האוניברסיטה העברית בירושלים

THE HEBREW UNIVERSITY OF JERUSALEM

THE MYSTERIES OF THE DIAGONAL: GENDER-RELATED PERCEPTUAL ASYMMETRIES

by

JUDITH AVRAHAMI, TALY ARGAMAN
and DVORA WEISS-CHASUM

Discussion Paper # 348 February 2004

מרכז לחקר הרציונליות

CENTER FOR THE STUDY
OF RATIONALITY

Feldman Building, Givat-Ram, 91904 Jerusalem, Israel
PHONE: [972]-2-6584135 FAX: [972]-2-6513681
E-MAIL: ratio@math.huji.ac.il
URL: http://www.ratio.huji.ac.il/

The Mysteries of the Diagonal: Gender-Related Perceptual Asymmetries

Judith Avrahami,[1,2] Taly Argaman[1], and Dvora Weiss-Chasum[3]

[1] The Goldie Rotman Center for Cognitive Science and Education, School of Education, The Hebrew University of Jerusalem

[2] Center for the Study of Rationality, The Hebrew University of Jerusalem

[3] Psychology Department, The Hebrew University of Jerusalem

ASTRACT

The paper reports a perceptual asymmetry for the two diagonals that is related to gender such that females prefer the diagonal spanning from top-right to bottom left (/) while males the opposite one (\). This relationship is observed in a variety of tasks: Aesthetic judgment of paintings, spotting differences between two paintings, and visual search for a tilted line among similarly tilted distractors. The paper does not provide an explanation of the relationship between this asymmetry and gender but rules out several potential mediating factors, such as eye dominance, head tilt, handedness, and hemispheric differences. At the same time, the paper does outline the scope of the phenomenon: The asymmetry is found both for meaningful and for meaningless stimuli and both at brief and at extended presentation. Moreover, the asymmetry is found related to the tilt of the visual elements that require processing not to their location in the visual field.

The Mysteries of the Diagonal: Gender-Related Perceptual Asymmetries

Even with only little awareness of perceptual phenomena one might notice a prevalent asymmetry between the two diagonals. Painters like Jan van Eyck, for example, structure their paintings mostly along one of the diagonals. Thus, in a van Eyck painting furniture, floor boards, and sometimes even people, lie along the diagonal spanning from the top-right end of the painting to the bottom-left end. The painter David, on the other hand, consistently prefers the opposite diagonal – that from the top-left end to the bottom right.

Advertisers too tend to favor one diagonal more often than the other. Web sites of shoe vendors are a good example: in some all shoes are diagonally oriented in one direction and in others in the opposite direction. Another, quantifiable, example can be found in the corpus of line drawings of everyday objects by Snodgrass and Vanderwart (1980). In that corpus there are a number of elongated objects, like a screwdriver or an asparagus, all oriented diagonally. Interestingly, those oriented along one diagonal exceed those oriented along the other by a factor greater than two to one. Even figures in scientific papers, that depict an experimental procedure as a procession of displays a participant would experience over time, use the one diagonal more often than the other for representing the arrow of time. It is important to note, however, that although painters and designers may be found to use one diagonal over the other, they do not all prefer the same one. It would be therefore interesting to find out whether this differential preference is related to any other individual characteristics.

The asymmetry between the two diagonals is particularly intriguing since it cannot be reduced to asymmetries between the right and left hemifields (e.g., Kosslyn, 1987) or between the upper and lower hemifields (e.g., Christman, 1993; Rubin, Nakayama & Shapley, 1996) both of which have been studied extensively. The two diagonals span both the right and left visual fields and both the upper and lower fields.

Still, like any perceptual asymmetry, if the asymmetry between the diagonals is experimentally established it would have important implications for understanding various aspects of visual processing like efficiency and preference. In particular, the asymmetry would illuminate the temporal component of the visual process: Assuming that the more efficiently processed parts of a stimulus reach a threshold of activation faster than others it would indicate what aspects of a stimulus have precedence in visual processing, namely, what aspects have a more important role in constraining the interpretation of a visual scene.

There are at least three possible ways to conceive of precedence in visual processing. One involves a scan along the display with attention (and/or the eyes) moving from one end of the display to another; the second relates to a differential perceptual accessibility of the content in different locations in the visual field, and the third corresponds to greater featural availability or higher salience of one type of stimulus over another. The set of experiments reported here are attempts to characterize the asymmetry and relate it to one of these classes.

The study comprises three experiments testing the perceptual asymmetry between the two diagonals. The first experiment compared aesthetic preference for paintings having a diagonal structure (the one diagonal or the other) and for the same paintings' mirror image. The second experiment tested whether flipping a painting to its mirror image affects the order of detecting differences in a "spot the differences" task. The third experiment compared the efficiency of a visual search for lines tilted to the right or to the left of vertical under either extended or brief presentation. To anticipate, all the studies reveal the asymmetry to be related to gender.

EXPERIMENT 1

Since much of the evidence for the asymmetry of the diagonals comes from art, we first wanted to find out whether people have a preference for paintings whose dominant diagonal is the one or the other. To this end, we asked participants to aesthetically compare paintings with one dominant diagonal to their mirror image. Thirty-two paintings, half originally structured along one diagonal and half along the other, were used. Each painting was printed on one side of an A4 sheet and its mirror image on the other side. Participants were asked to indicate which version they liked better. The experimental question was whether participants would tend to prefer the original, irrespective of the orientation of its dominant diagonal, or whether preferences would be mediated by the layout. An example of a painting is presented in Figure 1.

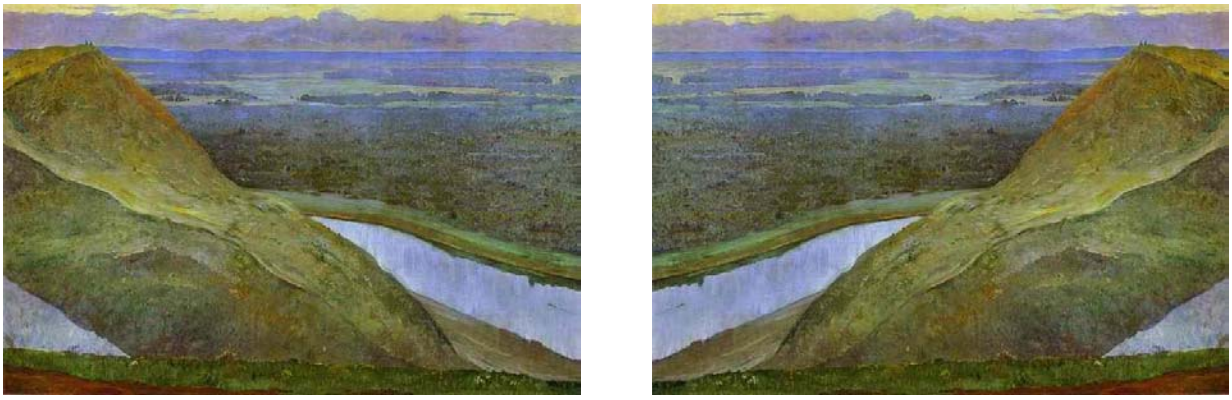

Figure 1: Example of a painting and its mirror image used in Experiment 1 (Mikhail Nesterov: Homeland of Aksakov, 1914)

Method

Participants. Forty-eight students of the Hebrew University, half male and half female participated in the experiment for a small monetary reward. A quarter of both male and female participants were left-hand dominant.

Stimuli. The corpus of paintings was comprised of four groups of eight: paintings focusing on a single male, paintings focusing on a single female, paintings of landscapes, and paintings of people assemblies. The orientation of the dominant diagonal of a painting was balanced within each group of paintings. A pretest ensured that observers agree with our perception of the dominant diagonal in each painting. The paintings were fitted to the size of an A4 page with the original printed on one side and its mirror image on the other. The paper was then laminated to avoid wear and tear. The paintings were all realistic, dating from 1510 to 1928.

Procedure. Participants were presented with one painting at a time, in random order. They flipped the sheet back and forth until they made up their mind as to which side they liked better. The experimenter recorded the following information: a) which version of a painting (original or mirror image) the participants happened to see first and b) which version of a painting the participants preferred. For control, the experimenter also recorded the participant's gender and handedness. The experimenter was unaware of which version was the original. Participants enjoyed the paintings, enjoyed the task.

Results

Every choice of each painting was scored +1 if the original version was chosen and –1 if the mirror image was chosen. This revealed that the original version of the painting was preferred in 52.9% of the cases. The scores were then subjected to an analysis of variance with painting as the unit of analysis and with Dominant-Diagonal (of the original) and participants' Gender as factors. The analysis revealed that the intercept, i.e., the preference for the original over its mirror image, deviated significantly from zero ($F(1,46)=7.526$, $MSE=.044$, $p=.009$). This preference may indicate that some participants had seen few of the paintings before – even if unaware of it – or it may possibly indicate that the original does, somehow, look better[1]. There was also a slight tendency to prefer the original more often when it was structured along the top-right to bottom-left diagonal (henceforth TR to BL '/') than along the top-left to bottom-right diagonal (henceforth TL to BR '\'), but the analysis of variance shows that the effect of Dominant-Diagonal is not significant ($F(1,46)=2.157$, $MSE=.074$, $p=.149$).

The analysis did reveal a significant interaction, one between Dominant-Diagonal and Gender ($F(1,46)=5.465$, $MSE=.074$, $p=.024$). Females were found to prefer the original more often when it was structured along the TR to BL (/) diagonal while males preferred the original more often when it was structured along the opposite diagonal (\) (see Figure 2). The percentages of cases the original was chosen by males in each Diagonal are 53.6% and 56.0% for the (/) and (\) diagonals, respectively, and the percentages for females choices are 56.3% and 45.8% for the (/) and (\) diagonals, respectively.

---

[1] The late artist Raaya Redlich, when discussing this issue with the first author, argued that a mirror image reveals a painting's imperfections.

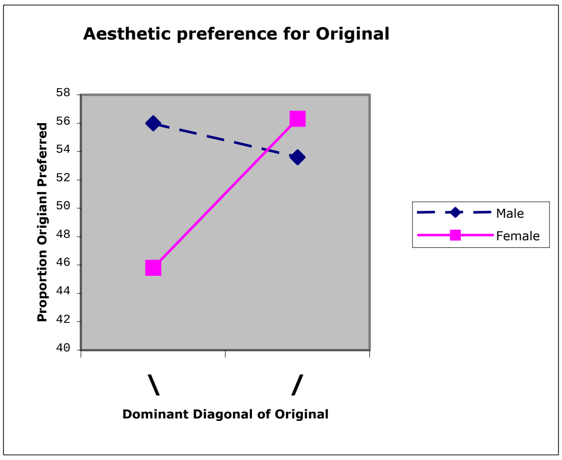

Figure 2. Percent of cases in which the original, in each diagonal, was preferred over its mirror image by males and females

Yet another analysis, this time including also handedness as a factor did not reveal any new effects. Neither the interaction between Handedness and Diagonal nor that between Handedness Gender and Diagonal were found to be significant (both *F*'s<1).

The interaction between Dominant-Diagonal and Gender came as a surprise. We therefore tried to explain it away by a difference in attitude towards the orientation of the body of the same or the opposite sex, specifically in the single male and single-female groups of painting. An additional analysis, with the four groups of paintings as another factor, showed a similar pattern in all groups of painting, namely, for landscapes and assemblies as well (for the triple interaction of Diagonal, Gender and Groups *F*<1).

Another possible explanation of the interaction that had to be checked is that what participants actually preferred was the version they had seen first. Since the version of the painting seen first was randomly determined, it could be that, accidentally, males happened to see first more original paintings oriented in the TL to BR (\) diagonal while females more original paintings in the other; such a difference could explain the gender-related difference in preference. Indeed, a slight correlation was evident between the version seen first and the version preferred: .147 for males and .167 for females. The percent of participants in each gender who happened to see the original first in paintings of each dominant diagonal orientation is as follows: In the TL to BR (\) dominant-diagonal, both males and females saw an original first more often (55% in the males, 51% in the females). In the TR to BL (/) dominant-diagonal males saw the original as often as its mirror image (i.e., 50%) and females slightly less (49%). These values cannot explain the pattern of results: Although order of presentation could contribute to the pattern of male preferences it can explain neither the difference in preference evident in females, nor why the difference in females is the larger of the two.

Discussion

Although the result of differential preference in the different genders was, as we said, a surprise, it solved a puzzle that had preoccupied us before. When searching the literature for treatments of the diagonals in the theory of art we found two art-historians who consider the diagonal in paintings. Both argue that, the experience derived from looking at a painting, changes in an important manner when viewing the reflection of the painting in a mirror or when viewing a printed mirror image of the original.

One art-historian Rudolf Arnheim, argues in his book "The Power of the Center" (1982): "There is a well known tendency, largely independent of actual eye movements, for viewers to perceive the area in the left corner of the visual field as the point of departure and the entire picture as organized from left to right. Also contributed by the viewer is a downward pull…" (p.37). This obviously results in a TL to BR (\) organization. To prove his argument Arnheim presents the painting of "Napoleon Crossing the Alps" by David, in which Napoleon's horse appears to halt. "If one looks at David's painting in the mirror one sees the horse bounding much more freely" (p. 108). With the question of an active scan left aside for the time being, it is obvious that Arnheim considers the TL to BR (\) diagonal as primary in viewing a painting.

Another art-historian, who considers, what she calls "the glance-curve", is Mercedes Gaffron (1950). She argues that "[the glance-curve] begins in the left foreground, penetrates toward the depth, then turns over towards the right" (p.317). Although Gaffron speaks of the three dimensionality of a painting, she clearly sketches a path consistent with the BR to TL (/) diagonal that later curves down. To prove her point she presents several paintings and their mirror images. One of the paintings is "Pope Leo X" by Raphael. In the original, objects lying along the path from bottom-left towards the top-right (/), she says – like the pope's illuminated manuscript and elaborate bell – are seen as related to the Pope's face. In the mirror image, she argues, they can only be seen separately, as a still life, “but we cannot perceive them in immediate connection with the face of the Pope, and thus they lose the special meaning they have within the composition of the original” (p.323).

Arnheim and Gaffron both believe in a diagonal path of the viewer’s glance but they differ in which diagonal it is. Interestingly, Gaffron, a woman, argues for the diagonal preferred by the females in our experiment whereas Arnheim, a man, advocates the diagonal preferred by the males!

To further understand the phenomenon on our hand we asked whether the gender-related differential preference to diagonals was restricted to aesthetic judgment or was more generally related to perceptual processing. If flipping a painting to its mirror image changes the way the painting is perceived then parts which are salient in one layout may loose their salience in the other and vice versa.[2]

To test this hypothesis we used the well-known “Spot the Difference” game, comparing performance in paintings and in their mirror images. We reasoned that, if a change in layout changes the processing of a painting, then differences that are spotted before others in the original might be spotted later in its mirror image.

EXPERIMENT 2

Ten paintings were selected for the experiment and two changes were made in each. Observers watched the intact and changed version of a painting displayed side by side on a computer screen. When spotting a difference, observers indicated its location with the computer’s mouse, pressing the mouse’s key.

Method

Participants. Fifty-two students, half of them male and half female, participated in the experiment for a monetary reward.

---

[2] The effects of flipping a painting to its mirror image on aesthetic preferences have been studied before (e.g., Levy, 1976; McLaughlin, 1986; McLaughlin, Dean & Stanley, 1982), but were related to the laterality of the major object of interest in the painting and handedness, not to diagonality and gender. Still, to rule out an alternative explanation to our results based on the location of objects-of-interest in the painting (though handedness was fully balanced in our gender groups), a new group of 14 participants was asked to indicate where, in each (original) painting, the “major object of interest” lay: to the right, the left, or in between; above, below, or in between. We then looked for correlations between ‘righthood’ of an original painting – as judged by this new group of participants – and its preferences in the male and female participants of Experiment 1. We similarly analyzed the ‘uphood’

Materials and Procedure. Ten classical paintings with an asymmetric structure were used. In each painting one of the diagonals was more salient than the other. Two changes were introduced into every painting. The differences between original and modified versions were neither very easy nor too difficult to spot. This level of difficulty was reached after extensive pre-testing. The locations of the changes in the paintings were varied, to avoid learning. For every pair of paintings – intact and modified – there were two versions: the original orientation or a mirror image of it. For an example, see Figure 3.

Figure 3: A pair of paintings for spotting two differences, once in the original and once in a mirror image (William Strang: Bank Holiday, 1912)

Every participant spotted the differences of a painting either in its original pairs or in the mirror-image pairs. In addition, half the pairs presented to each participant were structured along one diagonal and the other half along the other diagonal.

The paintings were presented on the monitor of a portable Toshiba Satellite computer. A computer program presented the paintings in random order. The assignment of the intact and changed painting to the left or right half of the computer monitor was also random. The program recorded the time the mouse-key was pressed in the vicinity of a difference. Participants could point the mouse and click its key at either the changed or intact version of a painting in the pair, as long as it was in the area of a difference between the paintings.

Design. The two variables manipulated in the experiment were Layout, namely, the basic structure of the paintings in a pair (which changes, of course, in the

---

of an original painting as indicated by the new group and the preferences of the old groups. No correlations were found.

mirror image), and Gender. For every painting, each Layout was presented to half of the male and half of the female participants. The dependent measure was the order in which the differences were spotted, namely, which of the two differences was spotted first.

Results

At this stage we still did not know what the effects of flipping a stimulus to its mirror image would be. Moreover, since – as indicated above – the locations of changes made to the paintings were varied in the different paintings, we had no theory as to which change would be spotted first and by which group. All we tested here is the hypothesis that whatever effect the flipping from one layout to the other would have on females' processing – it would have the opposite effect on the males'.

Looking at the spotting order of the female group for the two layouts we found a difference. This difference could, naturally, be a matter of chance. To establish an interaction between layout and gender we must see the opposite difference in the male group. In other words, changes that are more likely to be spotted first in one layout over the other by females should also be more likely to be spotted first in one layout over the other by males – but for them it should be the opposite layouts.

To find that out, we scored the order of finding the two differences '1' if it agreed with the order the females tended to spot these differences when the paintings were in the version with the TR to BL (/) Layout and '-1' if it did not. Thus, every trial (i.e., every completion of spotting the two differences in a painting) received a value of either 1 or -1 depending on the order of spotting the differences. We then calculated the mean value of every painting separately for either Layout and for either Gender (see Figure 4).

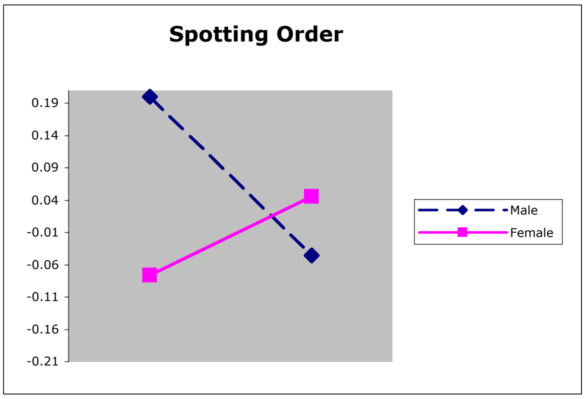

Figure 4: *Mean value for spotting order, where spotting in the order the majority of females spotted in the (/) Layout is scored '1' while spotting in the opposite order is scored '-1'*

The mean values for spotting the differences are +0.046 and -0.076 for females in the (/) and the (\) diagonals, respectively, and -0.046 and +0.200 for males in the (/) and the (\) diagonals.

Note that, while for females the value is higher in the TR to BL (/) diagonal than in the other (being so defined), the opposite is true for males, namely, the value is higher in the TL to BR (\) diagonal than in the other. An analysis of variance of Spotting Order, for the ten paintings with Layout and Gender as factors, revealed a significant interaction between the two factors ($F(1,9)=13.505$, $MSE=.006$, $p=.005$).

One could argue, of course, that the interaction could have resulted from the way we scored Order. Therefore, two planned comparisons, one for females and one for males were conducted. The effect of Layout in the separate analysis for females is ($F(1,9)=10.288$, $MSE=.002$, $p=.011$), but this, again, could be related to the way we scored order. Importantly, however, the separate analysis for males again revealed a significant effect of Layout on Spotting Order ($F(1,9)=6.000$, $MSE=.013$, $p=.037$) with the effect being opposite to that on females' Spotting Order (see Figure 4). Unlike the previous significant results, namely, the interaction between Layout and Gender and the effect of Layout for females only, this result cannot be attributed to the method of defining the differences as first and second.

Discussion

The results of this experiment clearly demonstrate an effect of Layout on the temporal aspect of perception. Even though some differences were, naturally, more meaningful, more salient, and hence easier to spot, than others, this saliency was still affected by the structure of the paintings: The same difference that was more salient than another in one layout could be less so in the mirror image of the same painting. Most importantly, the effect of Layout on the salience of a difference worked in opposite direction for males and females.

We have, by now, two pieces of evidence indicating a gender-related perceptual difference but it is not clear *why* flipping of a painting to its mirror image affected either the aesthetic pleasure derived from a painting or the order in which differences were spotted. There are two possible explanations for this effect. One is related to *locations*: If certain locations are more accessible than others – and differently so to males and females – then the same location can become more or less accessible in a mirror image. As a result, elements that are meaningful in one layout may become, as Gaffron argues, meaningless, and the painting less coherent, less harmonious. The same elements may also become less salient and hence changes introduced in them more difficult to spot. Differences in the accessibility of locations in the field could result, though not necessarily, from a scan of the display (see this issue addressed in more detail in the General Discussion). Another possible explanation is that there is a differential sensitivity to *orientation* in males and females. Since flipping a painting to its mirror image changes the orientation of its elements, elements that are more salient when in one orientation may become less so in the other. This, in turn, may again affect both the coherence of a painting (and hence its aesthetic experience) and the efficiency in spotting differences. Note that the two explanations are non-exclusive. Experiment 3 was designed to test the two hypotheses in a fully controlled display.

EXPERIMENT 3

The main goal of Experiment 3 was to test the *location* versus *orientation* hypotheses. To that end, the display in this experiment consisted of thirty-six short lines all tilted either to the right or to the left of vertical. In half of the trials one of the lines, serving as a target, was tilted less than the rest. Participants searched for a target, judging whether one was present or not. The possible locations of the target were confined to a circle around the center of the display and fully balanced.

To test the first hypothesis, the *location* hypothesis, we could ask whether efficiency in detecting a target in locations along the two diagonals (relative to display center) is differentially related to gender.

To test the second hypothesis, the *orientation* hypothesis, namely, that males and females differ in their sensitivity to the orientation of elements in the display, we could ask whether males and females differ in the ease with which they detect targets oriented in different directions, irrespective of their location.

Another function of Experiment 3 was to find out whether the asymmetry related to gender is in fact mediated by other individual characteristics. The individual characteristics recorded for every participant, in addition to gender, were eye dominance, head tilt, and handedness. The experiment also explored the relation between gender and perceptual sensitivity in the left versus the right hemi-field. We could thus also test whether hemispheric differences can account for the relation, found in the previous experiments, between gender and the diagonal.

In addition, the experiment tested a number of questions concerning the scope of the asymmetry.

A preliminary question was whether the perceptual asymmetry, found with rich and meaningful stimuli in the two previous experiments, would at all be evident with poor and meaningless stimuli. The stimulus in this experiment consisted of just a group of short tilted lines.

Two additional questions were whether the asymmetry is slow to build, requiring a long presentation that allows free eye movements and whether the asymmetry can be overcome by adjusting to a repeatedly presented stimulus tilted always in the same direction.

Concerning the individual characteristics that were recorded here, three conditions must hold to truly explain the gender-related perceptual asymmetry: 1) the relation between gender and diagonal must be replicated in the new experiment, 2) the individual characteristics must be more strongly related to the asymmetry than gender, and 3) these characteristics should be correlated with gender. If, however, only the second condition holds it could, at least, provide a potential explanation for the gender asymmetry found in the first experiments, under the (not very likely) assumption that the gender groups in those experiments were unbalanced in one of the other individual characteristics.

Experiment 3 consisted of two sub-experiments. In one, presentation lasted until the participant responded while in the other presentation was brief.

Experiment 3a

In Experiment 3 participants searched for a target among distractors in a display consisting of 36 short lines. Both target and distractors were tilted in the same direction, but the distractors were tilted more than the target.

Method

Participants. Sixty-two students of the Hebrew University participated in the experiment, some for a monetary reward and others in partial fulfillment of course requirements. Two participants were excluded from analyses: one female whose performance was at chance and the weakest male (to match the number in the two gender groups). Half of the participants were female and the other half male. Tests revealed that of the sixty participants 38 were right-eye-dominant, 49 were right-hand-dominant, 23 had a rightward head-tilt, 13 had a leftward tilt and 24 did not show any tilt.

Materials. Thirty-six lines all tilted either to the right or to the left of vertical were presented within an imaginary grid of 6 X 6 centered on a computer screen. Each line subtended .6° of visual angle, was 2 point thick (produced with anti-aliasing) and was randomly positioned within a cell of the imaginary grid subtending 1.3°x1.3°of visual angle. The whole imaginary grid subtended 8°x8° of visual angle. All distractors were tilted 45 degrees away from vertical while the targets were tilted only 30 degrees (see Figure 5). There were eight possible locations for targets, as indicated in Figure 5c, all equally distant from the center of the display.

The visual-search task was run on a Mac IICX computer with a 13″ monitor and was controlled by the VScope software package (Enns & Rensink, 1992).

In addition, a paper cone was used to determine eye dominance and a note stand - balanced by a level - was used to determine head tilt.

a b c

Figure 5: Examples of the display used in Experiment 3: a) target present, tilted right b) target absent, tilted left c) potential target locations

Procedure. Upon entering the laboratory participants took a seat facing the experimenter and were asked to read the instructions that were placed on the note stand. Meanwhile the experimenter used the vertical center bar of the note stand, extending above the instruction sheet, to determine the participant's head tilt.

The participant then turned to face the computer and perform the visual-search task. This task consisted of five blocks in all. The first was a short familiarization block of 8 trials, in which orientation of the display was mixed (i.e., the lines were tilted to one side in some trials and to the other side in other trials). The second block, the practice block, consisted of 64 trials and was again mixed. The three experimental blocks, each consisting of 64 trials then followed. The first two experimental blocks were pure blocks, i.e., in all trials within a block lines were tilted to one side. Each of the pure blocks had either a right tilt or a left tilt and their order was balanced across the participants of each gender. The third experimental block was mixed, like the practice block.

The schedule of a single trial was as follows: the experimental display was presented until a response was made. If no response was made within 3.6 seconds timeout was reached. After a blank of 75 ms the feedback – with a "+" for correct, "-" for incorrect and "0" for timeout – appeared at screen center for 675 ms. A 750 ms blank preceded the next experimental display.

Participants pressed a key with their left hand in target-present trials and with their right hand in target-absent trials.

When finishing the visual-search task the participant was asked to look at the experimenter through the paper cone, focusing on the experimenter's nose. This enabled the experimenter to determine the participant's dominant eye.

Design. Three within-participant variables were manipulated: The Orientation of the stimulus' lines (left or right of vertical), the Presence of a target (either present or absent) and the Location of the target. The third variable was, obviously, manipulated only within Present trials. Analyses therefore always involved only two of these variables: Orientation and Presence collapsing over target location and Orientation and Location for target-present trials only. Locations were collapsed in two ways: top-right and lower-left locations versus top-left and bottom-right locations or the four pairs of locations at the ends of both diagonals..

Other variables whose effects on performance were tested were Gender, Eye-Dominance, Head-Tilt and Handedness.

Results

Separate analyses were carried out for the pure and for the mixed experimental blocks. The pure blocks were more useful for testing the locations hypothesis, as the factor of location was not confounded with the orientation of the stimulus, which was fixed. In contrast, the mixed block was most useful for testing the hypothesis of object orientation.

Pure Blocks. The two pure blocks were lumped together and an analysis of variance, with line Orientation, target Presence and Gender as factors, was conducted both for accuracy and for speed. Analyses for speed here and in following analyses involved median response times for correct responses only. The only significant effects were revealed by the analysis of response time. One was a main effect of target Presence, with response being faster ($F(1,58)=53.42$, $MSE=43{,}083$, $p<.001$) when a target was present. This finding is common in visual-search tasks. The other was a main effect of Gender: Males were faster than females ($F(1,58)=5.59$, $MSE=198{,}648$, $p=.021$). There was no main effect of Orientation, nor an interaction between stimulus Orientation and Gender (both F's<1). The analysis for accuracy revealed no significant effects at all. At this stage it was unclear whether the interaction between Orientation and Gender was not found because the stimuli were meaningless, because the pure blocks enabled adjustment to stimulus orientation, or because the gender-related diagonal asymmetry, found previously, is related to location not to element orientation.

Further analyses of the data of the pure blocks focused on target location and were conducted for the target-present trials only. In the analyses, locations were collapsed to compare the diagonals of locations.

The analysis collapsed the four locations along each diagonal (i.e., the two upper-right and two lower-left locations in Figure 5c), to answer the following questions:

1. Would processing of locations along one diagonal be more efficient than processing along the other?

2. Would Gender and Locations – on the different diagonal – interact?

3. Would targets of one orientation be more efficiently detected in locations along one diagonal than in locations along the other diagonal?

Analyses of variance with Orientation and Diagonal-of-Locations as within-participants' variables and Gender as a between-participants' variable were conducted, both for accuracy and for speed. None of the new potential effects reached significance. The main effect of Gender for speed reappeared here, with males being faster than females, and a main effect of Diagonal-of-Location for accuracy almost reached significance ($F(1,58)=3.929$, $MSE=21.914$, $p=.052$), showing a small (1%) but consistent advantage of the TR to BL (/) over the TL to BR (\) Diagonal-of-Locations. Most important, performance in the two Diagonals-of-locations did not interact with Gender ($F<1$). There was only a hint of an interaction between Orientation and Diagonal-of-Locations for speed ($F(1,58)=1.94$, $MSE=5331$, $p=.169$) with participants slightly faster when Orientation matched the Diagonal-of-Locations than when it did not.

Since no effect of either Orientation or Diagonal-of-Locations (or their interaction) were found to be related to Gender, there was nothing to explain, at this stage, by other individual characteristics and therefore no further analyses were conducted on the pure blocks' data.

Mixed Block. Analyses of the mixed experimental block were then conducted. First, analyses for accuracy and for speed were conducted with Orientation, Presence and Gender as factors. These analyses again revealed a significant main effect of Presence ($F(1,58)=5.80$, $MSE=16.172$, $p=.019$ for accuracy, $F(1,58)=36.46$, $MSE=33247$, $p<.001$ for speed) with performance less accurate but faster in the target-present trials. In addition, the male participants were again faster than the females ($F(1,58)=10.19$, $MSE=143,997$, $p=.002$). An interaction between Gender and

Target-Presence revealed that the males were faster mostly in the target-absent trials (*F*(1,58)=6.89, *MSE*=33,247, *p*=.011).

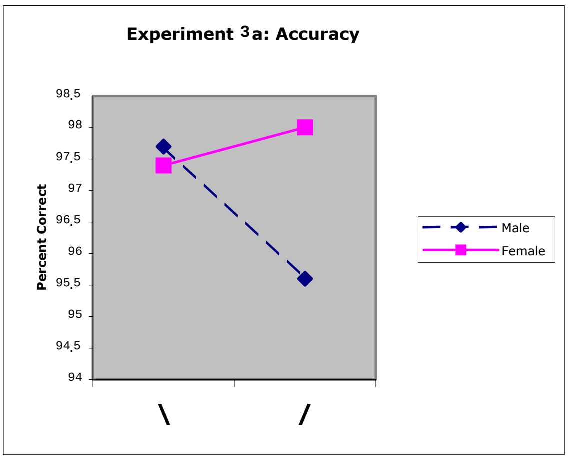

Figure 6: *Percent correct responses in the mixed block of Experiment 3a in each line-orientation, separately for males and females*

More important, the interaction between Orientation and Gender was significant for accuracy (*F*(1,58)=8.01, *MSE*=15.938, *p*=.006) though not for speed (*F*<1). A graph showing the interaction between Gender and Orientation (for accuracy) is depicted in Figure 6. The means are presented in Table 1 showing that, females were more accurate in the TR to BL (/) diagonal and males in the other. There was also a significant three-way interaction of Orientation, Gender, and Presence for both accuracy and speed (*F*(1,58)=6.491, *MSE*=16.953, *p*=.014 for accuracy and *F*(1,58)=4.165, *MSE*=3713, *p*=.046 for speed).

	Speed (ms)		Accuracy (%)	
Gender	(\)	(/)	(\)	(/)
Male	677(36.1)	670(34.0)	97.9(.7)	95.6(.7)
Female	838(36.1)	822(34.0)	97.4(.7)	98.0(.7)

Table 1: Performance in the Mixed Block of Experiment 3a: Mean of median response times and percent correct separately for the two Genders in the two Orientations (with standard deviations in parentheses)

The question arising now was whether any of the other individual characteristics was similarly related to Orientation. Analyses similar to that for Gender were conducted for Eye-Dominance, Head-Tilt, and Handedness. None of the two-way interactions of Orientation with these individual characteristics reached significance, with $F<1$ in most cases. The only interaction whose F rose above 1 was that of Orientation and Eye-Dominance for accuracy ($F(1,58)=1.491$, $MSE=17.695$, $p=.227$) with the left-eye-dominant participants more accurate in the TL to BR (\) orientation, but it was obviously weaker than that for Gender. The analysis with Eye-Dominance also revealed a significant three-way interaction, but only for accuracy ($F(1,58)=5.139$, $MSE=17.305$, $p=.027$). A test of the correlation between Gender and Eye-Dominance was found to be .277, with left-eye-dominance more prevalent in the male than in the female participants. Thus, rather than explain the interaction between Orientation and Gender it can be explained by it.

Having found the two-way interaction between Orientation and Gender in the mixed block, we wondered whether a similar interaction would emerge between Gender and Diagonal-of-Locations, even though it did not appear in the pure blocks, where it was more probable. Therefore, another analysis for the experimental mixed block, focusing on target-present trials only, was conducted, lumping together locations on the diagonals. Two ANOVA's, one for accuracy and one for speed, with Orientation and Diagonal-of-Locations as within-participant variables and Gender as a between participants variable were conducted. No main effects reached significance but the interaction between Orientation and Gender was again significant (in the target present only trials) for accuracy ($F(1,58)=11.844$, $MSE=10.000$, $p=.001$) but not for speed ($F(1,58)=1.674$, $MSE=5430$, $p=.201$), with females more accurate in the TR to BL (/) diagonal. There was no interaction between Gender and the Diagonals-of-Locations, neither for accuracy nor for speed (both F's<1). As to the relation between Orientation and Diagonals-of-Locations, there was a hint of an interaction for accuracy, with accuracy higher when the two matched than when they did not ($F(1,58)=3.033$, $MSE=6.484$, $p=.087$) but none for speed ($F<1$).

A last analysis of the target-present trials of the experimental mixed block data focused, separately, on the four pairs of locations at the diagonal ends. Although no differential effect was found for the different diagonals of locations, one could argue that a scan is initiated in one of the end sections and then gets diffused, hence the lack of interaction between Diagonals-of-Locations and Gender does not completely rule out an explanation based on *location*. To further test this, the two locations at each of the four ends of diagonals were lumped together to form four Diagonal-Ends. Efficiency was different in the different Diagonal-Ends: Performance was fastest and most accurate in the top-left pair of locations and slowest and least accurate in the bottom-right pair. The effect is significant for speed ($F(3,174)=6.439$, $MSE=12,181$, $p<.001$) and almost significant for accuracy ($F(3,174)=2.518$, $MSE=95.625$, $p=.060$). Importantly, however, performance in the different Diagonal-Ends did not interact with Gender ($F<1$ for both speed and accuracy). In other words, the gender-related asymmetry for the diagonals cannot be explained by a differential sensitivity in the different ends.

To summarize, Experiment 3a already provided answers to some of our questions: The gender-related perceptual asymmetry was evident also in simple, meaningless stimuli, at least with extended presentation; the asymmetry could be overcome with repeated presentation of similarly oriented stimuli; most important, the gender-related asymmetry was found for the orientation of objects but not for their locations. In other words, the *orientation* hypothesis but not the *location* hypothesis was corroborated. Experiment 3a also shows that none of the individual characteristics recorded, i.e., eye dominance, head tilt, or handedness, can account for the gender asymmetry.

One additional individual characteristic that was not tested in Experiment 3a but could be thought of as mediating the gender-related asymmetry is hemispheric differences. Specifically, the asymmetry could be mediated by hemispheric differences that are related to visual processing. Such differences ought to be manifested in differential efficiency in visual processing of stimuli in the left and right hemi-fields. But, to be able to refer to visual fields, eye movements must be precluded. Therefore, in Experiment 3b stimulus presentation was brief, too brief to allow free eye movements.

Experiment 3b

Experiment 3b was, in fact, a replication of Experiment 3a with the exception that stimulus presentation was brief. As such it could fulfill two objectives: to find out if the asymmetry between the diagonals is low-level or requires free eye movements to develop and to test the hypothesis that differential sensitivity to the right and left visual hemi-fields may be related to differential preference for one diagonal or the other.

Method

The method was almost identical to that of Experiment 3a. The only change was in procedure with the test display disappearing after 300 ms (pretests indicated that performance is at chance in shorter presentation). A new pool of 67 students participated in the experiment. Seven participants whose accuracy in the practice block did not exceed 55% were excluded from the analysis, leaving 30 males and 30 females. None had participated in Experiment 3a. Tests revealed that of the 60 remaining participants 25 were right-eye-dominant, 35 were right-hand-dominant, 22 had a rightward head-tilt, 16 had a leftward tilt and 22 did not show any tilt.

Results

Pure Blocks. In the pure blocks the only significant effect was that of Presence, with target-present trials less accurate ($F(1,58)=6.571$, $MSE=682.539$, $p=.013$) but faster ($F(1,58)=24.297$, $MSE=3646$, $p<.001$) than trials where no target appeared. Surprisingly, performance was slightly but consistently faster in the TR to BL (/) Orientation than in the TL to BR (\) Orientation ($F(1,58)=3.985$, $MSE=2308$, $p=.051$, the mean difference being 12 ms). Gender interacted with neither Orientation ($F<1$ for speed, $F(1,58)=1.426$, $MSE=220.977$, $p=.237$ for accuracy), nor the Diagonal-of-Locations ($F<1$ for both accuracy and speed). The only significant interaction was between Orientation and Diagonal-of-Locations. Here again, participants were more efficient when the diagonals matched than when they did not. This interaction was significant for accuracy ($F(1,58)=4.393$, $MSE=81.836$, $p=.040$) but not for speed ($F(1,58)=1.986$, $MSE=1149$, $p=.164$).

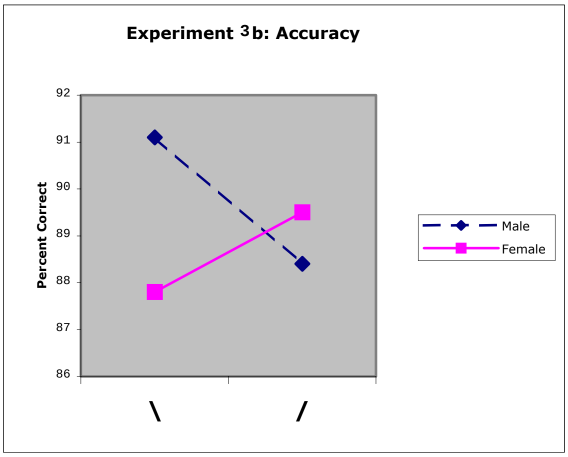

Figure 7: Percent correct responses in the mixed block of Experiment 3b in each line-orientation, separately for males and females

Mixed Block. In the experimental mixed block of Experiment 3b responses were again faster for target-present than for target-absent trials ($F(1,58)=15.396$, $MSE=5438$, $p<.001$) and less accurate (though not significantly so, $F(1,58)= 3.210$, $MSE=137.109$, $p=.078$). More importantly, the interaction between Orientation and Gender was again significant for accuracy ($F(1,58)=5.629$, $MSE=51.016$, $p=.021$). A graph showing this interaction is depicted in Figure 7. The interaction did not reach significance for speed ($F(1,58)=2.375$, $MSE=1714$, $p=.129$) but was in the same direction: Female participants were more efficient in the TR to BL (/) Orientation and male participants in the other (see Table 2).

	Speed (ms)		Accuracy (%)	
Gender	(\)	(/)	(\)	(/)
Male	615(21.4)	624(20.0)	91.1(1.7)	88.4(1.4)
Female	620(21.4)	613(20.0)	87.8(1.7)	89.5(1.4)

Table 2: Performance in the Mixed Block of Experiment 3b: Mean of median response times and percent correct separately for the two Genders in the two Orientations (with standard deviations in parentheses)

Similar analyses for accuracy and speed in the mixed block were conducted using the other individual characteristics of eye dominance, head tilt, and handedness even though this time none of these traits was correlated to Gender. None interacted with Orientation. In most cases F was less than 1 and in the few exceptions where F rose above 1, it did not exceed 1.2.

Further analyses, one for Diagonal-of-Locations and one for the pairs of locations at the four ends of the diagonals (see Experiment 3a) again did not reveal interactions with Gender. In the two analyses, one for accuracy and one for speed, with Orientation, Gender, and Diagonal-of-Locations as factors, tests of the interaction between Diagonal-of-Locations and Gender show $F<1$ for accuracy and $F(1,58)=1.045$, $MSE=1773$, $p=.311$ for speed. The analysis for accuracy did reveal a significant interaction between Orientation and Diagonal-of-Locations ($F(1,58)=11.905$, $MSE=30.195$, $p=.001$), with accuracy higher when the two were matched.

The analyses with the four pairs of locations at the ends of the two diagonals as factors revealed, as in Experiment 3a, a main effect of Diagonal-Ends ($F(1,58)=8.971$, $MSE=138.320$, $p<.001$, for accuracy and $F(1,58)=6.347$, $MSE=5792$, $p<.001$, for speed). Diagonal-Ends, however, did not interact with Gender (both *F*'s<1).

The other objective of Experiment 3b was to test the hypothesis that hemispheric differences mediated the gender-related asymmetry for diagonals. To test this we went back to the data of the pure blocks and first calculated, for every participant, in which side their accuracy was higher[3]. This value was used to divide participants into three groups: A group of 'left-preferrers' – having less errors in the left than in the right locations – (N=26), a group of 'right preferrers' (N=14), and a group for which the number of errors in the left and right locations did not differ that was left out. We then conducted a new analysis of variance for accuracy in the mixed block this time only for those who exhibited a side preference (with 'Side-Preference' instead of Gender). Orientation did not interact with Side-Preference ($F(1,38)=1.663$, $MSE=57.031$, $p=.205$). A similar analysis, using speed in the pure blocks to split participants into 'Side-Preference' groups and analyzing the variance of speed with 'Side-Preference' thus defined instead of Gender, also did not show an interaction between 'Side-Preference' and Orientation ($F<1$).

To summarize, Experiment 3b provides a full replication of Experiment 3a. The experiment also shows that the gender-related perceptual asymmetry is early, with the effect present even with brief presentation. However, none of the individual characteristics tested, not even hemispheric differences could explain the interaction between gender and orientation.

Discussion

The main objective of Experiment 3 was to test the two hypotheses regarding the perceptual asymmetry observed in the first two experiments, namely, whether the asymmetry results from different processing of locations along one diagonal and another, or from different processing of elements in one orientation and another. The results of both parts of Experiment 3 show that the source of the asymmetry is in the orientation of diagonally oriented objects and not in their locations.

Experiment 3 also shows that none of the individual characteristics we considered, namely, eye dominance, head tilt, handedness, or hemispheric differences can account for the gender-related asymmetry.

In addition, the asymmetry is apparently based on early, low-level processing since it is manifested for brief as well as extended presentation. Still, when stimuli of constant orientation repeat many times, as was the case in the pure blocks, participants apparently adjust to the orientation – as indicated by several hints to and interaction between elements' orientation and their location on the diagonals – and the asymmetry disappears.

GENERAL DISCUSSION

The three experiments taken together demonstrate a persisting perceptual asymmetry that is related to gender. The first experiment shows that this asymmetry can intervene in aesthetic preferences, with female observers preferring paintings whose basic structure is along the top-right to bottom-left (/) diagonal while male observers prefer paintings of the other diagonal (\). The second experiment shows that the layout of a painting (or, as we should now say, the orientation of the objects in the painting) intervenes in the order of processing the painting. As a result the order of processing objects in a painting may be different from the order of processing the same objects in its mirror image. Moreover, the change in the order of processing is opposite for the two genders. Experiment 3 provides a third demonstration of the

---

[3] The data from the pure blocks was used because it was not confounded with the manipulation of

gender-related perceptual asymmetry along the diagonal orientation. It also narrows the description of the phenomenon showing that it is related to the diagonal structure of the perceived objects, not to their specific locations in the visual field. In addition, it eliminates a number of potential mediators of the gender-related asymmetry.

In retrospect, since the gender-related asymmetry was found in both parts of Experiment 3 but none of the proposed individual characteristics was found to correlate with gender (with the exception of only eye-dominance only in Experiment 3a), there was no reason to expect that they would be strongly related to orientation, but we did not know this in advance. It is true that we did know, from the literature, that neither handedness nor eye dominance were correlated with gender (Arnold-Schulz-Gahmen, Selinski, & Ehrenstein, 1999), although the two are known to be correlated (McManus, Bryden, & Bourassa 1996). We also knew that head-tilt was related to eye-dominance (Greenberg, 1960) but since the latter was not related to gender there was only a slim chance that the former would. Even the evidence for a relation between gender and visual-field-dominance – as demonstrated, for example, in asymmetries found in line bisection tasks – is rather inconsequential (Jewell & McCourt 2000). Still, we could not rule out the possibility that any of these individual characteristics was independently related to the perceptual asymmetry and that it was accidentally unbalanced within the groups of males and females in the first two experiments.

One should remember that the comparisons in all three experiments involve stimuli and their mirror images. As such, the main manipulation in the experiments never changes the objective level of information in a stimulus. Differences in efficiency due to the change in layout can therefore not be attributed to differences in spatial visualization ability – for which gender differences have been found before.

What other candidates could there be? Would it be possible to track differences in life-experience with diagonal objects for the two genders as, for example, greater familiarity with the slash (/) than the backslash (\) for females in word-processing or heavier use of declining graphs by males[4]?

An important question left open is whether the perceptual asymmetry is related to the direction in which a scene is scanned. It is obvious that the visual field contains more content than that which can be processed at a time. Therefore, different

---

Orientation, as was the data of the mixed block.

parts must be addressed sequentially. The eyes move from one part of the field to another, bringing the elements of interest into the more acute fovea, and attention sequentially selects some elements in the fields before others. In other words, the field is scanned, no doubt, by either moving the eyes or by deploying attention from one part to another and these two levels are normally correlated. However, although it is clear that a scan does take place, it is extremely difficult to find out if it has a preferred, i.e., a default, direction.

One approach to studying the direction of visual scan is by recording eye movements. Unfortunately, when the eye-movements of a person are recorded, that person must be looking at something, at a stimulus, at a display and, as we have shown here, the characteristics of a display can greatly affect the order of visual processing. Not only effects of the contents of a picture but also of the goal of the viewer are clearly demonstrated in the recordings of eye movements performed by Yarbus (1967). Similarly, the movement of attention across a display is known to be influenced by the nature of the display, with straight lines, for example, encouraging movement along them (e.g., Avrahami, 1999). As a result, even if a particular direction of scan is found experimentally it may be specific to the experimental stimulus and to the type of the task used.

Another approach adopted to infer a visual scan is to compare visual efficiency in different parts of the field. This approach capitalizes on the assumption that greater efficiency in one part of the field would indicate that that part is processed before another and hence a scan from the former to the latter part can be inferred. But here too efficiency is measured for a specific task that involves a specific stimulus. Different parts of the visual field have been shown to excel in different tasks: for example, the left versus right visual field have been shown to differ in their efficiency for the local and global aspects of the field. The right hemi-field is better for processing local aspects of the stimulus and the left better for processing global aspects (Hellige, 1993). Viewed differently, it can be said that the left visual field is more efficient in holding and comparing several objects at once while the right visual field more efficient in detecting a single object. With efficiency related to visual task one can hardly infer a default scan direction from differential efficiency in different parts of the visual field.

---

[4] I thank an anonymous reviewer for suggesting these possibilities.

Moreover, the scan of a stimulus may be exhaustive. In that case, response time to different parts of the stimulus would not be different even if a scan did take place. Indeed, to infer a scan from the pattern of efficiency Avrahami (1998) compared efficiency in four locations (top, bottom, left, and right) in either mixed (several possible locations) or pure blocks (target location known in advance). The argument was that, if the different efficiency in the different target locations stemmed from differential sensitivity in these locations, then the difference between locations would be most pronounced in the mixed blocks. If, however, the difference stemmed from a scan in a particular direction, and if such a scan is exhaustive unless target location is known in advance, the superiority of locations that lie where the scan is initiated would be most pronounced in the pure blocks. Since greater differences were found in the pure blocks a scan, from top-right to bottom-left, was inferred. In retrospect, even this scan might be related to the type of task and the type of displays used in that study.

To summarize, although an explanation of gender-related perceptual asymmetry based on differential sensitivity to different locations was rejected here, a hypothesis of a differential scan was not. A new line of study is required to find out if males and females differ in their direction of scan. More precisely, whether the default direction of one's scan – if such a default is found – is related to one's preference for orientation, and whether that direction is related to gender. One should remember though, that even if the default direction of scan is found to correlate both with the preference for orientation and with gender, such correlations would still not provide the sought for causal direction: A differential scan, even if found, could be explained by, rather than explain, the differential preference for orientation. What we have, then, for the time being, is a gender-related aesthetic preference and a gender-related order of visual processing that is related to a gender-different sensitivity to a stimulus' diagonal orientation.

The implications of this phenomenon to art and science are obvious. Designers should be aware of the asymmetry and attempt to balance the two orientations when they address a mixed audience; they may wish to be selective when targeting a single-gender audience. Scientists, in particular students of visual perception, should be careful when choosing tilted stimuli. Such stimuli, if used, should be balanced in the orientation of their diagonals.

An important point about the gender-related perceptual asymmetry is that, although the effects reported here are all statistically significant, they are by no means absolute. Not all females prefer one diagonal and not all males prefer the other. The history of painting provides abundant examples of male painters who use the 'female' diagonal. Giotto, who is regarded as the father of the diagonal structure in middle ages painting, is an important such example. We still believe that there must, therefore, be some other individual dimension responsible for the asymmetry, a dimension that is correlated with gender. At the moment we do not know what that dimension might be and are left with the mystery of this gender-related perceptual asymmetry for the diagonals.

REFERENCES

Arnold-Schulz-Gahmen, B. E., Selinski, S., & Ehrenstein, W. H. (1999). Eye, ear, hand, and foot: Gender differences of individual laterality profiles. *27th Goettingen Neurobiology Conference*, **Vol. II**, p. 877. Stuttgart, New York: Thieme.

Avrahami, J. (1998). Presence and absence of top and right advantage as an indication of the attentional strategies underlying object selection. *Perception*, **2**, 431-438.

Avrahami, J. (1999). Objects of attention, objects of perception. *Perception & Psychophysics,* 61, 1604-1612.

Christman, S. D. (1993). Local-global processing in the upper versus lower visual field. *Bulletin of the Psychonomic Society*, **31**, 275-278.

McManus, I. C., Bryden, M. P., & Bourassa, D. C. (1996). Handedness and eye-dominance: Explaining the association. *Brain and Cognition*, **30**, 357-358.

Greenberg, G. (1960). Eye-dominance and head-tilt. *American Journal of Psychology*, **73**, 149-151.

Hellige, J. B. (1993). *Hemispheric Asymmetry: What's right and what's left*. Cambridge, MA: Harvard University Press.

Jewell, G & McCourt, M. E. (2000). Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia*, **38**, 93-110.

Kosslyn, S. M. (1987). Seeing and Imaging in the cerebral hemispheres: A computational approach. *Psychological Review*, **94**, 148-175.

Levy J. (1976). Lateral dominance and aesthetic preference. *Neuropshychologia*, **14**, 431-445.

McLaughlin, J. P. (1986). Aesthetic preference and lateral preferences. *Neuropsychologia*, **24**, 587-590.

McLaughlin, J. P., Dean, P., & Stanley, P. (1982). Aesthetic preference in dextrals and sinistrals. *Neuropsychologia*, **21**, 147-153.

Rubin, N., Nakayama, K., & Shapley, R. (1996). Enhanced perception of illusory contours in the lower versus upper visual hemifields. *Science*, **271**, 651-653.

Snodgrass, J. G. & Vanderwart, M. (1980). A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory,* 6(3), 174-215.

Yarbus, A. L. (1967). *Eye movements and vision*. Plenum Press: New York.