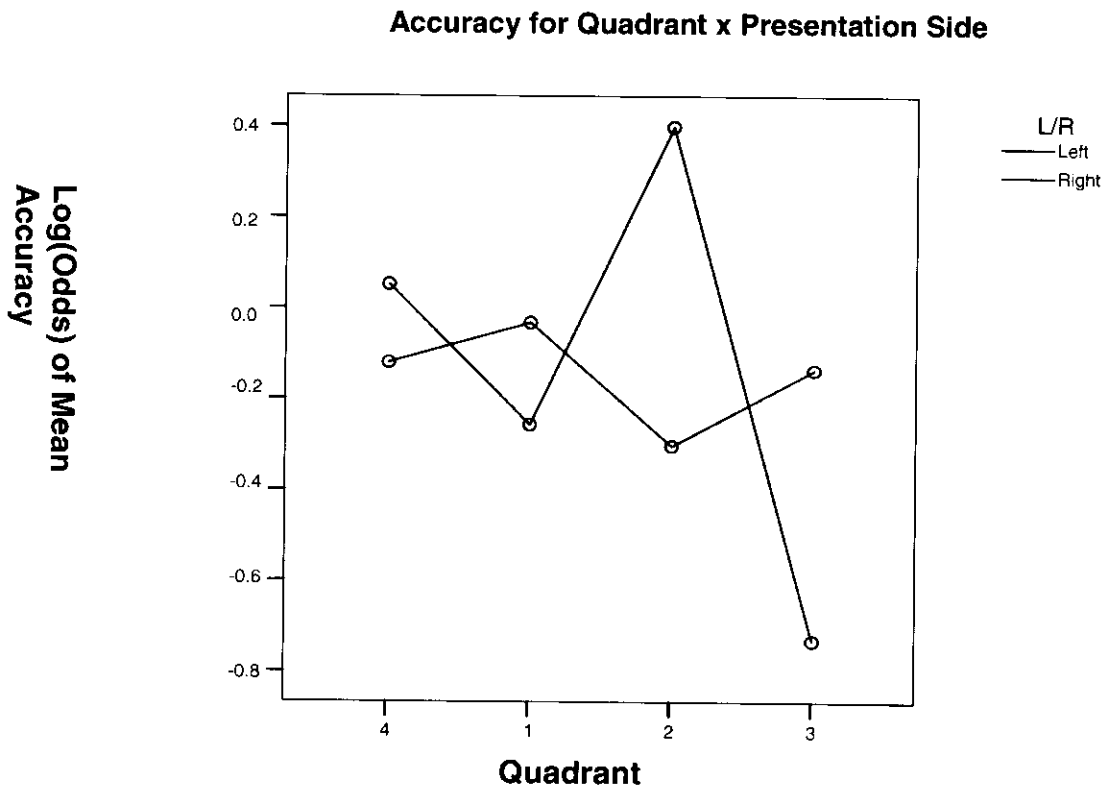


Figure 5. There was an interaction of quadrant and presentation side. Stimuli shown to the RVF were better for centrally located wedges and worse for peripherally located wedges than stimuli shown to the LVF.

As in Experiment 1, reaction time was normalized by only using values between 200 and 2000ms, and speed was calculated as $1/\text{reaction time}$. Reaction time and speed showed the same results: presentation side did not affect reaction time, ($F(1,15) = 2.119, p = 0.165$), but degree of difference did, ($F(7,15) = 4.581, p < 0.0005$). Figure 6 illustrates that when the quadrant is very similar to the rest of the circle, participants were slower to respond, and the interaction between presentation side and degree of difference is not significant, ($p = 0.485$).

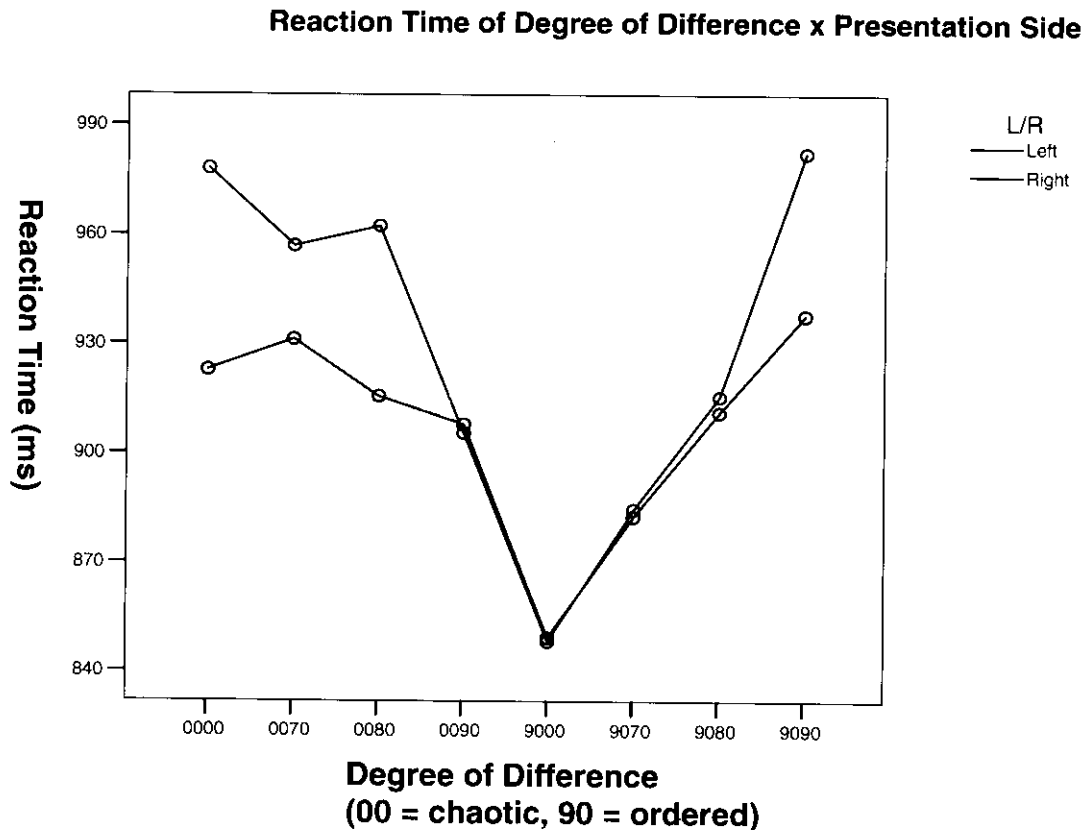


Figure 6. The higher the contrast (highest = 9000, 0090; lowest = 0000, 9090), the faster the reaction time to determine wedge location. There were no significant interactions.

General Discussion

The goal of this research was to investigate whether there were hemispheric differences in processing Gestalt principles. This research focused on a level below whole object processing, to isolate the grouping principles of proximity and orientation. In Experiment 1, the stimulus manipulations of proximity were effective in that the aspect ratio did not affect reaction time, but did affect whether participants reported the alignment as vertical and horizontal. Because this manipulation produced the expected results, participants were grouping by proximity in making their decisions. This experiment did not produce any significant effects or

trends for lateralization. There was a slight trend for a vertical bias, but closer inspection shows that such a bias is a matter of individual differences. Since Experiment 1 used a 2 alternative force choice (AFC), it is possible that there were effects, but they were too small to see with the relatively low power. However, since neither reaction time nor accuracy was affected by presentation side, this suggests that, at least in very simple tasks, grouping by proximity is not lateralized.

Experiment 2 was also successful as a grouping task, since there was an effect on reaction time based on how distinguishable the wedge's orientation was from the rest of the circle. Once again there were no main effects of lateralization in this experiment. There was a significant reaction between quadrant and presentation side. The quadrants that were closer to the center had faster reaction times, which is unsurprising since they would fall within central vision, which has a higher acuity. The surprising part of this interaction is that for stimuli presented to the LVF, the effect of having the wedge be located near the center was much larger than for stimuli in the RVF. Additionally, reaction times were much slower for LVF periphery than for the same position in the RVF. This interaction suggests that the RH is engaged in a greater amount of processing when grouping by orientation. By being the dominant hemisphere, when the stimuli are easy to visually process, the RH would be much quicker to respond. On the other hand, when stimuli are more difficult to see, the LH will process it more quickly because it is not dominant and has a looser criterion for making the judgment. The RH will take longer to try to piece together the information and thereby take a longer time to respond.

The boosting effect found for the LVF/RH is similar to the findings of Van Kleeck and Kosslyn (1989). In that paper they used embedded figures that were broken up either according to Gestalt figure principles or not. They concluded that this boost was evidence that Gestalt

principles used in figure identification were lateralized, and that the RH was dominant in their processing, which supported the theory that the RH is better at coordinate processing.

Experiment 1 indicates that it may not be such a simple split. In the case of grouping by proximity, we did not find any such lateralization effects, so it is unlikely that all Gestalt principles are lateralized in that way. However, grouping by orientation did show the same effect and so they may have been getting the effect they found based on this or other specific Gestalt principles. Some Gestalt principles do appear to fit the categorical/coordinate or local/global lateralization paradigm; however, not all of the Gestalt principles fit, at least in the same place. It may be the case that either some of these principles, such as grouping by proximity, are so simple that they are not lateralized at all. It may also be the case that their effects are much smaller and therefore more difficult to determine and perhaps they are even lateralized to the left hemisphere. Stronger manipulations for these principles are needed before an answer can be determined.

Conclusions

The goal of this research was to examine the relative contribution of the right and left hemisphere to visual perceptual grouping. Whereas the hemispheres appear to contribute equally when the grouping task is simple, the right hemisphere appears to play a greater role when the stimuli to be grouped are more complicated. This latter finding is compatible with some existing results and requires further investigation.

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