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Development in attention functions and social processing: Evidence from the Attention Network Test

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According to the attention network approach, attention is best understood in terms of three functionally and neuroanatomically distinct networks – alerting, orienting, and executive attention. Recent findings showed that social information influences the efficiency of these networks in adults. Using some social and non-social variants of the Attentional Network Test (ANT), this study was aimed to evaluate the development of the three attention networks in childhood, also assessing the development of the ability to manage social or non-social conflicting information. Sixty-six children (three groups of 6, 8, and 10 years of age) performed three variants of the original ANT, using fish, schematic, or real faces looking to the left or right as target and flanker stimuli. Results showed an improvement from 6 to 8 and 10 years of age in reaction time (RT) and accuracy, together with an improvement of executive control and a decrement in alerting. These developmental changes were not unique to social stimuli, and no differences were observed between social and no-social variants of the ANT. However, independently from the age of the children, a real face positively affected the executive control (as indexed by RTs) as compared to both a schematic face and a fish. Findings of this study suggest that attentional networks are still developing from 6 to 10 years of age and underline the importance of face information in modulating the efficiency of executive control.

Statement of contribution

What is already known?

- Younger children made more errors and slower reaction times (RTs) than older children, in line with the majority of the past selective attention studies.
- Younger children showed both greater conflict and alerting effect than older children. The prediction that younger children would display larger interference effects than older children was supported.

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What does this study add?

- Extending the findings observed in adults and children, independently from their age, demonstrated greater cognitive interference (i.e., slower RTs and higher percentage of errors to incongruent relative to congruent conditions) when fish and schematic faces were presented than when photographs of real faces were used as stimuli.
- Like adults, children have a greater ability in the control of social information as compared to non-social information.
- These results seem to indicate that the ability to handle social conflicts proceeds in parallel with the ability to manage non-social conflicting information.

The ability to control the extent that social information influences cognition is important for adaptive development. Among the social cues, faces represent the most important source of social information and gaze monitoring may have played a crucial role in the evolution of socialization. Gaze direction provides a very strong social cue which may be used by another people to learn information about internal or external states (Emery, 2000; Schultz, 2005).

The exceptionality of faces as a stimulus for the development of human attentional system has been demonstrated in an increasing number of studies using different methods (for a review see: Birmingham & Kingstone, 2009; Frischen, Bayliss, & Tipper, 2007). Merely seeing a face with an averted gaze can elicit a reflexive shift of attention to the gazed-at location and object (e.g., Friesen & Kingstone, 1998; Marotta, Casagrande, & Lupianez, 2013; Marotta, Lupiáñez, & Casagrande, 2012). The newborn preferentially attended the eye region of the face (Farroni *et al.*, 2005; Hainline, 1978; Johnson, Dziurawiec, Ellis, & Morton, 1991; Valenza, Simion, Cassia, & Umiltà, 1996). The direction of another person's gaze can reveal to an infant where she/he is attending and thus indicate sources of potential interest or danger in the environment. Typically, developing infants showed the ability to look in the direction towards which adults turn their heads and eyes, starting from very few month of life (Butterworth & Jarrett, 1991; D'Entremont, Hains, & Muir, 1997; Farroni *et al.*, 2005). In addition, spontaneous gaze-following at 10 months relates to language ability at 18 months (Brooks & Meltzoff, 2005, 2015; Kristen, Sodian, Thoermer, & Perst, 2011) and theory of mind in adulthood (Shepherd, 2010). Some authors proposed that this behaviour depends on the activation of a distinct neural module dedicated to the decoding of social stimuli (Emery, 2000; Johnson, 2005; Kingstone, Friesen, & Gazzaniga, 2000). For example, several studies (Calder *et al.*, 2007; George & Conty, 2008; Puce, Allison, Bentin, Gore, & McCarthy, 1998; Wicker, Michel, Henaff, & Decety, 1998) demonstrated the presence of neurons in the anterior superior temporal sulcus (STS), which are finely tuned for processing eye-gaze direction. Analogously, neurons in STS, specialized in distinguish eye-gaze direction, were also identified in monkeys (Perrett, Hietanen, Oram, Benson, & Rolls, 1992). Thus, preferential sensitivity to eye gaze develops very early and relates to subsequent communicative skills reflecting the operation of a specialized cognitive mechanism (for a review see: Shepherd, 2010).

However, in everyday life, people are often faced with a complex social array containing conflicting gaze information from multiple faces. Consequently, the ability to control the extent that gaze information influences cognition is also crucial for successful decision-making and social interactions.

Executive control of social information

Looking at faces is important to learn an array of social signals and visual communication cues, but looking away from faces at key points of an interaction is also critical. In certain circumstances, we need to reduce the cognitive load required by a mutual gaze interaction in order to complete other tasks (e.g., Doherty-Sneddon, Bruce, Bonner, Longbotham, & Doyle, 2002). A key question is how people control the processing of contrasting social relevant information, such as gaze direction from multiple faces, and how this ability develops during childhood. Processing of perceptual and social information related to face develops and improves during childhood (Bhatt, Bertin, Hayden, & Reed, 2005; Carver *et al.*, 2003) and may not reach adult-like levels until adolescence (Carey, Diamond, & Woods, 1980; Ellis, Shepherd, & Bruce, 1973). The goal of this study was to examine the development in the ability to exert cognitive control on the processing of contrasting social relevant information, such as eye-gaze direction from multiple faces.

Cognitive control and the Attention Network Test

Cognitive control is mediated by suppressing interference from competing responses yielding slower responses and/or lower accuracy on selective attention tasks, such as the flanker task (Eriksen & Eriksen, 1974). To examine the executive control of social information, such as eye-gaze direction, in this study, we used some variants (Federico, Marotta, Adriani, Maccari, & Casagrande, 2013) 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 (Petersen & Posner, 2012; 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. Alerting is assessed by comparing reaction times (RTs) to targets preceded by alerting cues informing on the temporal onset of the target with those not preceded by any cue (i.e., warning effect). The orienting is assessed by comparing RTs for spatially cued targets with RTs for spatially uncued targets (i.e., visual cueing effect). Of particular relevance to this 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, or conflict effect). Different types of stimuli have been used in different versions of ANT paradigm, such as fish (Rueda, Fan, *et al.*, 2004), cars (Marotta *et al.*, 2015; Roca *et al.*, 2012), fruits (Spagna *et al.*, 2014) and faces (Federico *et al.*, 2013). Adopting a child version of the Attention Network Test (Child ANT with fish stimuli), Rueda and colleagues found a substantial development of executive attention between 4 and 6 years of age (Rueda, Posner, & Rothbart, 2005; Rueda, Posner, Rothbart, & Davis-Stober, 2004; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005); as well as clear significant improvements in executive attention from 6 years of age to adulthood (Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004). Whether these developmental differences affect the ability to exert cognitive control in the context of social processing is not known. In a recent study (Federico *et al.*, 2013), we compared social variants of the ANT with schematic or real faces, to the ANT with fish stimuli in a sample of healthy adults, and results showed that photographs of faces positively affected executive control, as compared to both schematic face and fish. Of interest for this study, these findings showed behavioural evidence of cognitive interference (i.e., slower RTs to incongruent relative to congruent stimuli) only when fish and schematic faces were used, but not when photographs of real faces were used. 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, suggesting that people automatically attended to the central real faces, excluding the flanker faces, and thus receive a relative RTs benefit when are viewing incongruent stimuli. This benefit is not observed in the presence of non-social stimuli (such as fish) and schematic faces. These results were observed in adults, but it is unclear when the ability to control social information appears and how it develops during childhood.

The present research

In this study, we examined the development in the cognitive control of social information. Three age groups of children aged 6, 8, and 10 years performed two social variants of the ANT[1] (in which schematic or real faces looking to the left or right were used as target and flanker stimuli; Federico *et al.*, 2013) and the Child ANT with fishes as stimuli (Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004). The choice of these age groups was justified by recent studies showing that although some aspects of attention are relatively well developed at the time children reach the age of schooling, other components of attention continue to develop during middle (i.e., 6–9 years of age) and late (i.e., 10–12 years of age) childhood (e.g., Casey, Durston, & Fossella, 2001; Mullane, Lawrence, Corkum, Klein, & McLaughlin, 2014; Posner & Rothbart, 2007; Ridderinkhof, van der Molen, Band, & Bashore, 1997; Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004; van der Molen, 2000). We tested the following hypotheses: first, consistent with past ANT studies, younger children will be less accurate and slower than older children (e.g., Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004). Second, in line with previous studies (Mullane *et al.*, 2014; Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004), we hypothesized that younger children would display significantly weaker alerting and less efficient executive attention than older children. Orienting attention would, however, remain stable across ages. Third, given that developmental studies have not previously evaluated interference effects due to social and non-social variants of the ANT, we propose to evaluate performance in executive control of social stimuli. Because social cognitive functions related to face processing are critically developed at 6–10 years of age (Carey *et al.*, 1980; Jingling, Lin, Tsai, & Lin, 2015; Mondloch, Geldart, Maurer, & Grand, 2003), and the brain areas involved in gaze processing (e.g., the frontal lobe and STS; Frischen *et al.*, 2007) also reach a peak in 5- to 11-year-old children (Sowell *et al.*, 2004), we infer that the executive control of social stimuli should also develop during childhood. Whether the interference from social stimuli would be more or less than that from non-social stimuli is ambiguous because no past developmental study has compared interference effects from social and no-social stimuli in a context of the ANT task.

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[1] *Consistent with the general framework of the cognitive ethology (Kingstone, 2009; Kingstone, Smilek, & Eastwood, 2008; Smilek, Eastwood, Reynolds, & Kingstone, 2008), in this study, we have explicitly compared two types of social stimuli (schematic and real faces) differing in their approximation to a real social interaction. Indeed, as suggested by 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).*

Method

Participants

Sixty-six children participated in the study (27 males, $M = 8.15$, $SD = 1.63$). Twenty-two were 6 years, 22 were 8 years, and 22 were 10 years of age. Children were recruited from one public school in Rome, where the children executed the experiments. The study was approved by the local ethical committee, and a written informed consent was given by parents or legal guardians of the children included in the study, prior to the testing.

Apparatus

Stimuli were presented on a 12-inch colour monitor. A PC running E-Prime software (Psychology Software Tools, Inc. PST, Sharpsburg, PA, USA) 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 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 coloured fish as target and flanker stimuli, just as described in Rueda, Fan, *et al.* (2004). All participants also completed two new versions of the ANT that presented schematic or photographs of real faces instead of fishes. Stimuli and procedure were the same as described in Federico *et al.* (2013). 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 centre 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, which were different only in the type of stimuli used as target and flankers: the fish version (ANT.Fish), the schematic face version (ANT.Schematic Face), and the real face version (ANT.Real Face). Each of the tasks consisted of a practice block with 24 trials and two experimental blocks of 48 trials each. The practice block took approximately 3 min, and each test block took approximately 5 min. Each task usually lasted approximately 20 min. Participants could take breaks at the end of the practice block and between tasks. The entire session lasted no more than 45 min in total. The instructions were the same for all the versions of the task. Participants were told that a schematic or real 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 of the upcoming target. There were four cue types: no cue (neither alerting nor orienting cue was

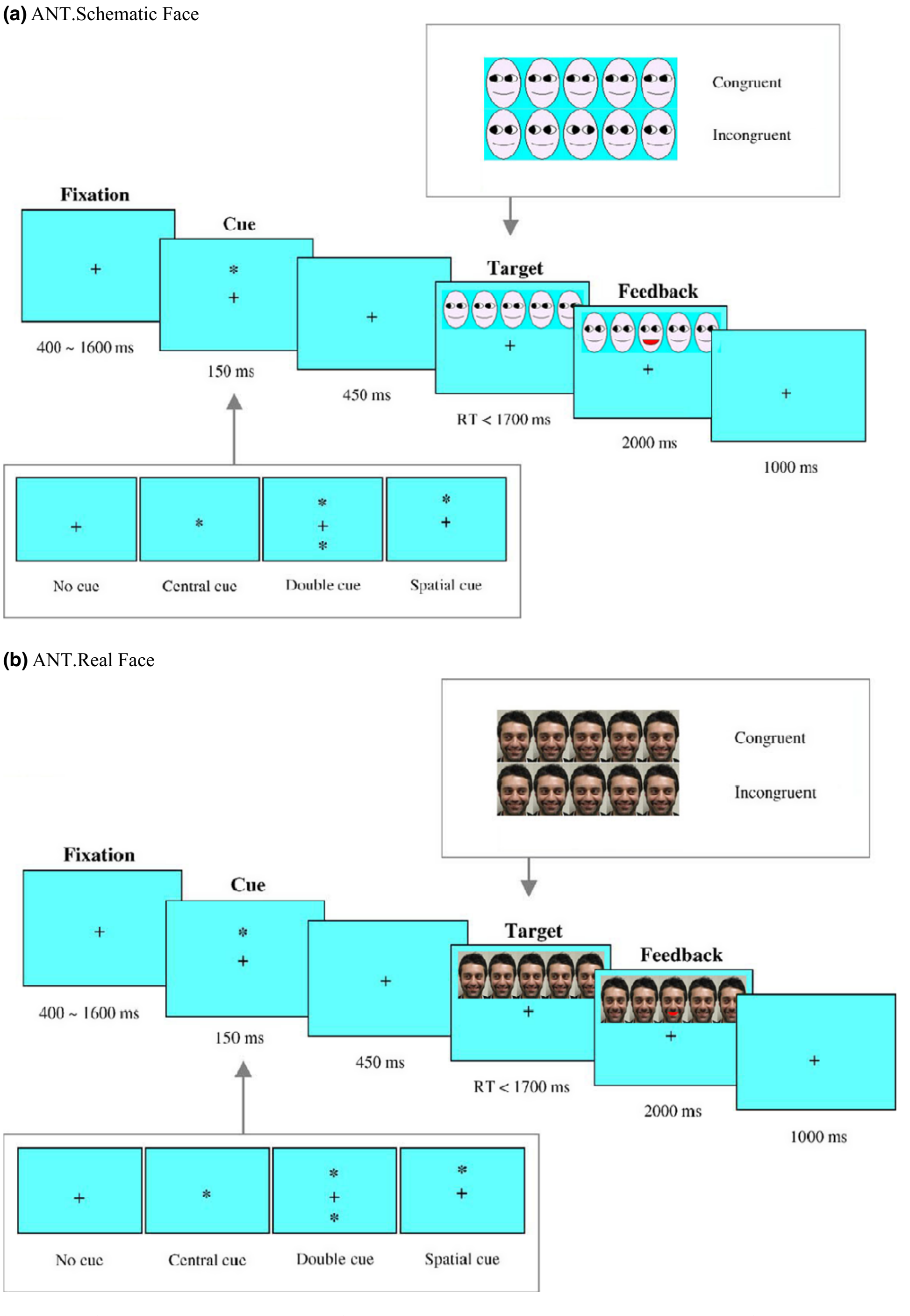


Figure 1. Schematic representation of both flanker and cue conditions. At the top of the figure, stimuli and procedure of ANT.Schematic Face are reported (a). At the bottom of the figure, stimuli of ANT.Real Face are reported (b). In the ANT.Fish, the same stimuli of Rueda, Fan, *et al.* (2004) and Rueda, Posner, *et al.* (2004) were used. ANT = Attentional Network Test. [Colour figure can be viewed at wileyonlinelibrary.com]

presented), double cue (a double-asterisk 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) and 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 of the gaze (or fish). Participants were instructed to maintain fixation on the cross in the centre 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 between 400 and 1,600 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 1,700 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 are obtained via simple subtractions of RTs (or percentage of errors) between conditions. The so-called conflict effect is calculated by subtracting the mean 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 cue vs. centre cue) attentional functions. The orienting effect is calculated by subtracting the mean RTs of the spatial-cue conditions from the mean RTs of the centre-cue conditions. Both centre 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. 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, 2009; Federico *et al.*, 2013; Martella, Casagrande, & Lupianez, 2011).

Experiment design

The experiment included one between-subjects factor (*ages*: *6*, *8*, and *10*) and three within-subjects factors. *Stimuli* had three levels: ANT.Real Face, ANT.Schematic Face, and ANT.Fish. *Flanker* had two levels: congruent and incongruent. *Cue* had four levels: spatial-cue, centre-cue, double-cue, and no-cue trials.

According to a consolidated ANT analysis, only the RTs of correct responses ranging between 200 and 1,400 ms were considered (Casagrande *et al.*, 2012; Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004). Two univariate analyses of variance (ANOVA)

Table 1. Means and standard errors of RTs and percentage of errors in the three versions of the ANT for each group of children

			6 years				8 years				10 years			
			RTs		%Errors		RTs		%Errors		RTs		%Errors	
Task	Flanker	Cue	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
ANT.Real Face	Cong	Spatial	1068.5	33.91	19.36	3.53	1015.54	30.13	8.70	2.57	1015.54	24.25	6.91	2.26
		Center	1101.78	37.08	24.27	4.58	1034.43	27.79	8.27	3.09	1034.43	23.25	6.41	2.89
		Double	1084.95	31.39	18.73	3.95	1005.79	29.89	10.64	2.52	1005.79	25.38	9.45	2.88
		No-cue	1117.79	28.94	29.18	4.98	1109.32	21.25	11.05	3.86	1109.32	29.31	6.41	1.65
	Incon	Spatial	1097.19	34.07	23.50	5.08	1017.76	28.38	9.80	3.29	1017.76	25.60	5.55	1.98
		Center	1078.33	37.07	24.95	4.85	1050.03	26.11	9.83	2.37	1050.03	24.74	7.55	2.27
		Double	1071.37	33.60	22.14	3.90	1006.52	24.37	12.27	3.40	1006.52	25.54	5.59	2.07
		No-cue	1162.31	30.28	29.32	4.87	1097.43	24.19	14.41	3.46	1097.43	25.06	9.45	2.98
ANT.Schematic Face	Cong	Spatial	1016.88	33.16	13.73	4.04	907.40	24.99	6.43	1.96	828.45	29.77	5.36	2.29
		Center	1031.32	27.87	14.05	3.99	956.56	29.77	6.18	2.23	838.12	31.97	6.05	2.59
		Double	1076.71	36.96	11.73	3.42	904.71	29.69	8.32	2.87	834.97	31.05	4.90	2.25
		No-cue	1108.29	37.29	19.91	4.81	981.07	23.63	6.59	2.28	893.59	26.64	6.09	3.18
	Incon	Spatial	1046.34	35.09	18.77	4.69	969.02	18.37	11.20	3.16	910.62	33.37	6.55	2.51
		Center	1079.73	33.08	18.91	4.14	979.78	33.18	5.95	1.63	903.36	31.85	4.50	1.96
		Double	1090.07	25.98	16.14	3.90	968.12	31.88	9.41	2.06	867.36	28.40	5.95	2.13
		No-cue	1143.89	30.25	24.50	4.60	992.18	26.79	10.64	3.63	942.43	24.02	6.59	2.20
ANT.Fish	Cong	Spatial	963.63	32.80	6.64	2.41	804.55	37.55	5.52	2.57	739.97	31.90	03.02	1.40
		Center	977.18	39.78	7.77	2.60	828.77	29.83	7.14	2.35	777.60	32.80	4.50	2.09
		Double	987.47	35.19	8.00	2.47	796.03	35.90	3.00	1.60	781.20	30.97	3.73	1.42
		No-cue	1036.46	30.55	8.82	2.68	893.38	31.82	8.82	2.43	860.36	32.21	4.86	2.09
	Incon	Spatial	1013.31	40.65	11.50	2.84	866.36	29.01	8.00	2.66	808.92	32.50	8.41	2.40
		Center	1081.20	34.93	8.09	2.17	885.72	36.13	5.00	2.44	841.09	33.04	2.64	1.39
		Double	1037.54	39.38	10.68	2.30	894.80	36.35	4.91	2.71	815.07	35.29	3.78	1.53
		No-cue	1075.81	32.59	17.50	4.75	951.69	37.21	8.32	2.20	889.07	31.58	10.32	2.68

ANT = Attentional Network Test; RT = reaction time; *SE* = standard error; Cong = Congruent; Incon = Incongruent.

Age × *Stimuli* × *Cue* × *Flanker* separately considered mean corrected RTs and percentage of errors as dependent variables.

Post-hoc comparisons were conducted using either the Tukey's HSD test (repeated measures) or the Duncan test (mixed measures). An α value of .05 was used to establish statistical significance for all analyses.

Results

Means and standard errors of both RT and percentage of errors are shown in Table 1.

Reaction times

The ANOVA has shown that all the main effects were significant: age, $F(2, 63) = 15.80$; $p < .00001$; partial $\eta^2 = .33$ (Figure 2); stimuli, $F(2, 126) = 42.32$; $p < .0000001$; partial $\eta^2 = .40$; flanker, $F(1, 63) = 89.32$; $p < .0000001$; partial $\eta^2 = .59$; cue, $F(3, 189) = 55.25$; $p < .0000001$; partial $\eta^2 = .47$. RTs were slower in children aged 6 years compared to both children aged 8 ($p < .003$) and 10 years ($p < .0003$), while RTs in children aged 8 and 10 years were only marginally different ($p = .09$) (children aged 6: 1064.50 ms, children aged 8: 954.87 ms, children aged 10: 887.26 ms; see Figure 2).

Reaction times were faster when children performed ANT.Fish compared to both ANT.Schematic Face ($p < .0001$) and ANT.Real Face ($p < .0001$); additionally, children were faster when performed ANT.Schematic Face compared to ANT.Real Face ($p < .0001$) (ANT.Fish: 900.30 ms, ANT.Schematic Face: 969.62 ms, ANT.Real Face: 1036.71 ms). RTs were faster when the flankers were congruent than when they were incongruent (949.83 vs. 987.92 ms). RTs were also faster in spatial-cue than in centre-cue trials ($p < .002$; 943.91 vs. 966.30 ms), RTs were faster in double-cue than in no-cue trials ($p < .00001$; 950.09 vs. 1015.20 ms), and further RTs in no-cue trials were slower compared RTs in all the other cue trials ($p < .00001$). The Age × Stimuli interaction was only marginally significant, $F(4, 126) = 2.37$; $p = .056$; partial $\eta^2 = .07$, while the Stimuli × Flanker interaction was significant, $F(2, 126) = 16.96$; $p < .00001$; partial $\eta^2 = .21$ (Figure 3) and mean comparisons revealed that the

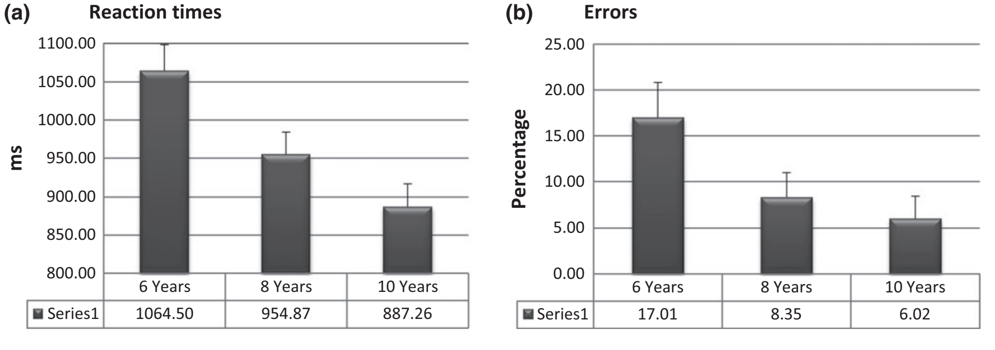


Figure 2. Means and standard errors of reaction times (RTs) (a) and percentage of errors (b) in children aged 6, 8, and 10 years. Children aged 6 years had a significantly worst performance (slower RTs and higher percentage of errors) compared to both children ages 8 and 10 years.

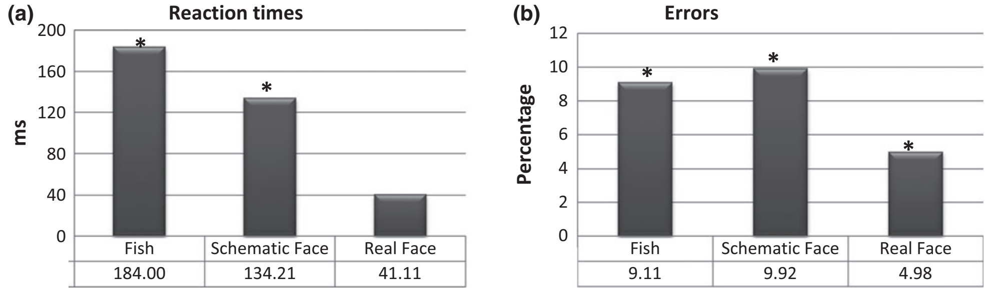


Figure 3. Mean conflict effect (incongruent–congruent trials) as indexed by reaction times (a) and percentage of errors (b) in Attentional Network Test (ANT) as a function of the kind of stimuli: fishes, schematic faces, and real faces. *$p < .0001$.

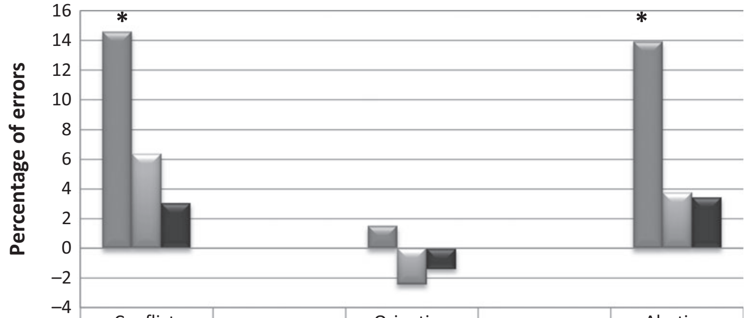
conflict effect was significant in ANT.Fish (mean conflict effect: 59.50; $p < .0001$) and ANT.Schematic Face (mean conflict effect: 42.90; $p < .0001$), but not in ANT.Real Face (mean conflict effect: 11.37; $p = .33$). None of the other interactions were significant ($p > .17$).

Percentage of errors

The ANOVA has shown that all the main effects were significant: age, $F(2, 63) = 6.89$ $p < .002$; partial $\eta^2 = .18$ (Figure 2); stimuli, $F(2, 126) = 14.21$; $p < .00001$; partial $\eta^2 = .18$; flanker, $F(1, 63) = 24.15$; $p < .00001$; partial $\eta^2 = .28$; cue, $F(3, 189) = 12.68$; $p < .0000001$; partial $\eta^2 = .17$. Percentage of errors was higher in children aged 6 years compared to both children aged 8 ($p < .02$) and 10 years ($p < .002$) (children aged 6: 17.01% vs. children aged 6: 8.35% vs. children aged 6: 6.02%; see Figure 2).

The children made fewer errors when performing ANT.Fish than both ANT.Schematic Face ($p < .03$) and ANT.Real Face ($p < .0001$), also children made fewer errors when performed ANT.Schematic Face than ANT.Real Face ($p < .02$) (ANT.Fish: 7.12% vs. ANT.Schematic Face: 10.35 vs. ANT.Real Face: 13.91). Percentage of errors was higher when the flankers were incongruent than when they were congruent (11.46 vs. 9.46). Percentage of errors was higher in no-cue trials ($p < .002$) compared all the other cue trials ($p < .0001$; spatial-cue = 9.94 vs. centre-cue = 9.55 vs. double-cue = 9.41 vs. no-cue = 12.93). The Age × Stimuli interaction was significant, $F(4, 126) = 4.24$; $p < .003$; partial $\eta^2 = .12$, and *post-hoc* comparisons revealed that children aged 6 years had a worst performance than children aged 8 and 10 years after completing both the ANT.Schematic Face and the ANT.Real Face ($p < .001$), while the three groups of children revealed a similar accuracy when performing the ANT.Fish.

The Age × Flanker interaction, $F(2, 63) = 4.45$; $p < .02$; partial $\eta^2 = .12$ (Figure 4) revealed a higher conflict effect (mean conflict effect: incongruent–congruent trials) in children aged 6 compared to children aged 10 years ($p < .001$). The Age × Cue interaction, $F(6, 189) = 2.75$; $p < .02$; partial $\eta^2 = .08$ (Figure 4) showed that the alerting effect (no-cue–double-cue trials) was higher in children aged 6 years compared to both children aged 8 ($p < .02$) and 10 years ($p < .01$); no age differences were observed for the orienting effect (centre-cue–spatial-cue trials). The Flanker × Cue interaction was significant, $F(3, 189) = 2.83$; $p < .05$; partial $\eta^2 = .04$, and post-hoc comparisons showed that the conflict effect was significant only in spatial-cue (mean conflict effect: 3.07; $p < .01$) and no-cue trials (mean conflict effect: 3.26; $p < .003$), but it was not



	Conflict		Orienting		Alerting
6 years	14.61		1.52		13.94
8 years	6.36		−2.43		3.76
10 years	3.05		−1.39		3.44

Figure 4. Mean attentional effects: *conflict effect* (incongruent–congruent trials), *orienting effect* (centre-cue–spatial-cue trials), and *alerting effect* (no-cue–double-cue trials) as indexed by percentage of errors in children aged 6, 8, and 10 years. *$p < .01$.

significant in the centre-cue (mean conflict effect: 0.31) and double-cue (mean conflict effect: 1.37) trials. None of the other interactions were significant ($p > .21$).

Discussion

The two main goals of the present study were (1) to further understand the development of attention networks throughout childhood and (2) based on the effect of face information in modulating the efficiency of executive control that has been documented in adults (Federico *et al.*, 2013), to investigate whether this effect was present or modulated by age during childhood. To this aim, two variants of the ANT with schematic or real faces as stimuli, in which attentional mechanisms are supposed to be modulated by the operation of specialized social processing, were compared to the ANT with fishes as stimuli in which attention is thought to reflect non-social attentional processes.

Development of the attention networks

The results showed that younger children made more errors and slower RTs than older children, in line with the majority of the past selective attention studies (e.g., Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004). Moreover, younger children showed both greater conflict and alerting effect than older children (e.g., Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004). In particular, the prediction that younger children would display larger interference effects than older children was supported. Our results replicate previous studies (Pozuelos, Paz-Alonso, Castillo, Fuentes, & Rueda, 2014; Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004) and extend the literature to the social variants of the ANT showing that interference control abilities in younger children were weaker than in older children. Moreover, regarding alerting, our results replicate those of Mullane *et al.* (2014) by showing that older children displayed smaller alerting effects than younger children. As speculated by Rueda, Fan, *et al.* (2004) and Rueda, Posner, *et al.* (2004), a large alerting score observed in younger children is probably due to the fact that they do poorly when there is no-cue, as a consequence of a difficulty in sustaining their alert state in the absence of an alerting cue. Consistent with this view, Casagrande *et al.* (2012) showed that children with attention-deficit/hyperactivity disorder, who are generally referred as impaired in sustained attention, presented larger alerting effect than typically developed children. Finally, we did not find differences among the three groups of children on the orienting scores. This result could be possibly explained by the fact that the time to disengage from a cued location is reduced with age, while the movement of attention towards a peripheral cue shows no change between children from 6 year olds and adults (as suggested by Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004). This view seems to predict no developmental change in a task (like that ANT we used) in which only the movement towards a peripheral cued location is evaluated, according with our results. Overall, the results show an improvement of attentional performance (faster RTs and greater accuracy) through the three considered ages, from 6 to 8 and 10 years of age, confirming well-known results (e.g., Rueda, Fan, *et al.*, 2004; Rueda, Posner, *et al.*, 2004). Moreover, developmental changes to alerting and executive control but stable orienting were observed. These latter results were only observed when percentage of errors was used as dependent variable, but not when RTs were considered. However, it is important to note that as the percentage of errors differed between incongruent and congruent trials, fewer correct trials contributed to the mean of RTs, increasing intra-individual variation, and making estimates of central tendency less reliable on conditions with more error. Moreover, several studies have showed that responses are slower in children following error trials (e.g., Swick & Turken, 2002), so reflecting not only processing speed of the type of trial, but also post-error slowing and contributing unequally to average latencies for conditions with different error rates. According to these reasons, it is likely that the percentage of errors and not the RTs was able to highlight the differences in the development of attentional performance in the present study.

The effect of face information on cognitive control

Extending the findings observed in adults (Federico *et al.*, 2013) and children, independently from their age, demonstrated greater cognitive interference (i.e., slower RTs and higher percentage of errors to incongruent relative to congruent conditions) when fish and schematic faces were presented, than when photographs of real faces were used as stimuli. These results suggest that, like adults, children have a greater ability in the control of social information as compared to non-social information and are consistent with several recent studies reporting greater interference effects from non-social than from eye-gaze stimuli by means of different methods (Barnes, Kaplan, & Vaidya, 2007; Dichter & Belger, 2007; Kuhn *et al.*, 2011). It should be noted that face photographs differ considerably from schematic faces and fish stimuli not only in terms of social significance, but also in their complexity. For instance, images of both schematic faces and fish are less complex and thus likely to be quicker and easier to process than photographs of faces. Therefore, it could be argued that another possible explanation for reduction of congruency effect with real faces is that it reflects a visual crowding effect (Whitney & Levi, 2011). However, from our point of view, the congruency reduction observed with real face stimuli was due to their social significance and attractiveness that induced a greater exploration of it, thus reducing the cognitive interference of distracting stimuli. Supporting this view, Dichter and Belger (2007) have reported greater interference effects from arrow stimuli than from face photographs only in typically developed individuals but not in individuals with autism, who are generally referred as impaired in social attention behaviour (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Leekam, Lopez, & Moore, 2000; Marotta, Pasini, *et al.*, 2013; Osterling, Dawson, & Munson, 2002). These results strongly suggest that the reason for the reduced congruency with face photographs in typically developed children is due to their social significance rather than their complexity. Moreover, the present study provides first evidence of a development improvement in the executive attention with eye-gaze stimuli during childhood in a context of the ANT task. However, this improvement was not unique to social stimuli and a better executive control performance across the ages was observed with both social and no-social variants of the ANT. Therefore, these results seem to indicate that the ability to handle social conflicts proceeds in parallel with the ability to manage non-social conflicting information. In particular, one may suggest that during the childhood the acquisition of the various attentional competencies (solving a conflict, effectively orienting attention, adequately increase alerting) is likely too important to provide different development lines according to the type of the stimuli surrounding the child's environment.

The lack of developmental differences between social and non-social stimuli could alternatively be explained assuming that the ability to manage social information is fully matured at the age of 6, while what is still being developed is the executive control in general. While further research is necessary to shed light upon this issue, the latter explanation seems unlikely. Indeed, there is evidence suggesting that the brain areas and the processing of perceptual and social information related to face develops and improves during childhood (Bhatt *et al.*, 2005; Carver *et al.*, 2003; Sowell *et al.*, 2004).

Limitations

Future studies will benefit from addressing some limitations of the present study. First, a longitudinal design in which one group of children completes the different versions of the ANT at several time points is required. Indeed, the present study was cross-sectional and therefore does not control for intra-individual differences across time. Second, we did not include adolescents and adults. This has to be kept in mind because our results cannot give information about any additional improvements in the three attentional networks which occur beyond 10 years of age. Third, in the present study, we used three variants of the original version of the ANT, originally elaborated by Fan *et al.* (2002). However, Callejas, Lupianez, and Tudela (2004), Callejas, Lupianez, Funes, and Tudela (2005) have developed a modified version of the ANT paradigm, the ANT-I that is more suitable for studying interactions among the attentional networks. Therefore, in a future study, it will be interesting to evaluate how the development of 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 in children. The results confirm the hypothesis of separate attentional networks (i.e., Posner, Rothbart, Sheese & Voelker, 2014); in fact, consistent with previous studies (Mullane *et al.*, 2014; Rueda, Checa & Combita, 2012), age differences were observed for alerting and executive control only, but not for the orienting network. These developmental changes were not unique to social stimuli, and no differences were observed between social and non-social variants of the ANT.

Moreover, independently from the age of the children, photographs of real faces significantly modulated the functioning of the executive systems. These findings suggest that attentional networks are still developing from 6 to 10 years of age and underline the importance of face information in modulating the efficiency of executive control.

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