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**Brief Report: Attenuated emotional suppression of the Attentional Blink in
Autism Spectrum Disorder: Another non-social abnormality?**

Sebastian B Gaigg

City University, London (UK)

Dermot M Bowler

City University, London (UK)

Running Head: Emotional modulation of attention in ASD

Abstract

Twenty-five individuals with Autism Spectrum Disorder and 25 typically developed individuals participated in an Attentional Blink (AB) paradigm to determine whether emotional words would capture attention similarly in the two groups. Whilst the emotionality of words facilitated attention in typical comparison participants, this effect was attenuated in the ASD group. The magnitude of the emotional modulation of attention in ASD also correlated significantly with participants' VIQ, which was not observed for the comparison group. Together these observations replicate and extend the findings of Corden, Chilvers and Skuse (2008) and implicate abnormalities in emotional processes outside the broader context of social cognition in ASD. We discuss our findings in relation to possible abnormalities in amygdala function that may underlie the disorder.

Key Words: **Emotional modulation of attention, Attentional Blink, Autism Spectrum Disorder, Emotional processing, Amygdala.**

Emotional suppression of the Attentional Blink in Autism Spectrum Disorder

Traditionally, investigations of the emotional competences of individuals with ASD have focused on the study of emotional behaviours within the context of social cognition. Behavioural abnormalities are well established in this domain (e.g. Hobson, 2002) and although the developmental significance of these remains the matter of debate (see Baron-Cohen, 1995; Frith, 2003; Hobson, 2002; Leslie & Frith, 1990; Loveland, 2005 for relevant discussions), neuroscientific investigations converge on the idea that abnormalities of the amygdala are most likely responsible (e.g. Bachevalier, 2000; Baron-Cohen, Ring, Bullmore, Wheelwright, Ashwin & Williams, 2000; Schultz, 2005). The amygdala, however, is not only involved in the mediation of socially relevant emotional behaviours and processes. It plays an important role in our emotional lives regardless of whether we are alone or in the company of others – modulating learning and memory (e.g. LeDoux, 1994; Hamann, 2001; McGaugh, 2000; Phelps, 2004), altering decisions (e.g. Bechara, Damasio & Damasio, 2003; Bechara, Tranel, Damasio & Damasio, 1996) and influencing perceptions of the world (e.g. Anderson & Phelps, 2001). In recent years, several researchers have started to use this extensive literature on amygdala function heuristically to study the integrity of emotional processes in ASD outside the context of social cognition.

Studies of fear conditioning, for instance, have shown that individuals with ASD only learn the association between a noxious stimulus and a neutral one when the contingencies between the two are relatively predictable (Bernier, Dawson, Panagiotides & Webb, 2005) but not when they are more variable (Gaigg & Bowler, 2007). Individuals with ASD have also been found to retain emotionally significant information no differently from non-emotional information (Beverdof, Anderson, Manning et al., 1998; Deruelle, Hubert, Santos & Wicker, 2008; Gaigg & Bowler, 2008; Gaigg & Bowler, under review; but see South, Ozonoff, Suchy et al., 2008) and decision-making processes in such individuals seem to be atypically influenced by the motivational significance of the decision-making choices (Johnson, Yechiam, Murphy, Queller & Stout, 2006; but see South et al., 2008). In short, accumulating evidence suggests that emotional processing abnormalities in ASD extend to domains outside the broader context of social cognition.

The current experiment was designed to extend the aforementioned literature to the domain of attention where the amygdala is also known to play a modulatory role as a function of the hedonic value of environmental stimuli (e.g. Anderson & Phelps, 2001; Armony & Dolan, 2001). To date most studies relevant to this domain in ASD (see Schultz, 2005 for a relevant review), have involved assessments of attention to socially relevant emotional signals, with some studies noting abnormalities (e.g. Corona, Dissanayake, Arbelle, Wellington & Sigman, 1998) whilst others do not (Ashwin, Wheelwright & Baron-Cohen, 2006).

Only two studies have attempted to extend this literature to the non-social domain, and here too the findings are inconsistent. South et al., (2008) found that typical and ASD participants exhibit similarly enhanced detection of fear-relevant (e.g. snake) vs. fear-irrelevant (e.g. flower) stimuli in a visual search task, which supports the finding by Ashwin et al. (2006), that individuals with ASD demonstrate a typical anger-superiority effect in visual search paradigms employing socially relevant stimuli (i.e. faster detection of angry vs. non-angry facial expressions). A recent study employing a phenomenon known as the 'Attentional Blink' (AB), on the other hand, showed that the emotional significance of words did not capture the attention of individuals with ASD to the same extent as for typical participants (Corden, Chilvers & Skuse, 2008), which is in line with our observation that individuals with ASD do not seem to retain physiologically arousing words in qualitatively distinct ways over time (Gaigg & Bowler, 2008). The AB (Raymond, Shapiro & Arnell, 1992) describes a period of reduced awareness, elicited during tasks where participants are required to identify two target stimuli embedded among distracters in rapid serial visual presentation (RSVP). Correct identification of the first target (T1) markedly attenuates identification of a second target (T2) occurring between 180-500 ms following T1. When T2 is emotionally charged, however, the AB phenomenon is attenuated (Keil & Ihssen, 2004), and this attenuation is thought to be mediated by a neural system involving the amygdala (Anderson & Phelps, 2001).

The experiment we report here can be thought of as a replication of Corden et al. (2008) even though the two studies were conceived independently of one another (Corden et al's., 2008 findings only came to our attention after having prepared this manuscript). In fact, the two studies differ in important ways methodologically, thus strengthening the findings of each. Our rationale for the experiment is based on our previous finding that individuals with ASD do not seem to retain physiologically arousing words in qualitatively distinct ways over time (Gaigg & Bowler, 2008; Gaigg & Bowler, under review). On the basis of this finding we hypothesised that such individuals would not accumulate distinct representations of emotional words in long-term memory, making it unlikely that such words would capture their attention in an AB paradigm.

Method

Participants

Twenty five individuals with a diagnosis of ASD (20 male, 5 female) and 25 typically developed individuals (20 male, 5 female) participated in the current study. Individuals with ASD were diagnosed by experienced clinicians and a review of available medical records and/or assessment with the Autism Diagnostic Observation Schedule (ADOS; Lord, et al., 1989) confirmed that all met DSM-IV (American Psychiatric Association, 2000) criteria for Autism Spectrum Disorder. Typical participants were recruited from the local community,

and individually matched to within 7 points of verbal IQ (WAIS-III^{UK}; The Psychological Corporation, 2000) to ASD participants. Groups were also matched in terms of performance IQ, full-scale IQ and age. The relevant descriptive statistics for these group characteristics are set out in Table 1. The experimental procedures outlined below adhere to the ethical guidelines set out by the British Psychological Society and were approved by the University's ethical committee.

[INSERT TABLE 1]

Materials & Design

The stimuli included a pool of 590 distracter words and 120 target words. Distracter words were 7 letters long and had a minimum written frequency (Kucera & Francis, 1967) of 10 per million (average 60.2 per million). In order to ensure adequate masking during the RSVP stream, target words were 3-5 letters long. Sixty of these were designated T1 and included only emotionally neutral words. The remaining sixty were designated T2 and included 20 emotionally neutral words, 20 emotionally charged words (profanities, taboos, etc...) and 20 male first names. The latter were included to control for the possibility that semantic distinctiveness rather than the emotional quality of words *per se* facilitated T2 detection. In this context it is also worth noting that in previous studies ASD participants and typical participants did not differ in terms of either

their galvanic skin responses to emotionally charged words or their subjective ratings of arousal of such words (Corden et al., 2008; Gaigg & Bowler, 2008). T1 words and T2 words were closely matched on letter length as were the three sub-categories of T2 words. Neutral and emotional T2s were also equated on ratings of familiarity, which we obtained in a separate normative study in which 49 undergraduate students (35 female, 14 male) rated a set of 130 emotionally charged and neutral words on a 9-point scale (1 = not at all familiar; 9 = very familiar). The mean ratings for the neutral and emotional words included in the current experiment were 8.08 ($SD = .50$) and 7.84 ($SD = 0.32$) respectively. In order for the male first name T2s to be maximally distinct, we chose those that were most common in the UK.

Stimulus presentation was controlled by E-Prime software (Psychology Software Tools, 1996-2002), which presented words in bold, 26-point, Arial font in the centre of a Sony Laptop 15" monitor at a rate of 10 Hz (50 ms word durations + 50 ms blank intervals). Distracter words were always presented in blue font, target words were always presented in red font and the background colour of the screen was grey. Each trial started with a 1 second central fixation cross followed by the RSVP stream. Each of these streams consisted of 26 distracter words and 2 red targets. The first target (T1) occurred randomly between serial positions 5 and 20 whilst the second target (T2) occurred either one, three, or five distracter words after T1 (hereafter Lag 2, Lag 4 and Lag 6 trials). The resulting SOAs (Stimulus Onset Asynchrony) between T1 and T2

were therefore 200 ms for Lag 2 trials, 400 ms for Lag 4 trials and 600 ms for Lag 6 trials. Thus, Lag 2 and Lag 4 trials presented T2s within the AB period whilst on Lag 6 trials T2s occurred after this critical period.

The experiment consisted of a total of 180 trials including 60 trials for each of the three Lag conditions. Within Lag conditions, 20 trials each included either a neutral, emotionally charged or male first name T2. Target words were repeated three times during the experiment such that each of the T1 and T2 words appeared once in each of the Lag conditions. Distracter words were repeated 7-8 times during the experiment. The order of presentation of the various trial types was random without constraints.

Procedure

Participants were tested individually in a sound attenuated laboratory and informed that they would be shown 180 very rapid word sequences that consisted mainly of blue words but also two red words that they should try and identify (written responses were requested). For ethical reasons, participants were forewarned about the sexually explicit and offensive nature of some of the words included in the study. To avoid a bias in favour of detecting emotionally charged words, participants were also told that they would see male first names. They were not told that the first red word was always neutral. Following the instructions, participants were asked for their consent and given a series of

practice trials constructed from a separate pool of words (all neutral). Once they were confident that they had understood what was required of them, the experimenter started the experimental trials and left the room.

Results

Prior to analysing T2 detection rates, we computed the proportion of correctly reported T1 words for each of the 9 experimental conditions (3 T2 word types x 3 lag conditions). As expected, detection rates for these targets were very high ($M = .97$, $SD = .04$). A 2 (Group) x 3 (T2 word type) x 3 (Lag) mixed ANOVA of T1 reports revealed a main effect of Lag ($F(2,47) = 3.68$, $p < .05$), with detection rates on Lag 6 trials ($M = .97$, $SD = .04$) being significantly higher than on Lag 2 trials ($M = .96$, $SD = .04$; $t = 2.69$, $df = 49$, $p < .05$). Detection rates on Lag 4 trials fell in between ($M = .97$, $SD = .04$). No other main effects or interactions were significant ($F_s < 1.10$).

For the analysis of T2 detection rates, only trials on which T1 was correctly identified were taken into account since only these trials reliably index the AB phenomenon (e.g. Keil & Ihssen, 2004). Figures 1a and 1b set out the proportions of correctly identified T2s as a function of the experimental manipulations and participant group. A 2 (Group) x 3 (T2 word type) x 3 (Lag) mixed ANOVA of these data revealed the expected main effects of T2 word type ($F(2,47) = 14.09$, $p < .001$, Greenhouse-Geisser corrected) and Lag ($F(2,47) =$

82.12, $p < .001$, Greenhouse-Geisser corrected), and a T2 word type x Lag interaction ($F(4,45) = 13.48$, $p < .001$, Greenhouse-Geisser corrected). The main effect of T2 word type confirms that detection rates of emotionally charged words ($M = .85$, $SD = .17$) were significantly higher than detection rates of male first names ($M = .79$, $SD = .17$; $t = 3.55$, $df = 49$, $p < .01$) and neutral words ($M = .77$, $SD = .18$; $t = 4.11$, $df = 49$, $p < .001$). In addition, the detection of male first names was superior to that of neutral T2s ($t = 2.34$, $df = 49$, $p < .01$). The main effect of Lag, replicates the AB phenomenon. Detection rates during Lag 2 trials ($M = .62$, $SD = .28$) were significantly lower than during Lag 4 trials ($M = .88$, $SD = .14$; $t = 9.50$, $df = 49$, $p < .001$), which in turn were lower than during Lag 6 trials ($M = .92$, $SD = .10$; $t = 2.34$, $df = 49$, $p < .001$). As indicated by Figures 1a and 1b, the interaction between T2 word type and Lag was partially due to the near ceiling performance during Lag 4 and Lag 6 trials, which compressed detection rates across word types in comparison to Lag 2 trials. There is, however, more to this interaction than is first apparent. More specifically, whilst male first names and neutral T2s were detected with similar frequency during Lag 2 (Male names $M = .59$, $SD = .31$; Neutral $M = .56$, $SD = .32$; $t = 1.29$, $df = 49$, ns) and Lag 4 trials (Male names $M = .87$, $SD = .15$; Neutral $M = .86$, $SD = .17$; $t = 0.45$, $df = 49$, ns), during Lag 6 trials male first names were detected more frequently than neutral T2s (Male names $M = .93$; $SD = .11$; Neutral $M = .90$; $SD = .12$; $t = 2.91$, $df = 49$, $p < .01$). Thus, semantic distinctiveness seemed to facilitate T2 detection only after, but not during, the critical AB time-window.

[INSERT FIGURES 1A AND 1B]

The data set out in Figures 1a and 1b suggests that the ASD group was less susceptible to the emotional modulation of the AB than the typical comparison group. Although the foregoing analysis yielded no interactions or main effects involving the group factor, within group analyses, as predicted, showed that the effect of T2 word type on target detection was only significant in the typical comparison group ($F(2,23) = 21.69, p < .001$, Greenhouse-Geisser corrected) but not the ASD group ($F(2,23) = 2.61, ns$, Greenhouse-Geisser corrected). Calculations of effect sizes indicated that the effect of T2 word type was more than twice the size in typical ($r = .61$) as compared to ASD ($r = .28$) participants¹. To put these effect sizes into perspective, the sizes of the main effects of Lag within each group were .79 for the typical and .75 for the ASD group. In addition to this quantitative difference between groups, we also noted that the magnitude of the emotional modulation of the AB (i.e. difference between emotional T2 detection and male first name T2 detection²) in the ASD group was significantly correlated with VIQ (Lag 2: $r = .53, p < .01$; Lag 4: $r = .37, p = .07$), which was not the case for the comparison group (Lag 2: $r = -.24, ns$; Lag 4: $r = -.19, ns$)³. Fisher's z transformations showed that the differences in these correlations between groups were significant for Lag 2 ($p < .01$) and marginally significant for Lag 4 ($p = .052$). Figures 2a and 2b depict the relevant scatter plots for these correlations (for illustrative purposes average difference scores across Lag 2 & Lag 4 trials are presented) and show that the association in the

ASD group was not merely an artefact of individual variability (Fisher's transformations showed that correlations calculated on the basis of averages across Lags 2 & 4 (ASD $r = .502$, $p < .05$; Typical $r = -.252$, *ns*) significantly differed between groups ($p < .01$)).

Discussion

The current experiment adopted the Attentional Blink paradigm in order to determine whether a group of individuals with ASD, like typically developed individuals, would exhibit enhanced attention to emotionally significant words. Based on our previous observation that individuals with ASD do not retain emotionally charged words in a qualitatively distinct manner over time (Gaigg & Bowler, 2008; Gaigg & Bowler, under review), we predicted that the magnitude of the AB would not be modulated by the emotional significance of words in this group. Although our analyses revealed no between-group differences that would support this prediction, within-group analyses clearly indicated that the effect of emotion on T2 detection was reduced (and actually not statistically reliable) in the ASD group. In addition, the emotional modulation of the AB in the ASD group was unusually associated with participant's verbal IQ. Together, this pattern of results supports the recent observations by Corden et al. (2008) in showing that the emotional significance of words does not capture the attention of individuals with ASD as readily as that of typical individuals. Importantly, the present and Corden et al. (2008) studies differed with respect to the use of control measures

to rule out the possibility that general processing demands, rather than emotion-specific demands, were responsible for the atypical pattern of performance by individuals with ASD. Corden et al. (2008) manipulated perceptual properties of T2s (i.e. brightness) for this purpose whereas we manipulated the semantic properties of T2 words (i.e. by including male first names). In both cases, these manipulations affected performance in ASD and typical participants similarly and in both cases performance of typical participants was affected much more by the emotional properties of T2 words. Since it is difficult to know how best to equate emotional and non-emotional words on distinctiveness, the two studies together present a strong case for the specificity with which emotion *per se* modulates early perceptual processes in the AB paradigm. In turn, this strengthens the conclusion that the atypical pattern of performance observed in individuals with ASD represents abnormalities in emotion specific processes.

The present findings did not only strengthen the observations by Corden et al. (2008) but also revealed an interesting and unusual association between VIQ and the magnitude of the emotional modulation of the AB in the ASD group. Such associations between VIQ and task performance parallel findings from socio-emotional tasks, such as those assessing the ability to identify emotion from facial or bodily expressions (e.g. Ozonoff, Pennington & Rogers, 1990). This may suggest that difficulties in emotional processes within and outside the social domain in ASD are the result of a common developmental pathway. Corden et al. (2008) came to a similar conclusion after noting that the attenuated emotional

modulation of attention in the AB paradigm was associated with poorer performance on a facial fear recognition task. It will be important for future research to clarify how emotional processing difficulties within and outside the social domain relate to one another over the course of development, because such clarification would contribute valuable information to the long-standing debate as to whether ASD is fundamentally a disorder of socio-cognitive or emotional development (e.g. Baron-Cohen, 1995; Hobson, 2002). It will also be important to extend the work on non-social emotional processing to lower functioning individuals from the autism spectrum in order to establish whether findings such as the current ones are representative of the broader phenotype of the condition.

At the neural level of analysis, the present findings invite the inference that abnormalities in amygdala functioning may be responsible for the atypical pattern of performance by individuals with ASD. Although several lines of evidence from both the typical and ASD literature (e.g. Anderson & Phelps, 2001; De Martino, Kalish, Rees & Dolan, 2008; Schultz, 2005) would support this suggestion, it is important to remember that the amygdala operates within complex neural systems. In the context of the AB paradigm, for instance, interactions between the amygdala, cingulate cortex and frontal cortical areas seem to be important (De Martino et al., 2008) and the abnormality in ASD may lie anywhere in this system (or perhaps even outside it). As Corden et al., (2008) point out, functional imaging studies will be an important next step in this context and our prediction

for such studies would be that the functional connectivity between the amygdala and relevant cortical areas of the brain would be compromised in ASD (see Gaigg & Bowler, 2007; Gaigg & Bowler, 2008 for further discussion). Regardless of the nature of the neural correlate, however, a hypothesised amygdala involvement seems to serve a useful heuristic purpose for furthering our understanding of the cognitive characterisation of emotional processing difficulties in ASD. In this respect the current findings add to a growing literature that demonstrates atypicalities in this domain outside the broader context of social cognition.

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Author Note

Sebastian B Gaigg and Dermot M Bowler, Autism Research Group, Department of Psychology, City University, Northampton Square, London, UK

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Correspondence concerning this article should be addressed to Sebastian B Gaigg, Autism Research Group, Department of Psychology, City University, London EC1V 0HB, UK. Tel.: +44 (0) 207 040 8544. e-mail: s.b.gaigg@city.ac.uk

Footnotes

¹ These effect sizes are calculated on the basis of the Greenhouse Geisser adjusted degrees of freedom.

² It should be noted that difference scores between emotionally charged and neutral T2s yield the same pattern of results, which is not surprising given that semantic distinctiveness did not seem to facilitate T2 detection during the AB time-window. We present difference scores based on male first name T2s here as these more conservatively estimate the impact of emotion on the AB.

³ Correlations between the magnitude of the emotional modulation of the AB and Performance IQ or Full-scale IQ were not significant for either group of participants.

Table 1

Summary of Age and IQ characteristics of the ASD and Typical Group

| Measure | ASD (<i>N</i> = 25) | | Typical (<i>N</i> = 25) | |
|------------------|----------------------|-----------|--------------------------|-----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Age (years) | 38.4 | 13.6 | 36.2 | 11.8 |
| VIQ ^a | 106.9 | 14.4 | 106.3 | 13.8 |
| PIQ ^b | 104.8 | 17.0 | 104.5 | 16.6 |
| FIQ ^c | 105.2 | 15.5 | 105.8 | 15.1 |

^a Verbal IQ (WAIS-R^{UK} or WAIS-III^{UK})

^b Performance IQ (WAIS-R^{UK} or WAIS-III^{UK})

^c Full-Scale IQ (WAIS-R^{UK} or WAIS-III^{UK})

Figure Captions

Figure 1

Proportion of correctly reported 2nd Target Words (T2s) as a function of Word Type, Lag and Participant Group

Figure 2

Scatter plots depicting the association between the magnitude of the emotional modulation of the AB (across Lags 2 and 4) and VIQ for the Typical and ASD participant groups.

Figure 1

Top

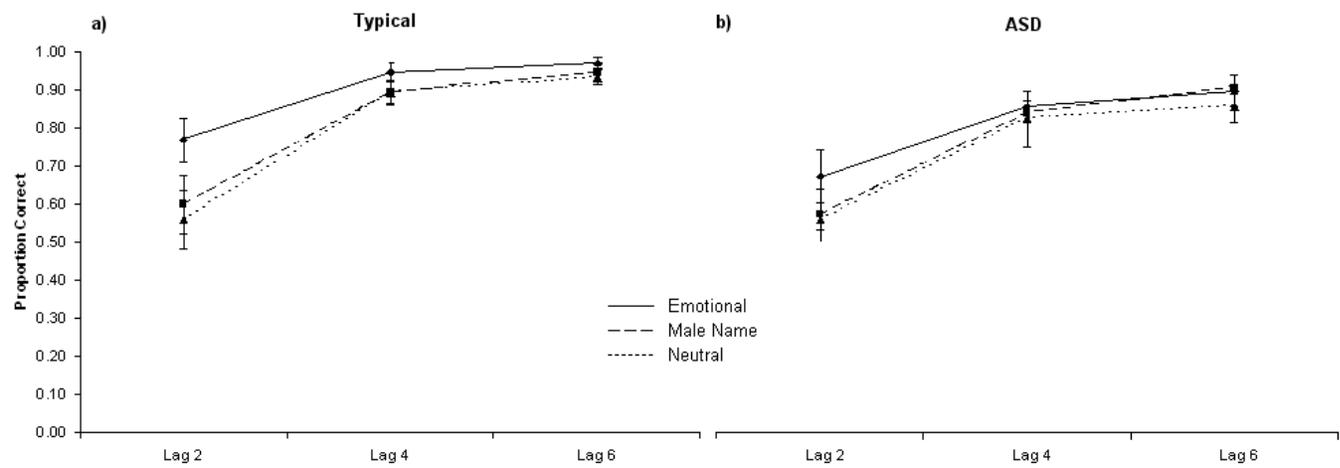


Figure 2

Top

