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Global and local dominance with concentric hierarchical stimuli and orientation classification task

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Prior studies have suggested the existence of global dominance for tasks involving decisions of stimuli orientation. This research used hierarchical stimuli, consisting of open-left and open-right semicircles, where participants had to indicate the direction of opening. The aim of this paper is to ascertain whether the opening size of the stimulus is a variable that modulates global dominance found in previous studies. In Experiment I and II, stimuli were presented having an opening of 25% and 10% of the total circle perimeter, respectively. The data show that global advantage depends on the opening size and attention conditions. The results can be explained according to the implications the opening size has on the classification of stimuli according to orientation.

Dominancia global y local con estímulos concéntricos y tareas de clasificación de la orientación. Estudios previos han sugerido la existencia de dominancia global para tareas que implican decisiones sobre la orientación de estímulos jerárquicos concéntricos. Estas investigaciones han presentado estímulos consistentes en semicírculos abiertos hacia la derecha o hacia la izquierda, en los que los participantes debían indicar la dirección de la apertura. El objetivo del presente trabajo es comprobar si el tamaño de la apertura del estímulo es una variable que modula la dominancia global encontrada en estudios previos. En el experimento I se presentaron estímulos con una apertura del 25% del perímetro total del círculo. Los resultados muestran ventaja global en atención dividida y ausencia de ventaja global o local en atención selectiva, así como interferencia local unidireccional. En el experimento II se presentaron estímulos concéntricos con una apertura del 10% del perímetro total. Los datos muestran ventaja local en atención dividida y, al igual que en el experimento I, ausencia de ventaja global o local en atención selectiva. Los resultados se explican en función de las implicaciones que tiene el tamaño de la apertura para la clasificación de estímulos en función de la orientación.

Navon (1977, 1981a, 1981b, 1983), on the basis of hierarchical network model (Palmer, 1975), suggested the processing of a visual pattern proceeds from global level towards analysis of more local details which he termed *global precedence hypothesis*. His experiments formed the basis for a line of research directed towards setting limits or generalization of global precedence.

The experiments carried out have included hierarchical stimuli, which are large figures, representing the global level, made up of small figures, representing the local level. The reaction time (RT) and response accuracy are the most common measurements. Two experimental results are drawn from these, known as advantage and interference. Global advantage occurs when the global level is processed more quickly and accurately than local, and global interference when identity of the global level does affect analysis of the local one.

In general, the research carried out has shown the existence of factors that can affect global versus local advantage and interference, casting doubt over the hypothesis of temporal order in the processing sequence. For this reason, we prefer use of the term *dominance* rather than *precedence*. These factors can affect either stimuli characteristics, such as size (Amirkhiabani, 1998, Amirkhiabani & Lovegrove, 1996, 1999; Antes & Mann, 1984; Arnau, Salvador, & Blanca, 1992a; Kinchla & Wolfe, 1979; Lamb & Robertson, 1990; Luna, Marcos-Ruiz, & Merino, 1995; Merino & Luna, 1997a, 1997b) and number of local elements (Arnau, Blanca, & Salvador, 1992b; Kimchi, 1988, 1998; LaGasse, 1993; Martin, 1979; Navon, 1983) or experimental procedure, such as exposure duration (Blanca, López-Montiel, Luna, Zalabardo, & Rando, 2001; Rumiati, Nicoletti, & Job, 1989; Paquet & Merikle, 1984) and stimulus location in visual field (Grice, Canham, & Borough, 1983; Lamb & Robertson, 1988).

Recently it has been suggested the experimental task demand can also modulate global dominance. Specifically, with concentric hierarchical stimuli consisting of circles and semicircles different results have been found according to whether the participant was asked to carry out a target detection task or an orientation classification task. In the first task, the participant is asked to identify a target, indicating whether the target is or is not present in the stimulus. In the second, the participant is asked to indicate the orientation (right or left) of the semicircle opening. Blanca, López-Montiel, Luna, Zalabardo and Rando (2000) and Blanca,

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Luna, López-Montiel, Zalabardo and Rando (2002) found local advantage with a target detection task, while Blanca, Luna, López-Montiel, Zalabardo and Rando (2001) and Blanca, Luna, López-Montiel, Rando and Zalabardo (2001) found global advantage in divided and selective attention with orientation classification task. The results therefore can indicate that orientation judgements for the global level are faster than for the local one, whereby the authors proposed the existence of global dominance for tasks implying decisions on stimulus orientation. This suggestion is also consistent with other experiments showing that global orientation is processed more quickly than local (Amirkhiabani, 1998; Han, Humphreys, & Chen, 1999) and interferes with the search for a local orientation feature (Lauwereyns & d'Ydewalle, 1997).

However, in orientation tasks it is also possible that certain characteristics of the stimulus influence and speed up global decisions. In this sense, for example, the opening of the global figure could be acting as salient feature or singleton (Yantis, 1993a, 1993b), maybe on account of its size, which captivates the attention and facilitates classification of global figures according to orientation. Along these lines, various studies have shown that visual searches are faster when the target has a distinguishing feature differentiating it from distractors (Bacon & Egeth, 1991; Duncan & Humphreys, 1989; Han & Humphreys, 2002; Sagi & Julesz, 1987; Theeuwes, 1991, 1992; Treisman & Gormican, 1988; Treisman & Paterson, 1984; Treisman & Souther, 1985).

The aim of this study is to ascertain whether the opening size of the concentric stimulus determines advantage and interference results in orientation classification tasks. To this end, two experiments were carried out, using the same procedure as that used by Blanca, Luna, López-Montiel, Rando and Zalabardo (2001) but reducing the degree of stimuli opening. In the above experiment, hierarchical semicircles with seven elements were used having an opening of 50% of the total circle perimeter. In these experiments, partial-circles are used, adding two elements to the global figure, which results in an opening of 25% (experiment I), and adding four elements to the global figure, which results in an opening of 10% (experiment II). If the task is the sole factor responsible for global dominance, then global advantage should be found in divided attention, and global advantage and global interference should be found in selective attention, being these results constant in both experiments. However, if the global opening acts as a distinguishing feature because of its size, which captivates attention provoking global dominance, then a reduction in opening size is expected to reduce or cancel out global advantage and interference.

Experiment I

Method

Participants

Twenty-seven undergraduate students (6 men and 21 women) from Málaga University volunteered to participate in the experiment, aged between 18 and 24 (M= 19.4, SD= 1.95). All the participants had normal or corrected-to-normal vision.

Materials and apparatus

Stimuli presentation was controlled by a personal computer fitted with a box around the screen to isolate the participant from distracting variables. The stimuli were hierarchical patterns, presented at a distance of 62 cm, consisting of circles and partial-circles. The partial-circles had an opening of 25% of the total circumference perimeter and could be opened either to the left or right. The perimeter of the global figure of the circle was made up of 12 local elements, and the partial-circle of 9. The global figure measured 11 cm (10.06º) high and the local one 1.1 cm (1.01º), whilst the distance between the centers of two consecutive elements was 2.5 cm.

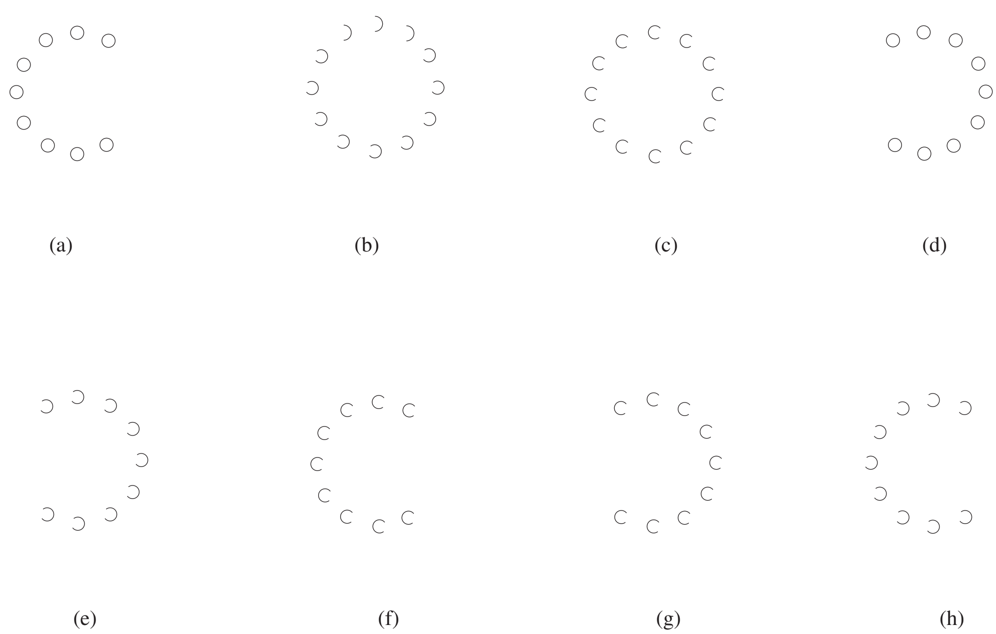

Figure 1. *Example of stimuli employed in the experiment I. (a)-(d): Divided attention. (e)-(f): Congruent condition in selective attention. (g)-(h): Incongruent condition in selective attention*

The participants were asked to indicate the opening orientation of the partial-circle (left or right) under two conditions of attention direction, divided attention and selective attention. In *divided attention condition*, the participant had to pay attention to both the global figure and the local one. On the two levels, one was made up of partial-circles and the other of circles, in such a way that the subject had to indicate the opening orientation of the partial-circle, irrespective of the level it appeared at. For this condition, two groups of stimuli were constructed. In the first one, the opening appeared at global level, whilst the local level was made up of circles. In the second, the opening appeared at local level, whilst the global level was made up of circles (figure 1).

In *selective attention condition*, two instructions were given: attention directed towards the global level, in which the participants were asked to indicate the opening of the global level, and attention directed towards the local level, in which they were asked to indicate the opening of the local one. The patterns could be congruent, if both the global and local levels were made up of partial-circles having the same orientation and incongruent if the orientation was different for both levels (figure 1). The difference in performance between the congruent and incongruent stimuli provided the interference measurement.

Procedure

One hundred and sixty-eight stimuli were constructed, 48 being for practice purpose (16 for each attention direction condition) and 120 for experimental trials, 40 for divided attention condition and 80 for selective attention. In selective attention condition, 40 stimuli were globally directed and 40 locally directed (20 for congruent condition and 20 for incongruent). The experimental session consisted of three blocks of stimuli, one block for each attention condition. At the beginning of the session, general instructions were given as well as specific ones in order to proceed with the practice trials.

Each trial began with the word *ready* in the center of the visual field. Afterwards, the stimulus appeared centrally for 150 ms, followed by a fixation point which remained on the screen until the subject gave the response, after which the word *ready* appeared again for 750 ms. The subject had to indicate the opening orientation of the partial-circle at the levels instructed by pressing a button with the index finger of the left hand for left orientation, or with the index finger of the right hand for right orientation. RT was recorded as well as response accuracy (percentage of correct answers). The attention direction conditions were counterbalanced between subjects, with a latin square, the first random sequence selected being attention to local, divided attention and attention to global. Within each experimental condition, stimuli were randomly presented for each participant.

In the divided attention condition, a repeated measures design was followed, the factor being *opening level* with two levels (global and local). In the selective attention condition, a 2x2 repeated measure design was followed, with the factors: *attention direction* (global and local) and *congruency between global and local levels* (congruent and incongruent).

Results

Mean in RT were calculated for each participant in each experimental condition, excluding those trials with a RT standard score greater than three in absolute value. Order effect was not found and the attention conditions were analyzed separately. For the *divided attention condition*, a *t*-test for related samples was performed in order to analyze whether differences exist between judgement on global orientation and local orientation. Accuracy showed a ceiling effect in both conditions, exceeding 98%, whereby the analysis was only carried out for RT. The difference between means was statistically significant, $t(26)= -2.15$, $p<.01$ (one-tailed), demonstrating the participants were quicker to provide a response when the opening appeared at global level than when it appeared at local level ($M= 527.31$ ms vs. $M= 541.85$ ms). Therefore, the results show global advantage.

In *selective attention condition*, a 2×2 analysis of variance (ANOVA) with repeated measures was performed, the factors being attention direction (global and local) and congruency between global and local levels (congruent and incongruent). Just as occurred in divided attention, the percentage of correct responses shows a ceiling effect, exceeding 98% in all experimental conditions, whereby the analysis was limited to the RT. Means are shown in figure 2.

The attention direction factor was not significant, $F(1, 26)= 0.008$, MSE= 7536.24, $p= .930$, however the congruency was, $F(1, 26)= 23.301$, MSE= 1008.204, $p<.001$ and the interaction between the two factors, $F(1, 26)= 12.909$, MSE= 1318.138, $p= .001$.

In order to evaluate the nature of this interaction, the *advantage in RT* was analyzed according to the congruency condition between levels, using a *t*-test with separate error terms for the contrast of interest. The results indicate that no significant differences exist when attention is directed at global and local levels, neither in congruent stimuli, $t(26)= -1.461$, $p= .08$ (one-tailed) nor in incongruent stimuli, $t(26)= 1.339$, $p= .09$ (one-tailed).

As far as *interference in RT* is concerned, through performance comparison with congruent and incongruent stimuli, it was observed that when attention is directed at global level, the incongruent stimuli slow down the response by 54.60 ms, $t(26)= 5.034$, $p<.01$ (one-tailed), indicating the existence of local interference. When attention is directed at local level, no differences were observed between the congruent and incongruent stimuli, $t(26)= -0.594$, $p= .55$ (one-tailed), indicating that no global interference occurs. Therefore, the results indicate the existence of unidirectional local interference.

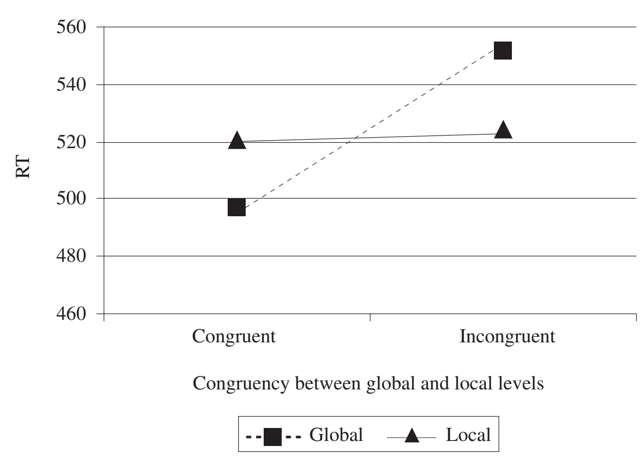

Figure 2. *RT mean as a function of attention direction and congruency between global and local opening*

Discussion

In divided attention condition, the results show global advantage, which is consistent with the results found by Blanca, Luna, López-Montiel, Rando and Zalabardo (2001) and Blanca, Luna, López-Montiel, Zalabardo and Rando (2001) and support the idea of global dominance in orientation decisions. However, in selective attention condition, the global advantage found by the above authors was vanished, since the results show equally rapid judgements in both global and local orientation. These results do not coincide with the hypothesis of global dominance and suggest that certain stimulus features, such as greater closure in the figure, influence orientation classification, impairing global analysis in selective attention.

On the other hand, unidirectional local interference was found, as compared with the bidirectional interference found by Blanca, Luna, López-Montiel, Rando and Zalabardo (2001). This result indicates that local information cannot be ignored in global level attention.

Finally, the changes found in advantage and interference in selective attention condition in relation to the experiment by Blanca, Luna, López-Montiel, Rando and Zalabardo (2001) suggest that global dominance was not insensitive to manipulation of the degree of stimuli opening. However, a transition to local dominance was not found by reducing the opening. Experiment II was planned with the aim of analyzing how a greater reduction would affect processing of global and local levels.

Experiment II

In this experiment, experiment I was replicated, reducing opening of the partial-circle by 25% to 10% of the total circumference perimeter. This reduction was expected to yield more consistent results in both attention conditions, thereby contributing more consistent data on the hypothesis of global dominance for orientation classification task.

Method

Participants

Thirty-three volunteer students participated in the experiment (12 men and 21 women), aged between 19 and 31 (M= 21.48, SD= 2.6). All the participants had normal or corrected-to-normal vision.

Materials and apparatus

Presentation of stimuli was controlled in the same way as in the previous experiment. The hierarchical patterns were made up of circles and partial-circles with a 10% opening to the right or to the left. The perimeter of the global figure of the circle was made up of 12 local elements, whilst the partial-circle was made up of 11 (figure 3). The rest of the conditions such as size of figures, distance between local elements, number of stimuli and experimental task were the same as in experiment I.

Procedure

The procedure and design followed were the same as in the previous experiment.

Results

The data regarding accuracy in all conditions presented a ceiling effect, exceeding 98% of correct responses, whereby analysis was only carried out for RT. Order effect was not found and the attention conditions were analyzed separately. A t-test for related sample was performed for the *divided attention condition* with the factor being the opening level (global and local). The difference between means was significant, $t(32)= 3.8$, $p<.01$ (one-tailed), showing the participants were quicker to provide a response when the opening appeared at local level than when it appeared at global level (M= 438.76 ms vs. M= 483.49 ms). The data therefore show local advantage.

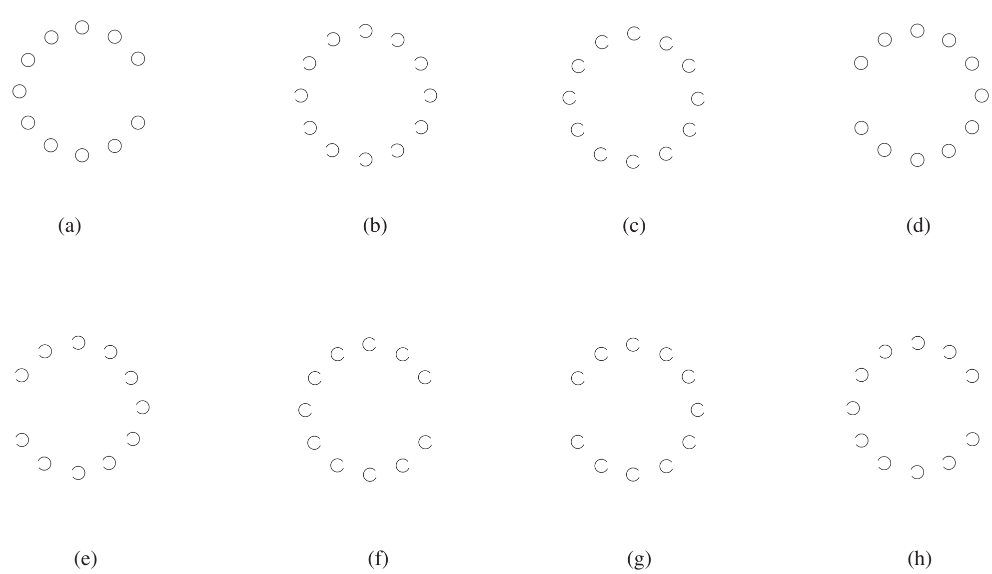

Figure 3. *Example of stimuli employed in the experiment II. (a)-(d): Divided attention. (e)-(f): Congruent condition in selective attention. (g)-(h): Incongruent condition in selective attention*

In the *selective attention condition*, a 2×2 ANOVA with repeated measures was performed, the factors being attention direction (global and local) and congruency between global and local levels (congruent and incongruent). The factor attention direction did not reach statistical significance, $F(1,32)= 0.007$, MSE= 8669.36, $p= .932$, nor congruency, $F(1,32)= 1.574$, MSE= 4342.29, $p= .21$. However, the interaction between the two factors was significant, $F(1,32)= 6.953$, MSE= 2448.43, $p= .01$. Means are shown in figure 4.

In order to study the nature of this interaction, the *advantage in RT* was analyzed according to the congruency condition between the levels, using a *t*-test with separate error terms for the contrast of interest. No advantage was found at any level, neither with congruent stimuli, $t(32)= -1.057$, $p= .15$ (one-tailed) nor with incongruent stimuli, $t(32)= 1.475$, $p= .08$ (one-tailed).

On the other hand, the *interference in RT* was also analyzed by comparing performance with congruent and incongruent stimuli. When attention is directed at global level, incongruent stimuli slowed down response to 37.10 ms, $t(32)= -3.69$, $p<.01$ (one-tailed), indicating the existence of local interference. When attention is directed at local level, no differences was observed between congruent and incongruent stimuli, $t(32)= 0.472$, $p= .32$ (one-tailed), indicating an absence of global interference. Therefore, interference is unidirectional, having only found local interference.

Discussion

The results indicate changes occurred as compared with experiment I in divided attention condition, since local advantage was found when opening of the figures was reduced up to 10%. However, the results for selective attention condition were replicated, showing an absence of global or local advantage and unidirectional local interference.

The findings of this experiment show that the effect of global dominance can be inverted, with a transition to local dominance, depending on the stimulus opening and the attention condition in orientation classification tasks. This suggests the hypothesis of global dominance in orientation is influenced by certain stimulus characteristics, such as less or more closure in the figures presented.

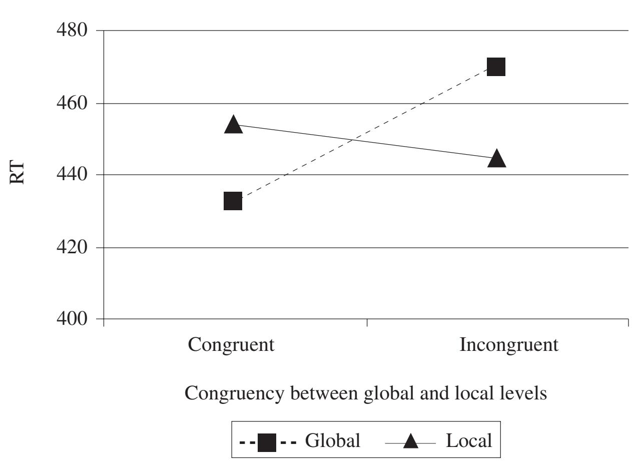

Figure 4. *RT mean as a function of attention direction and congruency between global and local opening*

General discussion

The present work was carried out for the purpose of studying whether the size of opening can explain the global dominance found in orientation classification tasks with concentric hierarchical stimuli as shown in prior studies (Blanca, Luna, López-Montiel, Rando, & Zalabardo, 2001; Blanca, Luna, López-Montiel, Zalabardo, & Rando, 2001). In order to do this, two experiments were performed, introducing variations in opening of the concentric stimuli in succession. Thus, firstly a modification took place in opening of the stimuli as compared with the work done by Blanca, Luna, López-Montiel, Rando and Zalabardo (2001), by 50% to 25% (experiment I) and, secondly, by 25% to 10% (experiment II). In a general way, if global dominance did occur for the orientation classification task, then global advantage should be found in both experiments carried out. However, if global dominance in these tasks is modulated by certain stimulus characteristics such as size opening, then the reduction in opening should show a reduction also in global advantage as found in previous experiments.

The results of experiment I show global advantage in divided attention, and an absence of global or local advantage in selective attention as well as a unidirectional local interference. In experiment II, local advantage was found in divided attention and, just as in experiment I, an absence of global or local advantage and unidirectional local interference in selective attention.

In both experiments one can note a lack of consistency in advantage in divided and selective attention conditions. This lack of consistency has also been found in other research (e.g., Blanca et al., 2002; Hoffman, 1980; Kimchi, Gopher, Rubin & Raij, 1993). However, the participants are faced with two different attention demands, whereby participants' performance may differ. In general, in divided attention condition the target can appear at global or local level with the same probability, and the attention system is equally distributed through the global and local levels. In selective attention condition, however, the attention system has to focus on the appropriate level, going ahead of the stimulus and thereby facilitating target identification. Considering spatial attention model, in case of attending to the global level, a wide attention focus can be used, which would also allow filter the local information. In case of attending to the local level, a very narrow focus of attention can be used so that the global shape would not be necessarily processed and global interference will not happen. As a consequence, these data appear to indicate that analysis of global and local features reflects not only modulation of sensorial mechanisms, but also visual selection mechanisms at a higher level.

As a whole, the results of experiments I and II are not consistent with Blanca, Luna, López-Montiel, Rando and Zalabardo (2001) and Blanca, Luna, López-Montiel, Zalabardo and Rando (2001) since global advantage and interference was not found in all conditions. In general, a reduction of opening size provoked a vanishing of global advantage and even a transition to local advantage. The findings appear to suggest that global orientation is not invariably processed more quickly than local one, and therefore that global dominance does not depend per se only on the demands of the experimental task

The question arising next is why global dominance exists in orientation classification tasks with stimuli having a 50% opening (Blanca, Luna, López-Montiel, Rando, & Zalabardo, 2001; Blanca, Luna, López-Montiel, Zalabardo, & Rando, 2001). One plausible hypothesis suggested in the introduction is that global opening size acts as a salient feature or singleton, that is to say, global opening may be a very conspicuous element that attracts attention automatically (Ponte, Sampedro, & Pardavilla, 2004) facilitating orientation classification in left and right categories. Reduction of the opening would cancel out this characteristic and therefore would also cancel out global dominance. The results of experiments I and II are consistent with this hypothesis.

Another possibility, which is not incompatible with the previous one, is that the global opening of 50% allows a perceptual reference frame to be created, from which the response is provided. Prior studies have demonstrated the importance of the reference frame in the perception of shape and orientation (Palmer, 1985, 1989; Pashler, 1990; Rock, 1990). From this point of view, opening of the global semicircle can coincide with the imaginary vertical symmetry axis of the contextual reference frame where the image is introduced. This information can be sufficient to make a decision on global orientation, facilitating responses towards global level. The results of the experiments carried out here are also consistent with this explanation, since reduction in opening of the semicircle would make creation of the perceptual reference frame impossible.

In order to clarify which of the two hypotheses is the more plausible to explain the global dominance found with semicircles, it is necessary to perform new experiments maintaining the orientation task and 50% opening of the stimulus, but eliminating the possibility of creating symmetry axes. One way of managing this is to present the stimuli randomly in several positions in the visual field. In this way, the opening has the same size but the creation of perceptual reference frames is difficult. Another alternative would be to display the stimuli in the center of the visual field but turned at 35º or 40º, in such a way that imaginary vertical axes cannot be created either.

In conclusion, the findings do not support the idea of global dominance in orientation classification tasks. Rather, it can be stated that global dominance in this type of task is influenced or modulated by stimulus properties and by attention conditions in which the experiment is performed.

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