ATTENTION NETWORK TEST – THE IMPACT OF SOCIAL INFORMATION ON EXECUTIVE CONTROL, ALERTING AND ORIENTING

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ABSTRACT

According to the attention network approach, attention is best understood in terms of three functionally and neuroanatomically distinct networks - alerting, orienting, and executive attention. An important question is whether social information influences the efficiency of these networks. Using the same structure as the Attentional Network Test (ANT), we developed a variant of this test to examine attentional effects in response to stimuli with and without social-cognitive content. Fish, drawings or photographs of faces looking to the left or right were used as target stimuli. Results collected from twenty-four university students showed that photographs of faces positively affected attentional orienting and executive control, whereas reduced the efficiency of alerting, as compared to both face drawings and fish. These results support the status of human faces as a special class of visual stimuli for the human attentional systems.

Keywords: Executive control, Alerting, Orienting, Eye-gaze, Attention Network Test (ANT)

Running head: The impact of social information on attentional networks

Research Highlights:

- Cognitive control in response to stimuli with and without social-cognitive content.
- Photographs of real faces positively affect attentional orienting and executive control
- Photographs of real faces significantly modulate the functioning of the three attentional networks

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Faces are the most important source of social information (including identity of the person, expression, gaze direction, age, and gender), often crucial in establishing social interactions (Shults, 2005). Among objects, the uniqueness of faces for the human attentional system has been demonstrated in a growing number of studies by using different methods (Birmingham & Kingstone, 2009; Kanwisher, 2000). Faces are more likely to capture attention than other objects (Bindemann, Burton, Langton, Schweinberger, & Doherty 2007; Langton, Law, Burton, & Schweinberger, 2008; Ro. Friggel, Lavie, 2007) and they cannot be ignored even under conditions of high perceptual load (Lavie, Ro, & Russel, 2003). In addition, merely seeing a face with an averted gaze can shift one's own attention in the corresponding direction of the seen gaze (e.g., Driver, Davis, Ricciardelli, Kidd, Maxwell, & Baron-Cohen, 1999; Friesen & Kingstone, 1998; Marotta, Lupiáñez, & Casagrande, 2012; Marotta, Lupiáñez, Martella, & Casagrande, 2012). These gaze-cueing effects occur after milliseconds of the appearance of a face (e.g., 14 ms, Hietanen & Leppanen, 2003) and even when gaze following is disadvantageous (e.g., Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004). Such findings imply that faces and eye-gaze direction are difficult to ignore. Obligatory gaze perception is consistent with the central role of gaze signals in social interaction and communication, as when gaze allows to establish joint attention (Moore & Dunham, 1995) or to infer the intentions or mental states of others (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995). However, in everyday life, people are often faced with complex social array containing conflicting gaze information from multiple faces. Consequently, the ability to control the extent that gaze information influences cognition is crucial for successful decision making and social interactions. A key question is how people control the processing of contrasting social relevant information, such as gaze direction from multiple faces.

In order to examine the executive control of social information, such as eye-gaze direction, in the current study we developed a variant of the Attention Network Test (ANT) (Fan, McCandliss, Sommer, Raz, & Posner, 2002), an experimental measure of the three attention networks: alerting, orienting and executive control (Posner & Petersen, 1990). The alerting network is concerned with an individual's ability to achieve and maintain a state of increased sensitivity to incoming information, the orienting network manages the ability to select and focus on the to-be-attended stimulus, and the executive control network manages the ability to control our own behaviour to achieve intended goals and resolve conflict among alternative responses. Of particular relevance to the present study, in the ANT the executive control has been generally measured by a flanker task in which participants are required to identify the direction of a central arrow target flanked by congruent or incongruent stimuli (arrows in the same or in the opposite direction as the target, respectively). Participants are typically faster when the target arrow and the flanking arrows are congruent, than when they are incongruent (i.e. flanker interference effect). Different types of stimuli have been used in different versions of this paradigm, such as fish (Rueda, Fan, McCandliss, Halparin, Gruber, & Pappert, 2004) and cars (Roca, Fuentes, Marotta, López-Ramón, Castro, Lupiáñez, & Martella, 2012). However, to our knowledge eye-gaze has never been used as target stimuli in the ANT and only one study (Dichter & Belger, 2007) has directly compared cognitive control in response to social and no-social stimuli in a flanker task (eye-gaze and arrow stimuli, respectively). Of interest for the present study, Dichter and Belger (2007) observed that only arrow stimuli, but not eye-gaze, produced interference effect in typically developing individuals. This suggest that people are engaged in more effective controlled processing when social relevant stimuli, such as eye-gaze direction, are used as compared to when no-social stimuli are employed.

In the present study, we examined cognitive control in response to stimuli with and without social-cognitive content by means of the ANT. We also assessed whether social stimuli can influence the efficiency of the other two attentional networks, alerting and orienting. In particular, we developed two social variant of the ANT, in which drawings or photographs of faces looking to the left or right were used as target stimuli. Moreover, the version of ANT developed by Rueda et al. (2004), with fish as stimuli was used to assess no-social attentional processes.[1]

We directly tested the following predictions: people will be engaged in more effective controlled processing when social relevant stimuli (drawings and photographs of faces) will be used as target compared to when no-social stimuli (fish) will be used. We also expect that social stimuli will facilitate attentional

[1] In this study we chose to use the ANT with fish as stimuli (Rueda et al., 2004) rather than original ANT with arrows (Fan et al., 2002) in order to ensure that we could match social stimuli (drawings/photographs of faces) and no social stimuli (colourful fishes) in relation to some of their saliency features.

orienting as compared to no-social stimuli, in line with previous findings showing that faces are more effective in attracting and holding attention than other object (Bindemann et al., 2007; Bayliss & Tipper, 2005). However, we make no prediction about differences between social and no-social stimuli in alerting.

Method

Participants

Twenty university students (13 females and 7 males; mean age 26.1 ± 2.4 years) signed an informed consent before participating as volunteers in the study. The local ethical committee approved the study. All participants had normal or corrected-to-normal vision, and were unaware of the purpose of the experiment.

Apparatus

Stimuli were presented on a 12-in. colour VGA monitor. An IBM-compatible PC running E-Prime software controlled the presentation of the stimuli, timing operations, and data collection. Responses were gathered with a standard computer mouse.

Stimuli

Stimuli and trial sequences are illustrated in the Figure 1.

Each participant completed three different versions of the ANT that differed only in the types of stimuli that appeared. All participants completed a version that presented colored fish as target and flanker stimuli, just as described in Rueda et al. (2004). All participants also completed two new versions of the task that presented drawings or photographs of faces instead of fish. The target array consisted of a central target stimulus and four flanker stimuli. Each stimulus subtended 1.6◦ (degree of visual angle) and the contours of adjacent stimulus were separated by 0.21°. The five stimuli subtended a total of 8.84°. The target was presented either about 1° above or below fixation. Each target was preceded by one of four cue conditions: a center cue, a double cue, a spatial cue, or no cue. Each cue stimulus subtended 1.5° of visual angle. The auditory and visual feedback was an animation showing the target fish blowing bubbles (or a red smile on the face) and exclaiming "Woohoo!" when a correct response was given. Incorrect responses were followed by a single tone and no animation.

Procedure

The experimental session consisted of three tasks: the fish version (ANT.Fish), the face drawings version (ANT.Face drawings) and the face photographs version (ANT.Face photographs). The order of each task was randomized across participants. Each of the tasks consisted of a practice block with 24 trials and two experimental blocks of 48 trials each. Participants could take breaks at the end of the practice block and between tasks.

The instructions were the same for all the versions of the task. Participants were told that a drawing or photograph of a face (or a fish) would appear on the screen and that the purpose of the task was to press the button on the mouse that matched the direction the face was looking (or fish was directed). Each target was preceded by a cue stimulus that either alerts or orients participants to the upcoming target. There were four cue types: no-cue (neither alerting nor orienting cue was presented), double-cue (a double-asterisks cue appearing simultaneously above and below fixation; alerting), spatial cue (a single asterisk presented in the position of the upcoming target; orienting), or central cue (an asterisk presented at the location of the fixation cross). Immediately after the cue, the target appeared and was flanked by one of two flanker types: congruent (flankers in the same direction as the target), incongruent (flankers in the opposite direction as the target). Participants were instructed to pay attention to the face (or fish) in the middle and press whichever button matched the direction gaze face (or fish). Participants were instructed to maintain fixation on the cross in the center of the screen throughout the task and to respond as quickly and accurately as possible. Each trial began with a fixation period of random variable duration of between 400 and 1600 ms. Subsequently, on some trials a cue was presented for 150 ms. A brief fixation period of 450 ms appeared after the disappearance of the cue, followed by the simultaneous appearance of the target and flanker. This display remained on the screen until a response was detected, to a maximum of 1700 ms. After responding, the participant received auditory and visual feedback from the computer. For correct responses the participant was presented with a recording of "Woohoo!" exclamation. Incorrect responses were followed by a single tone. Measures of the efficiency of the three attentional networks were obtained via simple subtractions of reaction times between conditions. The so-called "conflict effect" is calculated by subtracting the mean reaction times (RTs) of the congruent flanking conditions from the mean RTs of incongruent flanking conditions. 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 separately assess the alerting (improved performance following a double cue) and orienting (an additional benefit when the cue correctly indicates the target location, i.e., a spatial vs. center-cue) attentional functions. The orienting effect is calculated by subtracting the mean RTs of the spatial-cue conditions from the mean RTs of the center-cue conditions. Both center and spatial cues alert the participant to the forthcoming appearance of the target, but only the spatial-cue provides spatial information, which allows participants to orient their attention to the appropriate spatial location. Therefore, the RTs difference between spatial and center cues provides a measure of orienting attention. In the no-cue or double-cue conditions, attention tends to be diffused across the two potential target locations. Neither of these conditions provided spatial information about the target stimulus position, but the double-cue alerts the participant to the imminent appearance of the target. Therefore, the alerting effect is calculated by subtracting the mean RTs of the double-cue conditions from the mean RTs of the no-cue conditions. This represents the benefit of alerting on the speed of the response to the target (Fan et al., 2002; Fan Gu, Guise, Liu, Fossella, & Wang, & Posner, 2009; Martella, Casagrande, & Lupianez, 2011).

[INSERT FIGURE 1 ABOUT HERE]

Experiment Design

The experiment had a three-factor repeated measure design. *Task* had three levels: ANT.Face photographs, ANT.Face drawings, and ANT.Fish. *Flanker* had two levels: congruent and incongruent. *Cue* had four levels: spatial-cue trials (direction of the cue was congruent with target location), center-cue, double-cue trials, no-cue trials.

All data are presented as mean ± SD. For data analysis, only RTs ranging between 200 ms and 1400 ms were used. A *Task* (3) x *Cue* (4) x *Flanker* (2) repeated measures ANOVA was performed on mean corrected RTs. In order to correct for the non-sphericity of the data, the Greenhouse-Geiser correction of the degrees of freedom was employed. To estimate the efficiency of each attentional system, separate one-way ANOVAs considering only the *Task* factor were performed on the following dependent variables: the orienting effect (RTs center-cue – RTs valid-cue); the alerting effect (RTs no-cue – RTs double-cue); and the conflict effect (RTs incongruent trials – RTs congruent trials).

Planned comparisons were used for the analysis of the effects.

Results

Mean response times and standard deviations are shown in Table 1. RTs faster than 200 ms or slower than 1200 ms (0.7% of the trials), as well as incorrect responses (1% of the trials), were excluded from the RTs analysis. The ANOVA showed that all of the main effects were significant: *Task* ($F_{2,38}$ = 11.78; $p<.0001$; partial η^2 = .38; Greenhouse-Geiser correction: Epsilon= 0.76; degrees of freedom: 1.5,28.8; p= .0005); *Flanker* ($F_{1,19}$ = 29.25; $p<.0001$; partial η^2 = .60); and *Cue* ($F_{3,57}$ = 126.40; $p<.0000001$; partial η^2 = .86; Greenhouse-Geiser correction: Epsilon= 0.59; degrees of freedom: 1.8,36.8; p= .0000001). Planned comparisons indicated the RTs were slower for the ANT.Face photographs (523.18 ms) compared to both the ANT.Face drawings (473.71 ms; $F_{1,19}$ = 8.64 $p<.005$) and the ANT.Fish (437.10 ms ;$F_{1,19}$ = 40.92 $p<.0001$). RTs were faster for congruent trials than for incongruent trials (469.46 ms vs. 486.53 ms). RTs were also faster in the spatial-cue condition than in the center-cue condition (444.72 ms vs. 471.16 ms; $F_{1,19} = 66.27$; $p<.0000001$) and slower in the no-cue condition than in the double-cue condition (527.77 ms vs. 468.34 ms; $F_{1,19} = 99.12$; $p<.0000001$). The interaction between *Cue* and *Flanker* condition was significant ($F_{3,57} = 4.86$; $p<.005$; partial $\eta^2 = .20$), suggesting some lack of independence among the networks (Fan et al., 2002; 2009). The *Task* x *Flanker* x *Cue* interaction ($F_{6,114} = 1.92$; $p=.08$; partial $\eta^2 = .09$) was not significant. However, of relevance for the present study, *Task x Flanker* ($F_{2,38} = 9.82$; $p<.0005$; partial $\eta^2 = .34$) and *Task* x *Cue* interaction ($F_{6,114} = 4.32$; $p<.001$; partial $\eta^2 = .18$) were significant.

A set of ANOVAs was conducted to examine the effects of *Task* on each of the network scores. The ANOVA on the Orienting effect ($F_{3,28} = 8.97$; $p<.001$; partial $\eta^2 = .32$) indicated a higher orienting with the ANT.Face photographs (42.95 ms) compared to both ANT.Face drawings (17.17 ms; $F_{1,19} = 22.99$; $p<.0005$) and ANT.Fish (19.22 ms; $F_{1,19} = 8.86$; $p<.01$). Alerting effect ($F_{3,28} = 3.61$; $p<.05$; partial $\eta^2 = .15$) was smaller with the ANT.Face photographs (44.09 ms) compared to both ANT.Face drawings (67.67 ms; $F_{1,19} = 4.87$ $p<.05$) and ANT.Fish (66.52 ms; $F_{1,19} = 7.32$ $p<.05$). Finally, Conflict effect ($F_{3,28} = 9.82$; $p<.0005$; partial $\eta^2 = .34$) was smaller with the ANT.Face photographs (3.94 ms) compared to both ANT.Face drawings (23.45 ms; $F_{1,19} = 12.26$ $p<.005$) and ANT.Fish (23.82 ms; $F_{1,19} = 15.99$ $p<.001$). Orienting, Alerting, and Conflict effects for each task are reported in the figure 2.

(INSERT TABLE 1 AND FIGURE 2 ABOUT HERE)

Discussion

This study examined the effect of social information on alerting, orienting and executive attention. Variants of the ANT with drawing/photograph faces, in which attentional mechanisms are supposed to be modulated by the operation of specialized social processing, were compared to the ANT with fish in which attention is thought to reflect no-social attentional processes. Results showed that photographs of real faces significantly modulated the functioning of the three attentional networks. Only real faces positively affected the efficiency of executive control. Participant demonstrated behavioural evidence of cognitive interference (i.e., slower reaction times to incongruent relative to congruent stimuli) only when fish and drawing faces were used, but not when photographs of faces were used. These results are consistent with those recently reported by Dichter and Belger (2007) who by means of flanker task showed significant interference effect only with arrow stimuli, but not with face photographs. Taken together these findings seem to suggest that people automatically attended to the central real faces, to the exclusion of the flanker faces, and thus receive a relative RTs benefit when are viewing incongruent stimuli. This benefit is not observed in presence of no-social stimuli (such as arrow or fish) and drawing faces.

Consistent with this view, the slowdown of RTs observed between the tasks (face photographs > drawings faces > fish) in the condition without conflict (i.e. on trials with congruent flanker) was instead reduced when participants were viewing incongruent stimuli (see table 1).

From our point of view, this reduction was due to the social significance and attractiveness of real face photograph that induces a greater exploration of it, thus reducing the cognitive interference of distracting stimuli. Supporting the importance of the social significance of real faces in modulating executive control, Dichter and Belger (2007) showed different interference effects between face photographs and arrow stimuli only in typically developed individuals but not in individuals with autism, who are generally referred as impaired in social attention behavior (Dawson, Meltzoff, Osterling, Rinaldi, Brown, 1998; Leekam, Lopez, Moore, 2000; Marotta, Pasini, Ruggiero, Maccari, Rosa, Lupiáñez, Casagrande., 2012; Osterling, Dawson, Munson, 2002; Werner, Dawson, Osterling, Dinno 2000).

Moreover, in the present study participants exhibited greater orienting to face photographs as compared to fish and drawing faces, indicating an orienting bias towards social relevant face information. This is consistent with prior studies indicating a greater ability of faces in attracting and holding attention as compared to other objects (Bindemann et al., 2007; Langton et al., 2008; Ro et al., 2007). Finally, a reduction in alerting scores was unexpectedly found in the ANT.Face photographs relative to both the ANT.Fish and the ANT-Face drawings. From our point of view, this result could be due to the salience and complexity of face photographs, which would make these stimuli more resistant to the manipulation of the visual alerting cue, thus explaining the smaller alerting effect (i.e. faster reaction times to double cue relative to no-cue trials) observed with face photographs as compared to both drawings faces and fish.

Taken together, the results of this study show that real faces significantly modulate the efficiency of the three attention networks and support the status of human faces as a special class of visual stimuli for the human attentional systems.

However, these modulations were only observed when photographs of real faces were used as stimuli, but not when drawing faces were used.

Examining various issues in face perception through schematic faces, many researchers have implied that drawings faces have effects similar to those mediated by real faces. However, evidences from studies directly comparing drawings faces and photorealistic faces have generally yielded mixed results (for a review, see Risko, Laidlaw, Freeth, Foulsham, Kingstone, 2012). For example, while Sagiv and Bentin (2001) have reported important differences in how faces are processed when those faces are schematic versus real images of faces, other studies have found subtle o no differences between drawings and photorealistic faces (e.g. Hietanen & Leppanen, 2003; Sato, Okada, & Toichi, 2007). According to the general framework for cognition referred to as cognitive ethology (Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006; Kingstone Smilek, & Eastwood, 2008; Kingstone, 2009), research approach should begin at the level of the phenomenon of interest (e.g., looking at real faces) and to systematically move toward the more simplified and abstracted level (e.g., looking at schematic faces). As suggested by Kingstone (2009), by beginning at the more simplified level, researcher run the risk of spending a great deal of resources investigating processes that are peculiar to (or products of) that simplified approximation.

For this reason, in the present study we have explicitly compared two types of social stimuli (photographs and drawings faces) differing in their approximation to a real social interaction. Supporting the cognitive ethology framework we showed that only the photographs of real faces were able to significantly modulate the functioning of the three attentional networks.

The Attentional Network Approach

The present research study is the first using the attention network approach to examine the effect of social (i.e. drawing/photograph faces) and no-social (i.e. fish) stimuli on attention. This approach is particularly useful since it allows investigating the effect of face information on attentional processing. Although, flanker and spatial cueing tasks have previously been used to examine face perception and attention, the use of faces within an ANT paradigm provides a theoretical framework functional to better understand the influence of face information on the efficiency of the attentional processes. In fact ANT allows to consider the three attentional networks in one test, permitting to distinguish between overall reaction times performance and the measures of each attentional system, i.e., alerting, orienting and executive control.

In the present study we used three variant of the original version of the ANT originally elaborated by Fan and collaborators in 2002, and still widely used (in his original version) to study attention in adults, children, as well as neuropsychological patients (e.g., Adólfsdóttir, Sørensen, Lundervold, 2008; Booth, Carlson, Tucker, 2007;Westlye, Grydeland, Walhovd, & Fjell 2011; Martella et al., 2011; Orellana, Slachevsky, Peña, 2012; Yin, Zhao, Xu, Evans, Fan, Ge, Tang, Khundrakpam, Wang, & Liu, 2012). However, Callejas, Lupiánez, Funes, & Tudela, (2004; 2005) have developed a modified version of the ANT paradigm, the ANT-I that is remarkable in two important aspects: 1) in this version, orienting is measured using a non-predictive cue, with 50% valid vs. 50% invalid cues. The original version of the ANT includes only 100% valid cues. 2) Alerting is assessed with an auditory alerting cue whereas a visuo-spatial cue is used in the original ANT. In Callejas et al.'s (2004) version, the warning sound stimulus fundamentally differs from the orienting visual stimuli, whereas in the ANT, the alerting and orienting networks are activated by the same four types of visual cues. These differences make the modified Callejas et al. version of ANT more suitable for studying interactions among the attentional networks. Moreover, Ishigami and Klein (2010) have directly compared the two versions of the ANT (ANT vs. ANT-I) and have demonstrated that although the two tests provided robust index of each attention network, overall the reliability of the network scores is greater with the ANT-I than the ANT. Therefore, in a future study it will be interesting to evaluate how face information affect the interaction among all the three attentional systems by means of the ANT-I.

Conclusion

The present experiment is the first to examine the effect of face information on attentional networks. Results indicate that photographs of real faces significantly modulate the functioning of the three attentional networks: photographs of faces positively affected attentional orienting and executive control, whereas reduced the efficiency of alerting network. Performances to the ANT with drawing faces not significantly differed from those to the ANT with fish. These findings underlie the importance of face information for the human attentional systems and suggest the use of real human faces for the study of the human social attention.

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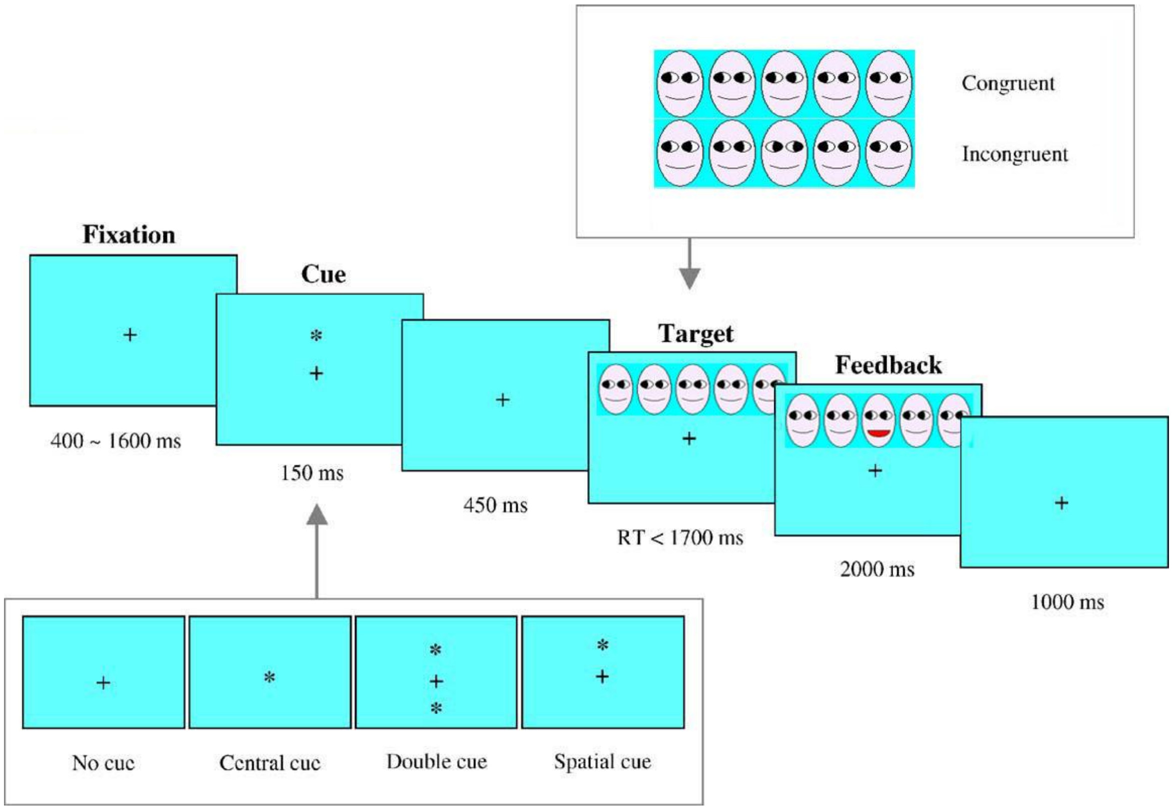
Table

Table 1. Mean (±SD) RT of correct responses for each dependent variable in ANT.Face drawings. ANT.Face photographs, and ANT.Fish.

		ANT.Face drawings		ANT.Face photographs		ANT.Fish	
		Mean	SD	Mean	SD	Mean	SD
Congruent	Spatial	435.83	82.25	475.79	24.61	409.24	65.43
	Center	457.35	90.65	516.88	26.10	417.64	59.55
	Double	446.89	67.89	523.27	29.27	408.70	53.03
	No-Cue	507.85	95.68	568.90	34.17	465.20	60.35
Mean congruent		461.98	84.12	521.21	28.54	425.20	59.59
Incongruent	Spatial	458.00	74.96	479.59	32.63	409.86	58.39
	Center	470.81	84.08	524.39	28.36	439.90	81.91
	Double	469.27	78.86	527.04	30.60	434.87	63.86
	No-Cue	543.66	107.99	569.59	38.99	511.43	
Mean incongruent		485.44	86.47	525.15	32.65	449.02	73.39

Figure

A) ANT.Face drawings



B) ANT.Face photographs

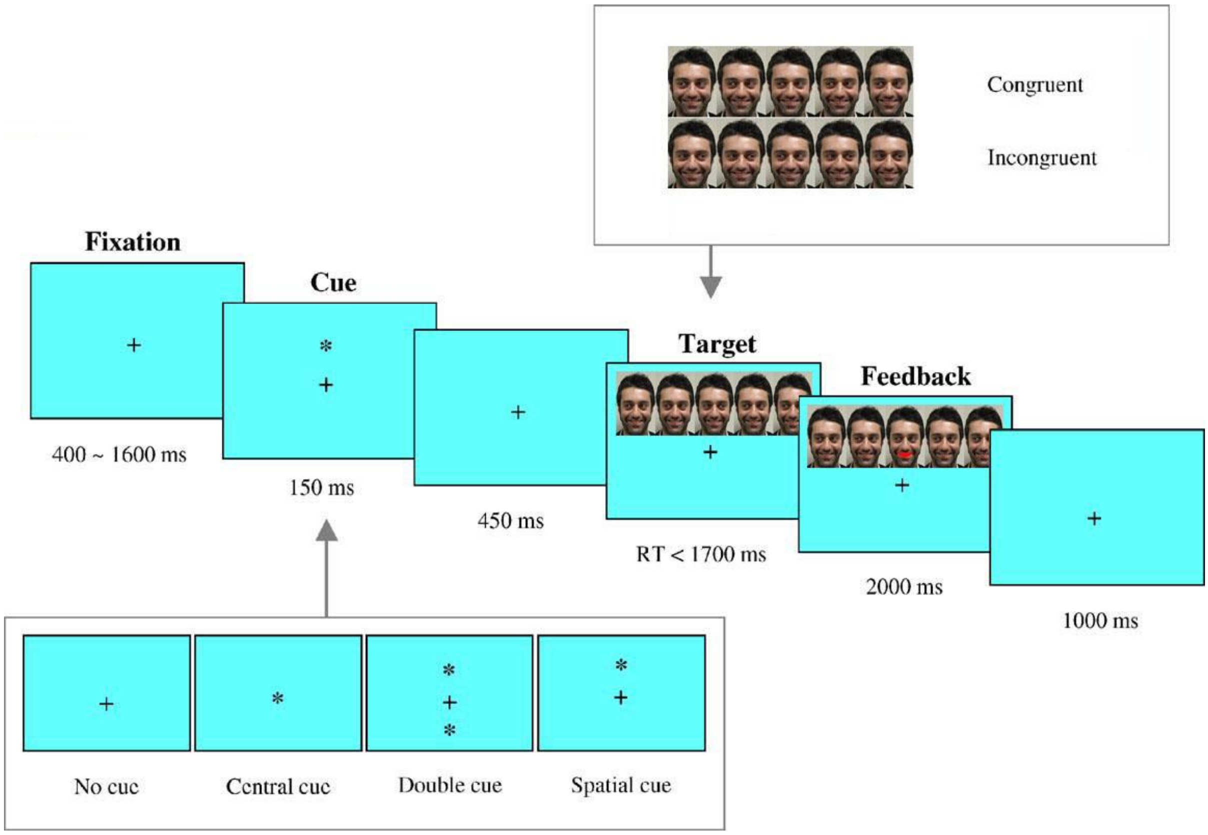


Figure 1. Schematic representation of both flanker and cue conditions. At the top of the figure, stimuli and procedure of ANT.Face drawings are reported. At the bottom of the figure stimuli of ANT.Face photographs are reported. In the ANT.Fish, the same stimuli of Rueda et al. (2004) were used.

Figure

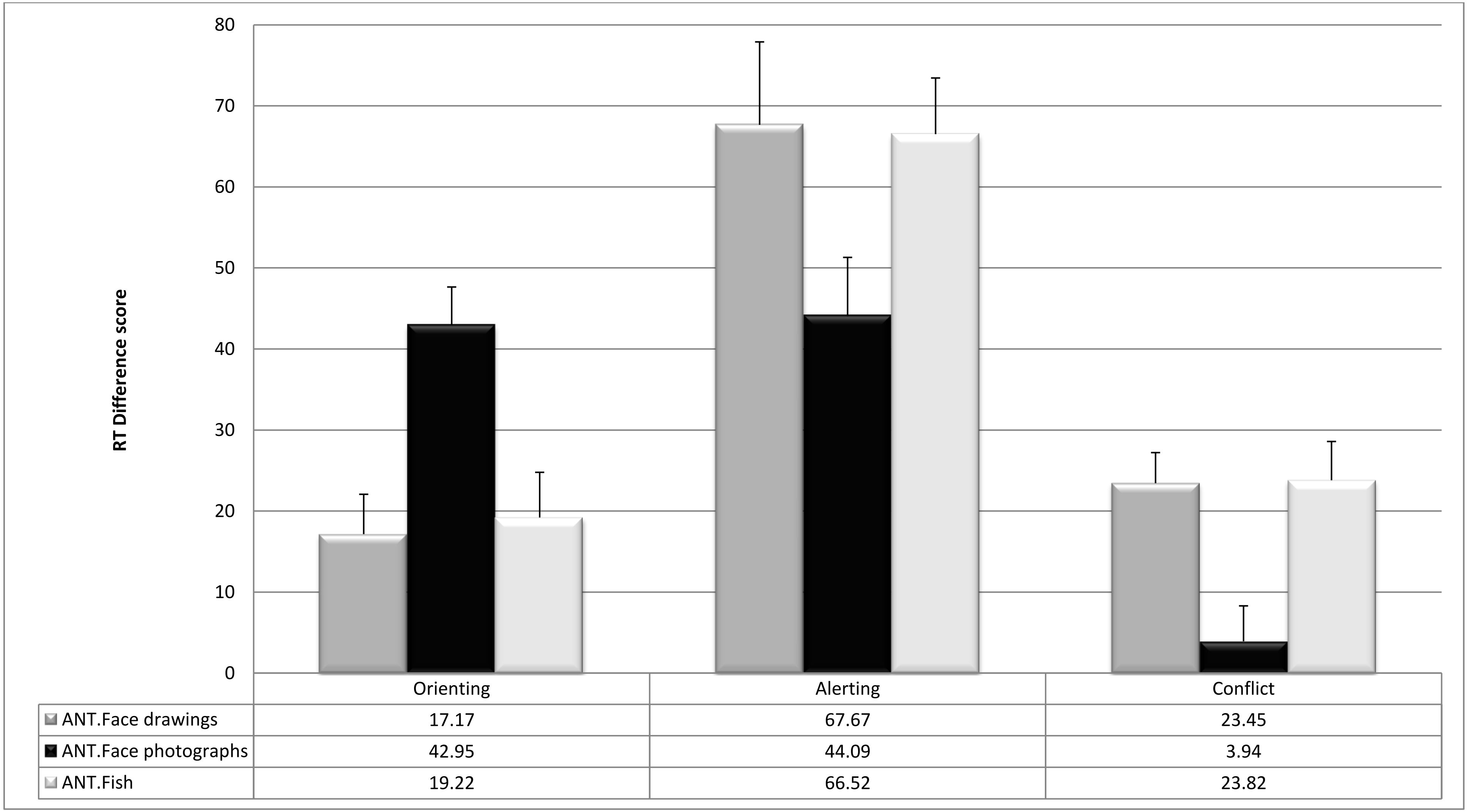


Figure 2. Orienting, alerting and conflict effects in ANT.Face drawing, ANT.Face photograph, and ANT.Fish.

ABSTRACT

According to the attention network approach, attention is best understood in terms of three functionally and neuroanatomically distinct networks - alerting, orienting, and executive attention. An important question is whether social information influences the efficiency of these networks. Using the same structure as the Attentional Network Test (ANT), we developed a variant of this test to examine attentional effects in response to stimuli with and without social-cognitive content. Fish, drawings or photographs of faces looking to the left or right were used as target stimuli. Results collected from twenty university students showed that photographs of faces positively affected attentional orienting, whereas reduced the efficiency of alerting and executive control, as compared to both face drawings and fish. These results support the status of human faces as a special class of visual stimuli for the human attentional systems.