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Efficiency and interactions of alerting, orienting and executive networks: The impact of imperative stimulus type

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ABSTRACT

The Attention Network Test (ANT) generates measures of three attention networks: alerting, orienting and executive control. Arrows have been generally used as imperative stimuli in the different versions of this paradigm. However, it is unknown whether the directional nature of these stimuli can modulate the efficiency of the executive control and its interaction with alerting and orienting. We developed three ANT variants to examine attentional effects in response to directional and non-directional stimuli. Arrows (ANTI-A), colored fruits (ANTI-F) and black geometrical-shape (ANTI-G) were used as imperative stimuli (i.e., flanker stimuli). Data collected from fifty-two university students, in two experiments, showed that arrows stimuli produced a greater interference effect and a greater orienting effect as compared to the other stimuli. Moreover, only arrows modulated the interaction between executive control and orienting: a reduced flanker effect in spatially cued trials was only observed in ANTI-A. These results suggest that the directional value of the stimuli increases the conflict and modulates the efficiency of executive control and its interaction with orienting network.

1. Introduction

According to the attention network approach, human attentional system can be subdivided into three functionally and anatomically independent networks — alerting, orienting, and executive control (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Fan, McCandliss, Sommer, Raz, & Posner, 2002; Posner & Petersen, 1990; Posner & Rothbart, 2007). The alerting network is concerned with the individual's ability to achieve and maintain a state of increased sensitivity to incoming information; the orienting network is responsible for the movement of attention through space in order to select and focus on the to-be-attended stimulus, and the executive control network allows one to the monitoring and resolution of conflict between expectation, stimulus, and response.

The Attention Network Test (ANT) was developed as an experimental measure of the three attention networks within the context of a quick and simple computerized task (Fan et al., 2002). The ANT is widely used to study the attentional performance in adults (Asanowicz, Marzecová, Jaśkowski, & Wolski, 2012; Callejas, Lupiánez, Funes, & Tudela, 2004, 2005; Fan, McCandliss, Fossella, Flombaum, & Posner, 2009; Fuentes & Campoy, 2008; Ishigami & Klein, 2010; Martella, Casagrande, & Lupianez, 2011), children (Rueda et al., 2004) and clinical populations (Casagrande et al., 2012; Chica, Bartolomeo, & Valero-Cabrè, 2011; Fernandez et al., 2011; Fuentes et al., 2010; Konrad, Neufanga, Hanischa, Fink, & Herpertz-Dahlmanna, 2006; Posner et al., 2002). This paradigm is a combination of the Covert Orienting Task (Posner, 1980) and the Flanker Task (Eriksen & Eriksen, 1974). It requires distinguishing the direction of a central arrow (the target) flankered on each side by two arrows (the flankers) pointing in the same direction (congruent condition) or in the opposite direction (incongruent condition). Target and flankers appear in the upper or in the lower visual field and are preceded by one of four experimental conditions: in spatial-cue trials, an asterisk appears in the same position in which the target will subsequently appear (100% valid-cue condition), in the central cue condition, the asterisk visually overlaps the fixation point; in the double cue condition it appears simultaneously in the upper and lower visual fields; lastly, in the no-cue condition any stimulus appears. A different score for each attention network is obtained by subtracting the mean reaction times (RTs) in specific experimental conditions: alerting effect (no-cue minus double-cue), orienting effect (center cue minus spatial cue), and executive control effect (incongruent minus congruent).

The original version of the ANT was suitable to obtain an appropriate index for each attentional network; nonetheless some authors (Callejas et al., 2004, 2005; Fuentes & Campoy, 2008) further examined the

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interaction between the alerting and orienting networks by including an acoustic warning tone to independently measure the phasic alerting and a non-predictive cue to assess the activation of a pure automatic orienting of attention. A different score for each attention network was obtained by subtracting the mean reaction times (RTs) in specific experimental conditions: alerting effect (no-warning minus warning), orienting effect (invalid cue minus valid cue), and executive control effect (incongruent minus congruent). These differences make the modified Callejas et al.'s version of ANT more suitable for studying interactions between attentional networks. In particular, it showed that alerting inhibits executive control and enhances orienting (Callejas et al., 2004, 2005; Fuentes & Campoy, 2008). Moreover, a significant interaction between orienting and executive control has been generally observed with both ANT and ANT-I (e.g.; Callejas et al., 2004, 2005; Fan et al., 2009; Federico, Marotta, Adriani, Maccari, & Casagrande, 2013; Fuentes & Campoy, 2008; Ishigami & Klein, 2010; Martella et al., 2011; Poynter, Ingram, & Minor, 2010; Roca, Castro, Lopèz-Ramon, & Lupianez, 2011; Trujillo, Kornguth, & Schnyer, 2009): showing that the executive control is enhanced on spatially cued trials.

This body of evidences suggests that any manipulation of the task design can depict at a behavioral level significant interactions among attentional networks. One relevant methodological aspect that may contribute to such interactions might be the type of the imperative stimuli (i.e. target and flankers) used to assess attentional performances. In the ANT, arrows have been generally used to assess executive control. However, it is unknown whether this type of stimulus can modulate by itself the efficiency of the executive control and its interactions with alerting and orienting. In fact, several studies have shown that arrows stimuli can reflexively trigger attentional shifts (Tipples, 2002, 2008) and modulate congruency effects as measured by spatial flanker tasks (Zeischka, Deroost, Henderickx, & Soetens, 2010; Zeischka, Deroost, Maetens, & Soetens, 2010). Moreover, it has been demonstrated that in flanker tasks response selection depends on the stimulus characteristics (Hazeltine, Bunge, Scanlon, & Gabrieli, 2003). In particular, comparing a letter and a color version of a flanker task, Hazeltine and colleagues found that different areas in the prefrontal cortex were active depending on the type of stimulus information that needed to be inhibited.

In the present study, we aimed to examine cognitive control in response to different types of stimuli information and assess whether arrows stimuli can influence the interaction among attentional networks. In particular, we developed three variants of the ANTI, in which arrows (ANTI-A), colored fruits (ANTI-F) and geometrical shapes (ANTI-G) were used as target stimuli. This manipulation enabled us to test the impact of the type of stimulus information on conflict processing, and allowed us to make a more detailed assessment of the interaction between the executive and the other two attentional systems: orienting and alerting. We expected that directional arrows stimuli might affect executive control, influencing its interaction with orienting. This prediction is based on the findings showing that in a spatial flanker task both target and flanker arrows can independently trigger spatial orienting of attention (Zeischka, Deroost, Henderickx, et al., 2010; Zeischka, Deroost, Maetens, et al., 2010). This could provide an amplification of the interference effect because in order to distinguish the direction of the central arrow from that of the flankers, participants need to resolve a double conflict raised by both the contrasting responses and attentional orienting processes associated with the two stimuli (target and flanker arrows). Consequently an increased allocation of attentional resources is also probably involved in an arrow flanker task as compared to flanker tasks using non-directional stimuli. The effect of this enhancement of attentional resources could be particularly evident in the condition with greater conflict (i.e. on trials with incongruent flankers).

We expected greater congruency and orienting effects in ANTI-A as compared to the other two tasks. Moreover, we assumed to observe the *Cue* by *Flanker* interaction only in the ANTI-A due to the use of directional stimuli as target and flankers. In order to test the conflict produced by non-directional stimuli we created two different versions of the ANTI, one with colorful fruits (ANTI-F) and the other with geometric shapes (ANTI-G); while the latter has been created in order to directly compare this version with the original version of the ANTI leaving the possibility to discriminate by means of two features, the shape and the name, the former version (ANTI-F) allows one to recognize the target by means of three features: the shape, the name and the color. We hypothesized that the greater number of features allowing one to discriminate the target should make the ANTI-F easier and thus the RTs should be faster than in the other two tasks.

2. Method

2.1. Participants

Twenty-four university students (24 female; mean age $= 24 \pm 1.24$) voluntarily took part to the study. The participants were selected as being right-handed having a Hand Preference Index > .85, as assessed by means of a Lateral Preference Questionnaire (Salmaso & Longoni, 1985). They were all naive to the purpose of the experiment and all of them reported normal or corrected to normal vision. All the experiments were performed in accordance with the ethical standards of the Declaration of Helsinki. The study was approved by the local ethical committee and all the participants signed an informed consent.

2.2. Apparatus

Stimuli were programmed and displayed by E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) on a 17 CTR monitor with a screen resolution of 1024×768 pixels. Responses were collected through the mouse, and headphones (Quasar Headset, Trust.com) were used to administer the alerting tones.

2.3. ANTI-Arrows (ANTI-A)

2.3.1. Stimuli

Each trial began with the presentation of a central cross of 1° (degrees of visual angle). The stimuli consisted of a row of five black arrows, presented on a gray background. The target was a left- or right-pointing arrow at the center, which was flankered on both sides by two arrows pointing either in the same direction (congruent trials), or in the opposite direction (incongruent trials). A single arrow consisted of 0.58° and the contours of adjacent arrows or lines were separated by 0.06°. The stimuli (one central arrow plus four flankers) subtended a total of 3.27°. The target and flankers were presented 1.06° above or below the fixation point. The cue was an asterisk of 1° and it could be presented at the position of the upcoming target (valid cue condition), in the opposite location (invalid cue condition), or it could be absent (no-cue condition). The auditory warning stimulus was 2000 Hz and lasted 50 ms.

2.3.2. Procedure

Subjects were tested individually in a silent and dimly illuminated room, at a 50 cm distance from the computer screen. Each trial began with a fixation period of variable duration (400–1600 ms). This was followed by a warning stimulus lasting 50 ms in 50% of the trials. Next, a cue of 150 ms was presented. In the valid condition (33% of the trials) an asterisk appeared in the same position of the target; in the invalid condition (33%) the target appeared in the opposite position than the one signaled by the cue; in the no-cue condition no orienting stimulus was presented. After a fixed interstimulus interval (ISI) of 350 ms, the target was presented for 150 ms and participants had a limit of 1700 ms to respond. The fixation point was at the center of the screen throughout the trial. The sequence of the events for each trial is shown in Fig. 1.