Spotlight masking effect in exogenous orienting

Emilio G. Milán and Francisco J. Tornay

Departamento de Psicología Experimental y Fisiología del Comportamiento

University of Granada

Spain

E-mail: egomez@goliat.ugr.es

Fax: 34-58-246239

Telephone: 34-58-246240

Abstract

Many experimental results about spatial attention have been explained by assuming the existence of an attentional "spotlight" which can move from one location in visual space to another. Such an account has been recently challenged by findings which show the influence of nonspatial factors in spatial attention. In particular, the so-called "spotlight masking" effect refers to the influence of the probability of occurrence of different stimuli. However, such an effect has only been reported in the case of endogenous (or central) orientation, rather than on exogenous (or peripheral) orienting. In a series of four experiments we present evidence showing that the spotlight masking effect can be obtained with exogenous orienting, only when both stimulus and response probabilities are varied. Besides, the effect can be modulated by voluntary attention.

PsycINFO classification: 2346

Keyword: Attention

1. Introduction

In the last decades, there has been a great deal of research about visual attention. Much of that research has been based on the cueing paradigm (e. g., Eriksen & Hoffman, 1973; Henderson, 1991; Posner, 1980; Posner, Nissen & Ogden, 1978; Yantis & Johnston, 1990), in which a position in the visual field is cued before the appearance of a relevant stimulus. Such a cueing improves performance when responding to that stimulus, which results either in faster or more accurate responses on valid trials (on which the cue signals the location where the target occurs) than on invalid trials (on which the target appears far away from the cued location). Such differences are usually referred to as an attentional effect.

A simple explanation of this attentional effect is to suppose that attention moves from one location in visual space to another, improving the processing of the stimuli that occur at the attended location. Spatial attention would, therefore, be similar to a spotlight that can "illuminate" that particular position. Because the attentional effect occurs even when the time between cue and target is shorter than the average duration of a saccade, the movement of the spotlight can be dissociated from eye movements (e. g., Posner, 1980).

One of the most important results of the cueing paradigm has to do with the distinction between endogenous and exogenous cueing (Jonides, 1981). Endogenous or central cueing is based on symbolic cues, which appear relatively far away from the cued location and are usually presented at the fovea (for instance, an arrow presented on the center of the visual field which points to the to-be-cued location). On the other hand, exogenous or peripheral cueing depends on the appearance of a stimulus (usually

a flash, or a light or an abrupt onset) near the to-be-cued location. Endogenous and exogenous orienting differ in a number of other features, including their temporal course (exogenous orienting produce faster effects), sensitivity to the informative value of the cue (endogenous, but not exogenous, orienting depends on the cue reliably informing about the location of the target), and possibility of ignoring the cue (it is possible to ignore endogenous cues but it is more difficult to do so when the cueing is exogenous). Such differences seem to suggest the existence of two different kinds of attentional (or "spotlight") movement.

Recently, a series of results have cast doubt on the spotlight account of attentional movement, especially in conditions of endogenous cueing. There is evidence which suggests that endogenous cueing is sensitive to nonspatial factors. For instance, if two targets differing in probability of occurrence are presented, the attentional effect is found only for the more probable target (Klein, 1980; Klein & Hansen, 1987). Such a result is usually referred to as the spotlight failure effect. Klein & Hansen (1990) preferred the term spotlight masking because analyses of errors and computer simulations led them to conclude that an early attentional effect was masked by a later response bias.

Is exogenous orienting similarly affected by nonspatial factors? In this respect, the results are far from clear. Stolz (1996) showed that exogenous orienting depends on linguistic factors, such as the semantic relationship between an abrupt-onset word, which acted as a peripheral cue, and a target word. However, Klein (1994) failed to find the spotlight masking effect using exogenous cueing. In the following experiments we will further explore the possibility of obtaining the spotlight masking effect with

peripheral cues.

2. Experiment 1

In this experiment we will use a costs and benefits paradigm with an uninformative peripheral cue. The task will consist in an easy discrimination between two equally probable targets. The aim of the experiment is simply to show that our paradigm produces the traditional pattern of results associated with attentional capture or exogenous orienting.

2.1. Method

Participants: Twenty undergraduate Psychology students (fourteen women, six men), with normal or corrected-to-normal vision, took part in the experiment for course credit. Their ages ranged from eighteen to twenty-nine years.

Apparatus: The experiments were designed using a software program called Micro Experimental Laboratory or MEL for short (Schneider, 1988). They were run in dimly illuminated rooms, on IBM 486 computers with a SuperVGA graphics card. Participants sat at approximately 60 cm from the computer screen.

Procedure: The experiment consisted of four trial blocks. It started with a 40-trial practice block, which was not analyzed. Three experimental blocks, each one with 180 trials, followed. Participants were allowed a short break between blocks.

On every trial a plus sign (+) appeared on the center of the screen. This stimulus was used as a fixation point and it remained on the screen until the end of the trial. 500 ms later, an asterisk was presented either to the right or to the left of the fixation point (with a 50% probability for either location), 6 degrees of eccentricity away. The asterisk served as a peripheral cue. It has been proved that the disappearance of a stimulus attracts attention in the same way as its appearance (Watson and Humphreys, 1996). In order to avoid cueing the target twice, the asterisk was kept on the screen until the end of the trial. A 100-ms stimulus-onset asynchrony (SOA) was allowed to elapse until the target appeared. The target was either the letter O or the letter X, each of which was presented on half of the trials in each block. The target was presented either to the right or to the left of the fixation point, 4 degrees of eccentricity away from it. The two positions were chosen at random, with equal probabilities and independently of the position of the cue, i. e., the cue had no informative value (its validity was 50%). The task consisted in pressing either the b key (with the left index) or the n key (with the right index) on the keyboard to signal which letter was presented. Half of the participants pressed the b key to signal the presence of letter O and the n key to signal the X, for the other half the stimulus-response mapping was reversed. The target disappeared after 33 ms. Participants were given 3 seconds to emit their responses. After an intertrial interval of 1500 ms the following trial began. All stimuli were written in white on a black background.

There were two independent variables in this experiment: a) attentional condition, i. e., whether the asterisk was presented on the same half of the screen as the target (valid trials) or not (invalid trials); b) target identity, either O or X.

2.2. Results

Reaction time (RT) data for correct responses were submitted to a 2 (attentional condition) x 2 (target identity) ANOVA. The analysis showed significant main effects for both attentional condition, $F(1, 19) = 10.761$, $MSE = 1633.885$, $p < 0.004$, and target identity, $F(1, 19) = 5.936$, $MSE = 1371.757$, $p < 0.025$, whereas their interaction was not statistically reliable, $F(1, 19) = 3.113$, $MSE = 261.796$, $p > 0.09$. As can be seen in figure 1, the pattern of results showed a clear attentional effect, valid trials being faster then invalid ones. Participants also responded faster to the X than to the O.

Please insert Fig. 1 about here

We also analyzed accuracy (proportion of errors). In this case, no source of variability reached significance, $F(1, 19) < 1$ for the three sources of variability.

2.3. Discussion

The results showed a clear attentional effect. We can conclude that the peripheral cue captures attention, even if it does not help to predict the position of the target. Such a pattern of results fits well with the usual spotlight account of visual attention (e. g., Posner, 1980): attention moves from the cue to the target, on valid trials the distance is 2 degrees of visual angle; on invalid trials the attention must move from the cue to the fixation point (6 degrees) and then to the cue (4 degrees), a 10-degree movement in total.

Interestingly, the attentional effect does not reliably depend on the particular target presented, as the nonsignificant interaction shows. We will use the same paradigm in subsequent experiments but with one important difference: one of the targets will appear more frequently than the other one. If the spotlight metaphor can be applied to exogenous orienting, such a nonspatial factor should not interact with the attentional effect.

3. Experiment 2

In this experiment we will explore the effect of target probability on exogenous orienting. Specifically, we intend to find out whether the spotlight failure effect can be obtained with a peripheral cue. We will use the same paradigm as in experiment 1 but one of the stimuli will be presented more frequently than the other one. To make sure that the differences are due to the frequency of the stimuli and not to the frequency of the responses, we will dissociate them by asking participants to respond to the color of the targets rather than to their identity. This allows us to equal the frequency of the responses while manipulating the frequency of the stimuli. Kingstone (1992) emphasized the importance of distinguishing between stimuli and response frequency.

3.1. Method

Participants: Six women and two men took part for credit course. They were between 20 and 25 years old. Their vision was normal or corrected to normal.

Procedure: It was identical to the first experiment except for the following

differences. First, the task consisted in responding to the color of the target. On 50% of the trials the target was red and on the other 50% it was yellow (all other stimuli were white, as in experiment 1, the background was black). Participants responded by pressing keys b or n. Similarly to the previous experiment, the color-key mapping was counterbalanced across participants.

Second, for every participant one of the targets (letter O or letter X) was presented on 70% of the trials, whereas the other target appeared on the remaining 30%. For half of the participants the O was the more frequent stimulus, whereas the X was presented more frequently for the other half. Participants were informed about this difference in frequency. The two independent variables that we will analyze are: a) attentional condition, as in the previous experiment; b) target frequency. We will not analyze target identity, experiment 1 showed that it does not interact with the attentional effect.

3.2. Results

In the analysis of RT data, only the attentional effect reached significance, $F(1, 7) = 61.98$, $MSE = 757.596$, $p < 0.001$. In particular, the Target frequency x Attentional condition interaction was clearly nonsignificant, $F(1, 7) < 1$. In the analysis of response accuracy no source of variability reached significance.

Please insert Fig. 2 about here

3.3. Discussion

There was no reliable spotlight failure effect, which suggests that exogenous orienting is not affected by target probability. This finding can be interpreted as evidence that exogenous orienting is less dependent on nonspatial factors, such as target frequency, than endogenous orienting, in which the spotlight failure effect is found even when stimulus and response frequency are dissociated (Kingstone, 1992). This result agrees with the data reported by Klein (1994), although he did not dissociate stimulus and response probability. In the following experiment we will check whether the same pattern of independence between attentional effect and target frequency also occurs when participants respond to features that differ in frequency.

4. Experiment 3

The data obtained in experiment 2 did not show the spotlight failure effect in exogenous orienting, which agrees with previous reports (Klein, 1994). In the following experiment we will check whether exogenous orienting can produce a spotlight masking effect when there is no dissociation between target identity and response.

4. 1. Method

Participants: Eight women and three men participated. They were undergraduate Psychology students (ages between 20 and 28) who took part for course credit. Their vision was normal or corrected to normal.

Procedure: It was identical to experiment 2 except for the color of the stimuli, which was white in all cases and the required responses. Participants were asked to respond to the identity of the target, i. e., whether it was an X or an O, similarly to experiment 1. This procedure entails a difference in response frequency, as well as a difference in target frequency.

4.2. Results

The analysis of RT for correct responses revealed a significant Attentional condition x Target frequency, $F(1, 9) = 7.802$, $MSE = 126.044$, $p < 0.021$. Neither the main effect of attentional condition, $F(1, 9) = 1.87$, $MSE = 448.01$, $p > 0.205$, nor that of target frequency were significant, $F(1, 9) = 3.234$, $MSE = 907.772$, $p > 0.106$.

The interaction was due to a significant attentional effect for the more frequent stimulus, $F(1, 9) = 15.45$, $MSE = 117.682$, $p < 0.004$, which was not present for the less probable one, $F(1, 9) < 1$. That is there was a reliable spotlight masking effect (figure 2).

In the analysis of accuracy data, no source of variability reached significance.

Please insert Fig. 3 about here

4.3. Discussion

The data are consistent with the presence of spotlight masking effect in

exogenous orienting. In contrast to experiment 2, the attentional effect for the less probable target is not reliable. This finding supports the hypothesis that the exogenous orienting of attention can be influenced by a nonspatial factor.

The results of this experiment contrast with those reported by Klein (1994). He failed to obtain the spotlight masking effect with a peripheral cue. The paradigm he used and the one presented here differ in a number of important points, which makes it difficult to figure out the reason for such a discrepancy. Two differences may be especially worth noting. First, the task was a discrimination between an increase and a decrease in size of a peripheral object, rather than between two letters, as was the case in the present study. Second, the two targets varied not only in their probability but also in the validity of the cue. For the more probable target the validity was about 80%, whereas for the less probable one, the cue was not informative. In average, therefore, the cue was informative, unlike the one used here. Klein justified this procedure by noting (footnote 2, p. 172) that a previous work by Klein and Hansen (1990) failed to find an effect of cue validity on the spotlight masking effect. However, such results were obtained only with central cues.

Klein's results are very conclusive in showing that the spotlight masking effect can be obtained more easily with central than with peripheral cues. However, the results presented here show that exogenous orienting is also affected by target frequency.

5. Experiment 4

In this experiment we study the nature of the spotlight masking effect found in experiment 3 more deeply. The effect can be explained by assuming that participants'

attention is captured by the more frequent stimulus (which produces a reliable attentional effect) but not by the less frequent one. Would it be possible to eliminate or revert the effect by voluntarily attending to the less frequent stimulus? If so, it would suggest that voluntary attention can modulate exogenous orienting. We will check this possibility by manipulating the instructions given to the participants.

5.1. Method

Participants: Fourteen undergraduate Psychology students took part for course credit. There were eight women and five men. Their vision was normal or corrected to normal and their ages ranged between 20 and 26 years.

Procedure: The stimuli, equipment and procedure were identical to those of the previous experiment except for a change in the instructions. After telling participants that one of the stimuli would be presented more frequently than the other one, they were instructed to try to attend to the less frequent one and to take special care to avoid errors when it was presented.

5.2. Results

The analysis of RT data showed reliable main effects of both attentional condition, $F(1, 13) = 23.74$, $MSE = 524.57$, $p < 0.001$, and target frequency, $F(1, 13) = 22.56$, $MSE = 519.30$, $p < 0.001$. Their interaction, however, was not reliable, $F(1, 13) < 1$.

In the analysis of accuracy both the main effect of target frequency, F(1, 13) = 7.19, MSE = 0.002, p < 0.019, and the Attentional condition x Target frequency interaction were significant, F(1, 13) = 5.46, MSE = 0.001, p < 0.037. Further analyses showed a significant attentional effect for the less frequent stimulus, F(1, 13) = 6.20, MSE = 0.002, p < 0.028, but not for the more frequent one, F(1, 13) < 1, i. e., a reversal of the spotlight masking effect was obtained.

Please insert Fig. 4 about here

5.3. Discussion

One first interesting feature of the data is the fact that the more frequent stimulus produces both faster and more accurate responses than the less probable one, despite the instructional emphasis on attending to the latter. However, the instructions do seem to affect the spotlight masking effect, which is absent in terms of RT data and reversed with respect to accuracy data. Taken together, the results seem to agree with Klein and Hansen's (1990) interpretation of the spotlight masking effect: after an initial attentional effect, a later bias masks it.

5. General discussion

In a remarkable set of experiments, Stolz (1996) studied the possibility that exogenous orienting is not an encapsulated set of processes. The term encapsulation was initially proposed by Fodor (1983) as the key feature of modular systems. A system

is encapsulated when "of all the information that might in principle bear upon a problem of perceptual analysis only a portion is actually admitted for consideration" (p. 70). Stolz (1996, p. 189) distinguished between two different versions of encapsulation. In Fodor's view, the mere fact that some information affects the output of a system does not reject the possibility that the system is encapsulated, it is necessary to show that the information does not merely affect the output of the system but also some intermediate level of processing. This definition makes it very difficult (Jusczyk & Cohen, 1985) to prove empirically that a system is not encapsulated. In contrast, Stolz proposes a weaker version (p. 189) of encapsulation, according to which a system affected by different sources of information at the output stage would not be encapsulated. Stolz showed that exogenous orienting is not encapsulated in this weaker view because it is affected by semantic information, even when taking that information into account does not improve performance.

The results of the present report may be interpreted in a similar way as those of Stolz's experiments. Nonspatial information seems to affect a spatial-attention system. As was the case in Stolz's data, the information involved (namely, the different probability of occurrence of the presented stimuli) does not seem to result in an improved performance. A comparison of the results of experiment 1 and experiments 3 and 4 does not show a better performance for the latter ones. Overall performance seems even worse when the additional information is taken into account, at least in terms of proportion of errors.

The fact that the probability of occurrence of the targets does not affect exogenous orienting when the response probability is not affected (experiment 2)

suggests that the influence of target probability is associated with response processes. This is further confirmed by the results of experiment 4, which seem to support the view that a relatively late stage is responsible for the disappearance and reversal of the usual spotlight masking. The overall results of the reported experiments may, therefore, challenge the encapsulation of exogenous orienting in the weaker, but not in the stronger sense.

References

Eriksen, C. W. & Hoffman, J. E. (1973). The extent of processing of noise elements during selective encoding from visual displays. Perception and Psychophysics, 14, 155-160.

Fodor, J. A. (1983). The modularity of mind. Cambridge, MA: MIT Press.

Henderson, J. M. (1991). Stimulus discrimination following covert attentional orienting to an exogenous cue. Journal of Experimental Psychology: Human Perception and Performance, 17, 91-106.

Jonides, J. (1981). Voluntary versus reflexive control of the mind's eye's movement. In J. B. Long & A. D. Baddeley (Eds.), Attention and Performance IX (pp. 187-203). Hillsdale, NJ: Erlbaum.

Jusczyk, P. W. & Cohen, A. (1985). What constitutes a module: Précis of the modularity of the mind. The Behavior and Brain Sciences, 8, 20-21.

Kingstone, A. (1992). Combining expectancies. Quarterly Journal of Experimental Psychology, 44A, 69-104.

Klein, R. M. (1980). Does oculomotor readiness mediate cognitive control of visual attention? In J. B. Long & A. D. Baddeley (Eds.), Attention and Performance VIII (pp. 259-276). Hillsdale, NJ: Erlbaum.

Klein, R. M. (1994). Perceptual-motor expectancies interact with covert visual orienting under conditions of endogenous but not exogenous control. Canadian Journal of Experimental Psychology, 48, 167-181.

Klein, R. & Hansen, E. (1987). Spotlight failure in covert orienting. Bulletin of the Psychonomic Society, 25, 447-450.

Klein, R. & Hansen, E. (1990). Chronometric analysis of spotlight failure in endogenous visual orienting. Journal of Experimental Psychology: Human Perception and Performance, 16, 790-801.

Posner, M. I. (1980). Orienting of attention. Quarterly Journal of Experimental Psychology, 32A, 3-25.

Posner, M. I., Nissen, M. J. & Ogden, W. C. (1978). Attended and unattended processing modes: The role of set for spatial location. In H. Pick & I. J. Saltzmann (Eds.), Modes of perceiving and processing information. Hillsdale, NJ: Erlbaum.

Stolz, J. A. (1996). Exogenous orienting does not reflect an encapsulated set of processes. Journal of Experimental Psychology: Human Perception and Performance, 22, 187-201.

Watson, D. G. & Humphreys, G. W. (1996). Attention capture by contour onsets and offsets: No special role for onsets. Perception and Psychophysics, 57, 583-597.

Yantis, S. & Johnston, J. C. (1990). On the locus of visual selection: Evidence from

focused attention tasks. Journal of Experimental Psychology: Human Perception and Performance, 16, 135-149.