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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.

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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.

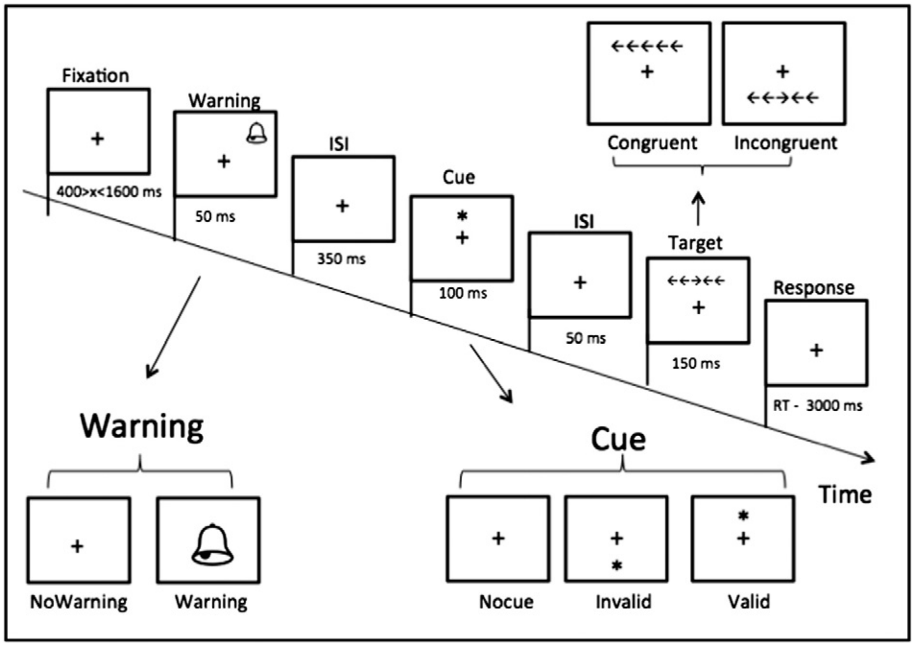

Fig. 1. Schematic view of a trial sequence. The example represents a valid trial. At the top of the figure a representation of the flanker is reported; and at the bottom of the figure, both warning and cue conditions are represented.

The central arrow was flankered by two arrows on each side, that were pointing in either the same direction (congruent condition) or the opposite direction (incongruent condition) as the central arrow. In half of the trials the flankers were congruent while in the other half of the trials they were incongruent and the difference between these two conditions provides an index of the executive functions (conflict effect). The two conditions differ only in the information given by the flankers. When the images are congruent, they provide a facilitating effect on the discrimination of the target stimulus, whereas incongruent flankers distract participants. Visual cues are used to assess the validity effect. Both invalid and valid cues alert the participant to the forthcoming appearance of the target, but only the valid cue provides spatial information, which allows subjects to orient their attention to the appropriate spatial location. Therefore, the RT difference between valid and invalid cues provides a measure of orienting attention (Callejas et al., 2004, 2005).

The alerting effect is calculated by subtracting the mean RTs of the auditory warning conditions from the mean RTs of the no-warning conditions. This represents the benefit of alerting on the speed of the response to the target.

After a 16-trial practice block, participants performed three experimental blocks of 144 trials: 36 valid, 36 invalid, and 36 no-cue trials for each flanker and warning conditions. The trials were presented randomly within each block. The entire experiment comprised 432 trials.

Subjects were instructed to fixate the central cross and to respond to the stimulus as quickly and accurately as possible. The task was to identify the direction of the centrally presented arrow by clicking the right or left button on the mouse.

2.4. ANTI-Fruits (ANTI-F)

The participants and procedure were the same as those described for the ANTI-A. The only difference was in the stimuli. In the ANTI-F target and flankers stimuli were red strawberries and yellow pears. Three different characteristics allowed one to discriminate between the targets in this ANTI version: the color (yellow or red), the shape (strawberry or pear), and the name. The stimuli were positioned in a new configuration, with the four flankers that overlapped the border of an imaginary semicircle in which the target was at the center. This change was made to ensure that all flankers appeared at the same distance in respect to the central target avoiding any distortion caused by the reduced efficacy of the leftmost and rightmost flanker stimuli in a row (Muller, Mollenhauer, Rosler, & Kleinschmidt, 2005).

Participants were instructed to fixate the central cross and to discriminate the fruit on the center of the semicircle. Half of the participants responded left button on the mouse when the pear was the target and right button on the mouse when the strawberry was the target, while the other half of participants performed the opposite condition.

2.5. ANTI-Geometrical shape (ANTI-G)

The participants and procedure were the same as those described for the ANTI-F. The only difference was in the stimuli. In the ANTI-G stimuli were black rhombi and a black triangle. The stimulus configuration was the same as that of ANTI-F. Similarly to the ANTI-F, two different dimensions allowed one to discriminate between the targets in this ANTI version: the shape (rhombus and triangle) and the name. Participants were instructed to fixate the central cross and to discriminate the geometrical shape on the center of the semicircle. Half of the participants responded left button on the mouse when the rhombus was the target and right button on the mouse when the triangle was the target, while the other half of participants performed the opposite condition.

2.6. General procedure

In each experiment, half of the participants were required to respond by pressing the right button of the mouse when the right-pointing arrow, the strawberry, or the triangle appeared on the screen and by clicking the left button when the left-pointing arrow, the pear, or the rhombus was presented; for the other half, response buttons were inverted.

The administration of the three experiments was counterbalanced among participants. The stimuli of the three experiments are shown in Fig. 2.

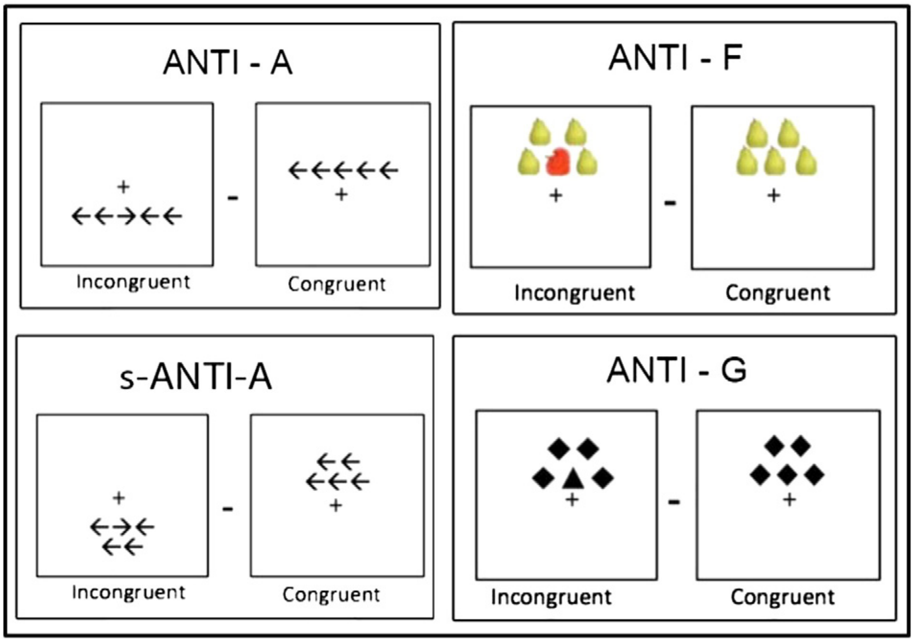

Fig. 2. Stimuli used in Experiment 1 (top-left, top-right and bottom-right) and Experiment 2 (top-left and bottom left).

2.7. Experimental design

According to a consolidated ANT analysis, only the RTs of correct responses ranging between 200 ms and 1200 ms were considered (Callejas et al., 2005).

A *Task* (ANTI-A, ANTI-F, ANTI-G) × *Warning* (No-warning, Warning) × *Cue* (Valid cue, Invalid cue, No-cue) × *Flanker* (Congruent, Incongruent) repeated measures analysis of variance (ANOVA) was conducted on RTs of the correct responses. The warning present/absent conditions were used to evaluate the auditory alertness, valid and invalid trials evaluated orienting, and congruent and incongruent flanker trials provided a measure of executive functions.

To estimate the efficiency of each attentional system, thus enabling us to compare the results of this study with previous studies using the ANT (Callejas et al., 2004, 2005; Fan et al., 2002; Fuentes & Campoy, 2008), a one-way ANOVA considering the *Task* was performed on the *orienting effect* (RTs invalid-cue − RTs valid-cue), the *conflict effect* (RTs incongruent trials − RTs congruent trials), and the *alerting effect* (RTs no-warning − RTs warning).

A high score of the *orienting effect* reflects the ability to rapidly orient the attention towards the targets appearing in the cued positions. A smaller *conflict effect* reflects participant's ability to inhibit the interfering effect brought by distractor stimuli (the flankers). The *alerting effect* represents the benefit of alerting on the speed of the response to the target.

In order to analyze the main effects of the Task and the Cue, LSD test has been used.

An α value of 0.05 was used to establish statistical significance for all analyses.

3. Results

Table 1 shows the means RTs (±SD) for each experimental condition. Trials with erroneous responses accounted for 4.90% of the trials. All main effects were significant: *Task* ($F_{(2, 46)} = 5.97$; $p < .007$; $\eta^2 = .21$); *Flanker* ($F_{(1, 23)} = 174.31$; $p < .0001$; $\eta^2 = .88$); *Cue* ($F_{(2, 46)} = 39.44$; $p < .0001$; $\eta^2 = .63$) and *Warning* ($F_{(1, 23)} = 91.90$; $p < .0001$; $\eta^2 = .80$). RTs were slower in the ANTI-G compared to ANTI-F (652.99 and 593.12 ms respectively; $p < .0001$), but not to ANTI-A (618.27, $p = .08$); ANTI-A and ANTI-F were not significantly different ($p = .18$).

RTs in the warning trials were faster than RTs in the no-warning trials (603.62 vs 639.31 ms; $p < .0001$). RTs were faster in the valid trials than in the no-cue trials and invalid trials (604.74 ms, 625.61 ms; $p < .0001$, 634.04; $p < .0001$ respectively). RTs in the no-cue trials were also faster than RTs in the invalid trials ($p < .02$). Finally, RTs were significantly faster in congruent trials than in incongruent trials (593.01 vs 649.91 ms; $p < .0001$). A *Warning* × *Cue* interaction ($F_{(2, 46)} = 24.57$; $p < .0001$, $\eta^2 = .52$) confirmed that the presence of the warning reduced RTs in the valid trials (the difference between invalid and valid trials in the warning trials was 38 ms and it was 20 ms in the no-warning trials). The *Warning* by *Flanker* interaction ($F_{(1, 23)} = 7.36$; $p < .01$; $\eta^2 = .24$) demonstrated a greater conflict effect in the warning present condition compared to the warning absent condition (64 ms and 49 ms respectively). Of relevance for the present study, the Task × Flanker ($F_{(2, 46)} = 28.68$; $p < 0001$; $\eta^2 = .56$) and the Task × Cue × Flanker ($F_{(4, 92)} = 2.78$; $p < .04$; $\eta^2 = .11$) interactions were significant. All the other interactions were not significant ($F \geq 1.6$).

Table 1
Mean RTs and (standard deviations) in the three versions of the Attentional Network Test.

		No-warning			Warning		
		No-cue	Invalid	Valid	No-cue	Invalid	Valid
ANTI-A	Congruent	619.09 (116.68)	589.87 (92.81)	576.04 (117.39)	556.26 (107.42)	565.46 (98.04)	531.78 (111.86)
	Incongruent	688.36 (132.33)	685.97 (118.12)	654.34 (122.94)	635.17 (112.47)	690.04 (119.85)	626.86 (106.63)
ANTI-F	Congruent	595.18 (79.44)	589.18 (93.01)	576.04 (78.40)	537.56 (98.49)	559.09 (97.75)	535.98 (88.70)
	Incongruent	645.65 (97.26)	641.50 (99.40)	618.33 (91.74)	598.34 (94.01)	624.25 (98.80)	596.39 (88.42)
ANTI-G	Congruent	679.94 (110.11)	663.46 (101.44)	643.56 (98.36)	605.90 (91.73)	644.20 (92.43)	605.61 (103.04)
	Incongruent	696.41 (88.69)	682.26 (79.10)	662.36 (89.47)	649.41 (90.98)	673.20 (89.34)	629.58 (79.99)

In order to examine further the Task by Cue by Flanker interaction, an ANOVA *Cue* by *Flanker* was separately carried out for each task. A significant interaction Cue × Flanker was only significant in the ANTI-A ($F_{(2, 46)} = 6.85$; $p < .003$; $\eta^2 = .23$), showing a greater conflict effect in the invalid trials than in valid trials (110 vs 86 ms, respectively; see Fig. 3), whereas this difference was not significant in both ANTI-F (59 vs 51 ms) and ANTI-G (24 vs 21 ms) (both $F < 1$).

3.1. One-way ANOVA on conflict effect

Fruitful information among the efficiency and interaction of the attentional networks has been provided by many authors (e.g. Greene et al., 2008) conducting one way ANOVAs on the attentional indexes, i.e. no warning − warning for the *alerting effect*; invalid − valid for the *orienting effect* and incongruent − congruent for the *conflict effect*.

To further analyze the interaction *Task* by *Flanker*, a One-way ANOVA was conducted on the *conflict effect* ($F_{(2, 46)} = 33.01$; $p < .0001$; $\eta^2 = .59$), revealing a greater effect in the ANTI-A compared to both the ANTI-F (173.83 vs128.56 ms; $p < .01$) and the ANTI-G (106.82 ms; $p < .0001$). Furthermore, the conflict effect was significantly smaller in the ANTI-G than in the ANTI-F ($p < .0001$; see Fig. 4).

As previously described, the different conflict effects as a function of task depend also on the *Task* by *Cue* by *Flanker* interaction; as shown in Fig. 3, the presence of a valid or an invalid cue condition modulates the *Task by Flanker* interaction only in the ANTI-A task.

4. Discussion

The results obtained across the three experiments show that all the ANTI versions reliably assess each attentional system, i.e. alerting, orienting and executive systems.

The main goal of this study was to compare the impact of the imperative stimuli used in the ANTI (Callejas et al., 2004, 2005) with other typologies of stimuli (colored fruits and geometrical shapes). In order to evaluate this hypothesis, we developed two other versions of the ANTI in which the arrows were substituted with colored fruits (ANTI-F) or geometrical black shapes (ANTI-G). According to other findings (Shahbaz Khan, van de Weijer, & Vanrell, 2009; Zeischka, Deroost, Henderickx, et al., 2010; Zeischka, Deroost, Maetens, et al., 2010), the conflict and the orienting effects were bigger in the ANTI-A than in the other two tasks. These results could be dependent on the double conflict raised by both the contrasting responses produced by the incongruent flankers and attentional orienting processes associated with the direction brought by the arrows. Consequently, both target and flanker arrows can independently trigger orienting spatial of attention (Zeischka, Deroost, Henderickx, et al., 2010; Zeischka, Deroost, Maetens, et al., 2010) producing the *cue* by *flanker* interaction: the increased allocation of attentional resources is probably involved in an arrow flanker task as compared to flanker tasks using non-directional stimuli, and the effect of this enhancement of attentional resources is particularly evident in the condition with greater conflict (i.e., on trials with incongruent flankers).

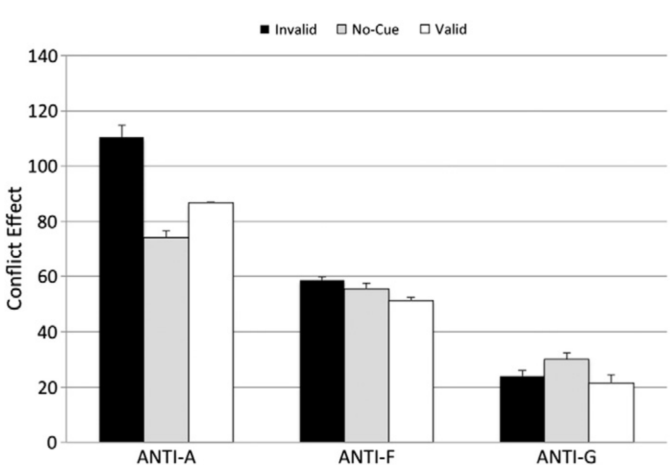

Fig. 3. Cue by Flanker interaction (represented as the difference between the incongruent and congruent trials) in each task.

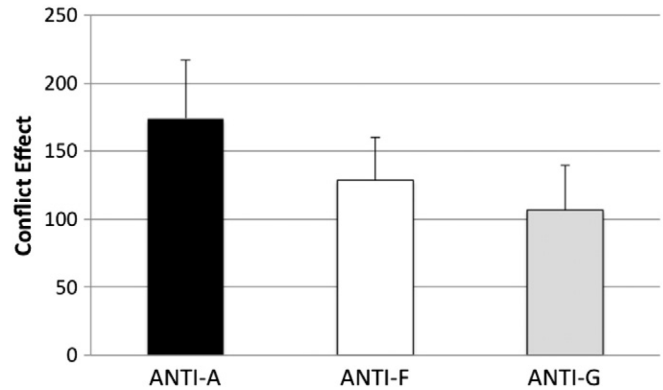

Fig. 4. Conflict Effect (mean RTs incongruent trials − mean RTs congruent trials) in the three different ANTI.

5. Experiment 2

The main goal of the second part of this study was to rule out the possibility that the any difference between the tasks might be due not only to the nature of the stimuli, but also to the different arrangements used. In Experiment 1, while the ANTI-A stimuli were arranged according to Fan et al. (2002) (two arrows on each side flank the target), in the ANTI-F and ANTI-G the flankers surrounded the target creating a semicircle of stimuli with the target on the center. Thus, the absence of an interaction between cue and target conditions in the new tasks proposed here might be due to the different positions in which the flankers are presented.

In order to test the different impacts of the arrangements used in Experiment 1, we compared the original version of the ANTI-A (with the same structure and number of trials of the one previously used) with a new version of the ANTI-A (s-ANTI-A) where stimuli are presented according to the shape used in the ANTI-F and ANTI-G versions in Experiment 1 (see Fig. 2).

We predict that if the differences between tasks observed in the precedent experiment were effectively due to the different nature of the stimuli (directional vs no-directional), rather than to the different arrangements of the stimuli, then no difference in flanker effects should be observed in the current experiment between the ANTI-A and the s-ANTI-A.

5.1. Methods

5.1.1. Participants

Twenty-eight university students (28 female; mean age = 24 ± 1.99) 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 local ethical committee approved the study and all the participants signed an informed consent.

Table 2
Mean RTs and (standard deviations) in the ANTI-A and the s-ANTI-A.

		No-warning			Warning		
		No-cue	Invalid	Valid	No-cue	Invalid	Valid
ANTI-A	Congruent	523.11 (54.18)	513.09 (54.18)	501.52 (55.88)	467.13 (55.17)	491.58 (52.28)	458.59 (53.74)
	Incongruent	594.63 (67.97)	600.71 (72.63)	566.99 (72.41)	565.38 (61.46)	592.38 (69.36)	546.34 (60.83)
s-ANTI-A	Congruent	557.13 (61.48)	555.76 (79.00)	528.84 (59.84)	492.10 (57.31)	512.45 (69.58)	477.98 (54.58)
	Incongruent	619.38 (80.75)	620.18 (75.96)	592.78 (72.85)	585.30 (73.69)	623.92 (92.64)	574.55 (74.68)

5.2. ANTI-Arrows (ANTI-A)

Stimuli, Apparatus, Procedure, Task and Experimental Design were exactly the same as ANTI-A in Experiment 1.

5.3. Semicircle-ANTI-Arrows (S-ANTI-A)

Stimuli, Apparatus, Procedure and Task and Experimental Design were exactly the same as ANTI-A in Experiment 1. The only difference was in the way stimuli were arranged on the screen: we replicated the configuration used in the ANTI-F and ANTI-G tasks, with the four flankers that overlapped the border of an imaginary semicircle in which the target was at the center.

Table 2 shows the means RTs ($\pm$SD) for each experimental condition. Trials with incorrect responses accounted for 1.98% of the trials. All main effects were significant: *Task* ($F_{(1,\ 27)} = 23.65$; $p < .0001$; $\eta^2 = .47$); *Flanker* ($F_{(1,\ 27)} = 228.49$; $p < .0001$; $\eta^2 = .89$); *Cue* ($F_{(2,\ 54)} = 70.17$; $p < .0001$; $\eta^2 = .72$) and *Warning* ($F_{(1,\ 27)} = 58.56$; $p < .0001$; $\eta^2 = .69$). RTs were slower in the s-ANTI-A compared to ANTI-A (561.70 and 535.12 ms respectively; $p < .0001$); RTs in the warning trials were faster than RTs in the no-warning trials (532.31 vs 564.51 ms; $p < .0001$). RTs were faster in the valid trials than in the no-cue trials and invalid trials (530.95 ms, 550.52 ms; $p < .0001$, 563.76; $p < .0001$ respectively). RTs in the no-cue trials were also faster than RTs in the invalid trials ($p < .02$). Finally, RTs were significantly faster in the congruent trials than in the incongruent trials (506.61 vs 590.21 ms; $p < .0001$). A *Warning* × *Cue* interaction ($F_{(2,\ 54)} = 19.99$; $p < .0001$, $\eta^2 = .43$) confirmed that the presence of the warning reduced RTs in the valid trials (the orienting effect in the warning trials was 42 ms and 25 ms in the no-warning trials). The *Warning* by *Flanker* interaction ($F_{(1,\ 27)} = 24.45$; $p < .01$; $\eta^2 = .48$) and the *Warning* by *Flanker* by *Task* interaction ($F_{(1,\ 27)} = 5.55$; $p < .03$; $\eta^2 = .17$) demonstrated slower RTs in the incongruent trials compared to the congruent trials only in the warning present condition, particularly in the s-ANTI-A task (ANTI-A: conflict effect in no-warning trials: 75 ms; warning trials: 96 ms; s-ANTI-A conflict effect in no-warning trials: 63 ms; in warning trials: 100 ms).

As expected, the *Task* × *Flanker* interaction was not significant ($F < 1$).

Surprisingly, the *Cue* and *Flanker* showed only a tendency to interact. According to the results found in Experiment 1, the use of directional stimuli as target and flankers should produce a significant interaction between these two factors. Results in Experiment 2 apparently contradict this hypothesis.

To further understand the lack of this pattern, we conducted two different ANOVAs, the first only on no-cue trials, which confirmed the three main effects as well as the W*arning* by *Flanker* and *Warning* by *Cue* interactions. In order to test whether the directional value of the stimuli used in both ANTI-A and s-ANTI-A interacted with the orienting conditions, the second ANOVA was conducted on both valid and invalid trials. As expected, results confirmed the four main effects as well as the interactions found in the main ANOVA. Further, the *Cue* by *Flanker* interaction was significant ($F_{(1,\ 27)} = 4.09$; $p = .05$; $\eta = .13$) confirming the pattern of a greater conflict effect in the invalid trials (91 ms) compared to valid trials (78 ms) when directional stimuli are used as target and flankers. All the other interactions were not significant ($F < 1$).

6. Discussion

Findings of Experiment 2 confirmed the effectiveness of paradigms used here to modulate the three attentional networks and their interactions. The presence of the interactions between *Warning* and *Cue* as well as *Warning* and *Flanker* confirmed the pattern shown in many other studies (Callejas et al., 2004, 2005; Fan et al., 2009; Federico et al., 2013; Fuentes & Campoy, 2008; Ishigami & Klein, 2010; Martella et al., 2011; Poynter et al., 2010; Roca et al., 2011; Trujillo et al., 2009) about the way these networks cooperate in a coordinated way in order to produce an effective behavior.

The main goal of Experiment 2 was to rule out the possibility that the difference in the arrangements used in Experiment 1 was responsible for the lack of *Cue* by *Flanker* interaction in the two versions of the ANTI which used non-directional stimuli as flanker and targets. To reach this goal, an additional group of participants performed the arrow ANTI with both the standard arrangement (ANTI-A) and a new version of the ANTI (s-ANTI-A), which presented similar stimuli arrangement as in the ANTI-F and ANTI-G.

The absence of the *Task* by *Flanker* interaction reinforced the assumption that the differences between the three tasks shown in Experiment 1 are due to the nature of the imperative stimuli.

7. General Discussion

Overall, the pattern of results obtained across the experiments shows that the new versions of the ANTI, proposed in this study, reliably assess each attentional system, i.e. alerting, orienting and executive systems, underlining the strong validity of the Attentional Network Test.

Results of Experiment 1 confirmed our hypothesis: RTs in the ANTI-F were significantly shorter than RTs in the ANTI-G and marginally different compared to the ANTI-A ($p = .08$). As expected, when three features (shape, color and name) allow the participant to discriminate the target from the flankers, as in the ANTI-F, the task results easier (faster RTs) rather than when only two features allow one to discriminate the target stimulus from flankers (ANTI-A and ANTI-G).

Furthermore, both ANTI-A (in Experiments 1 and 2) and s-ANTI-A (in Experiment 2) confirmed the results previously shown by other studies (Callejas et al., 2004, 2005). In fact, a greater conflict effect was present when subject's attention was directed towards an invalid position than a valid position. Equally, a greater orienting effect was evident in the warning present condition than in the no-warning condition.

Importantly, the main goal of this study was to compare the impact of the imperative stimuli used in the ANTI (Callejas et al., 2004, 2005) with other typologies of stimuli (fruits and geometrical shapes). In order to achieve this goal, we developed two other versions of the ANTI in which the arrows were substituted with colored fruits (ANTI-F) or geometrical black shapes (ANTI-G). According to other studies (Shahbaz Khan et al., 2009; Zeischka, Deroost, Henderickx, et al., 2010; Zeischka, Deroost, Maetens, et al., 2010), the conflict and the orienting effects were greater in the ANTI-A than in the other two tasks. These results could be dependent on the double conflict raised by both the contrasting responses produced by the incongruent flankers and attentional orienting processes associated with the direction brought by the arrows. Consequently, both target and flanker arrows can independently trigger orienting spatial of attention (Zeischka, Deroost, Henderickx, et al., 2010; Zeischka, Deroost, Maetens, et al., 2010) producing the *cue* by *flanker* interaction: the increased allocation of attentional resources is probably involved in an arrow flanker task as compared to flanker tasks using non-directional stimuli, and the effect of this enhancement of attentional resources is particularly evident in the condition with greater conflict (i.e. on trials with incongruent flanker).

The conjoint possibility to 1) avoid the double conflict produced by the target and flankers stimuli that modulated both the orienting and executive networks and their interaction; 2) to delete the visuo-spatial properties of the stimuli that modulate the orienting network — observing a reduction of the orienting score in a colored shape ANTI version; 3) the reduction of the overall reaction times in the ANTI-F, adds new and interesting information regarding the way in which our attentional systems interact to reach an effective behavior in front of the different kinds of stimuli. Taken together the results of the ANTI with fruits as target and flankers open to the possibility that this version might be suitable to compare performance between toddlers, children, adults and clinical populations, even if both ANT and ANTI have been previously used with adults (Asanowicz et al., 2012; Callejas et al., 2004, 2005; Fan et al., 2009; Fuentes & Campoy, 2008; Ishigami & Klein, 2010; Martella et al., 2011) and clinical populations (Casagrande et al., 2012; Chica et al., 2011; Fernandez et al., 2011; Fuentes et al., 2010; Konrad et al., 2006; Posner et al., 2002).

The novelty of the independence between the orienting and executive networks when non-directional stimuli are used as target and flankers sets new and interesting perspectives in the possibility to create a test that evaluates efficiency and interactions of the attentional systems.

Finally, our findings confirm that the ANT is a reliable tool to assess the efficiency and interaction of attentional systems. To our knowledge, for the first time this test has been used to evaluate the modulation related to different imperative stimuli (targets and flankers) on orienting, alerting and executive systems.

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