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The cost of being watched:

Stroop interference increases under concomitant eye contact

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Abstract

Current models in social neuroscience advance that eye contact may automatically recruit cognitive resources. Here, we directly tested this hypothesis by evaluating the distracting strength of eye contact on concurrent visual processing in the well-known Stroop's paradigm. As expected, participants showed stronger Stroop interference under concomitant eye contact as compared to closed eyes. Two control experiments allowed ruling out low-level account of this effect as well as non-specific effect of the presence of open eyes. This suggests that refraining from processing eye contact is actually as difficult as refraining from word reading in the Stroop task. Crucially, the eye contact effect was obtained while gaze was not under the direct focus of attention and the participants were faced with another powerful distracter (the incongruent word) in the task at hand. Thus, there is a cost of being watched even in circumstances where the processing of direct gaze is strongly disfavored. The present results emphasize the crucial status of eye contact in human cognition.

Keywords: Eye contact effect; Stroop interference; Social perception; Visual cognition

The cost of being watched:

Stroop interference increases under concomitant eye contact

Eye contact is one of the first and most important visual cues processed by human infants with normal development (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Csibra, Simion, & Johnson, 2002). Its processing appears currently fundamental for building critical inferences about another's level of interest and state of mind (Baron-Cohen, 1995; Kleinke, 1986; Patterson, 1983), but also for acquiring self-other consciousness (Vasudevi, 2003). For these reasons, eye contact perception is considered as one of the basic building blocks for the development of the so-called “social brain” (Adolphs, 2009), a network of structures involved in human inter-individual interaction. In line with this view, several authors proposed that eye contact may be processed by a specialized brain module (Batki et al., 2000; Perrett & Emery, 1994; Senju & Johnson, 2009). Furthermore, according to the ‘fast-track modulator’ model (Senju & Johnson, 2009), a brain network involved in eye contact processing i) allows detecting direct gaze automatically in the visual environment, and ii) subsequently induces modulation of concurrent cognitive processing and behavioral response (hereafter referred to as the “eye contact effect” or ECE).

Consistent with Senju and Johnson’s view of the ECE, human observers are faster at detecting a face or eyes with direct gaze than at detecting averted gaze in visual search tasks (Conty, Tijus, Hugueville, Coelho, & George, 2006; Senju, Hasegawa, & Tojo, 2005; Von Grönau & Anston, 1995). Direct gaze also facilitates other face-related tasks such as gender discrimination (Macrae, Hood, Milne, Rowe, & Mason, 2002) as well as the encoding of individual faces and recognition of face identity (George, Driver, & Dolan, 2001; Mason, Hood, & Macrae, 2004). However, most empirical support for the ECE comes from experiments with

tasks focused on face perception and/or recognition. This may have encouraged gaze processing, as the eyes are a key facial feature (Yarbus, 1967).

The idea of a brain module involved in eye contact processing should imply more largely that the mere presence of direct gaze automatically calls for processing resources (Fodor, 1983), at the expense of any concurrent visual processing outside the facial area. In line with this argument, Senju and Hasegawa (2005) found evidence that peripheral target detection was delayed when the target was preceded by a centrally fixated face gazing directly at the subject, as compared with a face gazing downward or with closed eyes (the detection of a peripheral target asterisk was slowed down at least when the presence of direct gaze overlapped in time with the target). This finding suggests how difficult the attentional disengagement from eye contact may be, with sometimes negative effects on concurrent cognitive processing outside the facial area. However, in Senju and Hasegawa's experiment, the face was the central stimulus on which the participants had to focus before performing the peripheral-target detection task. Again, this may have favored the observation of an ECE. Here, we make a step further by showing that eye contact is a so powerful distracter that it can burden processing resources even when gaze stimulus is not initially presented under the direct focus of attention and when participants are faced with another powerful distracter on the task at hand: the incongruent word in Stroop's Paradigm.

The Stroop task requires individuals to identify the color of the ink in which a letter string is printed. Typically, the time needed to respond is greater when the string represents a word incongruent with the ink color (e.g., the word RED printed in green), as compared to neutral signs (e.g., XXX printed in green), a robust finding called Stroop interference (Stroop, 1935). A core assumption of virtually every theoretical account of this interference is that skilled readers

process automatically the incongruent word (MacLeod, 1991), which is therefore conceived as a powerful distracter. If eye contact is itself a powerful distracter, one may expect that the mere presence of concomitant on-screen direct gaze during the Stroop task enhances processing during word reading and/or imposes further delay to the inhibition of the predominant colour word response. This should result in higher Stroop interference under concomitant direct gaze, as compared for example to closed eyes. Such finding would constitute the first direct behavioral evidence for the distracting strength of eye contact.

Experiment 1

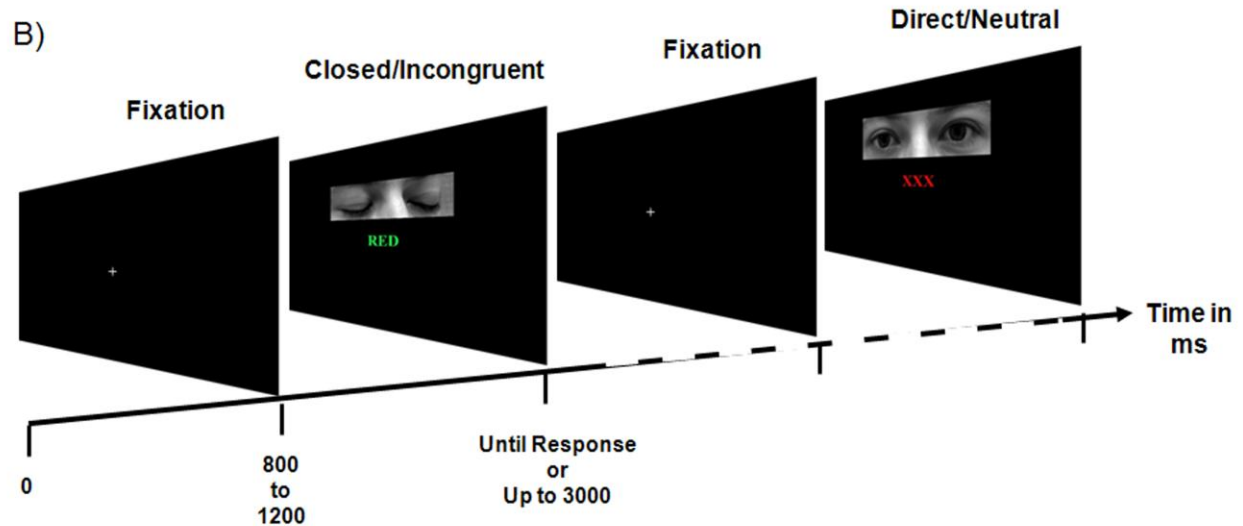
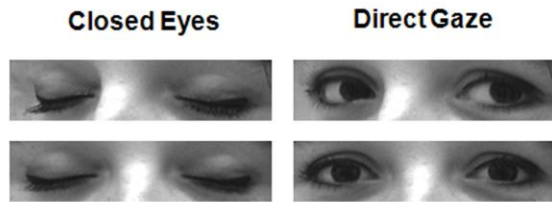
Method

Participants. Thirty four undergraduates (mean age=21.2±0.5 years) volunteered to participate, all reported normal or corrected-to-normal vision and were naïve about the purpose of the experiment (presented as part of a larger research project on colour perception).

Stimuli. Letter string stimuli in the incongruent condition were four colour words (RED, BLUE, GREEN, YELLOW) presented in the three colours that did not match their meaning (e.g. RED printed in blue, green and yellow). In the neutral condition, four strings of neutral signs matched for grapheme-length with the four colour words were used (e.g. XXX for RED). Each letter string subtended 1° of visual angle horizontally and 0.5° vertically. Eye stimuli consisted of the eye region cut from 24 face photographs (Conty et al., 2006). For each original face, there were four different stimuli in which the eye condition (gazing directly at the observer or closed) and head position (frontal or rotated sideways by 30°) were varied in a 2 × 2 factorial design (Figure 1A). Eye stimuli were mirror imaged resulting in a total of 192 pairs of eyes. All eye stimuli were in grey scale and subtended 6-7° of visual angle horizontally and 1.6° vertically.

Procedure. The participants arrived individually and were met by either a male or a female experimenter (random assignment) who described the Stroop task. Each participant began by a practice period of 128 to 224 trials during which he/she learned to associate the ink colour (red, green, blue, yellow) of neutral words (e.g. WIND) to the appropriate keyboard response (S, F, K, M). Then, the participant was trained to the classical Stroop task with the incongruent color words and the neutral strings presented randomly and in equal proportion over 96 trials. Finally, in the test period of 192 trials, the participants performed the Stroop task but with the eye stimuli now appearing 0.5° of visual angle above the string. The association between eye and string stimuli was counterbalanced within subjects. These stimulus pairs were presented in random order. At the beginning of the test period, participants were told that each string would appear concomitantly with opened or closed eyes and that the eyes were not informative for the task. They were requested to ignore the presence of the eyes and avoid reading the strings. Thus, they were explicitly focused on the ink color. In every trial, the stimulus display was preceded by a fixation cross centred on the letter string (see Figure 1B).

A) Stimuli of Experiment 1



C) Stimuli of Experiment 2



D) Stimuli of Experiment 3

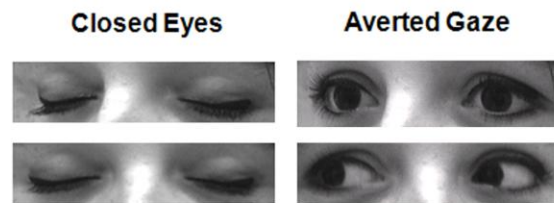


Figure 1: A) Example of eye stimuli under the 4 experimental conditions in Experiment 1. Direct gaze and closed eyes were presented under deviated (top images) and frontal (bottom images) head orientation. B) Time course of a trial. Prior to stimulus presentation, a central fixation cross appeared for 800 to 1200 ms. Then the letter string was presented at fixation, whereas eye stimuli were displayed above the string. Participants were required to name the string colour as

accurately and as quickly as possible using a four-alternative forced choice keyboard press. The stimuli remained on the screen for 3000 ms or until a response was collected. C) Example of control images used in Experiment 2. D) Example of eye stimuli under the 4 experimental conditions in Experiment 3. Averted gaze and closed eyes were presented under deviated (top images) and frontal (bottom images) head orientation.

Statistical Analyses. The percentage of correct responses was very high in all conditions ($mean = 96.1 \pm 0.4\%$) and thus was not analysed. Outlier reaction times (RT) exceeding two standard deviations above the mean were rejected ($<5\%$ per subject and string condition). Only RT data from correct responses were analyzed. We checked that these data showed normal distribution in every condition according to the Kolmogorov-Smirnov test (all $p > .15$). Thus, a three-way ANCOVA was carried out on RTs of the test period with Gaze Condition (direct/closed), Head Orientation (frontal/deviated), and Type of string (incongruent/neutral) as within-subjects factors, and the interference score (RT difference for incongruent minus neutral strings) of the training period as a covariate ($F_{(1,32)} = 12.5$, $p < .001$). Removing the covariate did not change the findings. Effect size (η^2) are reported together with F and p values for the main effects and interactions. Planned comparisons were performed for the analysis of simple main effects when interactions were observed.

Results and Discussion

Not surprisingly, we found the classical Stroop interference. RTs were longer for the incongruent words than for the neutral signs ($F_{(1,32)} = 82.8$; $p < .001$; $\eta^2 = .72$). More importantly, the type of eyes appearing above the string clearly modulated this interference ($F_{(1,32)} = 7.4$, $p = .01$; $\eta^2 = .18$): the Stroop effect was stronger in the context of direct gaze ($M = 87 \pm 11$ ms; $F_{(1,32)} = 85.1$,

$p < .0001$) than in the context of closed eyes ($M = 53 \pm 11$ ms; $F_{(1,32)} = 24.7$, $p < 0.001$) (Figure 2A). This influence of eye gaze on Stroop interference was independent of head orientation ($F < 1$, non significant, ns). Furthermore, the modulation of the Stroop interference by gaze was uniquely due to the effect of the Gaze Condition on incongruent trials (planned comparison, $F_{(1,32)} = 5.8$; $p < .03$) (Figure 2B). No other effects were found (all $F_s < 1$, ns).

A) Eye contact interference effect:

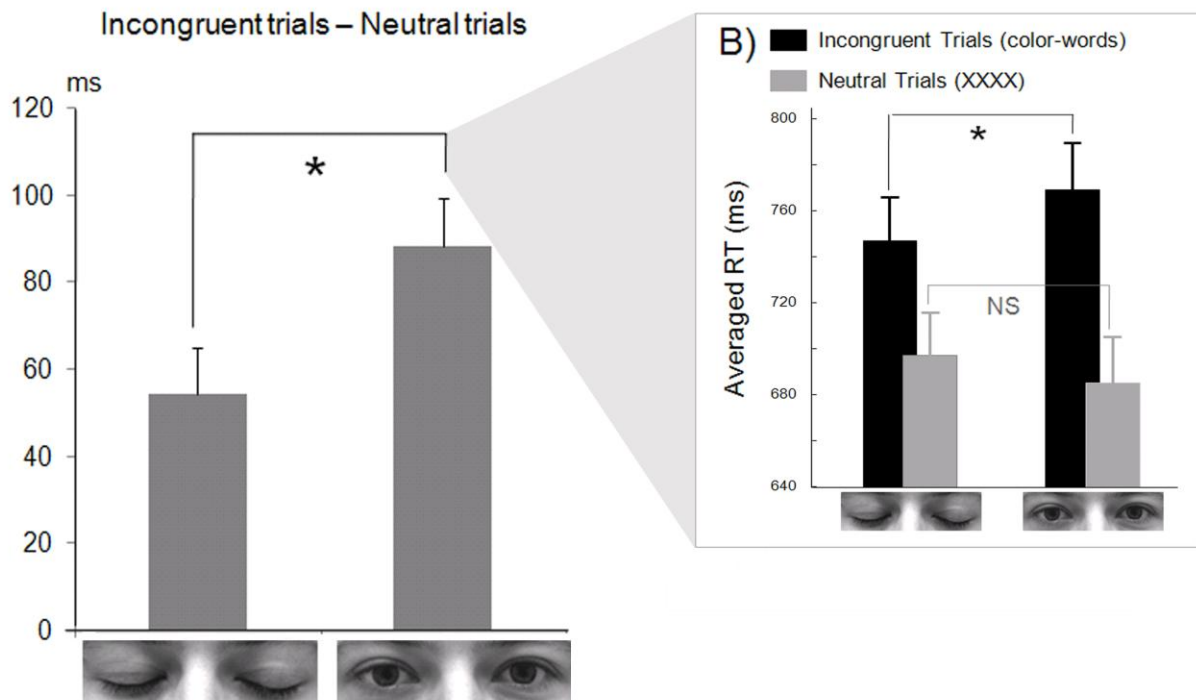


Figure 2: The Eye Contact Effect (ECE) on Stroop interference. Data were averaged over Head Orientation, as there was not any effect of this factor in our analyses. Moreover, all averaged RT were controlled for the interference effect of the training period. A) Mean Stroop interference effect (RT for incongruent word condition minus RT for neutral string condition, in ms) with

standard error bars, for each Gaze Condition. B) Mean RT (in ms) with standard error bars for incongruent word and neutral string trials respectively, under each eye gaze condition.

Despite the image for direct gaze was very different in frontal and deviated views of a face, the present ECE occurred for both head orientations. This suggests that the ECE could not be driven simply by low-level image properties. Nevertheless, whatever head orientation, direct gaze and closed eyes physically differed. This difference is inherent to the strong local contrast between the iris and the sclera characterizing opened eyes (Kobayashi & Kohshima, 1997), which makes these stimulus visually more complex and possibly more salient than closed eyes. Thus, we ran a control experiment where eye stimuli were replaced by control images preserving the mean luminance of the original photographs while showing clear different local contrast and complexity.

Experiment 2

Method

Participants, stimuli, and procedure. A new sample of 34 participants (12 females, mean age = 19.8 ± 0.4 years) was exposed to the same procedure as before. However, direct eye gaze stimuli were replaced by vertical gratings of the same size and global contrast as the corresponding eyes, and closed eyes were replaced by uniform gray images. All control images were matched for mean gray level with the original eye stimuli (Figure 1C).

Statistical analyses. As before, the percentage of correct responses was very high in all conditions ($mean = 96.1 \pm 0.4\%$). Outlier RTs were rejected ($< 5\%$ per subject and string

condition). These data showed normal distribution in every condition according to the Kolmogorov-Smirnov test (all $p > .15$). A two-way ANCOVA was carried out on RTs of the test period with Grating Condition (grating/uniform gray), and Type of string (incongruent/neutral) as within-subjects factors, and the interference score (RT for incongruent minus RT for neutral strings) of the training period as a covariate. Removing the covariate did not change the findings.

Results and Discussion

As before, the participants showed the classical Stroop interference ($F_{(1,32)} = 73.6$, $p < .001$; $\eta^2 = .69$). However, the type of image appearing above the strings had absolutely no effect on the size of the Stroop effect ($F < 1$, ns - *mean interference effect for gratings* = 85 ± 10 ms; *mean interference effect for uniform grey image* = 89 ± 13 ms). Accordingly, Grating condition modulated the RT neither for the incongruent words nor for the neutral strings (all $F < 1$, ns- see Table 1). This control experiment strengthened our confidence that the enhanced Stroop interference under concomitant eye contact (Experiment 1) was not simply due to low-level visual properties of direct gaze compared to closed eyes. However, at this stage, it cannot be rejected that this result reflected the impact of any gaze direction (i.e. the mere presence of open eyes) rather than a specific effect of direct gaze. We addressed this important issue in a third experiment where direct gaze stimuli were replaced by averted gaze stimuli.

Experiment 3

Method

Participants, stimuli, and procedure. A new sample of 34 participants (21 females, mean age = 20.0 ± 0.2 years) was exposed to the same procedure as in Experiment 1. However, direct

gaze stimuli were replaced by the corresponding averted gaze configurations. Thus, for each original face, there were four different stimuli in which the eye condition (gazing sideways from the observer or closed) and head position (frontal or rotated sideways by 30°) were varied in a 2 × 2 factorial design (see Figure 1D).

Statistical analyses. As before, the percentage of correct responses was very high in all conditions ($mean = 95.8 \pm 0.4\%$). Outlier RTs were rejected (<5% per subject and string condition). These data showed normal distribution in every condition according to the Kolmogorov-Smirnov test (all $p > .20$). A three-way ANCOVA was carried out on RTs of the test period with Gaze Condition (averted/closed), Head Orientation (frontal/deviated), and Type of string (incongruent/neutral) as within-subjects factors, and the interference score (RT for incongruent minus RT for neutral strings) of the training period as a covariate. Removing the covariate did not change the findings.

Results and Discussion

As before, the participants showed the classical Stroop interference ($F_{(1,32)} = 56.7, p < .001; \eta^2 = .64$). However, the type of eyes appearing above the strings had absolutely no effect on the size of the Stroop effect ($F < 1$, ns - *mean interference effect for averted gaze* = 76 ± 12 ms; *mean interference effect for closed eyes* = 76 ± 13 ms). Accordingly, Gaze condition modulated the RT neither for the incongruent words ($F_{(1,32)} = 1.1; p = 0.30$) nor for the neutral strings ($F_{(1,32)} = 2.7; p = 0.11$ – see Table 1). This last result strengthened our confidence that the higher Stroop interference under concomitant direct gaze relative to closed eyes (Experiment 1) was specifically related to an eye contact effect.

	Experiment 2		Experiment 3	
	Grey Image	Grating	Closed eye	Averted gaze
Incongruent string	742±28	745±27	720±26	730±27
Neutral string	655±20	653±24	643±18	653±18

Table 1. Mean reaction times with standard error of the mean obtained in the main experimental conditions of control experiments 2 and 3.

General Discussion

Preliminary findings in the ECE literature have indicated that, when attention is initially engaged on faces, direct gaze (i.e., eye contact) can hold attention at the expense of concurrent visual processing outside the facial area (Senju & Hasegawa, 2005). Here, we make a step further by directly showing the distracting strength of eye contact in circumstances where its processing was strongly disfavored. The ECE was indeed obtained despite the gaze stimulus was not under the direct focus of attention and the participants were faced with another powerful distracter (the incongruent word) in the task at hand. The instructions discouraged eye processing as well. Consistent with our expectation that eye contact may interfere above and beyond word reading in Stroop's paradigm, participants displayed significantly more color-word interference in the presence of direct gaze, as compared to closed eyes. Hence, processing eye contact seems actually as difficult to refrain as word reading in the Stroop task. There is ample evidence that word reading is automatic in that readers cannot refrain from accessing word meaning (MacLeod,

1991). If refraining from processing eye contact was not at least as difficult, the presence of direct gaze in the vicinity of the incongruent words would not have influenced the size of the Stroop effect. Instead, this effect was stronger under concomitant eye contact. As indicated by experiment 2, this finding can hardly be explained by differences in local contrast characterizing direct gaze relative to closed eyes. Moreover, the size of the Stroop effect did not change under averted gaze (Experiment 3), indicating that the stronger Stroop interference found under direct gaze in experiment 1 was specifically related to eye contact perception. Thus, our findings can be taken as evidence that eye contact is processed even when initially presented outside the direct attentional focus, which also reinforces the view that this contact involves specific mechanisms of detection (Conty, N'Diaye, Tijus, & George, 2007; Perrett & Emery, 1994).

The lack of averted gaze effect on the Stroop interference is consistent with Burton et al. (2009) who concluded that averted gaze does not interfere with performance when occurring outside the focus of attention. In their research, participants made directional (left-right) judgments to gazing-face or pointing-hand targets, which were accompanied by a distracter face (only averted gaze was used) or hand. Averted gaze actually never interfered with performance even when distracter sizes were increased to compensate for their peripheral presentation, or when making use of only the eye regions as distracters thereby eliminating a potential difficulty in extracting gaze from a face context. Of particular interest here, our own findings in Stroop's paradigm rather support a different conclusion regarding direct gaze, which seems to be an extremely powerful distracter. Future research might clarify whether this distracter does or does not operate in Burton's own interference paradigm. Importantly, in these authors' paradigm, eye gaze was presented in short display times of 200 ms. In our own research, the stimuli were on display until a response was made, and thus it is possible that the eye stimuli were processed

serially (being out the primary focus of attention). Future research therefore might also specify whether the present ECE in Stroop's paradigm can be found under the more drastic condition of short display times.

Of particular interest here, the ECE was actually restricted to the (most demanding) incongruent word condition. This supports the view that eye contact did not interfere with the selection of the letter color cues *per se* but rather competed with and/or delayed the inhibition of word reading. It may therefore be the case that eye contact consumed common processing resources shared with the inhibition of predominant colour word processing and/or response. Alternatively, eye contact may have selectively enhanced the processing of the words as suggested by recent studies emphasising the influence of direct gaze on the quality of information processing (Fullwood & Doherty-Sneddon, 2006; Yoon, Johnson, & Csibra, 2008). Interestingly, the present ECE fits with recent findings (Conty et al., in press) indicating that direct gaze may automatically and specifically increase arousal during the performance of demanding tasks. Future research shall clarify whether increased Stroop effect in presence of direct gaze is mediated by increased arousal. Furthermore, the absence of ECE in the neutral string condition contrasted with Lavie et al.'s findings (2003) indicating that visual distracters, especially faces, produce interference in visual search task independently of the task perceptual load. However, in Lavie et al.'s (2003) research, the targets (persons' names) were always semantically linked to the distracters (faces). Here, the targets (string color) were completely unrelated to the distracters (gaze). This major difference may help explain the inconsistency between Lavie et al.'s (2003) findings and our own results. It seems that when there is no relationship between the targets and the social distracters, the task must be difficult enough (incongruent string condition as opposed to neutral string condition) for an interference to occur (for a similar argument about direct gaze

and arousal, see Conty et al., in press). This point will deserve special attention in future research on the ECE.

In any case, our results show for the first time that direct gaze selectively enhances Stroop interference. Complementary with Senju and Hasegawa's (2005) findings, the present results indicate how distracting eye contact can be, at least when this contact occurs concomitantly with the task at hand. Perhaps more importantly, our results offer first evidence that eye contact can be distracting even when direct gaze is not presented under the direct focus of attention and competes with another powerful distracter. This is the key contribution of the present research. It reinforces the view that eye contact processing may be mandatory, in agreement with the idea that it is adaptive not to ignore faces looking at us (Emery, 2000). Moreover, our findings extend previous research demonstrating that the processing of social stimuli (such as faces) can have automatic discrete influences on our behavioural responses (Bateson, Nettle, & Roberts, 2006; Csibra & Gergely, 2009; Doherty-Sneddon, Bonner, & Bruce, 2001; Fergusson & Bargh, 2004). In sum, the present results provide the first direct behavioral evidence for the distracting strength of eye contact in circumstances where its processing was strongly disfavored by the experimental context. They bring support to the intuitive feeling that there is a cost of being watched. This cost may be related to the interpretation of direct gaze as an evaluative (Droney & Brooks, 1993) or threatening (Von Grünau & Anston, 1995) social signal, or to the adaptive value of paying attention to faces looking at us for the purpose of social interaction (Emery, 2000). It would be interesting to test whether the eye contact effect on Stroop interference is or is not observed in individuals suffering from severe social and communicative deficits such as autism, who typically display deficient attention to others' eyes and gaze (Senju et al., 2005; Spezio, Adolphs, Hurley, & Piven, 2007). Paradoxically, such individuals may show a benefit of their indifference

to the eyes (relative to control subjects) in the present paradigm. As for now, the present findings emphasize how much eye contact constitutes a crucial visual cue in the cognitive functioning of healthy individuals.

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