Abstract

In daily life an individual perceives different stimuli in space. Among other things, these stimuli include social cues to which he reacts in different ways according to the interpretation he gives them. These cues can be bodily movements of other people, facial expressions, eye movements and so on. Thus, for example, when two people are present at a social event, one of them can signal to his partner who is standing at the other side of the room that he wants to go, by moving his eyes toward the entrance door. Gaze orienting by the former causes the latter to direct his eyes in the same direction, that is, toward the door. According to this signal, he concludes that his friend wants to leave. Gaze orienting in this example causes the observer to shift his attention toward an object in space so that both participants are attending to the same object or event. This phenomenon has been called “joint attention” in social and developmental psychology.

Baron-Cohen (1995) described a model in which he related to a gaze cue in a more extensive context. Since an individual is a social creature, he needs to be able to explain and predict the behavior of others in order to function better and more efficiently in his environment. According to this model, there is a system named “mind reading”, which has as a goal, among other things, to compute the direction of gaze. This system is of great importance in analyzing the mental state of humans and primate species. “Joint attention” as described above is actually related to a much broader field: spatial visual attention.

Spatial visual attention is one of the most frequently researched topics in cognitive psychology. Attention orienting can occur in response to a visual cue that draws the attention of an individual toward a specific direction. In general, cues can be of two types: 1. Exogenous cue, an external visual cue that appears in the peripheral visual field and causes reflexive orienting of attention to the cued location. 2. Endogenous cue, in which inner factors lead to a shift of attention. In the literature, one of the basic paradigms that explores spatial attention processes is that of Posner (1980). In a typical trial from this paradigm three boxes arranged in a row appear on a computer screen. A subject sitting in front of the computer is instructed to fixate his eyes on a central fixation

dot located in the central box. After a short period of time a cue appears in one of the peripheral boxes. The cue might be a flickering of one of the boxes. Following that, the target - an asterisk - will appear. The target can appear in the same box that was cued before and thus the cue is a valid cue, or in the box at the opposite side and thus the cue is defined as an invalid cue. The subject's task is to press on a specific key as soon as he perceives the target. In this paradigm the flickering of the peripheral box is an exogenous cue. An endogenous cue might be an arrow that appears in the central box and points toward one of the peripheral boxes. In most of the trials the arrow is directed in most of the trials to the box where the target will appear, hence, it predicts the location of the target's appearance. In contrast, if an exogenous cue does not predict where the target will appear then the target will appear with equal probability in the cued location and in the location that was not cued. Hence, with exogenous cues, any effect of the cue on reaction time is evidence of reflexive orientating of attention as compared to the willful orientation of attention to endogenous cues.

There are differences cited in the literature between the pattern characteristic of attention orienting in response to an exogenous cue and the pattern characteristic of attention orienting in response to an endogenous cue (Jonides, 1981). For example, it has been found that cognitive load has much more influence on endogenous cues than on exogenous cues. An essential difference found between these cues is that the exogenous mechanism is biphasic. When the time period between the appearance of the cue and the target onset (SOA= stimulus onset asynchrony) is shorter than 300 ms, there is facilitation, that is, shortened reaction time (RT) for valid trials (i.e., cue and target appear at the same location) than for invalid trials (i.e., cue and target appear at different locations). This facilitation in RT is termed the "validity effect". When the SOA is greater than 300 ms, there is a longer RT for valid trials than for invalid trials. This is referred to as inhibition of return (IOR), and was first reported by Posner and Cohen (1984).

As opposed to the described in response to exogenous cues, with endogenous cues in most cases only the validity effect appears, without IOR. From a neuroanatomical perspective there is direct evidence of the contribution of the superior colliculi (SC) to the IOR phenomenon (Sapir, Soroker, Berger, & Henik, 1999).

Recently, several studies have combined the two research domains described above, that is, joint attention and spatial attention. In these studies the researchers used Posner`s (1980) paradigm but instead of using a flickering box or an arrow as a cue, they used schematic or real faces with eyes gazing to the left or to the right. Since, in these studies, gaze direction did not predict the location of the target, facilitation in RT to a valid trial indicated reflexive orienting of attention. The main finding from these studies was a validity effect without IOR. The absence of IOR in these studies has led several researchers to propose different hypotheses about the nature of the gaze cue. Some described this cue as an unusual exogenous cue while others tended to emphasize the similarities between the gaze cue and the endogenous cue.

Careful consideration of these studies raises methodological questions that will be systematically explored in this work as it focuses on the nature of the gaze cue. Because an understanding of the gaze cue is based on two research domains as described above, the guiding principle in this work is to explore the nature of this cue by making an optimal comparison to Posner`s (1980) paradigm while giving maximum consideration to what we know about the characteristics of the "joint attention" phenomenon. The overall goal of this work was to determine whether a gaze cue is an endogenous or exogenous cue in nature and accordingly, to understand the underlying brain mechanisms.

In order to explore this topic, ten experiments were conducted that focused on different aspects of the gaze cue. The work is divided into 3 parts. The first part considers the reason for the absence of IOR in the studies that used gaze cues. In the second part the influence of cognitive load on gaze and exogenous cues is examined. The third part deals with the question of whether the mechanism underlying gaze cues is similar to or different from those underlying other exogenous cues. This question is explored by presenting a gaze cue before an exogenous cue in one experimental trial and then examining the influence the gaze cue has on reaction time to the exogenous cue.

The main results from the first part were: 1. A validity effect appeared for gaze cues. This result replicates what was found in similar studies described in the literature. 2. The more important finding was that in contrast to the results cited in previous studies, IOR was found. There were two main variables that contributed to the appearance of IOR. One was moving attention back to the center by returning the pupils back to the

center of the eyes after they were previously directed to the left or to the right. The second variable was marking the target in the periphery by adding two boxes on both sides of the schematic face. It is important to note that these two variables appeared in the original experiment carried out by Posner and Cohen (1984). However, in no other study using gaze cue were these variables studied.

In the second part the main finding was that the manipulation of cognitive load on gaze cues causes the disappearance of IOR while with exogenous cues IOR is preserved, even after adding cognitive load. In contrast, we found that different degrees of cognitive load have the same influence on RT to both, gaze cues and exogenous cues. These results suggest that the criterion of cognitive load makes only a partial distinction between a gaze cue and an exogenous cue.

In the third part an interaction was found between the two types of cues. The results indicate that these two cues influence one another and that they might share the same mechanism.

To sum up, in contrast to all previous studies in the literature, we have found IOR for gaze cues, an important and essential phenomenon that distinguishes between endogenous and exogenous orienting. In addition, the fact that the interaction between these two cues was found indicates that these cues have similar mechanisms that rest on similar attentional resources. The importance of this work lies in our conclusion, based on these findings, that a gaze cue is exogenous in nature and not endogenous, and for this reason there is no basis to the claim that the SC is not involved in gaze cues, as several researchers have argued.