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The three attentional networks: On their independence and interactions

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Abstract

The present investigation was aimed to the study of the three attentional networks (Alerting, Orienting, and Executive Function) and their interactions. A modification of the task developed by Fan, McCandliss, Sommer, Raz, and Posner (2002) was used, in which a cost and benefit paradigm was combined with a flanker task and an alerting signal. We obtained significant interactions as predicted. The alerting network seemed to inhibit the executive function network (a larger flanker-congruency effect was found on trials where an alerting signal had been previously presented). The orienting network influenced the executive function network in a positive way (the flanker effect was smaller for cued than for uncued trials). Finally, alertness increased orienting (the cueing effect was bigger after the alerting signal). This last result, taken together with previous findings, points to an influence in the sense of a faster orienting under alertness, rather than a larger one. These results offer new insight into the functioning of the attentional system.

1. Introduction

Recently, Fan, McCandliss, Sommer, Raz, and Posner (2002) developed a task that could be used to assess the efficiency and independence of the three attentional networks—Alerting, Orienting, and Executive Function. In their study, the authors show the independence of the three networks and the absence of interactions between them (they propose as a possible explanation of the interaction that they find an artifact of the specific features of their task). However, previous literature has suggested possible interactions between these networks in their ordinary functioning. Posner (1994) proposed an inhibitory relationship between the Alerting and Executive Function networks in the sense of a shutdown of the latter when the former is highly activated, promoting a fast reaction to the present stimulus, thus preventing the system from engaging in higher level processing. He termed this state as ‘‘clearing of consciousness.’’ Similary, interactions between the Alerting and Orienting networks have been studied but clear results have not been found. Fernandez-Duque and Posner (1997) concluded that there was no interaction between these two networks and hence, they are independent. Lastly, regarding the interaction between Orienting and Executive Function, Funes and Lupiáñez (2003) found that the Spatial Stroop effect (a measure of the Executive Function) was larger when the participants had been oriented to the location opposite to that of the target than when they were oriented to the target position.

We thought that the task proposed by Fan and colleagues would be an interesting tool to study the possible existence of these interactions between the attentional networks since it clearly measured the role of each one of them.

Therefore, we studied whether the three networks interact with each other and the features of this interaction. In order to do so, we modified Fan's task to introduce a new variable (a short duration high frequency tone) that would enable us to independently measure the three networks and the effect of each one on the other two networks (Fan and co-workers used

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different levels of the same variable to measure both Orienting and Alerting and thus, the effect of one on the other could not be measured).

2. Method

Twenty four undergraduate students of Psychology took part in this experiment for course credit. None of them knew the purpose of the experiment and all of them had normal or corrected to normal vision. Their ages ranged from 18 to 23. The procedure was a combination of a flanker paradigm and a cuing task. A factorial design 2 (*Alerting*) × 3 (*Cueing*) × 2 (*Congruency*) was used. The Alerting variable consisted of a short duration high frequency tone that had two levels (presence and absence). The Cueing variable had three levels (cued trials: an asterisk was presented at the same location as the subsequent target stimulus, uncued trials: the asterisk was presented on the alternative position to that of the target stimulus, and trials with no cue: no asterisk was presented to the participants).

The target stimulus consisted of an arrow pointing either right or left and was flanked by two arrows on each side that could be pointing in the same direction of the target (congruent trials) or in the opposite direction (incongruent trials).

On each trial, the students were presented a fixation point of a variable duration ranging from 400 to 1600 ms. and in half the trials, followed by a 2000 Hz 50 ms tone. After a stimulus onset asynchrony (SOA) of 400 ms, a cue was presented on 2/3 of the trials for 50 ms. Half of the times, the cue was presented on the location of the target (cued trials) and the other half on the location opposite to that of the target (uncued trials). Fifty milliseconds after this, the target was presented until a response was given. The target could appear either above or below the fixation point (the number of trials in which the target appeared on each location as well as the direction of the arrow was the same). The task of the participants was to discriminate the direction of the target arrow.

3. Results

The data were analyzed by means of a repeated measures ANOVA. Statistically significant differences were found for each of the three main effects. Responses were faster in alerting trials ($F_{(1,23)} = 22.21$; $p < .0001$), in cued trials ($F_{(2,46)} = 72.85$; $p < .0001$) and in congruent trials ($F_{(1,23)} = 278.17$; $p < .0001$) Table 1.

As predicted by Posner (1994), the interaction between the *Alerting* and Congruency was significant in the sense of a larger congruency effect—difference between congruent and incongruent trials—when an alerting sound was present compared with those trials in which it was absent ($F_{(1,23)} = 19.40$; $p < .0002$). A significant interaction was also found between *Cueing* and *Congruency* ($F_{(2,46)} = 4.58$; $p < .0153$) in the sense of a larger congruency effect when the participant viewed a cue in the location opposite to the target than in the conditions in which the cue was either absent or presented in the same location of the target.

Table 1
Mean RT in ms (percentage of errors) for each condition

	No alerting tone			Alerting tone		
	No cue	Cued	Uncued	No cue	Cued	Uncued
Congruent	573.5 (1.39%)	533.6 (1.22%)	561.1 (1.56%)	530.1 (1.74%)	519.6 (1.04%)	547.6 (1.56%)
Incongruent	644.1 (2.60%)	617.3 (3.82%)	648.9 (6.08%)	625.3 (7.64%)	603.6 (3.82%)	659.3 (7.47%)

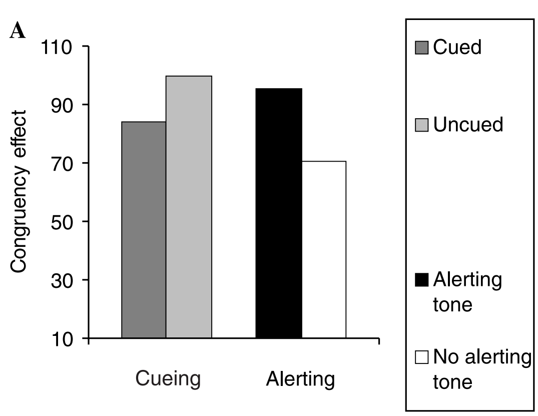

Fig. 1. Interactions between the variables. (A) Congruency (mean RT for incongruent trials – mean RT for congruent trials) as a function of cueing (cued trials vs. uncued trials) and Alerting (trials with an alerting tone vs. trials without an alerting tone). (B) Cueing (mean RT for uncued trials – mean RT for cued trials) as a function of alerting (trials with an alerting tone vs. trials without an alerting tone).

Finally, an interaction between *Alerting* and *Cueing* was also found ($F_{(2,46)} = 14.61$; $p < .0001$): the cueing effect (difference between cued and uncued trials) was significantly larger in those trials with an alerting stimuli compared with the trials where the alerting tone was not presented. The three interactions are graphically shown in Fig. 1.

4. Discussion

The aim of this experiment was to study the way in which the attentional networks relate to each other. Previous literature had proposed possible ways in which these interactions were affecting the performance of the networks but as to our knowledge, no experimental manipulation had been conducted to actually study these predictions.

We found interactions between all the networks that offer very interesting new information on the way our cognitive system works and, most importantly, on how the attentional system is coordinated to produce an efficient performance as a whole.

As proposed by Posner (1994), the Alerting network produces an inhibitory effect on the Executive Function network to enhance fast responses to sensory input in order to detect an infrequent target and prevent the system from focusing on feelings or thoughts or on further processing of the stimulus. This inhibition was observed in our results as an increase in reaction time for incongruent trials (those in which the flankers pointed to the opposite direction as the target) when an alerting sound was presented. Thus, the inhibition of the Executive Function network in these trials was observed as an increase in the time needed by participants to discriminate the direction of the arrow when the flankers where not congruent with the target stimulus.

We also found an interaction between the Orienting and the Executive Function networks. As found by Funes and Lupiáñez (2003), the congruency effect (difference between response time for congruent and incongruent targets) was larger in uncued trials than in cued or no-cue trials. This could be due to the fact that in cued trials the asterisk appeared on the exact same position as the target arrow, thus helping in the focusing of attention and making it easier for the participant to ignore the incongruent flankers. In uncued trials, however, the participant had to move the attentional focus to the location of the target which would implicate the broadening of the focus to include the flankers.

Finally, the interaction found between the Alerting and the Orienting networks is of great importance considering the unclear previous findings in the literature (Fernandez-Duque & Posner, 1997). In order to fully understand the results obtained in this experiment, it is important to refer to our previous findings in which the interaction was not found in a task exactly the same as this but with a SOA of 500 ms between the orienting cue and the target. The absence of interaction under these conditions (500 ms SOA) led us to propose that the influence of the Alerting network on the Orienting network could be one of accelerating its function rather than increasing it. For this reason, we conducted the experiment we report here in which the SOA was reduced to 100 ms to be able to study the temporal course of orienting under alerting conditions and also under normal conditions (without alerting tone). Here we found that under alerting conditions the effect of an orienting cue (difference between cued and uncued trials) was larger than in those trials in which no alerting cue was presented. These results show for the first time that Alerting exerts an influence on Orienting and that the nature of it is not that of enhancing its effect but accelerating it.

From this study we can conclude that, although the three attentional networks are independent (Fan et al., 2002; absence of correlation across participants between the effects produced by each network), and are subtended by different neural networks (Posner, 1994), when we measure the functioning of the three networks in a complex task, interesting interactions between the attentional networks can be observed. Therefore, even though their functions and neural substrates are different, the three attentional networks act under the constant influence of each other in order to produce an efficient and adaptative behavior.

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