ATTENTION CONTROL IN ADULTS WITH HIGH AUTISTIC TRAITS AND ATTENTION TRAINING IN CHILDREN WITH AUTISM

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ABSTRACT

Attentional selection is crucial for successful interaction with the environment, including the ability to select relevant information while suppressing irrelevant distractors. While attention is not thought of as a core component of the autism phenotype, attention atypicalities are often reported in research. However, contradicting findings regarding attention in autism and the Broader Autism Phenotype (BAP) imply that the circumstances under which selection is successful or impaired are not yet clear. In a series of experiments this thesis attempts to delineate more clearly the contexts under which attentional control is enhanced or impaired in the BAP. Specifically, the question of whether differences in attentional control are driven by perceptual atypicalities (e.g., in face processing or a local bias) is investigated in Chapters 2 & 3, where both global/local stimuli and face/scene pairs are used while participants are asked to select one aspect and ignore the other. In Chapter 3, I also investigate the possibility that attentional atypicalities in the BAP are linked to the mode of attentional control that is called upon, using visual attention tasks that tap separately proactive and reactive distractor suppression. In Chapter 4, I ask whether attentional atypicalities in the BAP translate to the motor domain using a simple reaching task that may also tap proactive and reactive control processes as distractors appear and need to be avoided. As the results in these chapters all support the notion of attention atypicalities in the BAP, in Chapter 5 I move on to test whether attention training could prove beneficial for children with autism. The Computerized Progressive Attentional Training (CPAT) programme was therefore carried out in a special and mainstream school setting with children with autism, while transfer effects were tested (in behaviour, cognitive and academic performance). Results give evidence for enhanced distractor suppression in adults with more autistic traits, when preparatory control is utilized, while the CPAT is shown to bring transfer effects from attention training to cognitive and academic skills of children with autism. Results are further discussed in Chapter 6.

DEDICATIONS

To all the people out there in the Spectrum and especially to the lovely children I had the pleasure to work with, I hope my small contribution finds its way to help brighten your future.

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Chapter 1

General Introduction

Autism Spectrum Disorder (ASD) or autism is a neurodevelopmental condition diagnosed on the basis of two behavioural impairments: 1.Impaired social interaction, including difficulties in communication and 2. Restricted and repetitive interests and activities. According to the DSM-V (American Psychiatric Association, 2013) ASD involves not only these multiple deficits, but the new diagnostic criteria specifies that a person with autism must show problems reciprocating social or emotional interaction, problems maintaining relationships, and non-verbal communication impairments. The individual must also present two of the following deficits: extreme attachment to routines and patterns and resistance to change in routines; repetitive speech or movements; intense and restrictive interests; problems integrating sensory information, hyper or hypo reaction to sensory input or strange interest in sensory aspects of the environment.

Importantly, autism tends to be heterogeneous in its presentation, but nevertheless various atypical attentional processes are often found amongst individuals with ASD, with accounts of early impairments in attention disengagement linked to the development of ASD symptoms (Keehn, Müller & Townsend, 2013). In this first chapter, I will review pertinent issues within the attention and ASD literature, starting with early deficits on the disengagement of attention, which combined with atypical attention towards socially relevant information in autism, might contribute to symptoms seen in ASD. I also move on to review findings regarding global vs local processing and advantage in visual spatial tasks seen in ASD, trying to link these findings together, bringing a new theoretical framework (Dual Mechanism of Control theory) to better understand differences in performance of individuals with ASD in visual experiments in the literature. I also introduce findings regarding attention in the Broader Autism Phenotype (BAP) and the potential impacts of attentional training in children with ASD. In order to further investigate discrepant findings from the literature, this thesis will then explore attentional selection in the BAP modulated by stimuli type (global vs local, faces vs scenes) in the visual and motor domains, also investigating under which circumstances attention is enhanced or impaired in individuals with more autistic traits. In the final experimental chapter, a computerized attention training program is utilized with children with ASD in order to investigate potential benefits of attentional training in this population.

Autism and disengagement of attention

Attention itself is a broad construct which may involve a variety of processes but in the context of ASD, previous research highlighted early deficits in switching or shifting attention (which involves disengaging from one item and moving and engaging attention with another) as a source of such atypicality. It was recently argued (Sacrey, Armstrong, Bryson, & Zwaigenbaum, 2014) that toddlers with autism show impairments in the disengagement and shifting of attention that are present from the first year of life. Retrospective analysis of home videos of later diagnosed children with ASD and prospective analysis of at-risk infant siblings, have shown impairments on disengaging and shifting of attention before the first birthday (Keehn et al., 2013). In a longitudinal study involving 65 siblings of older children with a diagnosis of ASD, at-risk infants between 6 and 12 months were tested in a visual orienting task. Once a child was engaged in a central fixation point, another stimulus appeared to the left or right side of the original fixation. Latencies to begin an eye movement to the outer stimuli were measured. High-risk infants demonstrated longer latencies to disengage from the central stimulus compared to a low-risk control group. The high-risk infants who showed longer latencies received an ASD diagnosis later at 24 months (Zwaigenbaum et al., 2005). Elsabbagh et al. (2009) also found that 9-10 months old siblings of children with ASD showed longer latencies of attention disengagement and less response to a facilitation cue in comparison to controls. Early deficits in disengaging attention may lead infants to focus on only one aspect of the environment, missing out on top-down visual exploration. In turn, attention could develop to be focused on stimuli of ASD interest (such as non-social information). This might lead to difficulties initiating or responding to joint attention, as joint attention means the child needs to be able to disengage from an object and follow the gaze of the caregiver. This in turn, could result in deficits related to social interaction seen in ASD (see Keehn et al., 2013; Sacrey et al., 2014, for a review).

Children, adolescents and adults with ASD also seem to show slower, less efficient visual disengagement and shifting of attention. Landry & Bryson (2004) measured eye-movements towards a peripheral target following a fixation point. Using a gap-overlap task, they measured the latency to begin an eye movement from a central fixation point to a peripheral stimuli. In the gap trials, the initial fixation point disappears at the onset of a peripheral stimuli. In the overlap trials, both remain on screen. ASD children took significantly longer to disengage visual attention in the overlap trials compared to controls, whilst similar response latencies where observed for the gap trials (Landry & Bryson, 2004). The authors suggest the difficulty in disengagement might be due to an over focused and/or narrowed focus of attention directed to the stimuli. Goldberg et al. (2002) also used a gap-overlap task, and found similar results in adolescents with ASD who showed increased reaction times in the overlap condition in comparison to a control group. Finally, Kawakubo, Maekawa, Itoh, Hashimoto & Iwanami (2004; Kawakubo et al., 2007) reported similar findings in adults with ASD as long as more “interesting” figures (vehicles, house objects or animals) were used in the periphery. The authors also found increased pre-saccadic ERP activation, suggesting more resources needed for attention allocation in disengagement in the overlap condition, for the autism group (Kawakubo et al., 2007).

Contrary to other reports of difficulties in disengaging attention in ASD, a null effect in attentional disengagement and social orienting in children with ASD was also reported in a recent study (Fischer, Koldewyn, Jiang & Kanwisher, 2014) using an eye-tracking task. In this task, a face or object appeared in the centre or periphery of the screen, and children had to disengage attention form the first central stimuli to shift it to the periphery while the central object remained (disengage trials) or disappeared (shift trials). Children were instructed to look at the objects on the screen and attention disengagement was measured in saccadic reaction time (time from the onset of peripheral stimuli to first eye movement towards it). The authors reported no group difference in disengaging attention or in orienting attention to social images or objects, between ASD and IQ matched controls (Fischer et al., 2014).

Studies show that ASD participants are quicker (or similar to typically developing controls; TD) to disengage when social stimuli are employed, possibly because faces and social features are less engaging to individuals with ASD (see Sacrey et al, 2014 for a review paper). In a gap overlap task, Kikuchi et al. (2011) investigated disengagement using faces and objects with children and adolescents with autism and a matching TD group. The ASD group showed no differences in disengaging between objects or faces (measured in saccadic reaction time) whereas the TD group showed a larger gap effect for faces, linked to an attentional engagement that was not found in the ASD participants. Interestingly, in a follow-up study in which fixation to the eyes was instructed, this elicited a larger gap effect for faces in children with ASD, and instructed fixation to the mouth in TD participants elicited a smaller gap effect for faces in that group, reversing the previous findings according to task instructions (Kikuchi et al. 2011). This indicates that when following clear task instructions (e.g. fixation to the eyes or mouth), performance in ASD and TD children can be reversed. One attempt to explain these supposedly opposing effects was proposed by Sacrey et al. (2014), who suggested that successful disengagement of attention in ASD might depend on sufficiently long ISIs. Thus, with enough time people with ASD can better regulate top-down processes.

Although the results are mixed when it comes to the disengagement of attention in ASD, there is evidence that endogenous as well as exogenous spatial attention seem to be intact in high functioning adults with ASD. Exogenous attention is involuntary, stimuli-driven and activated by a sudden appearance of stimuli in the visual field, while endogenous attention involves top-down, self-directed and voluntary attentional guidance. Grubb et al. (2013a) conducted a study using three different visuospatial tasks measuring contrast sensitivity using a peripheral precue in order to manipulate exogenous attention with a 1. Valid, invalid or neutral cue; 2. Reduction of distractor crowding in the visual periphery and 3. Improvements of visual search. High-functioning adults with autism performed as well as the control group showing enhancement of performance when provided with a peripheral precue (Grubb et al., 2013a). Using an orientation discrimination task with Gabor patches, Grubb et al., (2013b) investigated endogenous attention in high functioning adults with autism and controls. The tasks had three different versions with varying ISI (650 ms or 50 ms), valid and neutral precues and a response cue. The stimuli placeholder boxes were manipulated in size to control for high or low spatial uncertainty. Although overall there were no differences in reaction time or accuracy between the ASD and control group, pointing to intact endogenous spatial attention in autism, ASD participants showed slower reaction time with spatial uncertainty. This finding might indicate that people with autism need more time to process and react to stimuli under conditions of uncertainty (Grubb et al., 2013b).

Attention allocation in the context of faces

In addition to difficulties in attention disengagement seen in ASD, attention atypicalities have been particularly evident in people with autism in the context of face processing, often with less attention directed to faces (e.g., Behrmann, Thomas & Humphreys, 2006b; Riby & Hancock, 2009). A number of studies have documented reduced eye movements towards faces in people with autism, showing increased eye gaze towards the mouth and less to the eye area (Pelphrey et al., 2002; Klin, Jones, Schultz, Volkmar & Cohen, 2002). Bird, Catmur, Silani, Frith and Frith (2006) conducted an fMRI study investigating the modulation of attention in participants with ASD towards houses and faces. ASD participants showed diminished attention modulation towards social stimuli, but not houses. These results indicate a lack of salience for social stimuli, such as faces, in individuals with autism (Bird et al., 2006). Riby and Hancock (2009) used an eye-tracking experiment measuring spontaneous eye gaze towards faces embedded in scenes and found that participants with ASD showed reduced gaze towards faces (measured in fixation length) in comparison to TD controls, which the authors linked to a lack of interest in social information. In this task, an "incongruent" face was inserted in a typical image of a scene (incongruent here meaning a face being inserted in a manner that does not typically occur). ASD participants were not captured by the incongruent-social element as were controls, suggesting an underlying atypical attentional mechanism in how participants with autism responded to images including faces, when these are also distracting incongruent elements. In a review of the neural and cognitive mechanisms involved in face processing in autism, Behrmann et al. (2006a, 2006b), argued that face processing impairments occur due to core perceptual alterations, possibly due to an atypical attentional bias to local features of stimuli that could be combined with the social disinclination seen in ASD.

It has been suggested that people with ASD show a bias towards local processing, which could also explain intact discrimination of faces. Deruelle, Rondan, Salle-Collemiche, Bastard-Rosset, and Da Fonséca (2008) investigated face processing strategies where participants had to match a set of different faces according to gender, emotion and identity. While children with ASD did not differ from the control group for gender identity (which relies on a holistic approach), they seemed to rely on local facial elements to differentiate between identity and emotion. This is in accordance with theories suggesting that people with autism utilize atypical local-oriented strategies when processing faces (Deruelle, Rondan, Tardif & Gepner, 2004). In accordance with this approach participants with autism show less activation in the fusiform gyrus, when presented with faces (Schultz et al., 2000). In TD individuals, this area is activated when processing faces as a whole. This suggests that ASD participants may rely on a local, rather than holistic approach to process faces.

Furthermore, there is evidence of intact face discrimination and deficits in performance in ASD participants only appear when there is a need to recognize emotions or attribute mental states to faces. Adolphs, Sears and Piven (2006) carried out a study with eight high functioning adults with autism, using tasks involving recognition of emotional and social stimuli. They found that the ASD group showed atypical social judgements regarding faces, similar to patients with amygdala damage, but intact expressed ability to physically discriminate between the stimuli, pointing to a deficit in social comprehension but not low-level face processing. Humphreys, Minshew, Leonard & Behrmann, (2007) conducted a study showing different faces and emotion labels, and participants had to identify the equivalent emotion corresponding to the face expression. ASD participants performed as well as the control group at identifying the correspondent emotion to the face (except for the emotion of "fear"), and differentiating between the faces. As there were no deficits differentiating the facial expressions, it was suggested that the impairment might be linguistic (associating the emotion label e.g. "fear" to the face expression). Also, as suggested in the previous paragraphs, the findings might be linked to a local bias, where ASD participants would focus on a particular part of the faces, in this case the authors argued that they would avoid the eye area (found to be involved in the recognition of the emotion “fear”), and focus on the mouth in order to differentiate between varied face expressions.

There is a body of research on the neural correlates of face processing in autism and, although it is agreed that faces elicit atypical responses in ASD, findings point to different possible brain abnormalities, with different neural correlates being active in participants with autism in comparison to TD when responding to faces and social stimuli. In neurotypical individuals, the recognition of familiar objects and social stimuli comprises neural correlates such as the inferotemporal cortex, superior temporal sulcus or the amygdala. It is suggested that this correlates modulate early visual areas and feed into the control of spatial attention and eye movements in the prefrontal cortex (Treue, 2003). Differently, in autism the cerebral cortex (inferior frontal cortex, inferior parietal lobe, superior temporal gyrus) has been found to be thinner in areas involving social cognition. Hypoactivation was also found in face-processing areas (right amygdala, inferior frontal cortex, superior temporal sulcus, and face-related somatosensory and premotor cortex (Hadjikhani, Joseph, Snyder & Tager- Flusberg, 2006; 2007; Pelphrey, Morris & McCarthy, 2005). Although the fusiform gyrus shows hypoactivation in participants with ASD when responding to faces (Hall, Szechtman & Nahmias, 2003; Hubl et al., 2003; Piggot et al., 2004; Wang, Dapretto, Hariri, Sigman & Bookheimer, 2004), it has been demonstrated that when viewing highly familiar faces, the fusiform gyrus is activated in autism (Aylward, Bernier, Field, Grimme & Dawson, 2004; Pierce, Haist, Sedaghat & Courchesne, 2004). This suggests that individuals with ASD respond differently when viewing familiar versus unfamiliar faces, showing relatively ‘typical’ responses to highly familiar faces (Gillespie-Smith, Doherty-Sneddon, Hancock & Riby, 2014) but impairments when responding to unfamiliar faces (Riby, Doherty-Sneddon & Bruce, 2009). This shows that brain and behavioural differences are present in ASD compared to TD only when processing socially relevant information from unfamiliar faces.

Another neural correlate related to differences in face processing in autism is the amygdala. The amygdala seems to be involved in core social impairments found in autism, due to its atypical function and structural abnormalities seen in people with ASD (e.g. Adolphs et al., 2006; Kleinhans et al., 2009; Lombardo, Chakrabarti & Baron-Cohen, 2009). The amygdala encompasses processes related to emotion, memory and decision making and in the context of autism and face processing, it might be related to a deficit in extracting the emotional information from faces. Indeed, anatomical abnormalities in the amygdala were documented in ASD with evidence of reduced volume and activation in a functional MRI study investigating perception of faces in ASD (Pierce, Müller, Ambrose, Allen & Courchesne, 2001). In this study the fusiform gyrus, inferior occipital gyrus and superior temporal sulcus also showed reduced activation, but no anatomical differences. Interestingly, participants with ASD performed as well as controls on the task, but none of the regions typically found to be active during face processing in TD were significantly active in ASD individuals, which implies that people with ASD use a different neural system when responding to faces (Pierce et al., 2001). Individual-specific neural sites in ASD participants (e.g. frontal cortex, primary visual cortex) were found to be active when processing faces, in contrast to the traditional fusiform face area that is active in TD (Pierce et al., 2001).

However, despite the different neural correlates that are active in ASD in comparison to TD when processing faces, attention towards faces can be effectively cued in ASD (for example, using clear task instructions as mentioned above in Kikuchi et al., 2011) to show a more ‘typical’ allocation pattern (Bar-Haim, Shulman, Lamy & Reuveni, 2006). In a study looking at attention directed to the mouth and eye area in neutral and static faces, participants were instructed to respond to the location of a probe presented either on the eyes or mouth of 16 different faces. The face was presented for 1500 ms after the probe offset. High functioning boys with ASD allocated attention firstly to the eye area and not the mouth, and disengaged from the eyes similarly to controls (Bar-Haim et al., 2006).

Typical attention allocation towards faces is also seen in van der Geest, Kemner, Verbaten and van Engeland (2002) research, where it is suggested that both ASD and TD children would direct their first looks to the eye area when viewing static faces. Loth, Gómez and Happé (2010) also found that ASD participants directed as much eye gaze as the control group towards the eyes in grey scale face stimuli. Riby, Hancock, Jones & Hanley, (2013) used eye-tracking to measure gaze behavior of ASD children and adolescents, presenting pictures showing people, eye cues and plausible and implausible target objects. While participants with autism showed eye gaze towards the face and eyes, they did not seem to follow eye cues to look at correct targets, and looked much more at implausible targets, showing difficulties when naming items, related to sociocommunicative deficits. Thus, the authors suggested that atypicalities in face processing in autism might not be due to impaired allocation of attention to parts of the face due to intact performance but social impairments. It is arguable that previous findings of abnormal gaze orienting to the eye area might be the result of the nature of static face stimuli versus more naturalistic and dynamic social scenes. Contradictory findings regarding eye-gaze could also be explained by later avoidance, problems in disengagement, lack of interest in social stimuli (e.g. eyes not being as naturally salient for people with ASD in comparison to TD individuals; Bird et al., 2006).

In addition, the manipulation of the task could influence the performance of ASD participants, exhibiting intact attention allocation towards faces when clear task instructions and more availability of time are employed (e.g. Bar-Haim et al., 2006). Individuals with ASD were in fact able to recognize different images of faces, showing that low-level perceptual atypicalities did not seem to underlie facial recognition (Adolphs et al., 2006; Humphreys et al., 2007). Atypicalities in face processing found in autism seem to be linked to impairments in spontaneously directing eye gaze to faces (Riby & Hancock, 2009) but not when clear task instructions are given (Bar-Haim et al., 2006; Fischer et al., 2014; Kikuchi et al., 2011). Impairments in face processing also seem to occur when ASD participants need to link faces to emotions (e.g. “fear”), or when experiments require social or verbal constructs, but not when discriminating between faces (Adolphs et al., 2006; Humphreys et al., 2007). These impairments found in research are directly related to difficulties in social skills (e.g. directing spontaneous eye-gaze to faces or parts of the face, following eye-gaze, recognizing emotions), which are core impairments found in ASD. These social skills are not utilized in visual tasks when performance of ASD participants is intact, particularly in experiments making use of clear instructions and static and neutral faces (e.g. Bar-Haim et al., 2006).

Global and local processing in autism

Not only face processing seems to be atypical in ASD, but there are also accounts of difficulties in processing global information and a bias towards the local level of stimuli in this disorder. Images or stimuli usually contain a local (smaller parts) and a global (the small parts put together to form the whole) feature. Earlier studies on global and local processing suggested that perception follows a global-to-local path where global level processing tends to precede local processing in TD individuals (Navon, 1977). It was later found, however, that such global precedence can be altered by manipulating various properties of the stimuli (e.g. the difference in salience or number of local elements) and that such properties can determine whether global or local aspects are attended to first (e.g. Mevorach, Hodsoll, Allen, Shalev & Humphreys, 2010). In contrast to TD individuals, Mottron and Belleville (1993) suggested that persons with autism demonstrate detail-focused processing. Specifically, ASD individuals were believed to show a reversal of the typical Navon (1977) direction of interference: from the local to the global level (Mottron & Belleville, 1993). In an early study, the authors tested this hypothesis in a case study with one participant with autism with exceptional graphic abilities, who was presented with a series of hierarchical structured stimuli formed by large letters constructed of small letters. While the ASD patient showed comparable global interference to participants without autism he also exhibited signs of interference from local to global (local interference) which were not evident for the controls (Mottron & Belleville, 1993). The authors concluded that although individuals with autism process the global level in a normal way, it does not have any special hierarchical precedence over the local processing (Mottron & Belleville, 1993) as initially found in TD adults (Navon, 1977). Later on, Plaisted, Swetteham and Rees (1999) further investigated hierarchical precedence from the global or the local level in children with ASD using a variation of the global-local task from Navon (1977). It was found that both ASD and TD groups were quicker at responding to the global target, pointing to normal global processing in children with ASD, although children with autism had more errors at the global target level, in comparison to the control group, which presented more errors for the local condition (Plaisted et al., 1999).

More recently, the notion of local bias and difficulties in global processing in ASD was further investigated by Wang, Mottron, Peng, Berthiaume and Dawson (2007). The authors used a task where participants had a free-choice or forced choice for the global or local level in a Navon-like task. In the free-choice task, participants with ASD showed no preference for level, but were faster at the local condition. The opposite was found in controls, who were faster for the global condition. In the forced choice task, participants with ASD showed local-to-global interference, whereas controls showed a global advantage and interference from both levels. Results indicate normal global processing, no hierarchical precedence but a local bias with local interference in individuals with ASD (Wang et al., 2007). Similar findings are reported by Koldewyn, Jiang, Weigelt and Kanwisher (2013); using the same free-choice and forced-choice task, they found that children with ASD showed less preference to report the global stimuli when given a choice, but their ability to process global properties when instructed to do so was intact. In turn, Kana et al. (2013) found similar performance between TD and ASD adults in global and local processing, although different neural correlates were active in the autism group. Taken together, these findings on global and local processing seem to show that individuals with ASD can process global information as well as TD if instructed to do so, but might show a preference, or advantage and interference from the local level (Koldewyn et al., 2013; Mottron & Belleville, 1993; Plaisted et al., 1999; Wang et al., 2007).

There are different possible explanations for the local bias in autism, some suggesting that longer fixation to elements in early infancy could be related to difficulties in disengagement of attention, and/or more time needed to process information culminating in a detail-oriented style of processing. Plaisted et al. (1999) argued that local bias might be related to a deficit in shifting attention from the local to the global level. If there is a local processing bias, children may find it difficult to disengage attention from local features of stimuli and to shift it to their global properties, making more errors processing the global target (Plaisted et al., 1999). In their case study, Mottron & Belleville (1993) also suggested that the atypicalities found in local to global precedence might be due to an impairment in disengaging and switching attention between the two levels. Research on typically developing infants investigating the mechanism underlying fixation duration has demonstrated that "long lookers" tend to show a local processing bias and seem to process visual information more slowly in comparison to "short-looking" infants (Colombo, Freeseman, Coldren & Frick, 1995). One possible explanation for increased fixation duration seen in "long lookers" may be difficulties in the disengagement of attention. In addition, Colombo et al. (1995) found that TD "short-lookers" infants processed global information before local properties, similar to findings in the non-ASD population. TD infants with longer fixation to stimuli seemed to show similar performance to infants who had increased fixation durations to stimuli, took longer to disengage attention and were later diagnosed with ASD (Elsabbagh et al., 2009; Zwaigenbaum et al., 2005), showing a link between attention to details, disengagement of attention and longer fixation times to stimuli related to the autism phenotype since early infancy. The relationship between these different attentional functions and ASD is further discussed in the section below.

Brief account of executive function in autism

Attention atypicalities in ASD may also be considered within the broader context of Executive control (EC), which is comprised of multiple overlapping systems, responsible for inhibition, planning, error monitoring, working memory or set shifting. Although there are accounts of impaired EC in ASD, it does not seem that all components of executive function are impaired in children with autism. Children with ASD exhibited impairments specifically in response monitoring in a cognitive estimation task, related to problems in cognitive flexibility (Liss, Fein, Bullard & Robins, 2000), and response monitoring and performance on a battery of cognitive tests improved with age, reaching TD levels (Happé, Booth, Charlton & Hughes, 2006). Distractor inhibition alone was previously found to be intact in autism (Kleinhans, Akshoomoff & Delis, 2005; Ozonoff & Strayer, 1997), although different brain areas are utilized to respond to the same demands (Kaldy, Giserman, Carter & Blaser, 2007). Difficulties in inhibition seem to appear particularly when more task demands, such as working memory, are involved (Gowen & Hamilton, 2013; Luna, Doll, Hegedus, Minshew & Sweeney, 2007; Rinehart, Bradshaw, Tonge, Brereton & Bellgrove, 2002; Sachse et al., 2013).

According to Keehn et al. (2013), ASD may be characterized by poorer performance in complex executive control tasks, which might be caused by a dysfunction of the modulation and regulation of arousal – possibly with subgroups of hyper and hypo-arousal (Watts, Rodgers

& Riby, 2016). A state of hyper-arousal has been suggested to lead to over-focused attention found in ASD (Liss, Saulnier, Fein & Kinsbourne, 2006). In a study using a range of questionnaires with parents of 144 children with autism measuring sensory behavior and attention profile, Liss et al. (2006) found a pattern predicting overfocused attention and sensation, specifically comprising items regarding overreactivity, perseverative behavior and interests, overfocused attention and exceptional memory. In this paper it is suggested that early impairments in arousal regulation may cause individuals with ASD to rely on less self-regulation to mediate hypo or hyper-arousal, which can result in inefficient executive control function. Increased sensory arousal, in turn, can result in a narrowed attentional focus ("overfocus"), in an attempt to filter out other sensory inputs. Indeed, such an overly narrow focus of attention could potentially be linked to the local processing inclination seen in autism. This developmental framework of sensorial and attentional functions could also have broader impacts on the development of ASD symptoms (Keehn et al., 2013).

Enhanced performance in visuospatial tasks

Attention atypicalities in ASD may also lead to benefit in certain tasks. For instance, an over-focused attention could be beneficial when participants perform visuospatial tasks that require attention to small elements, such as visual search and learning patterns, which have been shown to be better performed in ASD compared with controls (see Dakin & Frith, 2005 for a review). Indeed, there are accounts of enhanced discrimination skills for visual stimuli in people with autism (Brown & Bebko, 2011). This ability can be seen in visual search tasks, where participants with ASD performed better than controls when asked to find a target hidden among distracting stimuli, showing the ability to differentiate between them, even when target and distractor are highly similar.

O‘Riordan, Plaisted, Driver and Baron-Cohen (2001), for example, tested children with autism against matched controls in a conjunctive search task (where target and distractor share similar features), and a hard feature search task, where participants had to discriminate between a tilted line amidst vertical distractors. They found that children with autism were more accurate and showed faster responses in both visual search tasks. The authors attribute this enhanced ability to superior discrimination skills between items, and/or better inhibition of irrelevant distractors. O’Riordan (2004) also employed three visual search tasks in adults with autism and matched controls and found that ASD participants showed superior searching abilities, and were less affected by the increasing similarity between target and distractor (ASD participants did not reduce speed as much as controls). Results indicate that adults with autism also show superior visual discrimination ability (O’Riordan, 2004). The increased capacity for visuospatial processing in ASD was also demonstrated by Remington, Swettenham, Campbell & Coleman, (2009) who used a perceptual load paradigm (Lavie, 1995) to test attentional selection in ASD. Findings in this study showed that even with higher levels of perceptual load ASD participants performed at the level of low perceptual load in TD participants. In this research, it is suggested that people with autism may have an advantage in perceptual skills, which contributes to an enhanced visual search ability, evidenced by the processing of a greater number of distractors in comparison to controls (Remington et al., 2009).

Furthermore, Brian, Tipper, Weaver & Bryson (2003) did not find significant reaction time differences between ASD and control groups when they were detecting a target while inhibiting distractors. The authors investigated selective distractor inhibition of spatial location with a negative priming task in which individuals with autism were instructed to detect a target, which matched to a primed color, while inhibiting responses to a co-occurring distractor. The ability to selectively inhibit a task-relevant distractor was intact in ASD and the irrelevant feature of colour produced a facilitation effect. These results suggest enhanced performance in visual tasks that require not only low-level perceptual abilities but also distractor suppression in individuals with ASD, supporting the notion that individuals with autism excel in visual tasks in comparison to typically developing peers when inhibition is required (Dakin & Frith, 2005; O'Riordan et al., 2001; O'Riordan, 2004; Remington et al., 2009).

Different theories, including the Enhanced Perceptual Functioning or EPF (Mottron et al., 2006) and the Weak Central Coherence – WCC (Happé, 1999), have been proposed to explain these atypicalities. The EPF theory argues that enhanced performance in visuospatial tasks is due to differences in low-level perceptual abilities that are overdeveloped and enhanced, based on a local processing bias. The WCC hypothesis also points to a detail focused cognitive style in autism coming from a difficulty in extracting meaning from complex situations that require a more holistic approach. Happé (1999) also suggests that the local processing bias can be overcome in tasks that require global processing with explicit demands. Both theories propose that enhanced ASD performance in visuospatial tasks is due to, at least in part, a local processing bias and individuals with autism might find it easier to focus on local pieces of information, thus benefiting performance when such ability can be used.

Dual Mechanism of Control (DMC) theory

A different theoretical framework that could explain the divergent findings in the literature and advantage or impairments seen in participants with ASD in visual tasks is the DMC theory, in which a possible bias towards proactive and difficulties in reactive control of attention could be influencing the performance of participants with autism. Reactive control is triggered by external stimuli, it requires a quick shift of attention occurring "on-the-go". For example, when driving a car on the road, after the green signal from the traffic light, a sudden appearance of an ambulance would require the driver to stop and adaptively change its course in response to the sudden occurrence. Proactive control of attention refers to tasks that require previous preparation in anticipation of a known situation. It includes tasks where the requirement to inhibit certain targets is known in advance. For example, when driving a car it is anticipated that speed should be reduced when approaching a zebra crossing.

An example of a task that requires reactive control is the gap-overlap task. Participants respond to a target unaware of the timing of the appearance or disappearance of the distractor (gap or overlap trials), requiring 'on-the-go' responses. Other tasks with no clear instructions or preparation time, such as eye-tracking experiments measuring spontaneous eye gaze to specific stimuli also rely on reactive control. Thus, previous findings pointing to impairments in disengagement of attention and reduced eye gaze to faces or certain parts of the face might rely on reactive control of attention. Some studies that did not utilized strict task instructions might have elicited reactive control, which might be atypical in participants with autism (e.g. Elsabbagh et al., 2009; Goldberg et al., 2002; Kawakubo et al., 2004, 2007; Klin et al., 2002; Landry & Bryson, 2004; Riby & Hancock, 2009; Zwaigenbaum et al., 2005). On the other hand, tasks that rely on proactive control of attention, providing specific instructions and enough time for preparation, tend to produce similar performance between ASD and TD, or even superior abilities for participants with autism in search tasks, when ignoring distractors or attending to faces (e.g. Bar-Haim et al., 2006; Brian et al., 2003; Fischer et al., 2014; Grubb et al., 2013b; Humphreys et al., 2007; Kikuchi et al., 2011; O'Riordan et al., 2001; O'Riordan, 2004; Remington et al., 2009). Indeed, excessive adherence to routines, ritualized bahaviour, resistance to change and rigid thinking are all common ASD symptoms (DSM V, American Psychiatric Association, 2013). Considering that individuals with autism might rely on a proactive cognitive style assumes that more time and preparation is needed before activities. Therefore, one could argue that those individuals would depend on structured and predictable routines (inherent to a proactive cognitive mode). Moreover, if reactive control is atypical in autism it could be inferred that people with autism would have difficulties when 'on-the-go' (reactive) changes are necessary, showing increased attachment to routines, resistance to change, and rituals and stereotyped behaviors, found within core ASD symptoms.

Developmental model

Attentional differences have been present since the first descriptions of autism (Kanner, 1943) and there is evidence to support early and lifelong impairments in modulating different areas of the attentional network in ASD (Elsabbagh et al., 2009; Landry & Bryson, 2004; Zwaigenbaum, et al., 2005). Keehn et al. (2013) proposes a developmental model where impaired disengagement of attention in early childhood may cause many other dysfunctions found in autism, also culminating in enhanced visual search abilities, linking attentional differences to the development of ASD symptoms. The same model has been used by Karmiloff-Smith (2009) to explain delayed language development in Williams Syndrome. This model is based on findings on the disengagement of attention as the earliest deficit reported in children at-risk for ASD (Elsabbagh et al., 2009; Zwaigenbaum, et al., 2005), which is an initial cue that atypical disengagement of attention is a primary difference in autism. Different attention functions develop rapidly in the first year of life and continue into childhood and adolescence (Lin, Hsiao & Chen, 1999; Rueda et al., 2004), and lower attentional functions may be essential for the development of higher-level social and communicative processes. Difficulties in attention disengagement have been linked to impairments in joint attention (Schietecatte, Roeyers & Warreyn, 2012) and problems in the development of joint attention are linked to impairments in social communicative behaviours (Dawson et al., 2004; Schietecatte et al., 2012), and may also be associated with the development of perceptual biases (Colombo et al., 1995). In addition, disengagement of attention might have great influence in the development of arousal regulation (Watson et al., 2007) and it is suggested that a state of hyperarousal leads to an overselective attention in attempts to filter out irrelevant information (Liss et al., 2006).

Therefore, early disturbances in attentional disengagement, combined with other primary dysfunctions, may result in a phenotypic end-state associated with ASD. Furthermore, it may be argued that early impairments in disengagement of attention in addition to a dysfunctional arousal regulation (which in turn can lead to a narrowed, over-focused attention), combined with atypical perceptual processing may ultimately lead to enhanced visual search ability in autism (Liss et al., 2006; Keehn et al., 2013).

Attention training in autism

Although there is much discussion about atypical attentional performance in autism, previous work is primarily descriptive and does not address the effects of training on the brain and behavioural development and functioning or how these mechanisms may change in autism. Furthermore, there is a need to examine whether attentional processes in ASD individuals, involving disengagement of attention or executive control, can be changed by targeted intervention in childhood and adolescence. Early interventions might train and improve attentional abilities in autism in order to prevent developmental consequences of impaired attention.

The idea that attention training can be used as a cognitive rehabilitation tool is not a novelty (Sohlberg & Mateer, 1987). In an early study, Sohlberg & Mateer (1987) used a program to train attention in four brain-injured patients, showing improvements in attention following treatment. It is further suggested that attention training, through repetition, can change brain functionality and bring generalized improvements not only to attention but also to cognition and executive control, and consequently help improving academic skills in children, such as numeracy or reading in school settings (Posner & Rothbart, 2007). An attention training program utilizing technology (computer "games") brought improvements in cognition and executive attention in children from 4 to 6 years old, showing that the attentional network is susceptible to intervention during development (Rueda, Rothbart, McCandliss, Saccomanno & Posner, 2005).

Another attention training program that has proven successful in training attention and showing generalized improvements in a variety of populations is the Computerized Progressive Attention Training (CPAT) developed by Shalev, Tsal and Mevorach (2007). The CPAT was first utilized with children with ADHD, improving academic skills such as maths, reading and copying. It was later tested as a cognitive rehabilitation tool with stroke patients, showing improvements in sustained attention and generalized cognitive skills (i.e. numeracy, language; Sampanis, Mevorach, Shalev, Mohammed & Humphreys, 2015). It was also effective for children and adolescents with foetal alcohol syndrome, bringing improvements to several attention measures including sustained and selective attention, as well as to cognitive performance, seen in improved working memory, maths, and reading abilities (Kerns, MacSween, Vander Wekken & Gruppuso, 2010). In the last empirical chapter of this thesis, the efficacy of the CPAT will be tested in children with autism, investigating possible improvements in cognitive and academic skills of children with ASD in school settings. Attention training and its rationale will be further explored in Chapter 5.

Autistic traits in the TD population

Although research in autism and attention mainly focuses on the clinical population, there is a growing body of research on how high autistic traits present in the neurotypical population manifest for those who do not have a diagnosis of ASD, in the Broader Autism Phenotype (BAP). There are reports suggesting that people with a high amount of self-reported autistic traits show a better performance in comparison to those with a low amount of autistic traits, in various visual search tasks (Almeida, Dickinson, Maybery, Badcock & Badcock, 2013; Brock, Xu & Brooks, 2011; Milne, Dunn, Freeth & Rosas-Martinez, 2013). There are also accounts for enhanced discrimination skills in individuals with high autistic traits, related to a possible increase in levels of GABA (Dickinson, Jones & Milne, 2014), while parents of children with autism showed a similar profile of sensory alterations to their children (Glod, Riby, Honey & Rodgers, 2016; Ronconi et al., 2014). Considering autism as a continuum, ranging from very low autistic traits to ASD, autistic-like traits should also be present in varying degrees in the typical population (Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001). In fact, a recent study found similar neural structural differences in reduction of cortical thickness in ASD and higher degrees of autistic traits in TD participants, showing that the neural differences found in ASD extend along a continuum into the TD population (Gebauer, Foster, Vuust & Hyde, 2015). When it comes to face processing, participants with high autistic traits showed no attentional bias towards fearful faces (Miu, Pană & Avram, 2012), but seemed to have difficulties identifying emotions (anger, disgust and sadness; Poljac, Poljac, & Wagemans, 2013), similarly to some findings within the ASD population (e.g. Humphreys et al., 2007; Bird et al., 2006). The Autism Quotient Questionnaire (AQ) from Baron-Cohen et al. (2001) will be employed in this thesis in order to measure autistic traits in the typically developing population. In the following three chapters, attention atypicalities - particularly suppression of irrelevant stimuli, mediated by properties of the stimuli found to be atypical in ASD and the BAP - will be further explored (e.g. faces and global vs local) in individuals with high vs low autistic traits.

The AQ (Baron-Cohen et al., 2001) is a well-known instrument used in research to measure autistic traits in the normal population (see Woodbury-Smith, Robinson, Wheelwright & Baron-Cohen, 2005; Ruzich et al., 2015). It consists of 50 questions divided in 5 sets of 10, each set measuring an area generally atypical in autism: social skills, communication, imagination, attention switching and attention to details. The average score in the normal population is around 17 points and 33 points and above is the average for the clinical or ASD population. Participants are required to respond to a 4 point Likert scale ranging from "strongly agree" to "strongly disagree" to statements such as: "I prefer to do things with others rather than on my own", "I prefer to do things the same way over and over again" or "If I try to imagine something, I find it very easy to create a picture in my mind". The higher the score, more autistic traits the person possesses.

Thesis outline

This thesis will explore attentional atypicalities within the BAP and attention training in autism, utilizing a set of behavioural, mainly non-spatial psychophysics experiments in order to induce certainty and control for proactive attention mode, as well as a cognitive training program. Specifically, in chapters 2, 3 and 4 I tested how autistic traits may modulate the ability to suppress distractors. Suppression was investigated to measure if attentional abilities were altered in the BAP rather than low-level perception of stimuli, evidenced in conditions where inhibition was not required. This was investigated due to conflicting findings of alterations in perception vs attention found in the literature in ASD. In chapter 5, the potential of using CPAT as an attention intervention in autism is described, particularly with respect to transfer effects to improvements in cognition and academic performance. In chapters 2-4, the Autism Quotient Questionnaire (AQ) from Baron-Cohen et al, (2001) was completed by more than 300 adult neurotypical participants in order to measure the expression of autistic traits in the TD population taking part in the studies. Using the scores from the AQ, participants were divided in two groups with high vs low autistic traits.

In the first experimental chapter (chapter 2), I investigate whether the expression of autistic traits modulates perceptual biases towards global vs local features, as well as faces vs scenes (that are more or less salient), or rather whether they determine attentional selection and suppression processes regardless of stimulus type. First, a global-local task (from Mevorach, Humphreys & Shalev, 2009) developed in accordance to Navon (1977) was employed in order to investigate salience-based selection, when this was also mediated by global or local properties of stimuli in individuals with high vs low autistic traits. Secondly, a face-scene task (Abu-Akel, Apperly, Wood, Hansen & Mevorach, 2016), developed using the same structure as the global-local task (except for the inclusion of a 'neutral' condition where distractors were not present) was employed, in order to investigate selection and suppression mediated by faces vs scenes, also accounting for perceptual differences (neutral condition). Both tasks enabled the investigation of attentional selection and distractor suppression based on the relative salience of stimuli, which could facilitate (when the target was visually salient) or impair performance (when the distractor was salient), in a non-spatial task where certainty of target and distractor location would easily elicit proactive control of attention.

The contrast between attentional and perceptual differences was further investigated in Chapter 3 utilizing a morph-face task adapted from Rotshtein, Henson, Treves, Driver & Dolan (2005). Here I assessed whether differences in familiarity ratings of famous faces could explain group differences in high and low AQ, as familiar faces seem to elicit typical responses in ASD (Aylward et al. 2004; Pierce et al. 2004). I also used a face-categorization task to assess whether improved capacity to differentiate between faces is mediated by High and Low AQ. The rationale here is the attempt to assess whether differences between high and low AQ groups responding to faces is evident in low-level processing, when distractors were not present. Lastly, a distracting scene changing in contrast was added on top of the faces, measuring participants' contrast threshold for the distractor in order to evaluate capacity for distractor suppression. Higher contrast threshold corresponded to increased ability to suppress the distractor, and would be expected to be found in the group with more autistic traits if the ability to suppress distractors is enhanced in this population, linked to superior attentional abilities.

In this chapter, a question was also raised regarding different modes of attentional control and their influence on performance within the BAP: could it be possible that a bias towards proactive/preparatory control of attention contributes to enhanced performance in the High AQ group, whilst if reactive control was needed it would be detrimental? To answer this question, a second experiment was added investigating visual search in the BAP (from DiQuattro & Geng, 2011), using a spatial task in which participants could benefit from the addition of a high salient non-target to guide attention away from the distractor and towards the target, eliciting reactive control. If indeed more autistic traits in the TD population are associated with a bias towards proactive control, and impairments in reactive control, then performance in the morph-face task would be enhanced and no advantage from the salient distractor would be seen in the visual search task for participants with more autistic traits.

Changing the focus towards motor control in the third experimental chapter, it was investigated if findings in visual attention could also be present in movement, and if advantage (or disadvantage) in distractor suppression would translate to participants' performance when reaching for a target and ignoring distractors. Using a simple reaching task (same as Mevorach, Spaniol, Soden & Galea, 2016), I had participants reaching for a target initially without distractors (baseline). When distractors were added it was also measured if the availability (or lack) of visual feedback elicited differential effects on performance as a function of the individual traits. If there is a bias towards proactive control in the BAP, then differences in performance were expected to be found specifically when no visual feedback was available which promotes proactive processes of motor control.

In the final experimental chapter of this thesis I move to explore the possibility of attention intervention in autism, the rationale being that, if attentional differences are present in the BAP and especially in early ages in ASD, then an attention training program may be beneficial in children with ASD. I therefore carried out such an intervention with children with autism (6 to 10 years old), in a special and mainstream school setting for a total of 10 weeks including pre- and post-intervention assessments. The CPAT program mentioned above has been shown to induce non-trained improvements (e.g., in academic performance) in other clinical populations (Shalev et al., 2007; Kerns et al., 2010) and the present work represents the first attempt to use this program in ASD. Importantly, here too the focus was on identifying potential improvement in non-trained tasks and behavioural measurements including ASD symptoms (CARS; Schopler, Reichler, DeVellis & Daly, 1980), cognitive ability (Raven CPM – Raven, Raven & Court, 2008), academic performance (copying, maths and reading tests) as well as semi-structured interviews with class teachers and TA's. This study also included an active control group where readily available computer games were used in sessions of similar length, frequency and format.

Finally the results of the various chapters are brought together in the general discussion chapter (chapter 6) where I discuss possible explanations of the results and their relevance and implications for the general field of attention and ASD (and the BAP).

Chapter 2

High autistic traits in the typical population are associated with improved distractor filtering

Abstract

Attention and/or perceptual atypicalities are evident in autism and its broader phenotype, with reports highlighting a local-bias and difficulties in holistic processing, and altered attention allocation (e.g., towards faces). However, conflicting findings are also reported, as some studies document advantage in search tasks, discrimination and distractor suppression. In this chapter, we measured expression of autistic traits in over 200 neurotypical participants who performed two non-spatial attention tasks involving the identification of global-local (experiment 1) and a face-scene (experiment 2) stimuli. Thus, we were able to assess whether expression of autistic tendencies drives atypicalities in attentional processing irrespective of the type of visual input. Importantly, both tasks involved conditions of distractor competition so that the capacity to ignore distractors was assessed. Across the two experiments adults with high AQ (autistic traits) were overall better able to ignore distractors than adults with low AQ irrespective of the type of perceptual processing involved. In the global-local task the high AQ group exhibited smaller distractor interference for both global and local target identification and in the face-scene task participants in the high AQ group were also better able to ignore distractors, particularly when salient scenes had to be ignored. Critically, however, we found no evidence for perceptual difference between the groups. Results support the notion that autistic tendencies are associated with increased attention filtering and may reinforce the notion that such processes are atypical in ASD. [1]

[1] Chapter 2 is a manuscript in preparation for publication, collaborative work between the PhD student and supervisor, Spaniol and Mevorach; Spaniol contributions: Study conception and design; acquisition of data; analysis and interpretation of data; drafting of manuscript and revision.

Introduction

The world around us is comprised of complex information, and we must be able to actively select important and relevant aspects of our surrounding environment, while at the same time being able to ignore salient but irrelevant pieces of distracting information. This process is a part of our daily lives, for example when driving a car, we need to be able to ignore flashing billboard signs and attend to the road and traffic. As attention selection tends to follow bottom-up cues, certain situations require top-down attention selection to override such bottom-up signals (as in the billboard example above).

There are accounts of atypical top-down control of attention in children with ASD (Autism Spectrum Disorder), while bottom-up processing seems to be intact. In a study investigating top-down control of attention using a spatial-cuing task and a series of visual search tasks containing irrelevant distractors, it was found that children with autism had differences in top-down modulation, showing similar accuracy but no distraction (increase in reaction time) at the sudden onset of an irrelevant distractor, in contrast to controls (Greenaway & Plaisted, 2005). Riby and Hancock (2009) also found that an incongruent (social) stimulus did not capture the same level of attention from ASD participants. Although inhibition as a key component of executive function has inconsistently been found to be impaired in autism (Hill, 2004), advantage in visual search tasks is well documented in ASD, where faster reaction times and briefer fixations on distractors were reported (Joseph, Keehn, Connolly, Wolfe & Horowitz, 2009; Kemner, Ewijk, van Engeland & Hooge, 2008), suggesting more efficient top-down regulation and distractor suppression.

Although attention seems to be atypical in children and adults with ASD (Ames & Fletcher-Watson, 2010), a question arises whether such differences are mediated by the type of stimuli being perceived rather than differences in attention processes per se. For instance, Freeth, Foulsham and Chapman (2011) found that individuals with autism did not automatically fixate on faces as rapidly as controls. Not only did they take longer to direct attention towards faces, but also the pattern of attention allocation to face components was atypical (Klin et al., 2002). For instance, when recognizing emotions and differentiating between faces children with autism showed increased fixations on the mouth compared to TD (Typically Developing) controls, although performance on the task was comparable (Neumann, Spezio, Piven & Adolphs, 2006). Accordingly, they seem to have difficulties in judging complex information coming from the eyes, but not the mouth (Baron-Cohen, 1997) yet, when participants are instructed to differentiate between faces, performance is similar to controls (Adolphs et al., 2006; Humphreys et al., 2007).

There is also evidence that individuals with autism are captured by salient visual information as much as the non-clinical population, but differences are present when the information involves social content (Loth et al., 2010), although contradicting findings are also reported, where children with ASD showed similar fixation patterns towards pictures of faces and objects (Gillespie-Smith, Riby, Hancock & Doherty-Sneddon, 2013). Nevertheless, when TD participants are instructed to switch their attention from a distracting face to a different non-social target (top-down processing) the cost is higher, especially when the face is depicting an emotional state which is naturally salient, such as “fear” (Hsu & Pessoa, 2007). On the other hand, social stimuli do not seem to be naturally salient to participants with autism (Bird et al., 2006), who show a smaller cost when switching from faces to objects in comparison to the TD population (Kikuchi, Senju, Tojo, Osanai & Hasegawa, 2009). The authors found that changing task instructions (e.g. instruct fixation to the eyes) elicited typical responses from ASD participants, even when faces were involved (Kikuchi, et al., 2011; Kikuchi, et al., 2009). At the same time, adults with autism showed less distraction detecting a target and inhibiting a distracting face (Riby et al., 2009) in comparison to TD controls, possibly indicating not only less salience for social stimuli but also better inhibition.

Another example of possible perceptual differences that mediate attention behavior in autism relates to the preference sometimes documented in ASD for local processing. Participants with ASD seem to show an advantage when performing tasks requiring attention to details (Happé & Frith, 2006; Pellicano, Maybery, Durkin & Maley, 2006). While they are able to process the global level of information when required, they tend to show a preference or advantage when attention to local stimuli is needed (Koldewyn et al., 2013; Mottron & Belleville, 1993; Plaisted et al., 1999; Wang et al., 2007). Similarly, participants with higher self-reported autistic traits also seem to show an advantage when processing the local level, showing faster performance in the embedded figures test (EFT; Grinter et al., 2009). The same result was found amongst parents of children with autism, who showed faster reaction times in the same EFT task, showing that enhanced performance and possible local bias is also present in the broader autism phenotype (Bölte & Poustka, 2006). Similarly, in a study utilizing a task measuring biological motion processing, Van Boxtel and Lu (2013) found that participants with higher autistic traits were not automatically processing the global distractors present in the periphery, showing no differences in performance when a distracting motion figure was present, in contrast to the group with low autistic traits. It seems that the global information is not naturally salient to people with more autistic traits or ASD as it is for TD participants (Navon, 1977), although when directed to process and respond to global stimuli, they seem to demonstrate comparable performance to controls (Almeida et al., 2013; Wang et al., 2007). These results may suggest that a perceptual bias in people with ASD (and the Broader Autism Phenotype - BAP) might play a role in atypical bottom-up and top-down regulation in this population.

In contrast, the notion that a local bias lies at the heart of improved performance in the EFT task in autism was recently challenged by Almeida et al. (2013). They used a variation of the EFT task, but also asked their high/low autistic traits participants to perform additional visual search tasks that highlight either local or global aspects. Relative to low autism scores, participants with more autistic traits showed an overall advantage in the search task for both global and local levels, suggesting enhanced visual search ability (either global or local). Importantly, the authors also found that visual search performance was correlated with performance on the EFT task (Almeida et al., 2013). This suggests that performance differences in people with high vs. low autistic traits are not necessarily attributed to a local bias but rather to a general enhanced top-down visual search ability. Thus, this points to the ability to identify a predefined target in the context of non-target distractors as being mediated by ASD (and expression of autistic traits; Almeida, Dickinson, Maybery, Badcock & Badcock, 2010; Almeida et al., 2013; Bölte & Poustka, 2006; Van Boxtel & Lu, 2013). Such findings also raise the question of whether inhibition of irrelevant distractors might be an advantage in individuals with autism, and not only enhanced search ability or detail oriented processing, as previously suggested.

Taken together, these previous studies highlight the possibility that top-down attention selection and suppression in autism (and the broader phenotype) is indeed enhanced regardless of the type of perceptual processing (local or global) that is required. Their performance in these tasks seem to indicate enhanced visual search capacity, but also enhanced focus of attention, and potentially enhanced inhibition of distractors (or maybe a combination of these skills). Effectively, these findings highlight less distractibility by irrelevant information (Joseph et al., 2009; Kemner et al., 2008), which is not necessarily associated with differences in perceptual bias (e.g., Almeida et al., 2013).

To test these notions further, in the present chapter we assess whether target selection and distractor suppressions are enhanced in people with high expressions of autistic traits. We utilize two non-spatial top-down attention tasks in which the relative salience of the target and distractors are manipulated. To put together the concepts of perceptual differences (local bias/ social content) and attention differences in autism we used global and local displays (Experiment 1) and face and scene stimuli (Experiment 2) to tear apart perceptual differences. Specifically we ask: 1.Whether more autistic traits are associated with enhanced suppression of salient distractors, linked to improved attention? and 2. Is this capacity for suppression modulated by the level of processing required (global vs. local) or the social content of the stimuli (faces vs. scenes) linked to the perception of stimuli?

Autistic traits are present in the normal population in varying degrees and studies point to a genetic link between autism and autism-like traits. In a twin study, social traits related to autism were found to be common, continuously distributed and heritable, indicating that the cut-off for a disorder might be arbitrary (Constantino & Todd, 2003). Over the past decade, more research has been done investigating the mechanisms underlying the Broader Autism Phenotype (BAP), including instruments such as the Autism Quotient Test (AQ) measuring autistic traits (Baron-Cohen et al., 2001), and family members of persons with autism (Sucksmith, Roth & Hoekstra, 2011). Therefore, the AQ test will be used in this study to measure autistic traits in a relatively large cohort of TD participants in order to assess its relation to task performance.

Methods

Participants

Two hundred and eighteen healthy participants mainly UG psychology students from the University of Birmingham, ranging in age from 18 to 31 years old gave consent to participate in the study, being naïve to its purpose. The data initially consisted of 50 male and 168 female individuals, who were recruited through an online research participation scheme in exchange for course credit or a small cash reward. Participants were excluded from the study if they had a history of psychiatric illness, epilepsy, neurological disorders, had suffered brain injury or ever lost consciousness for more than five minutes. Also excluded were participants who performed at 50% accuracy or less on the global-local and the face-scene task. Based on these exclusion criteria, 7 participants were excluded from the global-local study, and 17 from the face-scene experiment. The data presented in this report is from the remaining 211 participants on the global-local task, and 201 participants on the face-scene task.

General Procedure

Participants signed a consent form, followed by a quick demographics questionnaire (approximately 5 minutes). Additionally, they had to complete a self-report questionnaire: the Autism-Spectrum Quotient - AQ (Baron-Cohen et al., 2001). After this, participants were presented with two computerized tasks: a global-local task, followed by a face-scene task. The session lasted 60 minutes overall. The study was approved by the Ethics Review Committee of the University of Birmingham. The questionnaire and experimental procedure and materials description follows bellow.

__The Global-Local Task__

In this task, participants had to respond to a global-local compound letter (Mevorach et al., 2009), which is an adaptation of the classic global-local task (Navon, 1977). They were asked to identify the global or the local elements of the figure (letters S or H) while ignoring information on the other level. In half the trials the compound figures were formed by the same letters (congruent displays) or two different letters (one was H and the other was S), which consisted the incongruent displays. The relative saliency of the global and local elements was also manipulated (figure 2.1A).

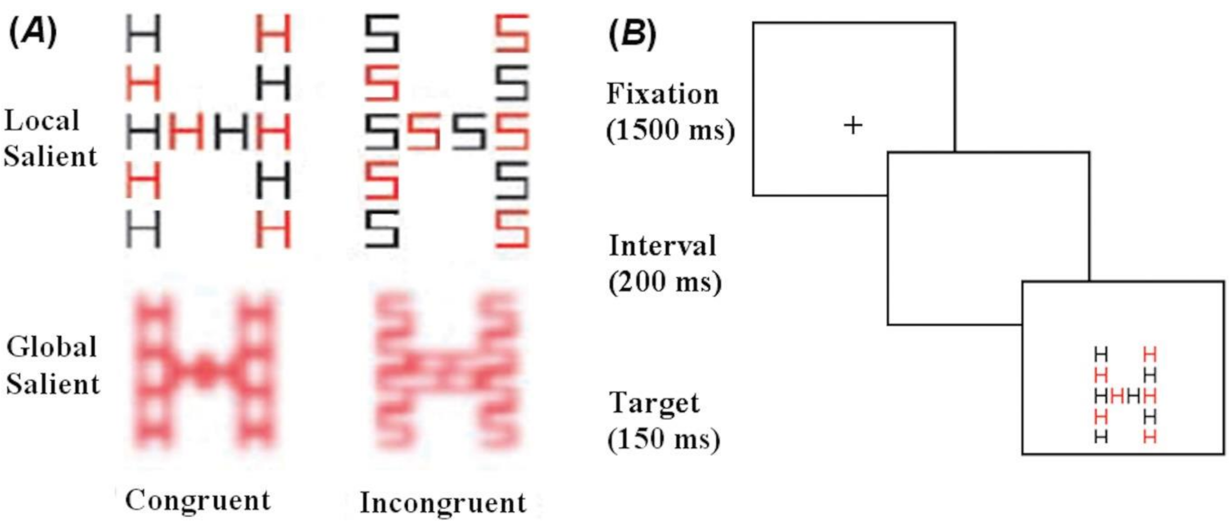

Figure 2.1: **2.1A.** Example of stimuli for the global-local task. **2.1B.** Typical display and sequence of the task.

Participants were seated approximately 60cm from a 17-inch monitor so that each centimeter on the screen represented ~0.96 degrees of visual angle. All the stimuli appeared against a black background.

Global-Local Stimuli

Two different displays were used: one with high global saliency and another with high local saliency. For both displays, the stimuli were created from the orthogonal combination of the letters H and S at the global and local levels. For the display with high local saliency, each stimuli contained red and white local letters. Local letters subtended a visual angle of 1.348° and 1.068° in width and height, respectively. The global letter subtended 8.268° and 5.388° of visual angle (in width and height, respectively). The inter-element distance was 0.388°. In the display with high global saliency, all the local letters were red. Each local letter subtended 1.348° and 1.068° of visual angle (in width and height, respectively) and the global letter subtended 5.668° and 4.518° of visual angle (in width and height, respectively). The distance between local elements was 0.968°. These letters underwent a blur procedure in Paint Shop Pro 7.0 with factor = 7. A white cross (0.578°) served as fixation and was presented in the center of the screen (Mevorach et al., 2009). The figures were not jittered so participants could perform the local task by fixating a fixed point/local letter, facilitating perceptual bias to local elements, if present in the BAP.

Global-Local Procedure

The global-local task consisted of 4 blocks containing 32 trials each for a total of 128 trials. The four blocks corresponded to the four possible conditions – 2 (identify the global or the local letters) x 2 (global salient or local salient displays). Blocking saliency and target controls predictability and does not require changes within a block, eliciting proactive/preparatory control of attention. Two seconds prior to the beginning of each block, instructions were presented on the screen to either detect the *local* level or the *global* level of the letters, while ignoring the other level. Participants had to respond to letters H or S by pressing the ‘K’ or ‘M’ keys on the keyboard respectively. Each trial began with a 1500 ms fixation cross presented against a black background. The stimuli then appeared for 100 ms following a 200 ms interval (figure 2.1B). Participants were asked to respond to the target letter as quickly and as accurately as possible. Key presses recorded the participants' responses in accuracy and reaction times. The task was presented using Presentation® (Neurobehavioral Systems, www.neurobs.com). Participants had a practice block before task initiation and a paper sheet with task instructions so visual information regarding the task was available before and during task execution to avert memory constraints and elicit proactive control.

The Face-Scene Task

The face-scene task was developed similarly to the global-local task. In this task, participants were required to identify either a face or a scene. Similarly to the global/local task, the relative saliency of the face and the scene was manipulated to induce 'scene more salient' and 'face more salient' displays. There were two possible faces and two possible scenes that were associated with two keys on the keyboard. To be consistent with the response keys from the global-local task, the two faces and two scenes were associated with the same response keys on the keyboard: 'K' and 'M', relabeled 'S' and 'H'. Accordingly, participants were required to associate the scene or the face with the corresponding letter (H or S; see figure 2A). These faces and scenes were superimposed onto each other (figure 2B) to manipulate saliency and congruency. Thus, (and similarly to the global/local task) each face/scene display could be congruent (both the face and the scene were mapped to the same response) or incongruent (the face and the scene were mapped onto competing responses). In contrast to the global/local task, here we also included a neutral condition. In the neutral condition, the face (or the scene) was presented together with a scrambled version of the scene (or the face) (2.2B).

To avoid memory constraints, a sheet depicting these associations was placed in front of the participant whilst performing the task (see figure 2.2A) and participants also had a short practice block before task initiation.

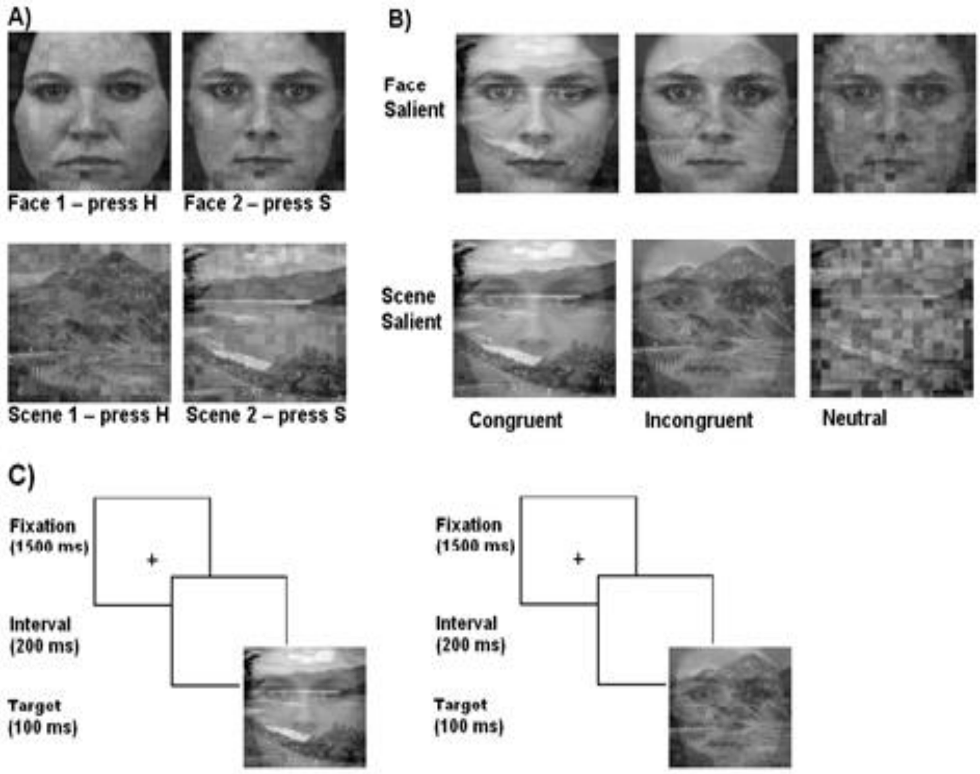

Figure 2.2: 2.2A. Stimuli used in the face-scene recognition task. **2.2B.** Faces and scenes in salient/non-salient, congruent/incongruent and neutral conditions. **2.2C.** Typical trial display sequence for congruent and incongruent stimuli.

Face-Scene Stimuli

The displays were all the same square size and subtended a visual angle of ~12.88^{O} horizontally and ~12.79^{O} vertically. The face and scene pictures (or scrambled version) were superimposed so that the opacity of one picture was set to 30% while the other was set to 70%. This created two types of displays – face salient (where the opacity of the face was set to 70%) and scene salient (where to opacity of the scene of set to 70%). To create the neutral condition each face and scene picture was divided into 288 squares that were then randomly repositioned to create a scrambled version. This scrambled picture was then combined with a target picture (e.g., a scrambled face was superimposed with a non-scrambled scene) using the same opacity values as above. The superimposed face/scene pictures were presented centrally.

Face-Scene Procedure

The task consisted of 12 blocks of 12 trials each for a total of 144 trials, equally divided for congruent, incongruent and neutral conditions. Four block types were used (which were randomly repeated three times) – 2 (identify face or scene) x 2 (face salient or scene salient displays). Each block was preceded with an instruction to either identify faces or to identify scenes. Similarly to the global/local task, blocking saliency and target controls predictability and does not require on-the-go or reactive changes within a block, thus eliciting proactive/preparatory control of attention. The instruction remained on the screen for 5 seconds. Each trial then began with a 1500 ms fixation cross, and following a 200 ms interval, the face/scene picture appeared for 100 ms (see figure 2.2C for a typical display sequence of congruent and incongruent stimuli). Participants were seated approximately 60cm from a 17” monitor, and were asked to identify the presented faces and scenes as quickly and as accurately as possible. Key presses recorded the participants’ responses and reaction times. The task was presented using Presentation® (Neurobehavioral Systems, www.neurobs.com).

The Autism-Spectrum Quotient Questionnaire (AQ)

The AQ questionnaire (Baron-Cohen et al., 2001), as outlined in chapter 1, measures the degree to which an adult with normal intelligence has traits associated with autism. It is considered, in this research, that autism lies on a *continuum* of social-communication disability, with non-clinical ASD traits on one side, and the former Asperger Syndrome as a bridge between the non-clinical population and autism spectrum disorder. In this case, the view about the disorder changes from a diagnostic criteria, to a quantitative approach on ASD, considered to be present in some degree in the non-clinical population.

The AQ is a self-administered instrument consisting of 50 questions, 10 assessing each different impaired area in ASD: social skills, communication, imagination, attention switching and attention to details. The items were selected from ASD symptoms and randomly distributed from items 1 to 50. Baron-Cohen et al. (2001) first tested the AQ in participants with Asperger syndrome (AS) or high-functioning autism, randomly selected controls, students from Cambridge University and winners of the UK Mathematics Olympiad. It was found that participants with AS scored significantly higher in comparison to controls. Men scored higher than women only in the control group and the group of scientists scored higher than the control group. The average score in the control group was 16.4. Eighty percent of those diagnosed with autism or a related disorder (including Asperger Syndrome) scored 32 or higher. From this first application, it is concluded that the AQ is a valid instrument to quantify where an individual stands on the continuum from autism to normality (Baron-Cohen et al., 2001).

The score ranged from 0 to 50, a higher score means prevalence of autistic traits, while lower scores show individuals with very low autistic traits. The AQ's internal consistency in this study was good (Cronbach's $\alpha = .82$), and was comparable to the values reported in other studies (e.g., Austin, 2005).

Data analysis

For both tasks, the inverse efficiency scores were used (reaction time (RT)/accuracy; Townsend & Ashby, 1983), generating an adjusted measure, AdjRT. This is recommended for tasks in which the accuracy is above 80%, allowing the use of reaction time and accuracy in one single measure and in accordance to previous studies using the same paradigms (Mevorach, Humphreys & Shalev, 2006a; Mevorach et al., 2009). Calculating the RT/proportion correct scores, allows us to combine reaction time and accuracy into a single measure (Townsend & Ashby, 1983) and should be used if high and linear correlations are evidenced between the RT and accuracy but not in the case of a speed-accuracy trade-off. Overall, accuracy was 96.5% and 92.3% for the global-local task and the face-scene task, respectively. All subsequent data was analyzed using the AdjRT with SPSS software. Accuracy and Reaction Time were also separately analyzed. The means and ± standard error of the mean (SEM) are reported. Significance level was set at $p<0.05$. Effect sizes are reported as partial eta squared (η_p^2) for ANOVAs and Hedges' g (Hedges, 1981; Hentschke & Stuttgen, 2011) for t-tests. This is a measure of effect size which is similar to Cohen's d but controls for different group sizes.

To evaluate differences in performance according to the quantity of autistic traits, initially, the participants' scores on the Autism Quotient (AQ) were independently divided in two groups with low and high autistic traits, using K-means cluster analysis on SPSS software. Cluster analysis is very useful in the process of organizing a heterogeneous sample into relatively homogeneous groups, especially for large quantities of information (Clatworthy, Buick, Hankins, Weinman & Horne, 2005). This enabled analysis to be carried out using the whole data set of participants. Also, grouping the AQs to its nearest mean guarantees each group is more similar to its own and different from the other group, making it a good representation of low vs high autistic traits in this population. Additionally, analysis was also carried out using quartiles and median split of the sample.

Results

Global-local task

First, the entire cohort was split into high and low AQ using K-clusters. We verified that the two groups did not differ in age ($t(209)=-1.54$, $p=.125$) or gender ($\chi^2= .62$, $df=1$, $p=.43$;

see Table 2.1 below).

Table 2.1: distribution of participants according to scores in the AQ, age and gender.

	ALL (N=211)	HIGH AQ (N=65)	LOW AQ (N=146)
Gender (males, females)	49, 162	16, 49	33, 113
Age mean (std. deviation**)**	21.53 (4.11)	21.55 (3.32)	21.51 (4.43)
AQ mean (std. deviation, range)	16.01 (6.35) 33	23.60 (4.05) 18	12.64 (3.73) 14

Accuracy, Reaction Time and AdjRT were analyzed using a repeated measures analysis of variance (ANOVA) with target level (global vs. local), saliency (target salient vs. distractor salient) and congruency (congruent vs. incongruent) as within subject factors and the AQ group membership (high AQ and low AQ) as between-subjects factor.

Adjusted RT (AdjRT)

The analysis revealed a main effect for congruency ($F(1,209)=416.2$; $p<.001$, $\eta_p^2=.66$) as participants were overall better at identifying the target in the congruent condition (555±9), versus the incongruent (636±8.5; figure 2.3). There was also a main effect for saliency ($F(1,209)=263.34$; $p<.001$, $\eta_p^2=.56$), as performance was overall better when the target was salient (558±9) in comparison to distractor salient displays (633±9). There was no main effect for level, showing that participants had no level bias but were influenced by the manipulation of salience and congruency.

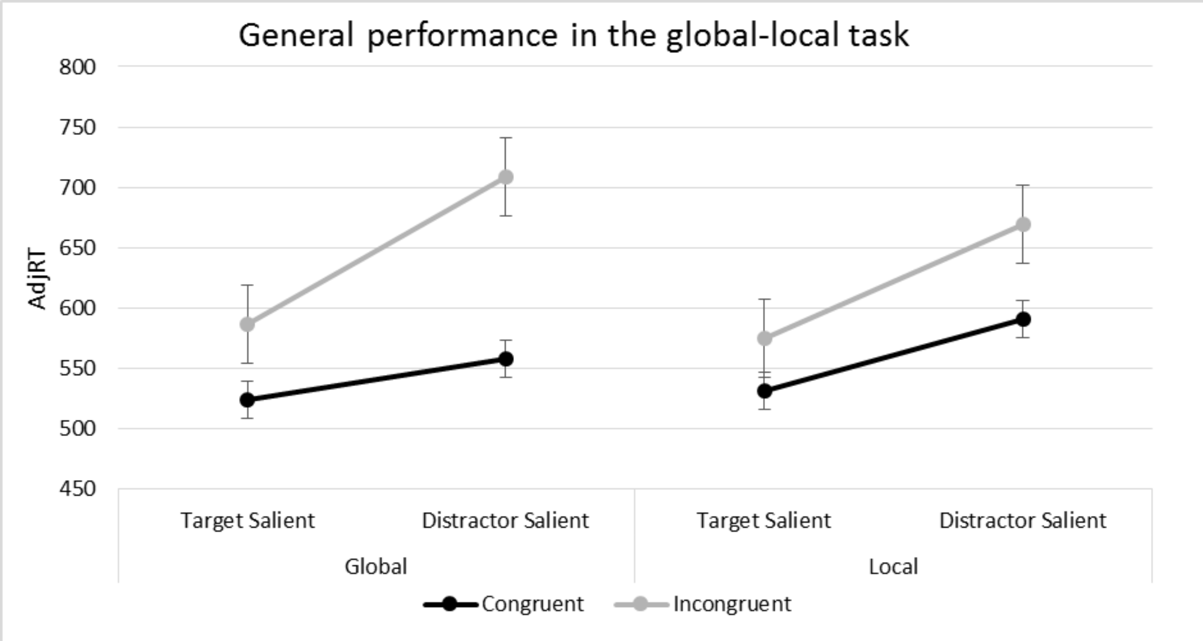

Figure 2.3: Overall performance for the global-local task, showing the mean AdjRT (±SEM) for congruent (black) and incongruent (light grey) conditions. Data are presented for the global and local target level and the relative salience (target or distractor salient).

A significant two-way interaction between congruency and level ($F(1,209)=50.37$; $p<.001$, $\eta_p^2=.194$), was found driven by a larger congruency difference (incongruent – congruent conditions) in the global compared to local target level (103±9 AdjRT and 58±9 AdjRT; for global and local, respectively; $t(210)=6.5$, $p<.001$). There was also a significant interaction between saliency and congruency ($F(1,209)=84.82$; $p<.001$, $\eta_p^2=.29$), driven by a smaller congruency effect when the target was salient (50±9 AdjRT) than when the distractor was salient (111±9 AdjRT, $t(210)=-10.4$, $p<.001$; similar to findings from Mevorach at al., 2009 utilizing the same task). There was also a significant interaction between level, saliency and congruency ($F(1,209)=12.35$; $p=.001$, $\eta_p^2=.056$). To test whether this interaction was driven by differences in the congruency effect we repeated the ANOVA using the congruency effect as the dependent measure. This analysis revealed an interaction between target level and saliency ($F(1,209)=12.35$; $p=.001$, $\eta_p^2=.056$). This 2-way interaction was driven by an increased effect of saliency on the congruency effect for the global target (146±11 and 61±9 for distractor salient and target salient, respectively) compared to the local target (38±10 AdjRT and 76 AdjRT±11, target to distractor salient, respectively). Thus the effect of saliency was bigger in the global condition ($t(210)=-4.33$, $p<.001$; figure 2.3).

More interestingly, there was an interaction between AQ groups and congruency ($F(1,209)=5.03$; $p=.026$, $\eta_p^2=.023$). Simple effects identified a significant difference between groups in the congruency effect (incongruent – congruent conditions), showing that the high AQ group exhibited a smaller congruency effect (72±6 AdjRT) in comparison to the group with less autistic traits (89±4 AdjRT; $t(209)=2.24$, $p=.026$, $G_{Hedges}=0.33$; figure 2.4). There were no other main effects or interactions involving the group factor.

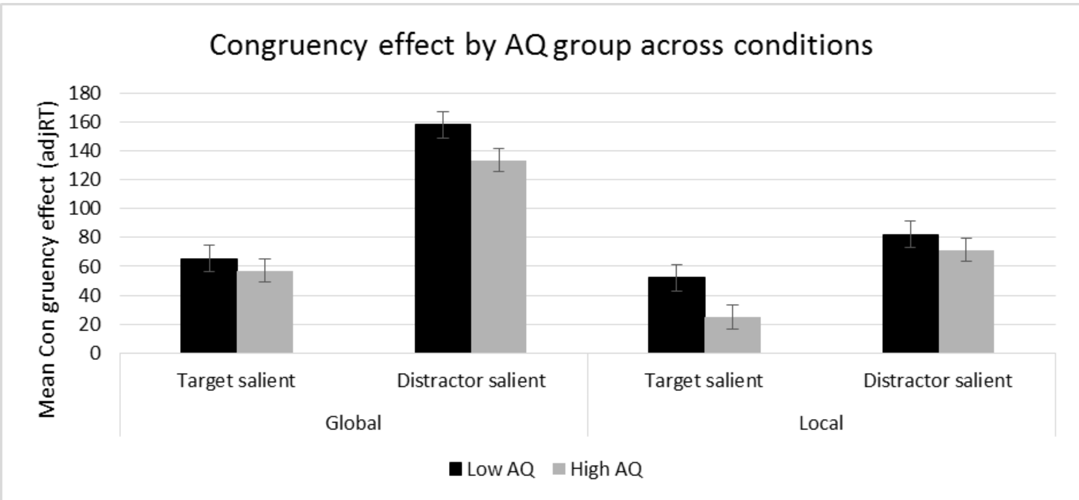

Figure 2.4: Congruency effect in AdjRT **(**±SEM**)** for the two AQ groups is shown for target level and relative saliency. Low AQ group (black) has an increased congruency effect in all conditions, in comparison to the high AQ group (grey*)*.

To further ascertain the link between autistic traits and distractor suppression we calculated the correlation between the overall AQ scores and the overall congruency effect in this task (figure 2.5). We found a small but significant negative correlation ($r=-.154$; $n=211$;

p=.026) supporting the notion that higher autistic traits were associated with reduced interference from the distractor level (a smaller congruency effect). In order to assess if any particular AQ subscale was driving this association we also calculated correlations between each subscale of the AQ and the congruency effect. However, there were no significant correlations between any of the AQ subscales and the congruency effect in this task.

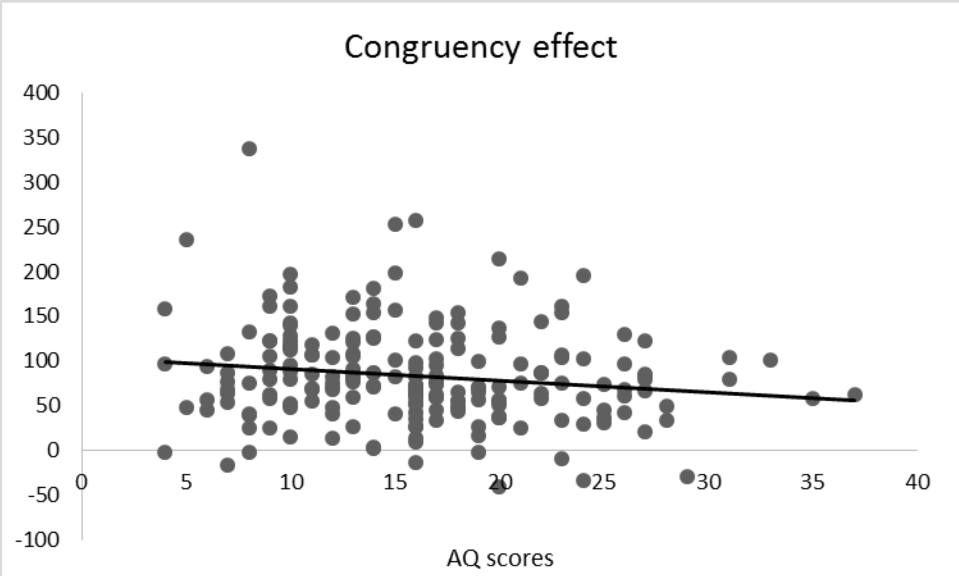

Figure 2.5: Correlation between overall AQ scores and congruency effect (AdjRT, p=.026), showing the data for all participants.

In addition, to ascertain that the way the groups were construed did not affect the main findings we repeated the analysis using either a median split (N=211, N: high AQ=105; N: low AQ=106) or comparing the bottom and top quartiles (N=114, N: high AQ=57; N: low AQ=57). Critically, similar effects were obtained across the different group formation techniques ($F(1,209)=5.56$; $p=.019$, $\eta_p^2=.026$ and $F(1,112)=3.74$; $p=.055$, $\eta_p^2=.032$ for the interaction between AQ group and congruency, for median split and quartiles split, respectively).

Accuracy

The analysis revealed a main effect for congruency ($F(1,209)=71.05$; $p<.001$, $\eta_p^2=.254$) showing that participants were better at responding to the congruent displays (.98±.002) in comparison to the incongruent condition (.95±.005). There were two-way interactions between level and saliency, saliency and congruency and level and congruency that were further qualified by a three-way interaction between level, saliency and congruency ($F(1,209)=13.75$; $p<.001$, $\eta_p^2=.062$). To tear apart the effects, separate 2x2 ANOVAs (level x saliency) were run on congruent vs incongruent conditions. While there was no interaction coming from the congruent condition (saliency and level $p=.985$), the interaction between level and saliency was significant for the incongruent displays ($F(1,209)=18.31$; $p<.001$, $\eta_p^2=.081$). To ascertain whether the effect was coming from the global or local level, the saliency difference was calculated for each target level (target salient minus distractor salient) and analyzed using a paired sample t-test. Results show that the saliency difference was more pronounced for the incongruent display in the global level (.03±.006) in comparison to the local level (-.01±.005) ($t(210)=5.24$, $p<.001$), similar to findings in the AdjRT.

In regards to group effects, there was an interaction between level, saliency and AQ groups ($F(1,209)=4.05$; $p=.046$, $\eta_p^2=.019$) and saliency, congruency and AQ group ($F(1,209)=5.19$; $p=.024$, $\eta_p^2=.024$). To further investigate this interaction, partial ANOVAs were run in target salient vs distractor salient conditions. There was no interaction between congruency and AQ group in the target salient condition ($F(1,209)=.004$; $p<.9506$, $\eta_p^2=.000$), but there was an interaction of congruency and group for the distractor salient condition ($F(1,209)=5.97$; $p=.015$, $\eta_p^2=.028$). To ascertain the origins of this effect, simple analysis using independent sample t-test were run in the congruent, distractor salient vs incongruent distractor salient conditions. While the effect was non-significant for the congruent, distractor salient condition ($t(209)=-.095$, $p=.925$), the group with more autistic traits showed better performance when responding to the distractor salient, incongruent condition (.96±.006) in comparison to the low AQ group (.93±.006) ($t(209)=-2.41$, $p=.017$), exhibiting again enhanced distractor suppression regardless of target level.

Reaction Time

Reaction time analysis reveal a main effect of congruency ($F(1,209)=592.3$; $p<.001$, $\eta_p^2=.74$) showing that participants were overall faster when responding to the congruent (544 ±9 ms) in comparison to incongruent conditions (600 ±9 ms). There was also a three-way interaction between level, saliency and congruency ($F(1,209)=72.6$; $p<.001$, $\eta_p^2=.26$).

Most importantly, there was a group interaction with level ($F(1,209)=5.24$; $p=.023$, $\eta_p^2=.024$), and the interaction between congruency and AQ groups approaches significance ($F(1,209)=3.8$; $p=.053$, $\eta_p^2=.018$), similar to findings within the AdjRT. An independent sample t-test on level difference (global – local level) shows that the group with more autistic traits shows a smaller level difference, taking longer to respond to the global condition (9.3 ±7 ms), while the group with low autistic traits showed the opposite effect, taking longer to respond to the local level and faster responses to the global condition (-9.5 ±4 ms; $t(209)=-2.29$, $p=.023$), exhibiting a larger difference between the levels.

Face-scene task

A repeated measures analysis of variance (ANOVA) was conducted with target (face, scene), saliency (target salient, distractor salient) and congruency (congruent, incongruent and neutral conditions) as within subject factors and AQ group (high and low AQ) as a between subjects factor. AQ groups were again divided into high and low autistic traits using a K-means cluster analysis (table 2.2). There were no group differences in age or gender ($t(199)=-.614$, $p=.54$; $\chi^2=.194$, df=1, $p=.65$, respectively).

Table 2.2: Distribution of participants according to scores in the AQ, age and gender.

	ALL (N=201)	HIGH AQ (N=66)	LOW AQ (N=135)
Gender (males, females)	43, 158	15, 51	28, 107
Age mean (std. deviation)	21.38 (4.31)	21.65 (3.73)	21.24 (4.58)
AQ mean (std. deviation, range)	16.32 (6.38) 33	23.59 (4.06) 18	12.76 (3.74) 14

Adjusted Reaction Time

A statistically significant main effect of target indicated that participants were generally better at responding to the scenes compared to the faces (626±9 AdjRT and 752±18 AdjRT respectively; $F(1,199)=49.46$; $p<.001$, $\eta_p^2=.199$). A main effect of saliency was also obtained as participants performed better when the target was salient in comparison to when the distractor was salient (579±8 AdjRT and 799±16 AdjRT respectively, $F(1,199)=312.52$; $p<.001$, $\eta_p^2=.611$), and performance was also affected by congruency ($F(2,398)=45.21$; $p<.001$, $\eta_p^2=.185$) as participants were generally worse for the incongruent displays (760±16 AdjRT), in comparison to congruent (653±11 AdjRT; $t(200)=-8.32$, $p<.001$) and neutral (661±9 AdjRT; $t(200)=8.41$, $p<.001$) conditions. There were significant 2-way interactions between target and saliency ($F(1,199)=36.31.53$; $p<.001$, $\eta_p^2=.154$) target and congruency ($F(2,398)=33.3$; $p<.001$, $\eta_p^2=.143$) and saliency and congruency ($F(2,398)=38.32$; $p<.001$, $\eta_p^2=.161$). However, they were further qualified by a three-way interaction between target, saliency and congruency ($F(2,398)=28.93$; $p<.001$, $\eta_p^2=.127$), figure 2.6. To further investigate this three-way interaction, we repeated the ANOVA using the salience cost (distractor salient- target salient) as the dependent measure. Results show a significant interaction between congruency and target level ($F(2,398)=29.93$; $p<.001$, $\eta_p^2=.127$), indicating that the salience cost was affected by the congruency change more so in the face task but not in the scene task. The saliency difference was more pronounced for the face displays when the response was incongruent

(526±44 AdjRT) in comparison to salience difference in the neutral or congruent conditions (neutral: 196±13 AdjRT; t(200)=7.97, p<.001; congruent: 203±25 AdjRT t(200)=-7.23, p<.001). The same significant differences were found for the scenes, between congruent (109±10 AdjRT) and incongruent conditions (153±16 AdjRT; t(200)=-2.97, p=.003) and congruent and neutral (160±11 AdjRT) but the same differences were not present between congruent and neutral displays for faces (p=.75) or between incongruent and neutral conditions for the scenes (p=.63).

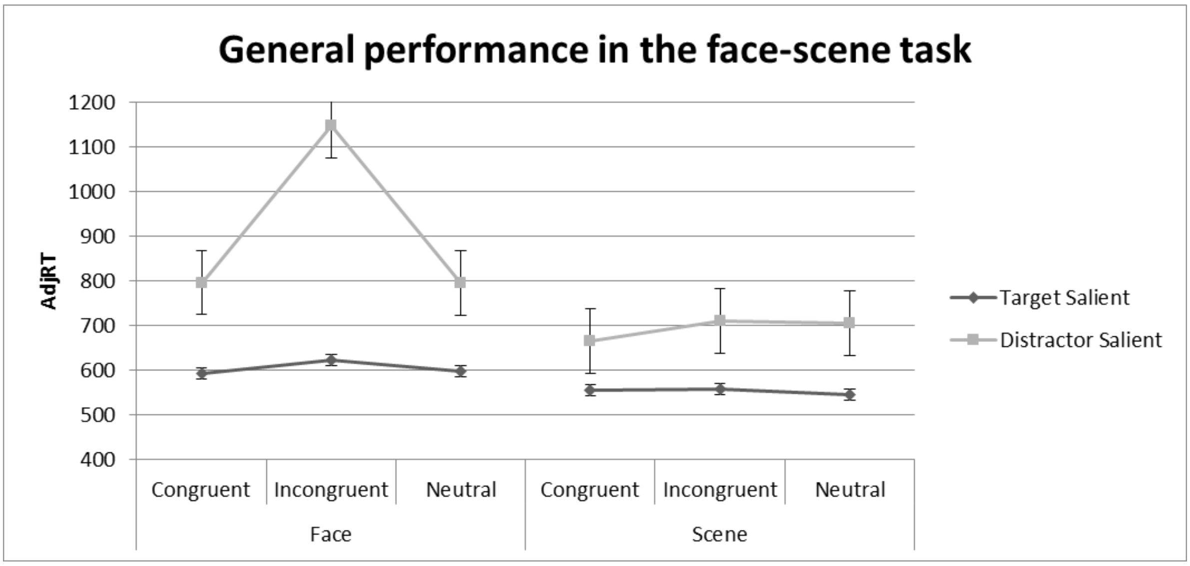

Figure 2.6: General performance in the face-scene task. Mean AdjRT **(**±SEM**)** data are presented for the distractor salient (light grey) and target salient (dark grey) conditions, distributed across target (face and scene) and congruency (congruent, incongruent and neutral displays).

Interestingly, the group factor interacted significantly with congruency (F(2,398)=3.3; p=.038, η_p^2=.016), with target and saliency (F(1,199)=5.27; p=.023, η_p^2=.026) and with target and congruency (F(2,398)=4.9; p=.008, η_p^2=.024). Importantly, however, these interactions were further qualified by a 4-way interaction of group, target, saliency and congruency (F(2,398)=4.61; p=.011, η_p^2=.023).

To further investigate this interaction partial ANOVAs were conducted with face and scene targets separately. While the ANOVA for scene target revealed no significant interaction of group, saliency and congruency ($F(2,398)=1.26$; $p=.285$, $\eta_p^2=.006$), this interaction was significant for the face targets ($F(2,398)=3.38$; $p=.035$, $\eta_p^2=.017$). This 3-way interaction was then further investigated using partial ANOVAs on target salient and distractor salient conditions separately. It was then established that a group by congruency interaction was only evident for distractor salient displays ($F(2,398)=4.04$; $p=.018$, $\eta_p^2=.020$) but not for target salient displays ($F(2,398)=1.59$; $p=.205$, $\eta_p^2=.008$). Multiple comparison analysis tests were then conducted using t-tests, pairwise comparisons revealed that in the incongruent condition the high AQ group performed significantly better (1002±46 AdjRT) than the low AQ group (1220±69 AdjRT; $t(198.6)=2.64$, $p=.009$, $G_{Hedges}=0.33$) but there was no difference for congruent ($t(199)=.466$, $p=.642$) or neutral ($t(199)=.375$, $p=.708$) displays between the groups (see figure 2.7).

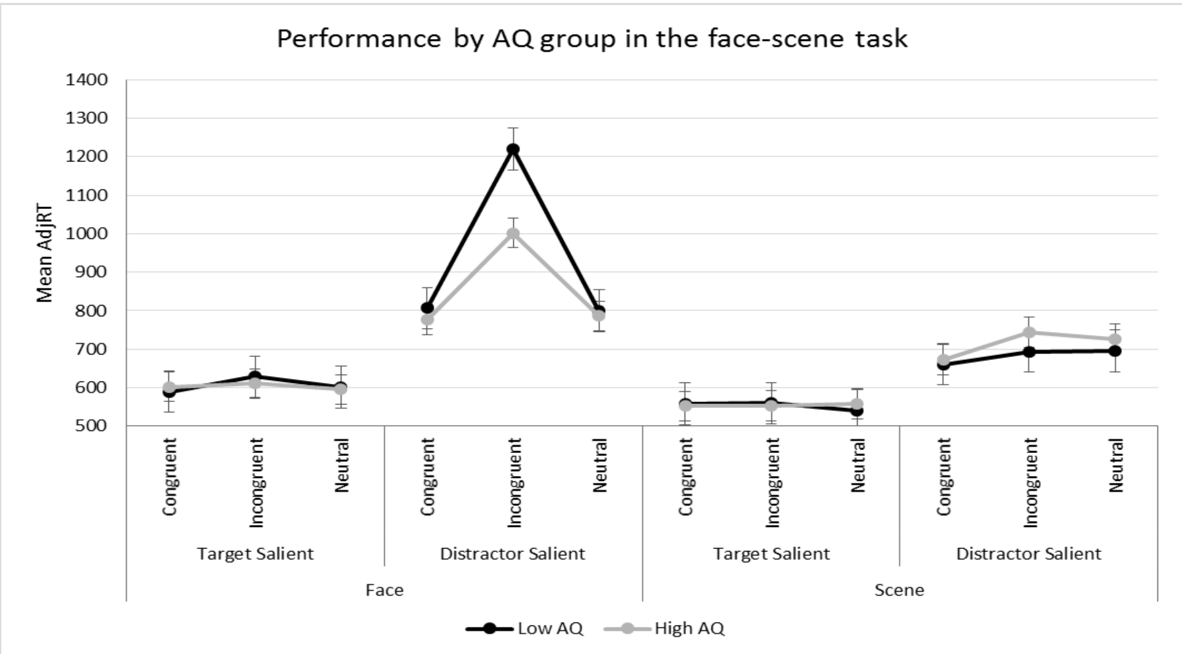

Figure 2.7: Performance (Mean AdjRT ±SEM) for high and low AQ group in the face-scene task. The high AQ group (grey) performed significantly better when discriminating between the faces in the incongruent condition, when the irrelevant scene was more salient.

The same analysis was carried out using quartiles to divide the groups into high and low autistic traits (N=102, 51 participants in each group). There were also significant interactions between AQ groups and target and congruency ($F(2,200)=3.28$; $p=.039$, $\eta_p^2=.032$) and saliency, congruency and AQ groups ($F(2,200)=3.57$; $p=.030$, $\eta_p^2=.034$). When median split was used to divide the sample, the same interactions still approached significance (AQ groups, target and congruency: $F(2,398)=2.55$; $p=.079$, $\eta_p^2=.013$; and saliency, congruency and AQ groups: $F(2,398)=2.85$; $p=.059$, $\eta_p^2=.014$). Although the same 4-way interaction was not found, the 3-way interactions that were still meaningful pointed towards the same results found using the K-cluster.

As the congruency difference in the previous task correlated with the AQ scores, here too, we further investigated the link between autistic traits and distractor suppression by calculating a correlation between the overall AQ rates (as well as the subscales) and the congruency effect. Although the overall AQ scores did not correlate significantly with the overall congruency effect in this task ($r=-.088$; $n=201$; $p=.213$), a small but significant negative correlation was found using the "attention to details" AQ subscale ($r=-.140$; $n=201$; $p=.047$), pointing to a possible link between the ability to inhibit the distractor and enhanced attention to details in this task (figure 2.8). The neutral condition did not correlate to the overall AQ score ($r=.035$; $n=201$; $p=.621$), indicating no perceptual biases when no distractors were present. The specific condition in this task found to significantly interact with AQ groups (face, distractor salient incongruent condition) did not correlate with the AQ scores nor its subscales in this task.

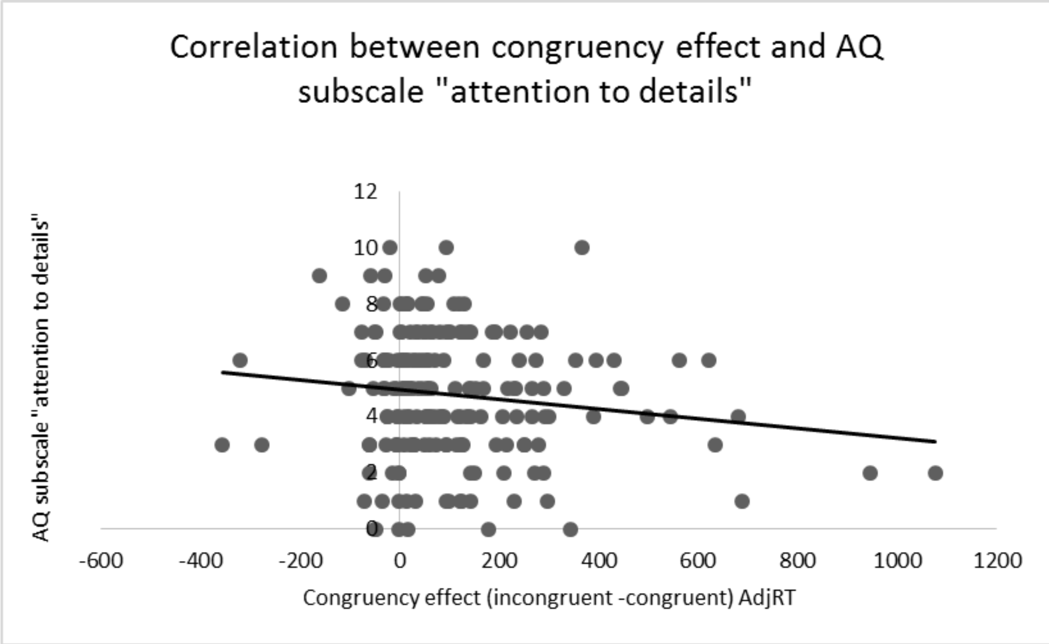

Figure 2.8: Correlation between congruency effect (AdjRT) and the AQ subscale "attention to details" (p=.047), showing the data for all participants.

Accuracy

Accuracy analysis revealed a main effect of target (F(1,199)=62.92; p<.001, η_p^2=.24), saliency (F(1,199)=195.5; p<.001, η_p^2=.5) and congruency (F(2,398)=40.8; p<.001, η_p^2=.17) and a three-way interaction between target, saliency and congruency (F(2,398)=28.6; p<.001, η_p^2=.126), similar results to the corrected measure (AdjRT). There was an interaction between AQ groups and congruency (F(2,398)=4.81; p=.009, η_p^2=.024) and target, saliency and AQ groups (F(1,199)=4.63; p=.033, η_p^2=.023), also similar to findings in the AdjRT although the four-way interaction was not present within the accuracy alone. Independent sample t-tests show that the group with more autistic traits performs better than the low AQ group when responding to the incongruent condition (t(199)=-2.07,p=.040; .91±.01 and .88±.007, respectively), but no differences in the congruent or neutral conditions (both ps>.3), supporting the notion of enhanced distractor suppression in individuals within the BAP, also evidenced in the AdjRT.

Reaction Time

There was a main effect of target ($F(1,199)=57.43$; $p<.001$, $\eta_p^2=.224$), saliency ($F(1,199)=617.9$; $p<.001$, $\eta_p^2=.756$) and congruency ($F(2,398)=17.35$; $p<.001$, $\eta_p^2=.080$) in reaction time, and a three-way interaction between target, saliency and congruency ($F(2,398)=17.57$; $p<.001$, $\eta_p^2=.081$), similar to results from the AdjRT. There were no interactions between AQ groups and the conditions of this task in reaction time performance.

Discussion

In this study we aimed at investigating whether high or low rates of autistic traits in TD participants will modulate top-down attention control (distractor suppression) and whether this will be dependent on the type of stimuli used (local processing or social content). Overall and across the two experiments, we found that participants exhibiting higher expressions of autistic traits showed *increased* ability to filter out distractors, which was manifested in a smaller interference effect for the high AQ group. Thus, these results point to atypical *enhanced* top-down control of attention in the BAP.

While previous studies also pointed to a benefit in top-down attention control in ASD and the BAP when it comes to distractor suppression (e.g. Greenaway & Plaisted, 2005; Joseph et al., 2009; Kemner et al., 2008), a possible explanation for such performance differences was associated with the type of stimuli that was used. For instance, it is plausible that participants with ASD are better at ignoring faces than TD ones because they are less sensitive to the social content available in the faces (Bird et al., 2006; Freeth et al., 2011; Kikuchi, et al., 2009; Klin et al. 2002; Loth et al., 2010; Neumann et al., 2006). Similarly, participants with ASD may be better at processing local than global information compared to controls (or to people with low expression of autistic traits) and therefore will exhibit a reduced interference from global information (Happé & Frith, 2006; Koldewyn et al., 2013; Mottron & Belleville, 1993; Pellicano et al., 2006; Plaisted et al., 1999; Van Boxtel & Lu, 2013; Wang et al., 2007). This was found within the reaction time in the global-local task, where the high AQ group took longer to respond to the global level exhibiting a smaller difference between target levels, in contrast to the low AQ group, which showed increased reaction times in the local target level. However, our findings partially challenge this conjecture (at least within the BAP). In Experiment 1 participants had to ignore either the global or the local aspect of a compound letter, under conditions of high local or high global salience. Importantly, performance differences between the low and high AQ groups held across both local and global processing – in both cases participants with high AQ showed reduced distractor interference. Similarly in Experiment 2 participants had to ignore a face while responding to a scene (or ignore a scene while identifying a face). If differences in performance are associated with processing the faces in this task we would have expected the high AQ group to be better at ignoring the faces (which are potentially less salient to them) but at the same time be potentially worse at identifying the faces while ignoring the scenes. In fact, our findings were an almost complete opposite. There were no group differences when participants were asked to identify the scene and to ignore the face. In contrast, a substantial difference between the groups was evident when participants were identifying the face and ignoring the scene, as participants in the high AQ group were considerably better at ignoring the distractor scene (especially in the incongruent condition). This is further supported by the accuracy analysis, where participants with more autistic traits exhibited higher accuracy for the incongruent condition. Thus, once again our high AQ group outperformed the low AQ group and showed reduced distractor interference which could not be explained by reduced sensitivity to social content.

Further support for the notion that performance differences in the groups were not attributed to perceptual differences come from the neutral condition in Experiment 2. While in experiment 1 perception of one level was always interleaved with perception of the other, in the neutral condition of Experiment 2 faces and scenes were coupled with noise images. If perceptual differences between the groups existed, they should have been manifested in the neutral condition. However, we found no evidence for such a difference across both face and scene stimuli. Thus, we argue that the findings in the two experiments point to an enhanced ability to ignore distractors (top-down control) in the group with high expression of autistic traits which is not dependent on the type of stimulus that needs to be ignored. These findings are in accord with recent research by Almeida et al. (2013) who also argued for an enhanced visual search capacity in this population which is not related to local processing advantages.

Atypical (but improved) attention selection and distractor filtering in autism was also recently described by Robertson, Kravitz, Freyberg, Baron-Cohen & Baker, (2013), who suggested that a sharper focus of spatial attention could explain improved performance. Measuring the spatial extent of the attention focus in autism, Robertson et al. (2013) documented a sharper spatial focus of attention, limited to the proximity of stimuli, with performance decreasing rapidly as exogenous spatial cues appeared further away from the target. Such a finding could explain superior performance in search, where detail-oriented processing can be beneficial, as a sharper gradient of attention could facilitate the inhibition of surrounding distractors, as well as interference from incongruent stimuli (Robertson et al., 2013). The finding we present here however, suggest that this sharper gradient of spatial attention may also translate to non-spatial selection as our high AQ participants were better able to focus on the target aspect in a non-spatial selection task (e.g., when responding to the global aspect and ignoring the local elements in Experiment 1, or when selecting the face and ignoring the superimposed scene).

Another noteworthy aspect of the present design was the orthogonal manipulation of the perceptual salience of target and distractor elements of the stimuli (so that either the target or the distractor could be salient). While performance differences between the groups were not affected by the relative salience in the AdjRT in Experiment 1, the high AQ group exhibited increased accuracy in both global and local levels when the distractor was salient, and the response incongruent. An interaction with salience also emerged in Experiment 2 (where performance differed specifically when a salient scene had to be ignored). Thus, our findings in the AdjRT in the global-local task (Experiment 1) fit with previous findings (e.g., Freeth et al., 2011) showing similar effects of salience in both ASD and TD, even when stimuli involved socially relevant information such as “heads”. In contrast, the findings we report in the accuracy in the global-local and in the face-scene task (Experiment 2) indicate a greater ability to ignore distractors in high AQ, particularly when they are more salient. Such a finding is also in accord with previous findings in ASD (Greenaway & Plaisted, 2005; Joseph et al., 2009; Kemner et al., 2008), showing that ASD individuals performed better and were less influenced by distractors. As several obvious methodological differences exist between the two experiments used here it remains an open question why salience played a more pronounced role in Experiment 2 compared to Experiment 1. Perhaps only when task demands are higher, group differences emerge (e.g. in the face-scene task, faces were significantly more difficult to identify in comparison to scenes). Importantly, however, the performance differences we documented in both experiments point towards more effective top-down control of attention in participants with higher expression of autistic traits (Almeida et al., 2010; Almeida et al., 2013).

In addition to significant group effects, we also found significant (albeit modest) individual difference effects. In both tasks the overall AQ score and attention to details correlated negatively with interference measures, supporting the notions that increased expression of autistic traits is associated with enhanced ability to suppress distractors (irrespective of their nature). In addition, the negative correlation in the face-scene task between distractor interference and the AQ subscale of “attention to details” raises the possibility that the difference in performance might be linked to an ability to better identify the target-defining features (Happé & Frith, 2006; Koldewyn et al., 2013; Mottron & Belleville, 1993; Pellicano et al., 2006; Plaisted et al., 1999; Wang et al., 2007). This is in accordance with Davis et al. (2016), as in this study the authors also found the AQ subscale "attention to details" to be related to increased ability to recognize faces, linking enhanced performance to the attention subdomain in the BAP. As a strategy, perhaps increased attentional focus to small details of the faces (e.g. the eyes or the mouth; Baron-Cohen, 1997; Klin et al., 2002; Neumann et al., 2006) might have aided enhanced performance when differentiating between two highly similar faces. Indeed, enhanced performance when discriminating between faces has been documented in ASD (Adolphs et al., 2006; Humphreys et al., 2007) as well as enhanced processing of face parts (Lahaie et al., 2006). Against this possibility, however, stands the finding we report here that when no distractors where present (in the neutral condition) there was no group difference in performance. In addition, 'attention to details' scored did not correlate with performance in the neutral condition. This strengthens the notion that autistic-like traits (including attention to details) are specifically associated with top-down control of attention under conditions of competition from distractors. Thus, detail oriented attentional focus might contribute to guiding attention to the target whilst ignoring a distractor. In fact, it is plausible that both the attention to detail trait and the improved ability to suppress distractors are associated with increased attentional selectivity in the high AQ group.

In contrast to the findings we report here, previous research in ASD and the BAP has also pointed to increased distractor interference or increased sensitivity to salience seen in over-selectivity in this population in certain conditions (Leader, Loughnane, McMoreland & Reed, 2009). For instance, in a recent study using EEG to record brain potentials, Dunn, Freeth and Milne (2016) identified reduced Pd (which is thought to represent distractor suppression) in individuals with high autistic traits compared to those with low rates of autistic traits. This also fits with other finding suggesting a failure of participants with ASD to suppress a salient distractor (e.g., Russell, Mauthner, Sharpe & Tidswell, 1991) or examples where behavior is dominated by the salient stimulus in ASD (e.g., Leader et al., 2009). While the reason for such discrepancy between previous findings is outside the focus of the current chapter and while various methodological differences across studies can be identified, we can still speculate about a specific possible difference which is noteworthy. Namely, in both tasks in this study, full information of what constitutes a target and a distractor was given in advance (before each block of trials). As such participants in our study could have used top-down control in a preparatory manner (c.f., Mevorach et al., 2009 for the contribution of the left parietal cortex to such a preparatory process). Indeed, previous research has shown that when encouraged to use such control – for instance when given full instruction regarding which part of a face to attend to, atypicalities in face processing in ASD can be overcome (Kikuchi, et al., 2011; Kikuchi, et al., 2009). Similarly, in Dunn et al. (2016) the reported smaller Pd amplitude associated with reduced distractor suppression was evidenced later on in the process – 200 ms after stimuli presentation, which suggests a measure of reactive suppression rather than a preparatory one. It is therefore plausible to speculate that increased distractor suppression (as we report here) in ASD (or BAP) is particularly associated with enhanced preparatory top-down control, but that when more reactive control is called for (such as when participant need to voluntarily switch from one element to another) performance is impaired. This idea will be explored further in the next chapter of this thesis.

This study has some limitations. Given that participants in this study do not meet diagnostic criteria for ASD, the attentional mechanisms and atypicalities found in individuals with ASD might not be present, at the same level. However, the AQ questionnaire is an instrument that evaluates autistic traits on a continuum from autism to normality, therefore the results presented in this research provide valuable insights into how autistic traits affect performance on global-local processing and faces and scenes selection, whilst inhibition of irrelevant distractors is needed. Looking at individuals that show subclinical traces of autism presumes that the same traces are shared, although in a milder form, in comparison to ASD. Also, it allows research to be done including a larger number of participants and utilizing tasks that otherwise would not be suitable for the clinical population. In addition, the majority of our participants were females (recruited from the Psychology undergraduate course). Autism is more prevalent in males, and research in face processing in the BAP, for example, points towards differences found in males, but not females when processing faces (Rhodes, Jeffery, Taylor & Ewing, 2013, Wilson, Freeman, Brock, Burton & Palermo, 2010, Halliday, MacDonald, Sherf & Tanaka, 2014). It is therefore possible that if more male participants were included in this study, higher contrast between the groups in task performance (especially within faces) might be found.

We conclude that our findings suggest that people with a higher expression of autistic traits demonstrate an enhanced distractor filtering and attentional focus irrespective of the type of stimulus that needs to be selected or suppressed. As such, it challenges some previous conjectures that performance differences in ASD and BAP are associated with atypicalities in local/global processing or reduced sensitivity to social stimuli. In the next chapter we attempt to further investigate this idea by measuring performance difference when distractors are present or absent. Furthermore, we also investigate whether the filtering benefit for high autistic traits we find here disappears when suppression cannot be achieved through a preparatory top-down mechanism.

Chapter 3

Preparatory and reactive suppression in individuals with high autistic traits

Abstract

Previously reported attention atypicalities in both ASD and the broader phenotype in neurotypical participants have highlighted both increased attentional capacities (e.g., when distractor faces are more easily ignored) and reduced ones (e.g., when distractor suppression is lacking). While one possibility is that these conflicting results are driven by perceptual differences in ASD and the BAP, another possibility is that different modes of attentional control are called upon in different scenarios and these control modes are differentially affected by the expression of autistic traits. To test this possibility, in this chapter, the capacity for distractor suppression was measured in two experiments differentially tapping preparatory (experiment 1) and reactive (experiment 2) distractor suppression. In a similar vein as in the previous chapter the expression of autistic traits in the cohort of neurotypical adults was assessed using the AQ questionnaire. Our results show that participants with high AQ rates were better able to ignore a distracting scene in the proactive scenario (experiment 1) while no differences in perception were evidenced between the groups. Strikingly, in experiment 2 (reactive control) high rates of AQ were associated with reduced capacity to ignore distractors. Thus, our data point towards the notion that high expression of autistic traits can be beneficial when distractors are suppressed proactively but detrimental when more dynamic, reactive suppression is called upon. [2]

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[2] Chapter 3 is being prepared for publication as a part of collaborative work between Spaniol, Mevorach and Abu-Akel. Spaniol contributions: Study design; acquisition of data; analysis and interpretation of data; drafting of manuscript and revision.

Introduction

Our capacity to attend to a target while ignoring irrelevant distraction has a major impact on our ability to successfully interact with our environment. Interference from distractors has been (albeit inconsistently) shown in autism and in neurotypical participants with high subclinical expressions of this condition (Blaser, Eglington, Carter & Kaldy, 2014; Riby, Brown, Jones & Hanley, 2012). The perceptual saliency of distracting information presents a major challenge for attention selection processes, which are partially driven by the bottom-up salience of objects in the environment (Serences & Yantis, 2006). Thus, selection in such a scenario should utilize top-down goal directed processes to bias selection away from distracting salient items. Lines of evidence in autism (ASD) and the broader spectrum of their traits (BAP) in neurotypical participants suggest that these conditions may have an effect on the selection and processing of a target in the presence of a perceptually salient distractor.

Previous investigations have highlighted attention atypicalities in children and adults with ASD (as well as in the Broader Autism Phenotype; BAP), associated at times, with the type of stimuli to be selected or ignored. Indeed, attention control seems to differ in ASD especially when participants are required to process socially relevant information such as faces, or parts of the face (Freeth et al., 2011; Klin et al., 2002; Neumann et al., 2006; Pelphrey et al., 2002). However, this notion has been challenged by studies pointing to improved attention capacity (e.g., visual search; Almeida et al., 2013; Joseph et al., 2009; Kemner et al., 2008) regardless of stimuli type. In chapter 2 of this thesis, this claim was further supported by findings highlighting improved distractor suppression in adults with high expression of autistic traits regardless of level of processing (Experiment 1) as well as when faces had to be selected while outdoor scenes were ignored (Experiment 2), thus pointing to an enhanced ability to suppress irrelevant distractors. This is in accordance with evidence showing that typical levels of interference are reduced in ASD (Blaser et al., 2014; Koldewyn et al., 2013; Riby et al., 2012).

Nevertheless, previous research in ASD and BAP has not only reported enhanced attentional skills (e.g. in distractor suppression, visual search) but also documented reduced attentional functioning, demonstrating increased processing cost in the presence of salient distractors in ASD (Becchio, Mari & Castiello, 2010; Behrmann et al., 2006b; Dunn et al., 2016; Leader et al., 2009). Dunn et al. (2016) for example, identified reduced Pd amplitude 200 ms after stimuli presentation (which is associated with decreased distractor suppression) in individuals with high autistic traits, compared to those with low autism. Thus, the conditions under which salience-suppression interferes with selection in ASD might depend on the demands made on attentional control.

The dual mechanisms theory of proactive and reactive cognitive control (Braver, 2012) may provide a better framework to understand this effect in ASD, as well as previous inconsistencies reported in the literature. In proactive control, individuals bias attention by maintaining goal-relevant information and preventing interference in an anticipatory manner before the onset of the stimulus. In reactive control, individuals respond "online" to interference after its onset. Thus, the presence of a perceptually salient distractor can elicit proactive (Mevorach et al., 2006a) as well as reactive suppression (DiQuattro & Geng, 2011, Geng & DiQuattro, 2010) depending on task demands. In Mevorach et al. (2006a; same task as that used in chapter 2 experiment 1), participants knew in advance at which perceptual level (global or local) a to-be-ignored element would appear, and therefore could benefit from proactive control. Indeed, transcranial magnetic stimulation (TMS) investigations have revealed the critical contribution of suppression mechanisms in the parietal cortex (Mevorach Mevorach, Humphreys & Shalev, 2006b, Chang, Mevorach, Kourtzi & Welchman, 2014) immediately before stimulus presentation—supporting the notion of a proactive mechanism

(Mevorach et al., 2009) that is engaged in advance of stimulus presentation. Conversely, when a salient non-target is contextually relevant (as in Geng & DiQuattro, 2010, where it can determine the location of the target), performance may benefit from a process of rapid rejection following stimulus presentation, indicating a reactive process. Such a reactive process seems to be associated with the neighboring temporal-parietal junction (DiQuattro & Geng, 2011).

While proactive and reactive control can be called upon according to task demands, individual differences also mediate the bias to one mode of control over the other (Braver, 2012). As such, individual biases towards reactive or proactive suppression may have differential effects depending on the specific task requirement. Accordingly, an individual with a proactive bias may show typical (or enhanced) performance in a proactive control task but impaired suppression in a reactive control task. Recent evidence points to failure in activating reactive control regions in individuals with ASD (Keehn, Nair, Lincoln, Townsend & Müller, 2016), and there are findings suggesting that healthy controls with increased autism tendencies tend to utilize proactive suppression more effectively (Abu-Akel et al., 2016; Chapter 2 of this thesis). It is therefore possible, that the inconsistency in the documented impact of ASD on distractor suppression may be attributed to the context under which the salient distractor is presented and whether performance would benefit from proactive or reactive suppression.

In this chapter, we investigate if different modes of attentional control might be responsible for discrepancies in visual discrimination and inhibition in ASD or people with high autistic-like traits.

Atypical face processing and discrimination skills in autism

In chapter 2, participants with more autistic traits exhibited better performance when identifying faces and suppressing distracting scenes. Although this might have been associated with enhanced perception of details of face stimuli, similar performance between high and low autism groups was found when no distractors were present, in the neutral condition of chapter 2 experiment 2. The data support the notion of intact but not enhanced bottom-up processing, as evidenced in similar performance between the AQ groups in the neutral condition of experiment 2 chapter 2, which gives support to enhanced distractor suppression instead of improved perception, when participants relied upon proactive control. This issue will be further investigated in this chapter.

Bottom-up and top-down processing are also influenced by different experimental and attentional control demands. For example, ASD individuals appear to be able to process low-level stimuli (bottom-up processing), even socially relevant information such as faces, but differences in performance are apparent when reactively orienting attention towards faces (e.g. Freeth et al., 2011; Riby & Hancock, 2009). Freeth et al. (2011) measured eye movements, instructing participants to merely look at pictures with no clear information about targets (reactive mode). Although individuals with autism were influenced by low-level salient properties of faces and objects to the same extent as controls (they looked at the more salient items in pictures as much as controls), they were not as rapidly captured by faces as typically developing (TD) individuals. Differences also appear in top-down regulation when proactive control is relied upon, as seen in better distractor suppression in chapter 2, even when suppressing scenes and identifying faces was required.

Some accounts of enhanced search ability seen in ASD attribute this advantage to superior discrimination skills, linked to enhanced perception of the stimuli (faces or objects; Brown & Bebko, 2011). While individuals with autism tend to show relatively intact abilities to differentiate between faces (Adolphs et al., 2006; Humphreys et al., 2007), improved performance is commonly seen in visual search tasks, where participants with ASD perform better than controls when asked to find a target hidden amongst distracting stimuli, even when target and distractor are highly similar. O‘Riordan et al. (2001; O‘Riordan, 2004) found that

ASD children were more accurate and showed faster responses in visual search tasks involving stimuli discrimination, attributing this enhanced ability to superior discrimination skills between items, but also better inhibition of irrelevant distractors.

Enhanced performance in visual search tasks in ASD could also be linked to proactive control required in these tasks, as in the examples above participants relied upon previous information given before task completion in order to discriminate between stimuli while searching for the target and suppressing previously known distractors. In accordance to this framework, children with autism showed atypical top-down modulation for moving, but not color of stimuli, suggesting that top-down control might be atypical for dynamic, but not static stimuli (Greenaway & Plaisted, 2005), relating atypical performance to reactive control. In this study, participants with ASD were less affected by the onset of a dynamic distractor and showed no improvements at the addition of a dynamic cue in a visual search task, as did TD controls (Greenaway & Plaisted, 2005). This points towards atypical performance at the sudden onset of new, dynamic information, potentially linking differences in performance to a bias towards proactive control.

In this chapter, we investigate whether the enhanced performance found in people with more autistic traits is related to atypical perception of stimuli or in fact enhanced distractor suppression. The Autism Quotient (AQ) questionnaire (Baron-Cohen et al., 2001) will be employed to measure high and low autistic traits in the TD population taking part in this study. We further assess the relationship between the expression of autistic traits in TD adults and attention control. Specifically, we ask whether the benefit in distractor suppression we identified in chapter 2 is dependent on the type of attention control required so that when proactive (preparatory) control is needed, high expression of autistic traits is beneficial but when reactive control is called upon it is detrimental. Hence, in Experiment 1 of this chapter we utilized another version of the Face/Scene task we used in chapter 2, tapping proactive control using a task where an irrelevant scene is superimposed on two sets of familiar faces, requiring inhibition of the scene and face identification. Also in the first experiment, using a set of morphed faces without distractors, we assessed potential perceptual differences in face identification. In addition, we explicitly tested whether differences in familiarity with the faces across the high and low AQ groups contribute to improved distractor suppression, as familiarity seems to elicit more typical responses from ASD participants (Aylward et al., 2004; Pierce et al., 2004). Thus, if group differences only appear when distractors need to be suppressed, but not when a distractor is not presented, we can conclude that group differences are particularly associated with attention control. To test for detrimental effects of high AQ on reactive control, in experiment 2 of this chapter we used the search task from DiQuattro and Geng (2011) where a salient non-target can be utilized reactively to facilitate target identification. If high expression of autistic traits is indeed related to difficulties in reactive control we expect our high AQ group to show a reduced benefit from the event of a salient non-target.

Therefore, according to previous research (e.g. Abu-Akel et al., 2016) and chapter 2 of this thesis, we hypothesize that the group with high autistic traits will perform as well as the group with low autistic traits when identifying faces without distractors, showing no differences at the perceptual level (intact bottom-up processing; e.g. Adolphs et al., 2001 Freeth et al., 2011; Humphreys et al., 2007; Neumann et al., 2006). In addition, we expect to find an advantage for the group with high autistic traits when suppressing the distracting scene, discriminating between two faces using proactive control (Brock et al., 2011; Milne et al., 2013; O‘Riordan et al., 2001) and less benefit from the anti-cue, when reactive control is available.

Methods

Participants

The two experiments were conducted on two independent samples of healthy adults. In experiment 1, 60 healthy TD participants voluntarily participated (47 female and 13 male). Participants aged between 18 and 34 years old (M = 20.9 years, SD = 3.8 years) and were predominantly psychology students from the University of Birmingham. In experiment 2, 69 participants completed the visual search task (19 males, 50 females, age mean (M) 26.26 years, standard deviation (SD) 4.06). Participation was rewarded with course credit and participants were recruited through the online system from the University of Birmingham. Participants were excluded from both experiments if they had a history of psychiatric illness, epilepsy, neurological disorders, drug abuse, suffered brain injury or ever lost consciousness for more than five minutes. They were also excluded if scored less than the accuracy chance criteria - 50% or less in the face categorization task or visual search task. Based on these criteria, 58 participants remained in experiment 1 (13 males 45 females, age M=20.95, SD=3.8) and 69 in experiment 2 (19 males, 50 females, age M=26.26, SD=4.06). All participants had normal or corrected-to-normal vision. The University of Birmingham Research Ethics Committee approved the study, and written informed consent was obtained from all participants.

To evaluate differences in task performance as a function of autistic traits, the Autism Quotient Questionnaire (AQ, Baron-Cohen et al., 2001) was employed and, due to smaller sample size in comparison to chapter 2, participants were divided in two groups with high versus low autistic traits using median split, table 3.1.

Table 3.1: Demographics and AQ (Autism Quotient) for all participants, average AQ scores, age and gender for the high and low AQ groups.

Group Overall	Morphed Faces Tasks (Experiment 1) (N=58)			Visual Search Task (Experiment 2) (N=69)		
	Gender (M/F)	**Age (SD)**	**AQ (SD)**	**Gender (M/F)**	**Age (SD)**	**AQ (SD)**
Low AQ	5/24	20.66 (3.41)	11.07 (3.69)	10/23	27.09 (4.27)	13.91 (3.57)
High AQ	8/21	21.24 (4.20)	22.48 (4.39)	9/27	25.50 (3.75)	22.61 (3.18)
Overall	13/45	20.95 (3.80)	16.78 (7.02)	19/50	26.26 (4.06)	18.45 (5.51)

Proactive control (Experiment 1): The morphed faces tasks

Here we firstly investigate how familiar participants were with a set of four famous faces. Secondly, tapping into proactive control, we used a morph-face continuum task, asking participants to differentiate between two faces, measuring low-level perceptual processing (adapted from Rotshtein et al., 2005), and thirdly, we superimposed an irrelevant scene on the faces, varying in contrast to measure participant's contrast threshold and ability to suppress a distractor while differentiating between the faces. This task required participants to actively ignore/suppress an irrelevant scene, measuring participants' contrast threshold for the distractor scene that still allowed for correct face identification. Efficient proactive suppression in this task results in higher contrast estimates.

Procedure, measures and materials

Participants were tested at the Attention and Perception Lab at the University of Birmingham. The experiment lasted around one hour. During the first 15 minutes, participants had to sign a consent form, fill in a short demographic questionnaire and respond to the AQ.

The questionnaire was followed by three computer tasks, taking up to 45 minutes: 1. Face Familiarity; 2. Face identity classification; and 3. Morphed Faces and distractor threshold.

Proactive control was examined in an adapted version of the face-discrimination task of morphed faces (Rotshtein et al., 2005) superimposed with a variable contrast scene distractor. The experiment consisted of three stages. In the first face familiarity task, the purpose was to evaluate how familiar participants were with two pairs of famous faces—a male pair (Robert Deniro and Kevin Spacy) and a female pair (Margaret Thatcher and Marilyn Monroe). The images were four neutral, grey-scale famous faces, on a grey background. Participants had to rate how well they knew each celebrity, on a Likert scale from 1 to 5, with 1 being 'not familiar at all', and 5 being 'very familiar' (see figure 3.1A).

In the second stage (face identity classification task), the famous male and female faces were paired by gender and morphed together with a finer grained test, using face morphs without a distractor (a similar approach was utilized by Humphreys et al., 2007). The faces were morphed in varying degrees of identity change, starting from 10% of face 1, going through nine different morph levels in steps of 10% and finishing at 90% of face 2 (see figure 3.1B, from Rotshtein et al., 2005). The face identity classification task for each of the pairs started with the unmorphed faces and their names, presented on the screen side by side. The morph was then presented for 750 ms followed by a fixation point that remained on the screen until a response was made. Participants responded by pressing the left or right key to indicate which of the previously presented unmorphed faces was more like the morphed face presented in each trial. The identity-classification for each morph continuum consisted of 27 trials presented in random order (3 presentations for each morph). The task consisted of 4 blocks equally divided between the two morph pairs, each block containing 45 trials for a total of 180 trials.

In the final stage of the experiment, as we were interested in unearthing group differences, we selected 2 points from the morphed continuum that yielded the greatest performance variability in a pilot run of the identity classification task with a number of different face pairs to be used. Here, however, we employed a psychophysical approach to measure the threshold of the distractor (scene) opacity that just enabled accurate identification of the target face. Consequently, in the third task (distractor threshold), morphed faces 3 and 6 from each continuum (Figure 3C) were combined with an irrelevant scene that was superimposed on top of the morphed faces. Participants were asked to ignore the scene and identify the faces. As in the previous task, the unmorphed female and male faces were first presented on the screen, before the start of the run. After pressing the space bar, participants were then presented after 500 ms with one of the morphed faces (at 20% contrast) superimposed with the scene for 168 ms (figure 3.1C-D). Responses were recorded by pressing the left or right arrow key of the keyboard to indicate if the face corresponded to the initially presented exemplar on the left or right side of the screen. The contrast of the scene would vary for each participant, according to an adaptive staircase procedure, with a 3-down-1-up structure, which changed the contrast by 10% in each step. In each block, two interleaved staircases were run, one with a high contrast starting value (50%) and another with a low contrast starting value (25%). Each staircase was dropped after 7 reversals, resulting in a varied number of trials per participant per block. The task consisted of 6 blocks (3 for the male and 3 for the female faces). The overall contrast threshold was calculated as the average of the 6 staircase procedures (2 per block) for each face pair. The contrast threshold ranges from 0-1, and is a measure of the participant's ability to identify the correct face at 72% accuracy, with the maximum contrast possible from the distracting scene.

The design of this task, with pre-knowledge about the to-be-ignored distractor (i.e., the scene which is always the same) and the location certainty, plus clear instructions and information sheet with targets and distractor always in sight, mimics that of previous investigations highlighting the role of the IPS in proactive suppression of distractors (Chang et al., 2014; Mevorach et al., 2009). Here, calling upon proactive control in advance of stimulus presentation can mitigate the interference from the scene and thus increase the participants' distractor threshold. Conversely, impaired proactive suppression (e.g., following TMS to the IPS) has been previously shown to reduce the amount of distractor/noise signal that can be effectively filtered out in such paradigms (Chang et al., 2014, Mevorach et al., 2009).

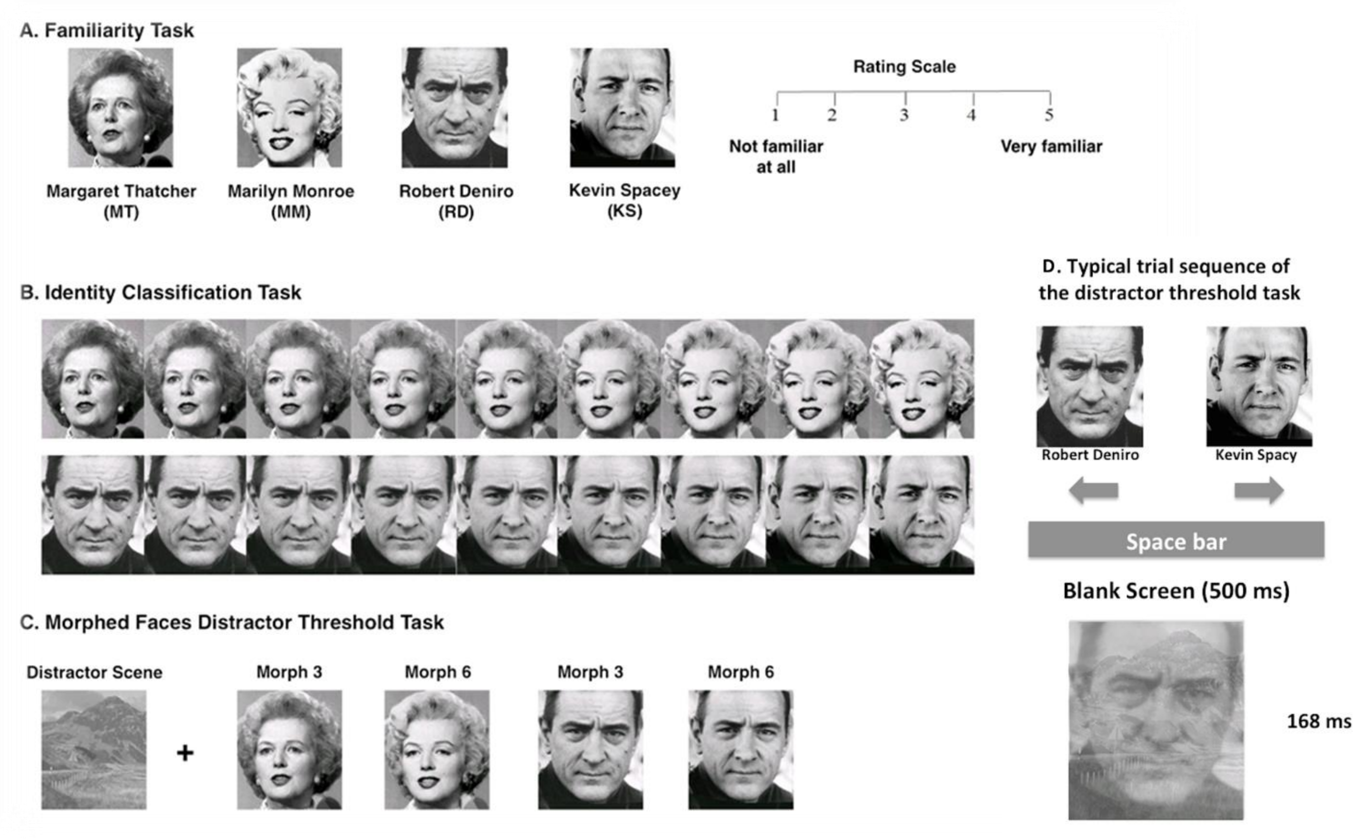


Figure 3.1: The morphed faces tasks. Panel A presents the unmorphed faces of 2 female (Margaret Thatcher and Marilyn Monroe) and 2 male (Robert Deniro and Kevin Spacy) celebrities which were judged on familiarity from 1 (unfamiliar) to 5 (very familiar). Panel B presents the continuum of morphed faces, from face 1 to face 2 in 10% increments used in the face classification task. Panel C presents the distractor scene and the morphed female and male faces used in the distractor threshold task. Panel D exemplifies the distractor threshold task with the distractor superimposed on the male face. It presents a typical trial sequence in the

distractor threshold task. The combined stimulus is of RD's face at 20% contrast and the scene at 50% contrast.

The experiment was programmed and administered using PsychoPy (Peirce, 2007; 2009). Participants sat 60cm from a 17" Samsung SyncMaster 720N LCD monitor, set to the native resolution of 1280 x 1024 at 75Hz. All face and distractor stimuli were presented centrally on this monitor and measured 6cm width x 6.5cm height (subtending 5.75° of visual angle horizontally and 6.18° of visual angle vertically).

Reactive control (Experiment 2): The visual-search task

In experiment 2, participants performed a visual search task (DiQuattro & Geng, 2011) that taps reactive control. Here participants searched for a low-contrast target accompanied by a single non-target that was either perceptually similar or more salient. Crucially, participants were informed in advance that the non-target would sometimes be salient (i.e., high contrast) but that the target would never be high contrast. Under this condition, the salient non-target element acts as an anti-cue that directs the participant to the target, and thus facilitates performance. The benefit gained by the presence of the salient non-target stimulus was assessed, which is indicative of a participant's ability to reactively reject it and select the target.

Procedure, measures and materials

The visual search task was carried out separately at a different date following the same demographics and questionnaires procedure as experiment 1, lasting approximately 30 minutes. Reactive control was examined in a visual search task (DiQuattro & Geng, 2011), in which an occasionally salient non-target element could act as an anti-cue, by redirecting attention towards the target. In this task, participants searched for a low-contrast target that co-appeared with a single non-target that was either perceptually similar (i.e., similar contrast) or salient (i.e., higher contrast). Participants were informed in advance that the non-target would sometimes be high contrast but that the target would never be high contrast. Previous work has demonstrated that even when participants attend or saccade to the salient distractor, knowledge of the anti-correlation between the salient stimulus and the target can be used to bootstrap performance compared to the similar condition (Mazaheri, DiQuattro, Bengson & Geng, 2011; Geng & DiQuattro, 2010). This presumably occurs because the salient distractor is attended, but can easily be reactively suppressed, releasing attention to select the actual target. In contrast, when the similar distractor is erroneously attended, it requires a greater degree of scrutiny in order to reject as a non-target.

In this task participants were presented with two ‘t’-like stimuli for 200 ms (figure 3.2). The non-target t was rotated 90° to the left or right from vertical, and the target t was either upright or inverted. The target and non-target stimuli appeared equally in the left and right visual fields. Participants were asked to find the target and indicate whether it was upright or inverted using manual speeded key presses. In 50% of the trials, the non-target was the same in contrast to the target (Michelson contrast ratio of 0.45; foreground, 35.5 cd/m2; background, 93.5 cd/m2) and thus non-salient, and in 50% of the trials the non-target had higher contrast and thus was more salient (Michelson contrast ratio of 0.91; foreground, 7.1 cd/m2; background, 160.3 cd/m2). The outcome measure of interest in this task was saliency benefit, which is the difference between the performance in the salient and similar conditions (i.e., Salient minus Similar contrast conditions). The horizontal distance of the closest part of the stimuli to fixation was 2.95° of visual angle, and the vertical distance was 0.85° of visual angle. The stimuli subtended 0.85° visual angle at fixation. The target was equally likely to appear in the left and right visual fields. The background throughout the experiment was an intermediate gray (77.8 cd/m2; as in DiQuattro & Geng, 2011).

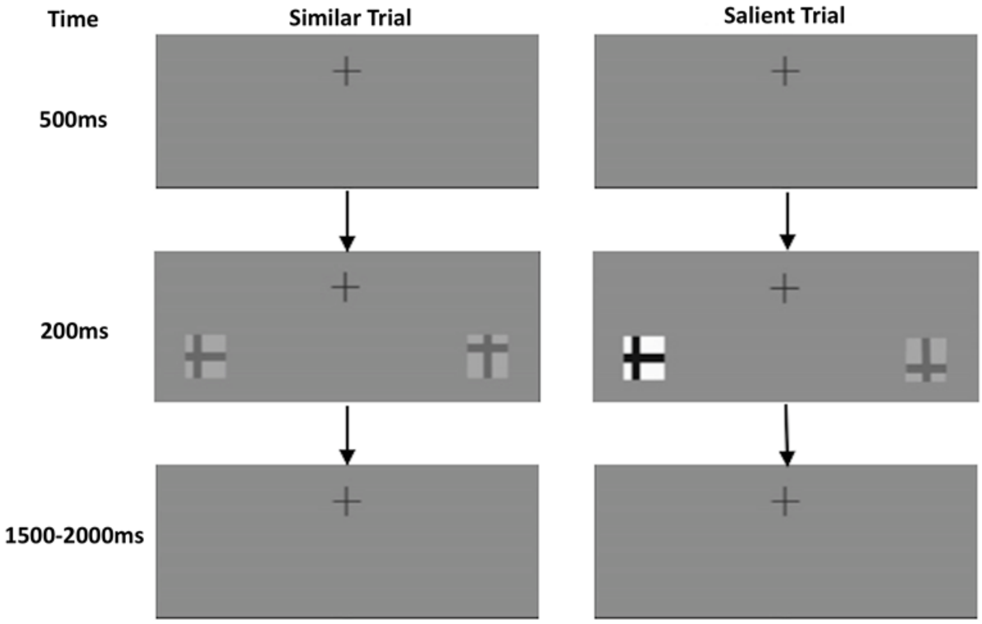


Figure 3.2: Trial procedure of the visual search task in the similar and salient conditions. The trial began with a fixation cross that appears for 500 ms. This was followed by a 200 ms search display. On 50% of the trials the target co-appeared with a similar contrast stimulus and on 50% of the trials it co-appeared with a salient (i.e., higher contrast) one. The trials were separated by a variable fixation interval ranging from 1500 to 2000 ms. Variable ITI makes temporal expectancies uncertain, supporting a reactive control mode (it being more difficult to prepare if time varies across trials).

Results

First, as the two samples from both experiments were not the same, we examined differences between the two samples performing the reactive and proactive tasks in terms of gender distribution, age and AQ scores, to make sure differences between the samples would not affect results in this study. The results revealed no significant differences between the samples in terms of gender distribution (x^2=.44, p=.51) or AQ scores (t(125) =1.50, p=.135). However, the sample performing the reactive task was older (t(125) = 7.57, p<.001), see table 3.1.

Proactive control (Experiment 1): The morphed faces tasks

Face Familiarity task

A 2x2 repeated measures analysis of variance (ANOVA) was conducted to identify whether high AQ or low AQ groups (as between-subjects factor) and the male or female pair of faces (as within-subjects factor) had an effect on the responses given by participants in the familiarity task. A significant main effect was found between face pair and familiarity rating (F(1,56)=136; p<.001; η_p^2=.71). This indicates that there was a significant difference in the familiarity ratings given to the female pair and male pair of faces, where participants were generally more familiar with the female in comparison to the male pair (M±SE=4.35±0.09, and M±SE=2.57±0.16 respectively). There was no main effect of group (high AQ or low AQ) on familiarity rating (F(1,56)=.384; p=.538; η_p^2=.007), indicating that there were no significant differences in the familiarity ratings given by the high and low AQ groups (see figure 3.3).

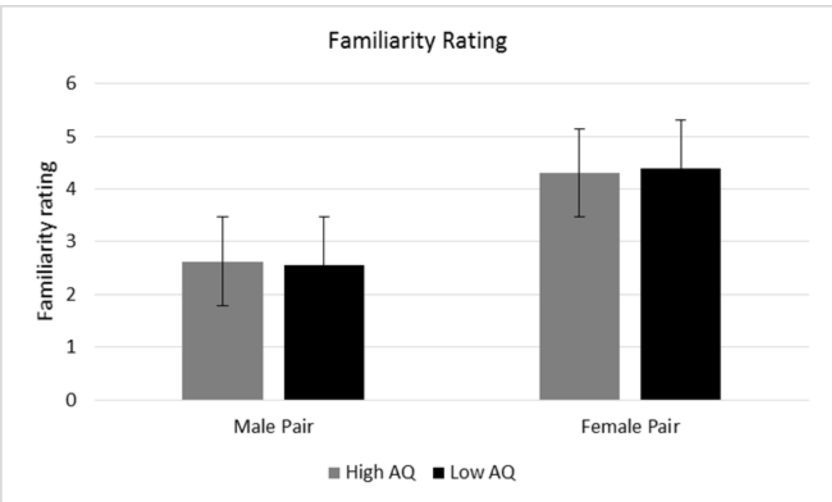


Figure 3.3: Familiarity ratings given to the male and female faces by the high (grey) and low (black) AQ groups.

Face Identity Classification task

To examine differences in the sigmoidal functions of the groups, we fitted a 4-parameter logistic (4PL) nonlinear regression, and compared the Hill slopes of the functions using Prism 6 (Graphpad Software). The Four Parameters Logistic Regression or 4PL nonlinear regression model is commonly used for curve-fitting analysis. It is characterized by its classic "S" or sigmoidal shape that fits the bottom and top plateaus of the curve, and the slope factor (Hill's slope), and this curve is symmetrical around its inflection point.

There was no difference between the slopes of the sigmoidal functions of the low autism and high autism groups for the male ($F(1,10)=.92$, $p=.36$; morph faces 2-8 Figure 3.4) and female pairs ($F(1,10)=.61$, $p=.45$; morph faces 2-8 Figure 3.4). There was no difference between the slopes of the sigmoidal functions of the low autism and high autism groups ($F(1,10)=.61$, $p=.45$), even after controlling for familiarity of the famous faces (Figure 3.4).

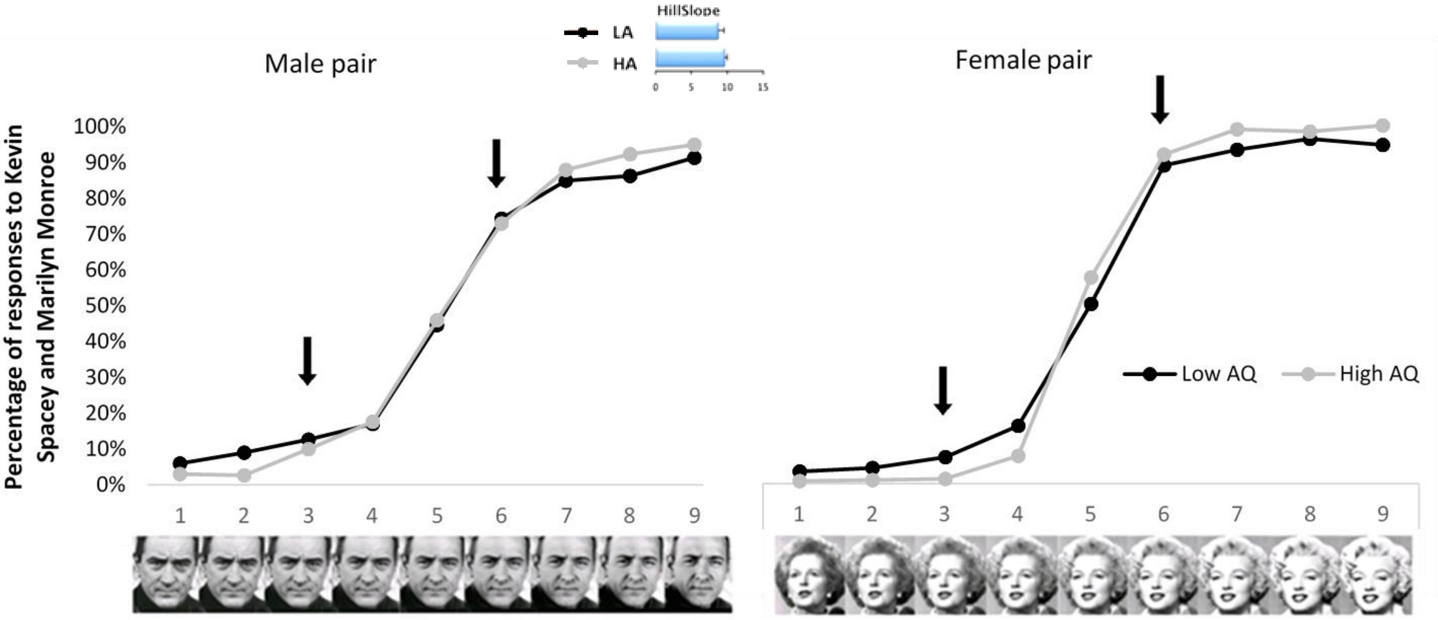


Figure 3.4: Performance of low and high AQ groups on the face categorization task for male and female morph pairs. The Figure depicts performance in the low autism (low AQ, black line) versus high autism (high AQ, grey line) groups. Black arrows indicate the set of pairs

used in the subsequent face-scene distractor threshold task. Bar graphs are the Hill slope values (LA: low AQ; HA: high AQ).

Comparing the overall slopes between each morph level (levels 2 to 8) for male and female face pair, discriminating between the male pairs was significantly more difficult than the female pairs for morphs 2-8 (all ps<.019). Accuracy identifying pairs with the same morph level (1 and 9, 2 and 8, 3 and 7, 4 and 6) was combined and converted into error rates, ranging from zero error to a maximum of 1 (100% incorrect responses). As mentioned before, participants made fewer errors when identifying the correspondent face for the female pair stimuli, which was also generally more familiar (Figure 3.5). Independent sample t-tests revealed no significant differences in error between high and low autism groups for any morph level in the female or male pair of the face classification task (all ps>.7).

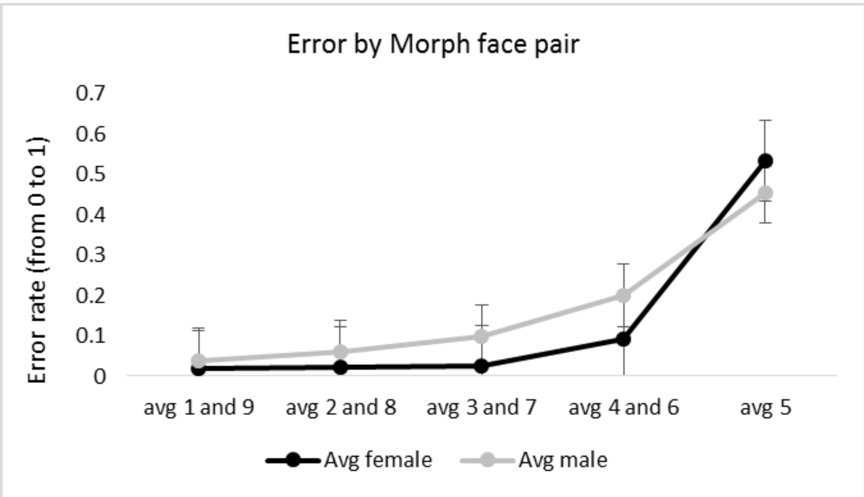


Figure 3.5: error average (avg) for the male (grey line) and female (black line) morph levels.

Morphed faces distractor threshold task

In the morphed faces threshold (proactive) task, we used a psychophysics procedure to estimate the contrast threshold (0-1) of the distractor scene. The threshold estimate for each staircase was extracted as the average of the reversals. The overall contrast threshold was calculated as the average of the 6 staircase procedures (2 per run). The contrast threshold ranges from 0-1, and is a measure of the participant's ability to identify the correct face with the maximum contrast possible from the distracting scene, at 72% accuracy.

Threshold estimates were significantly higher in male compared to female participants for the male pair condition (M±SE=.70±.02 vs .54±.02; $t_{(57)}$=4.09,p<.001), and marginally so for the female pair condition (M±SE=.76±.02 vs .71±.02; $t_{(57)}$=1.79, p=.08). Initially, a 2x2 repeated measures analysis of variance (ANOVA) was used to test effects of gender on performance, using male and female pairs contrast threshold as within-subjects factor, and gender as between-subjects factor. The analysis showed that there was an overall effect for pair threshold (F(1, 56) = 38.15, p < .001). This means that the average contrast threshold of the distracting scene was significantly higher for the more familiar female faces in comparison to the male faces (M±SE=.73±.027; M±SE=.62±.014 respectively). Gender also interacted with distractor threshold (F(1,56)=8.16; p=.006; η_p^2=.127), with females showing the lowest scores. Familiarity ratings were also correlated to male contrast threshold (r(58) =.43, p=.001).

To examine the association of threshold estimates with autistic traits during the male pair condition, we conducted an ANCOVA (low vs. high AQ) controlling for gender. The analysis revealed significantly higher thresholds for the high autism group (M±SE=.61±.02) compared to the low autism group (M±SE=.54 ±.02; F(1,56)=4.4, p=.04, η_p^2=.075; Figure 3.6). When controlling for familiarity with male faces, results are still significant (F(1,56)=4.15, p=.047, η_p^2=.073). There were no other significant main effects or interactions. In the female pair condition, the analysis revealed a similar pattern but non-significant results (F(1,56)=2.3, p=.135, η_p^2=.041).

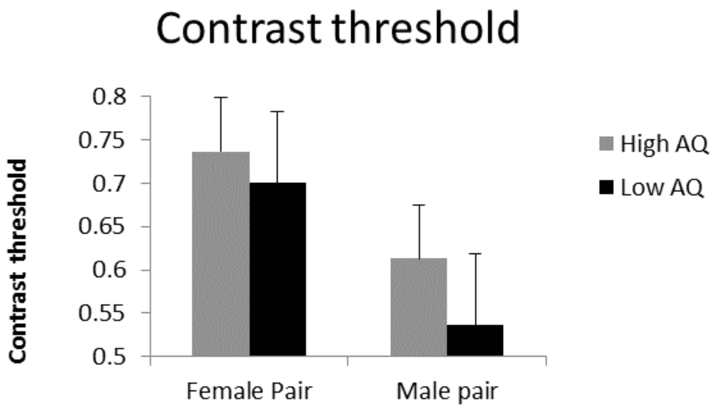
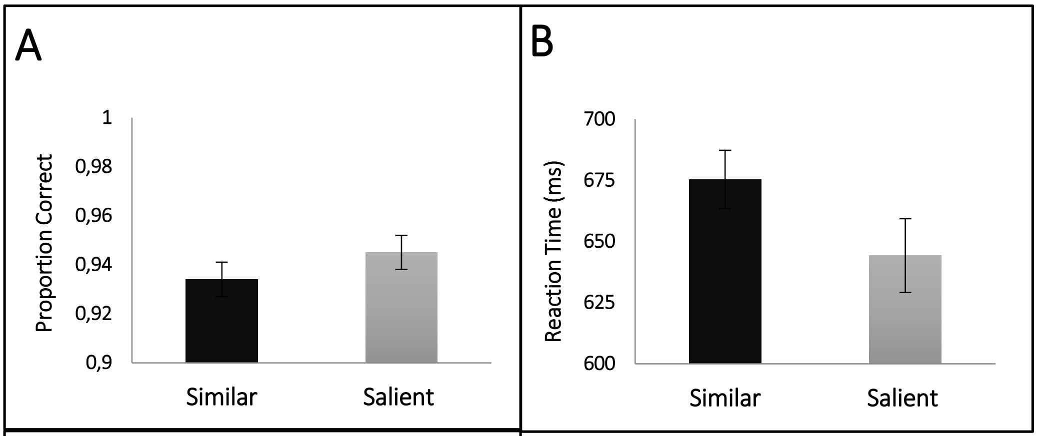


Figure 3.6: Mean contrast threshold for male and female pairs, high and low AQ groups. Error bars represent SEM.

Reactive control (Experiment 2): The visual-search task

In the visual search (reactive) task, the main outcome measure is saliency benefit, which is the benefit gained from the presence of the salient (i.e. higher contrast) non-target compared with the similar non-target. Preliminary analyses confirmed the overall benefit gained in the salient versus the similar conditions in terms of accuracy, RT and RT/proportion correct (Figure 3.7).

To ascertain the benefit gained in the salient versus the similar condition, we conducted a series of repeated measures analyses of variance for the overall sample (N=69) in terms of accuracy, reaction time (RT), as well as in terms of RT/proportion correct. The analyses show that, overall, particpants were more accurate ($F(1, 68)=6.03$, $p=.017$, $\eta_p^2=.081$; Fig. 3.7A), faster ($F(1, 68)=10.78$, $p=.002$, $\eta_p^2=.137$; Fig. 3.7B), and had lower RT/proportion correct scores ($F(1, 68)=11.18$, $p=.001$, $\eta_p^2=.141$; Fig. 3.7C) in the salient versus the similar condition. These findings confirm the benefit rendered by the presence of the salient non-target element.



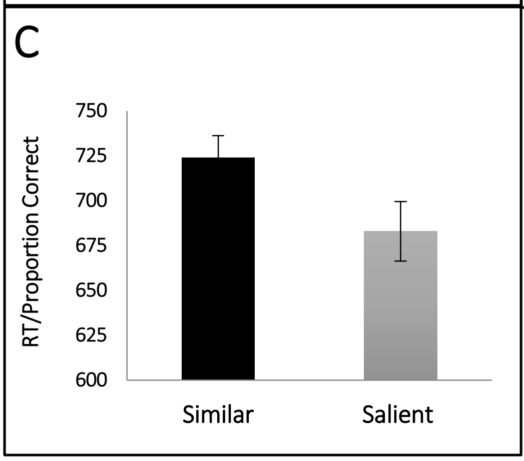


Figure 3.7. Overall performance in terms of accuracy, reaction time and reaction time/proportion correct on the similar versus the salient conditions of the visual search task. **A** shows the performance in terms of accuracy. **B** shows the performance in terms of reaction time. **C** shows the performance in terms of reaction time/proportion correct. Error bars represent SEM.

Group analysis

To examine the association of saliency benefit with autism traits, we used inverse efficiency, calculated by the RT/proportion correct scores, which allows us to combine reaction time and accuracy into a single measure (Townsend & Ashby, 1983). Given that saliency benefit scores correlated with age ($r=-.32$, $p=.008$), we conducted an ANCOVA (low vs high autism) while controlling for age. The analysis revealed less benefit for the high AQ (M±SE=68.10 ±17.11) compared to the low AQ group (M±SE=16.50±1.37; $F(1,66)=4.66$, $p=.035$, $\eta_p^2=.07$, see Figure 3.8). There were no other significant main effects or interactions.

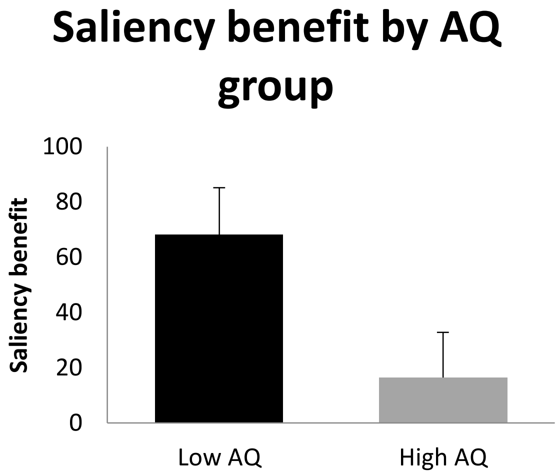


Figure 3.8: Mean saliency benefit (salient minus similar conditions) in the low versus the high autism groups. Error bars represent SEM.

Discussion

This study examined the effect of autism traits on the processing of a target in the presence of an irrelevant salient element in two experiments, independently tapping reactive and proactive attentional control mechanisms. Our results show group effects (high vs. low AQ) in both attention related tasks. Critically, however, the effects reversed from one experiment to the other. The pattern of the effects of autism in the proactive task was reversed in the reactive task. While participants with high expression of autistic traits outperformed those with low expression in the proactive face threshold task, they performed worse than low AQ individuals in the reactive task. This pattern of results suggests that persons with high autistic-like traits have inherent bias towards proactive attentional control and is consistent with current literature in ASD, showing difficulties in reactive control of attention (Keehn et al., 2016, Klin et al., 2002; Pelphrey et al., 2002). Keehn et al. (2016) for instance, found that children and adolescents with autism showed increased error rates when responding to an RSVP (Rapid

Serial Visual Paradigm) task, where target and distractors presence, location and response key was uncertain, thus eliciting reactive control.

In accordance with the findings we reported in chapter 2, here too we found no evidence that group performance differences in distractor suppression could be associated with perceptual differences. In the proactive experiment (Experiment 1), there were neither differences between high and low AQ groups in familiarity with the face stimuli, nor in classification of the morphed faces (without distractors). These findings further support the notion that perceptual differences do not underlie the attention control differences we report. We did find an overall effect of face pair on familiarity ratings as participants were overall more familiar with the female set of stimuli (Marilyn Monroe and Margaret Thatcher) than the male pair (Kevin Spacey and Robert Deniro). Consequently, performance for both groups was better when classifying the morphed female faces compared with the male ones and this also translated to the contrast threshold task as participants were overall better able to ignore the distractor scene when responding to the female pair.

The main finding of Experiment 1 was a higher contrast threshold for the irrelevant scene with male face pairs in the group with high autistic traits, demonstrating enhanced ability in this group to filter out the distractor. While a similar trend was observed for the female pair of face, it did not reach statistical significance levels. While we would argue that this most likely represents ceiling performance for this task, previous investigations have reported typical performance in ASD particularly when familiar faces are used (Aylward et al., 2004; Pierce et al., 2004) and therefore the comparable performance across groups here may be attributed to the high levels of familiarity.

The benefit we report for high autistic traits in the threshold task may arguably relate to the putative local bias in autism, which may somehow contribute to improved ability to suppress the distractor scene information. However, this might not be the case here as previous work has shown less interference of salient distractors in individuals with high expressions of autism traits across both faces and global-local tasks (chapter 2; Abu-Akel et al., 2016). In addition, our identity-classification task was used exactly in order to exclude such potential differences between the groups. Indeed, there was no difference between the low and high autism groups in the identity-classification task when distractors were not presented (and therefore not suppressed). Taken together, these findings suggest that the better performance of the high autism group in the morphed faces classification task is unlikely to be due some specific autism-related proclivity for face identification, emphasizing the notion that only when attention control was called upon, group differences emerged.

In experiment 2, the group with more autistic traits showed less benefit in performance with the addition of a more salient anti-cue, in comparison to the group with less autistic-like traits. Reactive control is used when performance needs to be adjusted on-the-go, such as at the appearance of a salient anti-cue which can help guiding attention away from the distractor and towards the target in the visual search task. Group differences could also be due to static vs dynamic stimuli (Greenaway & Plaisted, 2005) or due to problems in disengaging attention in the search task (e.g. Goldberg et al., 2002; Landry & Bryson, 2004), as a more salient item could capture attention and less benefit could be due to difficulties disengaging from the high salient non-target. Nevertheless, we argue that better performance in the distractor threshold task and less benefit in the search task is due to a bias towards a proactive mode of attention control, and difficulties when reactive control is needed in autism, possibly related to difficulties in disengagement. More research should be carried out investigating differences in proactive and reactive control utilizing static versus dynamic stimuli and spatial vs non-spatial tasks to assess attentional disengagement.

Static, neutral, grey-scale pictures of faces were used in this study, and the results we found in this chapter can also be explained by the difference between dynamic vs static face processing in ASD. While people with ASD seem to show normal eye-gaze towards the eyes in grey-scale, static faces, the same did not happen with dynamic and more naturalistic faces (Greenaway & Plaisted, 2005; van der Geest et al., 2002; Riby et al., 2013). Also, as we used neutral face expressions, requiring no social or communicative demands in this task, such as emotional state attribution, or eye-gaze direction, this could explain intact performance in the group with more autistic traits when responding to faces. Neural correlated areas responsible for deficits when responding to faces, previously found in ASD research such as the amygdala or fusiform gyrus (e.g. Adolphs et al., 2006, Lombardo et al., 2009, Kleinhans et al., 2009) might not be relied upon in order to complete this task, and areas responsible for attention modulation (e.g. distractor suppression) play a key role in the morph threshold task instead. Further research using TMS and fMRI could provide valuable insight into this.

In conclusion, we found no evidence for low-level perceptual abnormalities between people with low versus high autistic traits. We found evidence for enhanced ability, from the group with high autistic traits, for proactive suppression of irrelevant, salient information, filtering through a distracting scene when differentiating between two male, less familiar faces, and difficulties in reactive control, possibly related to problems with attention disengagement. We hypothesize these findings might be related to enhanced visual search abilities, specifically to enhanced proactive distractor suppression needed in visual search tasks seen in this study in people with high autistic traits when filtering out distractors, discriminating between neutral static faces. Results might also be related to a detailed focus of attention, directed to small parts of the stimuli when suppression is needed, and more importantly, revealing a bias towards proactive control of attention, which would explain the advantage in the proactive tasks and the opposite effect when reactive control is needed. More research is needed to investigate the mechanism involved in face processing and saliency suppression in people with high autistic traits and the neural correlates involved in proactive versus reactive control in this population.

Experiments that tap into the disengagement of attention and dynamic vs static stimuli are also suggested in order to further investigate the findings in this study. While our research gives meaningful insight into how autistic traits manifest in the neurotypical population, the results are suggestive and could be extrapolated to the attentional atypicalities involved in ASD.

Chapter 4

Motor distractor suppression in individuals with high and low autistic traits

Abstract

Performance differences in ASD are documented in the visual and also the motor domain. Previous findings demonstrate that in ASD, preparation time before task initiation tends to be longer in tasks requiring movement planning. Moreover, deficits in performance seem to appear when participants need to reprogram or self-develop strategies, which may highlight deficits in reactive processing. Thus, here we ask whether the attention atypicalities we have observed in adults with high expression of autistic traits in Chapters 2 & 3 translate to the motor domain. To test this, 78 neurotypical adult participants performed a reaching task with and without distractors while the visual feedback available was manipulated. We predicted that when reaching was performed under conditions of online visual feedback participants would use reactive processes. In contrast, when online feedback was not available, proactive processes would become more critical. Our results show that participants with high autistic traits took longer to initiate reaching towards the target particularly when proactive processes were engaged (without online feedback). Interestingly, we also found a significant relation between the "attention to details" subscale of the AQ and reaching performance when distractors were present. Specifically, participants with higher scores of attention to detail were better able to ignore the distractor in accurately reaching towards the target when online feedback was not available (proactive). We suggest that this finding supports the notion that attention and motor abilities are related, and that improved proactive control could be manifested in the motor domain. [3]

[3] Chapter 4 was conducted using the same reaching task as a published study, Mevorach, Spaniol, Soden and Galea, 2016, in which I am also an author, and it is being revised for possible publication between Mevorach, Spaniol and Galea. Spaniol contributions to this chapter: Study conception and design; acquisition of data; analysis and interpretation of data; drafting of manuscript and revision.

Introduction

Although motor control is not included as a core deficit in autism, ASD is frequently associated with a variety of motor alterations, such as sensorial and motor integration, movement execution (gait and balance) and motor planning (Fournier, Hass, Naik, Lodha & Cauraugh, 2010). Interestingly, there is evidence that movement preparation time in particular is atypical (longer) in individuals with ASD, even though movement execution might be intact or similar to controls (Rinehart, Bradshaw, Tonge, Brereton & Bellgrove 2001; Sachse et al., 2013). A variety of studies reported longer movement preparation time but intact task performance in individuals with ASD, in tasks requiring reaching movements (Glazebrook, Elliott & Szatmari, 2008; Glazebrook, Gonzalez, Hansen & Elliott 2009; Rinehart et al., 2001; Sachse et al., 2013). Rinehart et al. (2001), for example, used a serial-choice button pressing apparatus measuring down time (preparation) and movement time (execution) and found longer preparation times in individuals with ASD, while movement execution was intact. In a later study, Rinehart et al. (2006) used kinematics to measure again preparation and movement time, including inhibition and an anti-cue in the last task levels (e.g. target appearing in an unexpected location and instructions to move to the opposite side of the target). Participants with ASD again showed longer preparation times and intact movement execution, and surprisingly did not show differences in performance with the addition of inhibition and anti-cues, in contrast to controls (Rinehart et al., 2006).

Differences in motor performance in ASD may be more pronounced when participants need to reprogram or update their motor plan (Glazebrook et al., 2008; Glazebrook et al., 2009; Nazarali, Glazebrook & Elliott, 2009). In an experiment measuring how individuals with ASD plan and reprogram their movement, Nazarali et al. (2009) found that when direct information for the movement was given before task completion, ASD participants showed similar responses to controls, but when they had to unexpectedly reprogram and adjust their movement, they showed difficulties, requiring more time (preparation) and slowing down their responses (execution; Nazarali et al., 2009). Similarly, Glazebrook et al. (2008) found that participants with autism utilized information given before task initiation to better program their movement, similar to controls. However, when the strategy was self-generated (start position and target location was uncertain), they exhibited stereotyped behaviours in addition to slower movement and reaction times. Thus, these findings point to atypical movement planning when the task is cognitively more demanding, requiring participants to use information gathered throughout the course of the task to update their self-generated strategy.

The notion of a particular difficulty exhibited in ASD to update motor plans and strategies is further supported by studies assessing the effect of online visual feedback on motor control. Online visual feedback corresponds to trials where participants have vision of their movement available during task completion, whereas when no online visual feedback is available, participants only have start and end point vision of their movement. Typically developing participants are usually quicker and more accurate performing a reaching movement when online feedback of the movement is available (compared to when only end-point information is available; e.g., Mevorach et al., 2016), presumably because both feed forward and feed backward loops support the movement plan and execution. However, a study testing reaching performance of participants with ASD (Glazebrook et al., 2009) under conditions of visual feedback or no visual feedback, found detrimental effect of online vision in this population. Participants with ASD were able to reach the target with or without movement vision, but took longer to initiate movement when online vision was available. Moreover, performance was in fact improved (reduced variability) when no visual feedback was provided (Glazebrook et al., 2009). As the authors suggest, this might be attributed to difficulty integrating visual and motor information. Indeed, increased attention to details found in ASD, may lead to detail oriented processing and poor sensory integration (e.g visual and motor), alluding to weak central coherence accounts in autism (Gowen & Hamilton, 2013; Sharer et al., 2015). Critically however, this issue is manifested when online information is provided (and therefore dynamic updating is required) and not when the motor action is completely relying on preparatory processes. These findings therefore suggest that integrating information across domains to guide motor actions is potentially intact in ASD as long as the information is explicitly available during the planning phase. Atypicalities emerge particularly when the tasks require dynamic updating of the motor action - either as a consequence of unexpected information (e.g., Nazarali et al., 2009), ongoing accumulation of information about the task (Glazebrook et al., 2008) or the integration of online dynamic information (Glazebrook et al., 2009). Interestingly, this pattern of performance resembles the attention control related effects we have reported in this thesis (chapters 2 and 3; albeit in the context of high rates of Autistic traits in typically developing adults). We have reported that in adults with high expression of autistic traits (high AQ) performance is improved when irrelevant distractors are known in advance and can therefore be inhibited in a preparatory fashion (see also Abu-Akel et al., 2016). However, performance is detrimentally affected when distractors appear unexpectedly or need to be acted upon reactively once they are presented (experiment 2, chapter 3). It is therefore possible that the motor atypicalities observed in ASD may be attributed (at least to some extent) to a difficulty in reactive (or dynamic) attentional control that manifests itself both in a visual attention task context (chapter 3) and in a motor control context when reactive processes are engaged to correct or update a motor plan.

The potential link between attentional and motor atypicalities was recently investigated in the context of aging (Mevorach et al., 2016). Comparing young and old typically developing adults in a visual attention task, Mevorach et al. (2016) reported a reduced ability in old age to ignore distractors (similar performance was also previously reported in Tsvetanov, Mevorach, Allen & Humphreys, 2013). Furthermore, when tested for movement accuracy, using a reaching task with or without distractors, similar age effects were observed. While performance was comparable in terms of radial error (distance between the reaching end point and target position) when only targets were presented, the addition of an adjacent distractor had a considerably bigger effect in old compared to young adults. Furthermore, Mevorach et al. (2016) also reported a significant correlation between distractor interference in the visual attention task and error in the reaching task across the cohort, and Klimkeit, Mattingley, Sheppard, Lee and Bradshaw (2005), also found a link between attention impairment in ADHD and motor atypicalities. In a reaching task where participants had to ignore distractors, participants with ADHD showed slower reaction times (preparation) before movement start, which were related to attentional difficulties but no movement execution deficits, showcasing that attentional processes are related to longer preparation times (Klimkeit et al., 2005). These findings suggest a link between control mechanisms across the visual and motor domains.

Interestingly, the effects of age on visual attention in Mevorach et al. (2016) are the exact opposite of the effects reported earlier in this thesis with high AQ (and using a similar global-local task; experiment 1, chapter 2). While, distractor interference was augmented for old adults (Mevorach et al., 2016) it was reduced for adults with high AQ (chapter 2). Thus, if visual attention control processes contribute to motor control, then the ability to effectively suppress visual distractors in a proactive manner in the high AQ group should translate to better accuracy in reaching towards a target in the presence of a distractor.

Support for this hypothesis comes from studies reporting relatively intact motor inhibition in children with autism (Dowd, McGinley, Taffe, & Rinehart, 2012; Mahone at al., 2006; Sachse et al., 2013). Dowd et al. (2012) for instance, reported that children with autism were less affected in planning and execution of movement by the addition of distractors. Sachse et al. (2013) found intact inhibition of distractors and movement time in a motor task in participants with ASD, but reaction time increased with higher task demands (increased number of targets). Moreover, in a study investigating different inhibitory mechanisms in typically developing individuals, Friedman & Miyake (2004) found that preparatory response inhibition and reduced distractor interference were closely related, suggesting that preparatory inhibition processes might predict the ability to inhibit distractors. Therefore, it is possible that longer reaction times and motor planning, sometimes found in participants with ASD, are associated with less interference from a distractor through the reliance of this population on an effective preparatory control mechanism.

In order to examine this matter further within the BAP, the ability to inhibit distractors in a motor (reaching) task was tested, utilizing the reaching task from Mevorach et al. (2016). Therefore, and using a similar approach to chapters 2 & 3, in this chapter we investigated whether the ability to accurately reach towards a target in the presence of a distractor will be associated with the expression of autistic traits in typically developing adults. Specifically, we hypothesized that 1. Higher expression of autistic traits would be associated with longer reaction times before movement initiation, but not with error or movement time, in accord with previous findings within the ASD population; and 2. A link between expression of autistic traits and ability to inhibit a distractor would emerge when preparatory processes were dominant (when there is no online visual feedback regarding the movement). The latter may be particularly pronounced when the demand for control is at its peak (when target and distractors are harder to distinguish).

Methods

Participants

78 young adults (mean: 20.6 years, range: 18-36, 18 male) with no current health problems participated in the study. All participants provided written informed consent, and the

study was approved by the research ethics committee at the University of Birmingham. Participants were given either course credit or £7 cash for their involvement in the study. Participants were recruited through an internal recruitment system and personal invitations. All participants had normal or corrected-to-normal vision. The AQ (The Autism-Spectrum Quotient Questionnaire, Baron-Cohen et al., 2001) was used to assess the presence of autistic traits in the population taking part in this study. In order to investigate differences between high and low autistic traits, participants were divided in two groups (high AQ and low AQ) using a median split (cut point AQ=16; table 4.1). Age and gender did not differ between the groups (age: t(76)=-.215,p=0.83; gender: X (1)= .099, p=.75).

Table 4.1: Average gender, age and AQ scores for high and low AQ groups, and for all participants.

	All (N=78)	**High AQ (N=36)**	**Low AQ (N=42)**
Gender (Males, Females)	18, 60	9, 27	9, 33
Age (Mean, Std. Deviation, Range)	20.6 (3.6), 18	20.7 (3.9), 11	20.6 (3.8), 18
AQ (Mean, Std. Deviation, Range)	15.9 (6.8), 36	21.8 (4.9), 23	10.8 (3), 12

General procedure

The motor distractor task was performed in a single session lasting approximately forty minutes. Participants completed a short demographics questionnaire, consent form and AQ (Autism-Spectrum Quotient Questionnaire) test before the computer task.

Motor distractor task (from Mevorach et al., 2016)

The goal of this task was to examine the influence visual distractors have on motor accuracy. Participants were seated with their forehead supported on a headrest. Their semipronated right index finger was attached to a Polhemus motion tracking system underneath a horizontally suspended mirror. The mirror prevented direct vision of the hand and arm, but showed a reflection of a computer monitor mounted above that appeared to be in the same plane as the hand (Figure 4.1A). Participants controlled a cursor on the screen by moving their finger (which was attached to a motion tracking sensor) across the table. They were told to never lift their finger off the table and to make pointing movements. Apart from their index finger, the rest of their hand should be clenched into a fist. The visual display consisted of a 1-cm-diameter central white starting box, a green cursor (0.3cm diameter) representing the position of the index finger and a circular white target (0.5cm diameter; Figure 4.1B). The target could be positioned in one of five positions arrayed radially at 8cm from the central starting position (Figure 4.1C). Participants had to make a movement towards the target either with no distractors (Figure 4.1B) or with a single white or red square (0.5cm in width and height) distractor. This distractor could be placed 5°, 10°, 15°, or 20° clockwise or counter clockwise to the target (Figure 4.1C). We predicted that the colour and distance of the distractor (relative to the target) would manipulate distractor suppression difficulty. Specifically, a red distractor would be easier to suppress than a white distractor due to its reduced similarity with the target (Duncan & Humphreys, 1989), and the proximity of the target to the distractor would facilitate performance, while distractors that are further away from the target would decrease accuracy (Goodhew, Shen & Edwards, 2016). In addition, participants either had online vision (online) where they could see the cursor representing their hand position throughout the movement, or endpoint feedback (end point) where participants only received visual feedback relating to the end position of their movement (see following material). Visual feedback was manipulated so that movement accuracy was either based entirely on feedforward control (endpoint) or a combination of feedforward and feedback control (online; Heath, 2005; Tseng, Diedrichsen, Krakauer, Shadmehr & Bastian, 2007). We hypothesized that this would allow us to disentangle preparatory and reactive (feedback) distractor suppression. Finally, a square (0.5cm in width and height) at the top of the screen provided movement speed feedback (see following material).

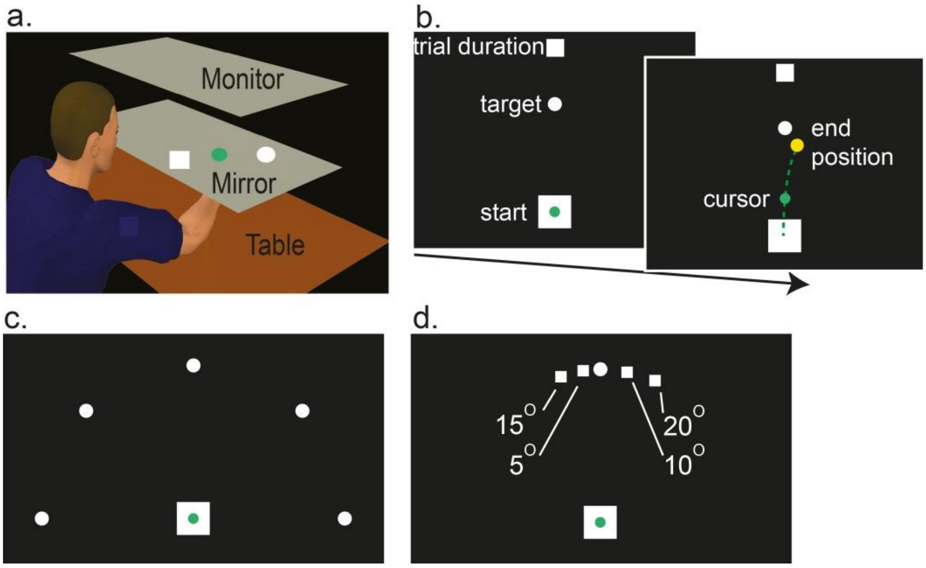


Figure 4.1. Motor distractor task. **A**. Task apparatus. Participants were seated with their semipronated right index finger attached to a Polhemus motion tracking system underneath a horizontally suspended mirror. The mirror prevented direct vision of the hand and arm, but showed a reflection of a computer monitor mounted above that appeared to be in the same plane as the hand. **B**. Task procedure. Participants made reaching movements (green circle representing index finger position) towards visual targets displayed on the screen (white circle). Feedback regarding trial duration was displayed at the top of the screen (white square). Participants could either receive online feedback (green) of their movement on simply end point feedback (yellow). **C.** Target positions. The target could be positioned in one of 5 positions arrayed radially at 8cm from the central starting position. **D**. Distractor positions. The distractor (white or red square) could be placed 5, 10, 15 or 20^0 clockwise or counter clockwise to the target.

A trial started by participants moving the cursor into the start position. A target then appeared. If this was a distractor trial then a distractor also appeared simultaneously with the target. Participants were instructed to make a movement towards the target and stop as close as possible to it, whilst ignoring all distractors. The end of each movement was defined by movement velocity falling below 0.05cm/s (note movement length had to exceed 4cm). At this point, a yellow circle appeared (Figure 4.1B) which indicated the movement end point. Therefore, the goal of each trial was to get the yellow circle as close as possible to the target. To ensure participants reacted and moved at a similar speed, trial duration feedback was provided at the top of the screen. Once the target (and distractor) had appeared, participants had 1200 ms to execute the movement. Therefore, this incorporated both reaction time (RT) and movement time (MT). If this was achieved the box at the top of the screen remained white (Figure 4.1A). However, if this was exceeded then the box turned red.

The task contained 5 blocks which involved different variations of the task (Table 4.2). Block 1 was a training block in which participants made 40 movements (8 movements to each target) with either online or end-point feedback without distractors. Blocks 2-5 involved 90 trials, with 18 movements towards each target. As distractors could be positioned 5, 10, 15 or 20^0 clockwise or counter clockwise to the target (8 positions in total), the 18 trials for each target involved 2 repetitions of each distractor position (16 trials) plus 2 trials which involved no distractors. The order of these trials within each block were randomized but remained constant across participants, increasing predictability thus eliciting proactive control. Blocks 2 and 3 involved white distractors with endpoint and online feedback, respectively. Blocks 4 and 5 involved red distractors with endpoint and online feedback, respectively. The order of the blocks was maintained across participants as it was previously shown (Mevorach et al., 2016) that performance remained comparable regardless of block order.

Table 4.2: Motor distractor task procedure.

	Trials	Online or end point feedback	Distractors	Distractor colour
Block 1	80	40 = online 40 = end-point	No	--
Block 2	90	End point	Yes	White
Block 3	90	Online	Yes	White
Block 4	90	End point	Yes	Red
Block 5	90	Online	Yes	Red

Data analysis and statistics

The 2-D position (x,y) of the hand was continuously recorded at a rate of 60Hz using a custom Matlab program (Mathworks) and the Psychophysics toolbox. Our main parameter of interest was the radial distance between the movement end position and target (radial error; cm). In addition, reaction time (RT; ms) and movement time (MT; ms) were calculated for each trial. RT was defined as the time between the target appearing and the participant's finger leaving the start position. MT was defined as the time between the participant's finger leaving the start position and movement velocity falling below 0.1cm/s (note movement length had to exceed 4 cm). We removed any trial in which radial error exceeded 5 cm or RT and MT exceeded 1500 ms. This accounted for 0.8% of all trials.

We regarded block 1 as a training block in which participants became accustomed to the task. Therefore, we used the no distractor trials within blocks 2-5 as our measure of no distractor performance. As these trials were interspersed with the distractor trials, they would provide us with a true measure of 'baseline' performance across blocks 2-5. For each participant, we obtained a global value for no distractor performance by averaging across blocks 2-5; this meant that both online (block 2, 3) and end-point feedback (blocks 4, 5) performance was included (2 trials for each target (5) from each block were included; total amount of trials included = 40 trials). This average no distractor value was compared between the low and high autism groups for radial error, RT and MT using 2-tailed independent t-tests. Next, we compared performance across distractor position (5, 10, 15 or 20^{o}), distractor colour (red, white) and visual feedback (online, end-point). In order to reduce statistical complexity, distractor performance was averaged across target position (1-5) and distractor placement (clockwise/counter clockwise). To measure participants' performance in relation to the cost of adding a distractor, the subsequent data was analysed subtracted from the no distractor condition (Δ). Separate 4 (distractor position) x 2 (distractor colour) x 2 (visual feedback) x 2 (autism group) repeated-measures ANOVAs compared Δ distractor performance for radial error, RT and MT. Significance level was set at $p<0.05$. Effect sizes are reported as partial eta squared (n_p^2) for ANOVAs and Hedges' *g* (Hedges, 1981; Hentschke & Stuttgen, 2011) for t-tests. This is a measure of effect size which is similar to Cohen's *d* but controls for different group sizes. All data are reported as mean ± standard error of the mean (across subjects) (SEM). In order to investigate if individual differences in attention control are associated to distractor inhibition in the reaching task, the AQ subscale "attention to details" was correlated to participant's performance, in addition to the group analysis.

Results

No distractor performance

The group with high autistic traits (0.93±0.04cm) and low autistic traits (0.91±0.04cm) did not show significant differences in radial error during no distractor performance ($t_{(76)}=-.565$, $p=0.574$, $g_{Hedges}=0.08$). High and low AQ groups displayed the same movement times (high AQ=367±11 ms, low AQ=362±11 ms; $t_{(76)}=.177$, $p=0.86$, $g_{Hedges}=0.07$), showing no significant differences in error or movement time performance when a distractor was not present. In contrast, reaction times were generally slower for the high AQ group (443±11 ms) in comparison to the low AQ group (413±8 ms; $t_{(76)}$=-2.20,p=0.030,g_{Hedges}=-0.5) when a distractor was not present. This finding in a non-clinical cohort fits with previous reports highlighting a prolonged RT for reaching tasks in clinical cohorts of ASD (Dowd et al., 2012; Glazebrook et al., 2008; Glazebrook et al., 2009; Nazarali et al., 2009; Rinehart et al., 2001; Sachse et al., 2013).

Distractor performance

Our objective was to evaluate the difference between high and low AQ groups when inhibiting a distractor during motor (reaching) behaviour. To measure participants' performance in relation to the cost of adding a distractor, the subsequent data were analysed after subtracting no distractor performance (Δradial error, Δmovement time and Δreaction time).

Error

There was a significant effect of gender on Δradial error ($t_{(76)}$=2.5, p=.014). Females showed larger Δradial error (1.54±0.21 cm) in comparison to males (0.47±0.36 cm). When controlling for gender, there were clear and significant effects of distractor colour ($F_{(1,75)}$=54.13, p=0.045,n_p^2=0.052) and type of visual feedback ($F_{(1,75)}$=14.9, p<0.001,n_p^2=0.17; Figure 4.2). Participants showed increased Δerror for the white distractor (0.145±0.017 cm) compared with the red (0.004±0.015 cm), and the Δradial error was greater for the no visual feedback trials (0.197±0.015 cm) in comparison to when participants had visual feedback of movement (-0.048±0.016 cm). There was also a significant interaction between distractor colour and visual feedback ($F_{(1,75)}$=4.52, p=0.037,n_p^2=0.052), showing that the visual feedback difference in the Δradial error was greater when the distractor was white (0.85±0.09cm) compared to the visual feedback difference for the red distractor (0.60±0.08cm, $t_{(77)}$=-2.3, p=.024). No main effect of AQ groups or interactions were found in the Δradial error.

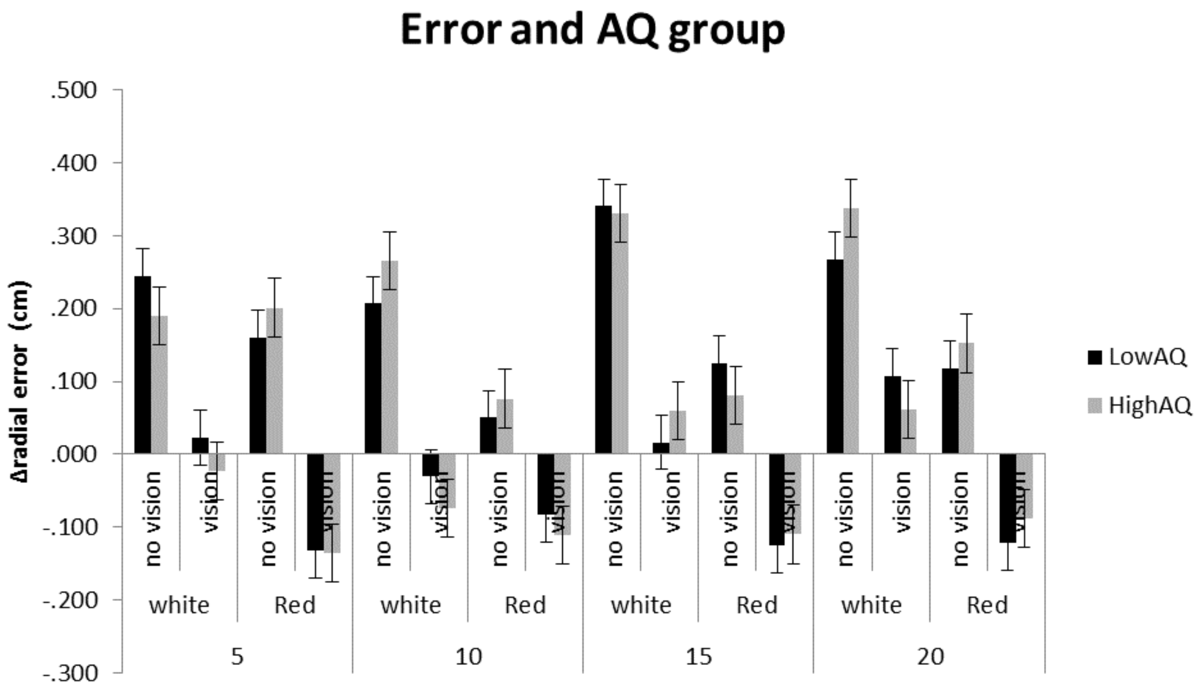


Figure 4.2: Δradial error for the motor distractor task. Δradial error (distractor – no distractor; cm) performance for the low AQ (black) and high AQ (grey) groups. Data are presented according to distractor position (5/10/15/20º), distractor colour (white/red) and visual feedback (online/endpoint).

Movement Time

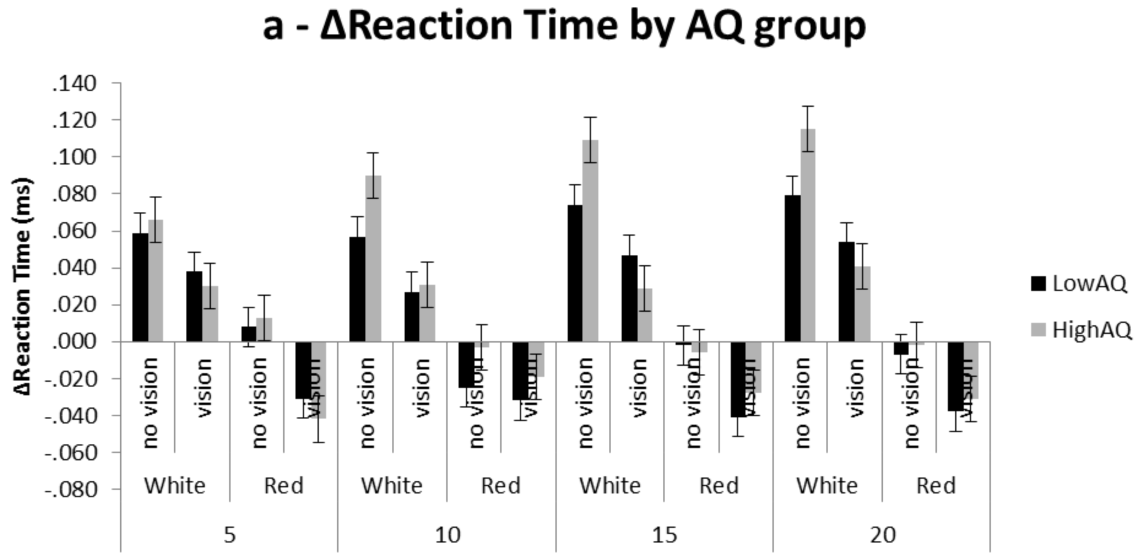
There was a main effect for colour ($F_{(1,76)}$=28.16, p<0.001, n_p^2=0.27) and also visual feedback ($F_{(1,76)}$=4.35, p=0.040, n_p^2=0.054). Participants had overall longer Δmovement times for the white distractor (162±43 ms) compared to red distractor (122±39 ms) and for no visual feedback (155±46 ms), compared to visual feedback (128±36 ms). There were no differences in performance between the AQ groups in the Δmovement time.

Reaction time

Overall, there was a main effect for distractor colour in the Δreaction time, where participants were generally faster to initiate their movement when the distractor was red (-18±3 ms) in comparison to the white distractor (59±6 ms; $F_{(1,76)}$=140,p<0.001,n_p^2=0.647). Participants were also faster to begin their movement with online feedback (1±4 ms) than without visual feedback (40±5 ms; $F_{(1,76)}$=71.85,p<0.001,n_p^2=0.49). There was also an effect of distractor position ($F_{(3.228)}$=3.2,p=0.024,n_p^2=0.40), participants took longer to initiate their movement in the 20^0 position (27±5 ms) in comparison to 10^{o} (16±4 ms; $t_{(77)}$=3.77,p<0.001) and 5^{o} (17±5 ms; $t_{(77)}$=2.19,p=0.032) and from 15^{o} (22±4 ms) in comparison to 10^{o} ($t_{(77)}$=-2.4,p=0.019). There was a three-way interaction between distractor colour, visual feedback and position ($F_{(3.228)}$=5.21,p=0.002,n_p^2=0.064).

Participants' age correlated negatively with the average Δreaction time (r=-.332, p=.003). When controlling for age, the main effects reported above disappeared, although distractor colour and vision interacted with AQ groups ($F_{(1,75)}$=6.74,p=0.011,n_p^2=0.083) as well as distractor position, colour, vision and AQ groups ($F_{(3.225)}$=3.54,p=0.016,n_p^2=0.045). In order to further investigate this interaction, partial ANOVAs were conducted separately for each distractor colour. There was a significant interaction of distractor position, visual feedback type and AQ group for the white colour distractor ($F_{(1,75)}$=3.86,p=0.018,n_p^2=0.072), but not for the red distractor ($F_{(1,76)}$=0.003,p=0.96,n_p^2=0.00). Next, separate ANOVAs on the white distractor data were conducted for each distractor position. These revealed a significant interaction of AQ and feedback both in the 15^{o} position ($F_{(1,74)}$=6.21,p=0.015, n_p^2=0.077) and the 20^{o} position ($F_{(1,74)}$=6.80,p=0.011, n_p^2=0.084) but not for the 5^{o} or 10^{o} (ps>.1). Each of these interactions was further investigated using independent sample t-tests comparing the effect of visual feedback (no-vision - vision). The simple effects analysis revealed that for both the 15^{o} and

20^{O} position, the group with high AQ exhibited a larger effect of the change in feedback in comparison to the group with lower AQ **(**15^{O}: low AQ: 28 ms±15 ms; high AQ: 80 ms±15 ms; $t_{(76)}$=-2.43,p=0.018,g_{Hedges}=0.54. 20^{O}: low AQ: 27 ms±12 ms; high AQ: 77 ms±10 ms; $t_{(76)}$=-3.09,p=0.003,g_{Hedges}=0.7). In order to investigate this further and verify if differences were present when participants relied upon proactive control, the no vision and vision conditions were separately examined using 1-tailed t-tests. The group with more autistic traits also showed increased Δreaction time when no visual feedback was available, in the 15^{O} and 20^{O} position when the distractor was white, in comparison to the group with low autistic traits (15^{O}: high AQ: 109 ms±15 ms; low AQ: 73 ms±15 ms; $t_{(76)}$=-1.68,p= .048,g_{Hedges}=0.38; 20^{O}: high AQ: 116 ms±10 ms; low AQ: 78 ms±16 ms; $t_{(67.2)}$=-1.92,p= .029,g_{Hedges}=0.41). The same effect was not present when online vision of movement was available (15^{O}: $t_{(76)}$=1.05,p= .148 and 20^{O}: $t_{(76)}$=.65,p= .259), Figure 4.3A-B.



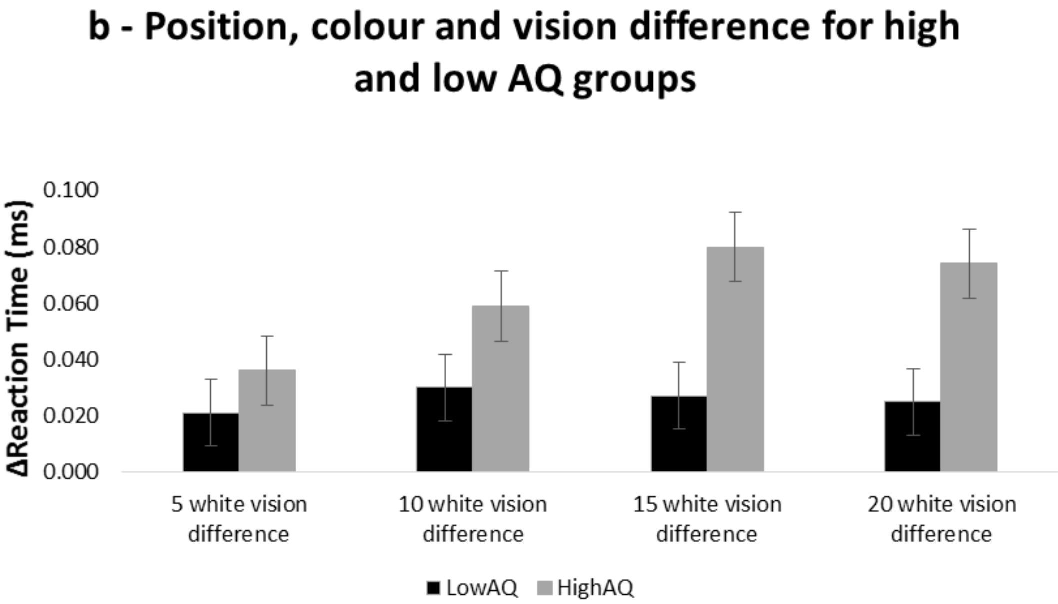


Figure 4.3 a: Δradial reaction time for the motor distractor task. Δradial reaction time (distractor – no distractor; ms) performance for the low AQ (black) and high AQ (grey) groups. Data are presented according to distractor position (5/10/15/20º), distractor colour (white/red) and visual feedback (online/endpoint). **b:** Interaction data showing the white distractor vision difference (no vision - vision) in the 5/10/15/20º, between the two groups (Data is mean ± SEM. *p=0.016).

In order to evaluate if the interactions found were not due to the chosen method used to divide the groups into high and low autistic traits, the same analysis was carried ou using quartiles to divide the groups, and the interaction between distractor position, colour, visual feedback and groups was still significant ($F_{(3,132)}$=7.1,p<0.001, n_p^2=0.14).

Individual differences

In order to further assess the link between attention and motor control in the BAP we investigated the correlation between attention related subscales within the AQ questionnaire and delta error, which were previously reported in this thesis to correlate with the ability to ignore distractors in the visual domain (chapters 2 and 3). Here, we were specifically interested in the ability to ignore distractors in the motor domain (delta error) either in a preparatory fashion (no-vision condition) or using reactive processes (vision condition). The overall Δradial error did not correlate significantly with the AQ rates or any of the AQ subscales (all ps>.1). However, the AQ subscale "attention to details" showed a significant negative correlation with the average Δradial error when no visual feedback was available (r=-.224, p=.049; Figure 4.4). In contrast, no correlation was found with the Δradial error when visual feedback was available (r=-.007, p=.954). This suggests a link between increased attention to details and the ability to better inhibit distractors in a preparatory fashion – in the condition where no online visual feedback is given. No other correlations between AQ subscales and performance in the reaching task were found.

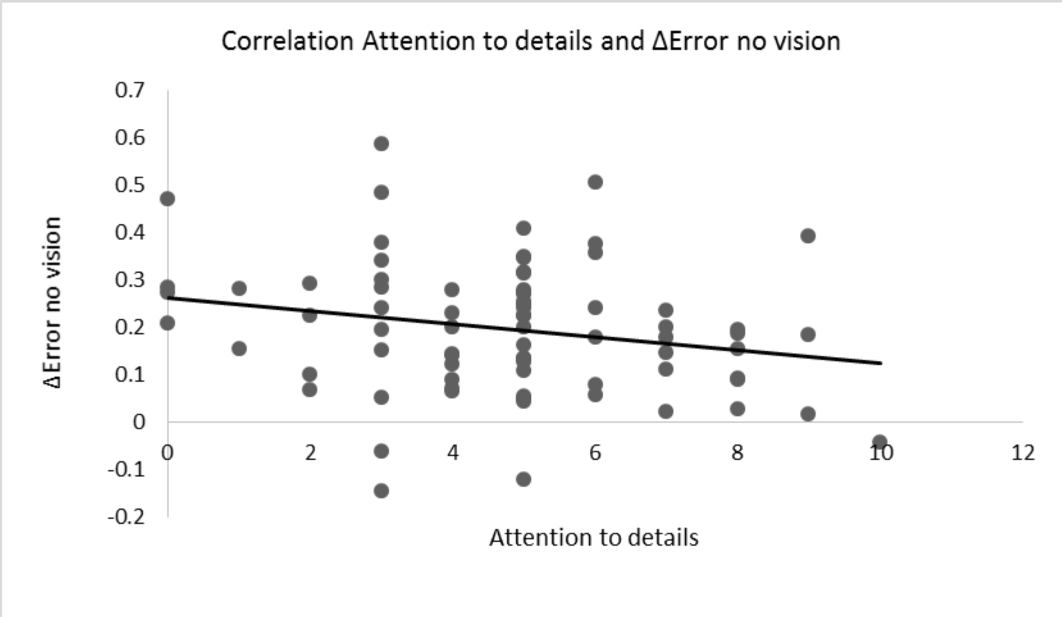


Figure 4.4. Correlation between Δradial error in the no visual feedback condition in the motor distractor task and the AQ subscale "attention to details" (r=-.224, p=.049).

Discussion

In this chapter we investigated the link between the expression of autistic traits in the typically developing population and atypicalities in motor control. During a simple motor (reaching) movement towards visual targets, participants with higher expression of autistic traits showed longer reaction times before movement initiation, but comparable radial error and movement time, similar to findings within the ASD population (Glazebrook et al., 2008; Glazebrook et al., 2009; Nazarali et al., 2009; Rinehart et al., 2001). This demonstrates that the same process and underlying mechanisms found in longer preparation times in ASD might also take part in the BAP. Furthermore, and in accord with previously reported findings with a similar task, participants' performance was most affected when a distractor which was similar to the target in colour was present, especially when no online visual feedback was available (cf. Mevorach et al., 2016). Although there was an overall difference in performance for these conditions, the accuracy of the motor control (final error) did not differ between low and high

AQ groups, who showed similar responses in end error and movement duration. This also fits within the current ASD literature, where participants show intact accuracy when inhibition is required in motor and visual tasks (Dowd et al., 2012; Mahone at al., 2006; Sachse et al., 2013).

It is clear from our reaction time data that participants overall found motor performance significantly more demanding (increased reaction time) in the presence of a white distractor, when no visual feedback of movement was available, and the distractor was further away from the target. Motor difficulties are more often seen in complex tasks that require some level of cognitive control (Heuninckx, Wenderoth & Swinnen, 2008). A recent study suggests that increased reaction times in a motor task might represent greater need of cognition-based processes related to action planning (Wong, Haith, & Krakauer, 2015). Differences in inhibition found in ASD also usually appear when the task is cognitively more demanding (Glazebrook et al., 2009; Gowen & Hamilton, 2013; Rinehart et al., 2002). In this case, in the most demanding task condition (white distractor, no visual feedback, distractor more distant from target), a 4-way interaction was found, where the group with more autistic traits showed a greater difference between visual and no visual feedback of movement, possibly as a result of increased reaction time when no visual feedback was available.

One possible explanation is that this difference reflects a shift in the dominant mode of cognitive control used to inhibit distractors in ASD, or in this case people with more autistic traits. Proactive mode is used to prepare the system to inhibit distractors before their appearance (e.g. when participants had no visual feedback of movement). In contrast, a reactive mechanism utilizes late correction, suppressing distractors after they appear (e.g. when participants have visual feedback of their movement; Braver, 2012; Braver et al., 2001). Previous research found atypicalities in people with ASD and more autistic traits when reactive control was required in reaching movements and visual distractor suppression (Dunn et al., 2016; Glazebrook et al., 2008; Glazebrook et al., 2009; Milne et al., 2013; Nazarali et al., 2009) and advantage when proactive control was required (Abu-Akel et al, 2016; chapters 2 and 3). A greater reliance in proactive control can be associated with longer preparation time required before task initiation, especially when there is no online visual feedback from movement. Furthermore, the group difference found in longer reaction times when no distractors were present could also reflect difficulties in reactive control, as such trials appeared unexpectedly within the distractor trials, thus eliciting on-the-go responses that are intrinsic to reactive control. The larger difference between conditions with and without movement vision (proactive vs reactive) in delta reaction time might also reflect a higher cost when changing from one mode of control to the other in this population, driven by longer preparation times required from people with more autistic traits, when proactive control was utilized in cognitively more demanding conditions. A bias towards a proactive control mechanism might be reflected in more time needed to plan a movement, seen in increasingly longer reaction times as cognitive demands increased when no visual feedback was given, and yet intact distractor inhibition.

Earlier in this thesis (chapters 2 & 3) improved ability to suppress visual distractors in high AQ was reported, as long as the information was available before each trial. As such, here we predicted that high expression of autistic traits would be associated with increased ability to inhibit motor actions towards distractors, especially when preparatory mechanisms of control are called upon. While there were no significant group differences in radial error, we found a significant (albeit small) negative correlation between the AQ subscale "attention to details" and the size of the radial error when no visual feedback was available. Attentional differences and specifically attention to details have previously been attributed to atypicalities seen in visuomotor performance found in ASD (Gowen & Hamilton, 2013; Klimkeit et al., 2005; Sharer et al., 2015). As such, our findings fit with this previous body of evidence. Interestingly, however, a similar negative correlation was reported earlier (chapter 2) linking 'attention to details' with reduced congruency effect in a visual attention task. Thus, we would argue that this trait is associated with an increase tendency for preparatory suppression of information which enables participants to reduce the effect of distractors on performance as long as the information is provided in advance. Importantly, our findings point to a possible benefit from high expression of this trait in the context of motor control – particularly when preparatory processes are relied upon.

Chapter 5

Effects of a computerized progressive attentional training program on children with autism: a control group school-based study

Abstract

Different functions of attention are documented to be impaired in children with ASD since early infancy, and the atypical development of attention has been associated with core impairments found in autism. Despite this, the effects of a computerized attention training program have not yet been studied in children with autism. This study investigated the effects of a Computerized Progressive Attention Training (CPAT) program on cognitive and academic performance of children with autism in a mainstream and special school. Fifteen 6-10 year old children with a diagnosis of autism were assessed pre- and post-intervention, on the Childhood Autism Rating Scale, Raven's Coloured Progressive Matrices and academic tests of maths, reading comprehension and copying. Teachers impressions were also evaluated using semi-structured interviews. Eight children were assigned to the experimental group and received CPAT sessions twice a week in an 8-week period, while seven children were assigned to the active control group, playing computer games for the same frequency, length and format. After training, the CPAT children showed significant improvement in cognitive scores and academic tests compared with controls. Teachers' reports were also in accordance with test results, indicating improvements in academic and attention skills for the CPAT but not the control group. Interestingly, all children were reported to have improved behaviour following training. Results suggest the CPAT is a feasible intervention program for application in a school setting, with the potential of showing transfer effects from attention training to cognitive and academic skills in ASD children. [4]

[4] Chapter 5 is a manuscript submitted for publication. Authors: Spaniol, Shalev, Kossyvaki and Mevorach. Spaniol contributions: Study conception and design; acquisition of data; analysis and interpretation of data; drafting of manuscript and revision.

Introduction

Autism Spectrum Disorder (ASD) or autism is a neurodevelopmental disorder characterized by difficulties in social interaction and communication, and repetitive and stereotyped interests and behaviours (DSM-5, American Psychiatric Association, 2013). ASD is a heterogeneous disorder with complex aetiology (Mandy & Lai, 2016), and although impairments in attention are not found amongst its core symptoms, atypical attention is often linked to autism in research, and even associated with the development of ASD symptoms (Keehn et al., 2013).

Atypical attentional processes have been noted in individuals with autism from early infancy. One such example is sustained attention (i.e. the ability to remain focused on a task over time), which was found to be poorer in children and adolescents with autism in comparison to typically developing controls (TD; Chien et al., 2015; Chien et al., 2014; Murphy et al., 2014). In a behavioural study measuring sustained attention, participants had to report whenever a specific sequence of numbers appeared within a serial visual processing stream (Chien et al., 2015). Differences in sustained attention in autism were particularly apparent in children showing fewer hits, correct rejections and more misses in comparison to typically developing (TD) children within the same IQ range (IQ<115) (Chien et al., 2015). In a previous study, children with autism also showed impairments in a Continuous Performance Task (CPT) in comparison to controls, also showing increased ADHD-related (attentional) symptoms (Chien et al., 2014). Interestingly, deficits in sustained attention performance are mainly seen within the younger and cognitively less able ASD population and less so with adults (Chien et al., 2015; Murphy et al., 2014). Such findings points to possible differences in brain maturation for attentional networks in ASD (Luna et al., 2007; Murphy et al., 2014). Even when behavioural differences are not present in sustained attention, brain activation still differs in ASD (Belmonte & Yurgelun-Todd, 2003a; Ciesielski, Courchesne & Elmasian, 1990; Murphy et al., 2014). Poor performance in sustained attention was found to be accompanied by reduced brain activation in relevant brain regions in autism compared to controls (Murphy et al., 2014). In a recent fMRI study with adolescents and adults with ASD, Murphy et al. (2014) found that poorer performance in sustained attention in ASD participants corresponded to lower activation in a network of regions including inferior prefrontal, medial prefrontal, striato-thalamic, and lateral cerebellar regions. While contradicting results were also reported (Sanders, Johnson, Garavan, Gill & Gallagher, 2008) indicating intact sustained attention in ASD, this may be attributed to scenarios in which the demand for sustained attention is lower (such as in the context of sustained attention to preferred objects).

Evidence for impaired selective-spatial attention (i.e. the ability to select relevant information and suppress irrelevant stimuli) has also been documented (Burack, 1994; Plaisted et al., 1999), with early brain activation differences found for participants with autism (Belmonte & Yurgelun-Todd, 2003a; Ciesielski et al., 1990). Belmonte and Yurgelun-Todd (2003a) used fMRI while participants performed a task consisting of two oddball streams, presented side-by-side. Participants had to attend to one or the other stream according to target colour. Typically, brain activation patterns represent the locus of spatial attention in such tasks so that activity in ventral visual cortex is enhanced for the attended stream and suppressed for the unattended one (Belmonte & Yurgelun-Todd, 2003b). In contrast, brain activation patterns in adults with ASD indicated no spatial attention modulation of ventral visual areas (i.e, there was no enhancement or suppression). This was also accompanied by performance differences where the ASD participants showed reduced selection of targets in the attended stream and compensatory suppression of items in the unattended stream (Belmonte & Yurgelun-Todd, 2003a).

Finally, perhaps the most frequently documented attention-related impairment in autism is in executive function, which is often linked to autism as a primary or secondary deficit (Geurts, Corbett & Solomon, 2009; Hill, 2004; Pennington & Ozonoff, 1996). Executive control (EC) comprises a large set of functions such as working memory, set shifting, inhibition, cognitive flexibility, reasoning and planning, all of which are needed for goal-directed behaviours. Specifically, set shifting or flexibility was found to be impaired in children with ASD (Happé et al., 2006; Verte, Geurts, Roeyers, Oosterlaan & Sergeant, 2006). Cognitive flexibility or set-shifting includes processes such as disengaging attention from stimuli and redirecting it towards different locations. Indeed, atypical disengagement of attention is documented in infants with ASD as early as during the first year of life (Elsabbagh et al., 2009; Landry & Bryson, 2004; Zwaigenbaum et al., 2005). In a gap-overlap task using eye-tracking, children with ASD showed longer latencies disengaging attention from a central fixation cross in the overlap trials, in comparison to TD controls (Landry & Bryson, 2004). Inhibition and working memory also seem to be impaired in ASD children in early ages, but may recover when entering into adulthood (Luna et al., 2007). While some studies have found no impairment in inhibition and working memory in autism (Dawson et al., 2002; Luna et al., 2007; Yerys, Hepburn, Pennington & Rogers, 2007), increased task complexity and consequently increased demand for executive control tend to bring out such differences. Rinehart et al. (2002) measured the capacity for inhibition in children with autism and TD controls using a Stroop-like task, where participants had to identify the direction of two arrows pointing right or left, which could appear on the right or left side of the screen. Levels of cognitive load were systematically increased, gradually adding congruency, conditionality and choice to the task. These authors found that only with increased levels of cognitive load the ASD group showed a decrease in performance (Rinehart et al., 2002).

Academic abilities of children with autism seem to vary across the spectrum (Estes, Rivera, Bryan, Cali & Dawson, 2011), but overall poor performance in a range of academic tests such as maths, reading and writing is well documented (Keen, Webster & Ridley, 2015). There is evidence for deficits in maths, but in some cases average performance in individuals with high functioning autism (HFA). However, some children might show advantage in maths (Chiang & Lin, 2007). When testing cognitively able children with ASD (IQ ≥ 70), academic skills such as maths and reading were found to be preserved (May, Rinehart, Wilding & Cornish, 2013; May, Rinehart, Wilding & Cornish, 2015). Reading skills also seem to be heterogeneous, as children with autism can show average reading ability but impaired reading comprehension, and variability in results is large from floor to ceiling levels (Nation, Clarke, Wright & Williams, 2006). Writing skills in HFA are reported to be poor, with children exhibiting frequent writing learning disabilities (Whitby & Mancil, 2009).

While attention represents a core cognitive process, critical for a variety of scenarios, its importance in the context of classroom settings and academic attainment is of particular interest. Recent research (Erickson, Thiessen, Godwin, Dickerson & Fisher, 2015) highlights the importance of selective and sustained attention in supporting learning in a classroom setting since early infancy. Evidence linking difficulties in academic skills to attentional difficulties in ASD come from studies by May and colleagues (May et al., 2013, 2015). Specifically, poor maths performance in children with ASD was found to be related to problems in attention switching in a visual search task (May et al., 2013). In a follow-up study, May et al. (2015) also found that attention switching correlated with both maths and reading performance in ASD. In fact, children with autism might show some similarities in learning and attentional profile to children with ADHD (Mayes & Calhoun, 2007), and children with learning disabilities (LD) (Calhoun & Mayes, 2005). In these studies, all groups were reported to have difficulties in attention and processing speed, which relate to poor performance in academic tests, particularly writing (Calhoun & Mayes, 2005; Mayes & Calhoun, 2007).

Thus, the behavioural and brain atypicalities seen in the performance of ASD participants in different attention tasks might not only have implications for the severity of ASD symptoms (Keehn et al., 2013), but also for skills needed in learning new abilities, and academic attainment in a school setting. Improvement of these attention skills in ASD is therefore of potential import in promoting successful learning for children with ASD in a school environment.

Previous studies have attempted a variety of training protocols in autism, typically targeting core ASD symptoms such as social interaction. Indeed, in a best evidence synthesis study (Reichow & Volkmar, 2010) of intervention studies targeting social functioning in ASD conducted between 2001 and 2008 the authors concluded that there is now evidence to support the efficacy of such intervention programs, particularly those using social skills groups and video modelling. For instance, training joint attention utilizing a behaviour modification procedure was successful as behaviours were effectively taught to ASD children, generalized to other settings and validated by naïve observers (Whalen & Schreibman, 2003). Pre-schoolers with autism were taught, through the use of scripts, sentences and comments which proved effective in interactions with typically developing (TD) peers (Ganz & Flores, 2008). Social skills were also taught in children with autism using LEGO therapy and a social language program, showing improvements in social, communication and adaptive behaviours (Owens, Granader, Humphrey & Baron-Cohen, 2008).

More recently, a growing number of studies utilising computer-based training programs were carried out in children with autism. These programs tend to target specific cognitive functions supporting social interactions such as emotion and face recognition (Golan et al., 2010), language and literacy (Pennington, 2010), and social skills (Bernardini, Porayska-

Pomsta, Smith & Avramides, 2012). Attempts at targeting more domain-general processes have also been carried out (Hilton et al., 2014; Vries, Prins, Schmand & Geurts, 2015). Working memory and cognitive flexibility were separately taught using a computerized program in children with ASD (Vries et al., 2015). In this case, marginal post training effects and generalization occurred, with improvements in working memory and near-transfer from working memory training to attention, and cognitive flexibility training showing improvements in flexibility (Vries et al., 2015). Hilton et al. (2014) also tested cognitive training for executive function and motor skills in children with autism, using an exergame (i.e. videogame that uses body movement) and found improvements in working memory, metacognition, strength and agility. While, certainly not all prior computer-based intervention studies have proven successful, as some failed to generalize to naturalistic settings (e.g. Golan & Baron-Cohen, 2006; Wass & Porayska-Pomsta, 2014), results tend to be overall positive, showing improvements of trained skills and transfer effects (Bernardini et al., 2012; Golan et al., 2010; Pennington, 2010) even when more domain-general processes such as working memory and attention are targeted (Vries et al., 2015). However, thus far comprehensive attempts to train a variety of basic attention functions are sparse, especially when applied in a school setting with the aim to impact academic attainment.

The notion of the potential benefit of attention training is not unique to ASD. Posner & Rothbart (2005) argued that attentional training, through repetition, can change brain functionality, and bring generalized improvements not only to the attentional network but also to intelligence, and consequently, academic performance. A computerized attention program has been used with children with attention difficulties in a school setting, showing long-term improvements in academic and attention skills (Rabiner, Murray, Skinner & Malone, 2010). In fact, a number of studies in different populations support the notion that attention can be modified with training (Gagnon & Belleville, 2012; Rabiner et al., 2010; Sampanis et al., 2015; Shalev et al., 2007; Wass, Scerif, & Johnson, 2012).

One attention-training program that has been shown in the past to have generalised training effects in different populations is the Computerised Progressive Attention Training (CPAT) program developed by Shalev et al. (2007). A study assessing the effectiveness of CPAT for 6 to 13 year old children with attention deficits showed improvements in both trained attention functions as well as non-trained academic skills and behavioural symptoms (Shalev et al., 2007). Similarly, a study assessing CPAT in sub-acute stroke patients demonstrated improvements in both specific attention functions (particularly sustained attention) and transfer to other cognitive domains, such as language, memory and number skills which were not directly trained (Sampanis et al., 2015). As CPAT attempts to train different attention functions – sustained, selective-spatial and executive attention, all of which could exhibit atypicalities in ASD, it may be particularly adequate in order to train attention in ASD, especially as its previous uses demonstrated transfer across different cognitive domains as well as to non-trained academic skills.

While various intervention programs for ASD have been studied (Bernardini et al., 2012; Golan et al., 2010; Hilton et al., 2014; Pennington, 2010; Vries et al., 2015), to our knowledge none of them has specifically targeted attention training in young children with ASD in a school setting with the aim of improving academic skills. Moreover, there is a growing need for research and interventions developed for and with schools, considering staff and school resources for effective program implementation (Kasari & Smith, 2013; Parsons et al., 2013). To overcome barriers employing interventions in schools, Kasari & Smith (2013) recommend the implementation of innovative programs in school settings, with key directives yet flexibility, and with generalization to real-life situations. Therefore, in the present study, the CPAT program developed by Shalev et al. (2007) was carried out in school settings (both mainstream and special education) with children with ASD, in an attempt to evaluate its viability for such a population. In particular, we ask whether CPAT is an appropriate program to use with children with ASD and whether any changes seen in attention skills can transfer to non-trained academic skills and cognition.

Findings from previous chapters (chapters 2, 3 and 4) suggest improved ability of distractor inhibition when proactive control of attention is used, and difficulties in reactive attentional control in individuals with more autistic-like traits. Considering these findings, the application of the CPAT with children with autism could be used as a tool to develop those areas of attention that are impaired in ASD such as reactive control, using proactive control of attention to aid performance at the beginning. As such, the CPAT begins making use of proactive control of attention in early levels, with simple training tasks with clear instructions, practice blocks and visual information of what is expected always available. It develops, in further levels, to train reactive control, when unexpected cues and distractors are included, eliciting on-the-go changes in response. Therefore, it is expected that reactive control will be trained within the CPAT, potentially bringing improvements to the aforementioned attentional mode of control.

Methods

The study took place at two different times in two primary schools in the Birmingham, UK area (one mainstream and one special). 15 children (6-10 years old) across the two schools with a diagnosis of ASD took part and were divided into two groups, one undergoing the CPAT intervention and the other engaging in standard computer games (active control; see details below). To measure the effects of attention training, pre- and post-intervention assessments were taken in the two groups which included an intelligence test (Computerized Progressive

Matrices, CPM; Raven et al., 2008), academic tests in maths, reading and copying, as well as the Childhood Autism Rating Scale (CARS) (Schopler et al., 1980) to measure the severity of autism, and semi-structured interviews with class teachers and teaching assistants (TAs). The entire study protocol took two months to complete. The intervention protocol and data collection were administered by a principal researcher (PR: Mayra Muller Spaniol) and three research assistants (RAs) (2 final-year Psychology Undergraduate students, 1 master student in Special Education), using personal and school laptops. Pupils were blind with regards to the main purpose of the study, and were all told that playing games would help them improve in school. School staff and parents were told all children were undergoing a computerized attention training. The possibility of using the CPAT with the active control group was offered to the participating schools following the completion of the study, providing the program as well as training for the school staff on its application. Institutional ethical approval for the study was obtained from the Science, Technology, Engineering and Mathematics Ethic Review Committee of the University of Birmingham.

Participants

Participants were recruited from the two aforementioned schools. All participants had a diagnosis of autism and a statement of special educational needs (SEN). Diagnostic criteria and ASD statements were checked and reviewed before children could take part in the study. A total of 15 children participated in the study, seven from the mainstream school and eight children from the special school (catering only for students with ASD). Pupils from the mainstream school came from different school years (i.e. 6 to 10 years old: 2 children in Year 1, 1 child in Year 3, 2 in Year 4 and 2 in Year 5) whereas pupils from the special school all frequented the same classroom (i.e. 7 to 8 years old). Pupils from each setting were assigned to an active control (computer games) or training (CPAT) group (i.e. 1 active control and 1 training group from each school). Participants were paired and matched in age (chronological age and cognitive age equivalent from the CPM, Raven et al., 2008) gender and intelligence (from the CPM; Raven et al. 2008) and randomly assigned to control or training group. Group allocation was also balanced across schools. Thus, overall the CPAT group was comprised of 8 children (2 females) and the control group included 7 children (1 female, see Table 5.1 below) across schools. To eliminate possible bias both groups were treated as intervention groups and this information was conveyed to teachers, parents and participants. Written parental consent was obtained prior to participation in the project. One child (female) in the active control group did not participate in the computer games sessions, and instead had education as usual (also missing post-intervention assessments for maths and copying). The age ($t_{(13)}$=.47,p=0.646), age equivalent ($t_{(13)}$=-.772, p=0.454) and the non-verbal intelligence ($t_{(13)}$=-.73, p=0.48) did not differ statistically between the groups.

Table 5.1*:* Control and CPAT groups, showing averages, standard deviation (stdv) and range for age, gender, mental age equivalent, and cognitive scores from the CPM, for both groups in the pre training assessment.

Groups	**All**	**Control**	**CPAT Training**
Total	15	7	8
Gender	3F, 12M	1F, 6M	2F, 6M
Age mean (Stdv) Range	8 (1.07) 6-10	7.86 (1.21) 6-10	8.13 (0.99) 7-10
CPM age equivalent (Stdv)	7.28 (2.07)	7.73 (1.3)	6.89 (2.4)
CPM standard (Stdv) Range	89.33 (17.2) 55	92.86 (15.5) 45	86.25 (19.04) 55

The intervention protocol *(CPAT, Shalev, Tsal & Mevorach, 2007)*

Attention training was employed using the CPAT, which was developed based on Tsal, Shalev and Mevorach's (2005) four-functions of attention model, which proposes that deficits in attention can be present in four networks within the human brain: sustained attention (responsible for maintaining attention for a prolonged time period), selective attention (focusing on relevant information while ignoring distracting stimuli), executive attention (solving conflicts, inhibition of irrelevant information) and orienting attention (directing and reorienting attention). In this study, three training tasks from the CPAT protocol were used, each separately focusing on either, sustained, selective-spatial or executive attention. The tasks were developed to be fun and interactive to engage and to be suitable for use with children from 6 years of age and above who show difficulties in attention (Shalev et al., 2007). These attentional functions were chosen to be trained based on the literature described in this chapter (pages 108 to 110) where deficits in sustained, selective and executive attention are evidenced in ASD.

The first of the three training tasks is *The Computerized Continuous Performance Task* (*CCPT)*, which was developed to improve the function of sustained attention, that is, to be able to maintain the focus of attention on a given task especially during monotonous activities. The *Conjunctive Search Task* (CST, based on Treisman & Gelade, 1980) was designed to improve selective-spatial attention. Even though O'Riordan et al., (2001; 2004) found advantage in visual search in ASD, there is also evidence of impartments in selective attention in ASD (Belmonte & Yurgelun-Todd, 2003a; Burack, 1994; Plaisted et al., 1999). Furthermore, the search task used in the CPAT trains reactive control of attention, using jittering stimuli, increasing speed and adding complex figures in further levels. The *Shift Stroop-like Task* (ST, based on Navon, 1977), was designed to improve the function of executive attention and cognitive control. Snapshots of the tasks are presented in Figure 5.1. These training tasks were designed with progressive levels of difficulty which are tuned to the individual performance of the trainee. All the training tasks use easy to understand visual and auditory feedback. The tasks and different levels of difficulty have been previously tested with children with ADHD

(Shalev et al., 2007), children with foetal alcohol spectrum disorder (Kerns et al., 2010) and with patients after stroke (Sampanis et al., 2015). In all these different clinical groups, the CPAT program produced positive outcomes.

In the present study, participants in the CPAT group had an average of 13 training sessions of approximately 45 minutes, twice a week across a two-month period. Sessions occurred in a distraction-free room, inside the school. Experimenters provided one-to-one supervision to each child. Each training task was divided into blocks of different number of trials. The CST and ST had 40 trials per block, while the CCPT had 80 trials per block for low levels of difficulty, or 160 trials for high levels of difficulty. All participants started at the lowest level of difficulty for each training task. Participants then progressed to higher levels of difficulty according to pre-specified criteria, based on maintaining high levels of accuracy and individual improvements in reaction time. The shifts between levels of difficulty in each task was controlled by the program. Training sessions had an average of 6 blocks from the three training tasks. This number varied according to age, individual differences and severity of ASD symptoms. In the CST and ST tasks, feedback was highly structured and immediate, with an auditory beep for incorrect answers and immediate positive visual feedback appearing on the screen for correct responses with average latency (e.g. "very good"), and correct responses showing improvements in reaction time (e.g. "excellent"). The CCPT did not show immediate visual positive feedback to maintain high demand of sustained attention. At the end of each block, feedback was translated into points that reflected participants' performance, including the number of correct and incorrect answers and quantity of positive feedback received (in accordance to Shalev et al., 2007, and Sampanis et al., 2015).

Figure 5.1. Example of displays from the three tasks from the CPAT. To the left, the Shift Stroop-like task (executive attention): in this task, participants were instructed to look for the large (global) smiley face (level 1) pressing the keyboard letter L if it was present, and A when it was abstent. In level 2, participants had to attend to the small (local) smiley faces, and in advanced levels they had to switch and attend to both large and small smiley faces, according to pre exposed cues. Middle: Conjunctive Search Task (selective attention). In this task participants had to decide if the display contained a target (red smiley boy), pressing L if present and A if target was absent (the display depicts level 1 where visual load is still low). Right: The Computerized Continuous Performance Task (sustained attention). In this task, participants had to respond to the appearance of a red car (target) while mantaining focus and inhibiting responses to other appearing objects (level1). The car was only present in 30% of the trials. At advanced levels participants only had to respond when the car appeared inside a black box, and ignore its appearance anywhere else on the screen.

Active control protocol (computer games)

For the active control group, three readily available computer games were used: Plants vs Zombies, Bejeweled 3 and Pacman. Participants in this group took part in a similar number of sessions as the CPAT group (i.e. 13 sessions) which were of the same length, frequency and format as the CPAT group. The control games also had feedback and had different levels of difficulty. Thus, both intervention groups used interactive games with positive feedbacks and rewards (stickers, reward game of their choice at the end of the session), over a 2-month period, twice a week (including school breaks) in a mainstream and special school setting. Importantly, the active control group had the same one-to-one interaction with the experimenters as the CPAT group.

<u>Pre- and post-intervention assessments</u>

To assess the outcome of the attention training (CPAT), performance was measured in a number of domains (see detailed description below) before and after the intervention for both the CPAT and active control group. These included severity of autism symptoms (CARS), cognitive ability (Raven CPM), and importantly, children's academic performance in maths, reading and copying. Class teachers' views were also captured via semi-structured interviews.

Assessments were carried out between one week and two weeks before and after the intervention, with an average of 3 to 4 sessions needed for completion of all assessments (with a frequency of two sessions per week). The assessments took place in the same rooms as the intervention (intervention rooms had sometimes to be changed due to limited room availability in schools but alternated between meeting room, library, computer room or empty classrooms). The PR and RAs had individual sessions with each child and were randomly assigned to work with different children to avoid possible bias. Results were compared within and across the training and control groups.

CARS

To assess behavioural symptoms of autism the classroom teachers filled in the Childhood Autism Rating Scale (CARS; Schopler et al., 1980; Schopler, Reichler & Renner,

1988) for the participating pupils. CARS is a behaviour observation scale where the child's behaviour is scored against 15 different dimensions, each question corresponding to an ASD symptom. CARS gives a total score measure ranging from non-clinical to severe autism (from a minimum of 15 to a maximum of 60). Each dimension is scored in a scale from 1 to 4. While originally scores below 30 were thought to correspond to the non-clinical range (Schopler et al., 1988), more recent studies point towards a cut-off score of 25 (Chlebowski, Green, Barton & Fein, 2010; Tachimori, Osada & Kurita, 2003). Scores above 37 indicate severe autism (Schopler et al., 1988). The reliability has been well documented, showing good internal consistency (alpha=.94, n=537), high inter-rater agreement (correlations ranging from .55 to .93, M=.71, n=280), and test-retest stability over a 1 year period is .88 for the total score (n=91; Schopler et al., 1988; CARS manual). High concordance between the CARS and the DSM-III-R and DSM-IV diagnostics is also documented (Perry, Condillac, Freeman, Dunn-Geier & Belair, 2005; Bebko, Perry & Bryson, 1996).

Raven CPM

The Raven's – Educational: Coloured Progressive Matrices (CPM) was developed to provide brief non-verbal screening measure of general ability. Using a set including visual patterns and shapes, it measures nonverbal skills that involve making meaning out of confusion and the ability to form nonverbal constructs that aid handling complex information (Raven et al., 2008). The test is sensitive to intellectual differences, and demonstrates good test-retest reliability (.80; Raven, Court & Raven, 1990). It is regarded as a good measure of fluid intelligence, especially for children with learning difficulties and disorders of language ability, as ASD (Carver, 1990; Cotton et al., 2005; Raven et al., 2008).

The CPM consists of 36 items, divided in three sets of 12 each: set A, Aʙ, and B. The sets are formed by visual shapes constituted by different patterns that need to be matched, requiring reasoning by analogy, and the ability to take this as a consistent way of thinking and method of inference for upcoming items. The test has coloured and black and white shapes and patterns, which makes the task completion easier with the least possible verbal explanation (Raven et al., 2008). Children can score a maximum of 36 in the raw score, which is converted into standard score, according to points obtained and chronological age from normative data. The test also provides percentile ranks and age equivalents. In this study, the principal researcher and research assistants administered the CPM individually, prior to and after training, following the administration procedure prescribed by Raven et al. (2008), with no time limitations imposed.

Academic assessment

In order to assess academic performance and the potential impact the intervention has on it, children in both groups completed two series of short tests in maths, reading comprehension and passage copying, one before and one after the intervention program. The tests were the same for all children, prior and post training, and children did not receive any feedback on their performance. The tests were selected from an online database of tests called *Testbase* (available at: http://www.testbase.co.uk/sec/primary.php) used by primary schools in the UK, from the basic level key stage 1 (KS1). *Testbase* provides online access to all the SATs questions (Scholastic Aptitude Test; standard tests to measure children's attainment in schools in England), marking schemes and examiner comments for maths or English since 1995. Children had 10 minutes to complete each test; the maths test had a total of 11 questions to be completed, reading comprehension had 17 questions and children had 3 paragraphs of 143 words in total to copy. The tests scores were converted into accuracy rates (percentage correct out of total number of questions) and the copying was scored using the number of words written per minute (total number of words divided by the time provided).

Semi structured interviews

Four different class teachers and two TAs took part in individual semi-structured interviews (3 class teachers from different classrooms from the mainstream school, 1 class teacher and 2 TAs from the same classroom from the special school, see Table 5.2). The interviews were carried out at the same time as the pre- and post-intervention assessments. Teachers and TAs were asked about social, academic and personal performance of children participating in the project, as well as attention skills prior to and after the training program. All interviewees were blinded to the existence of a control group, but were told that the pupils who participated in the research project would go through a computerized training on attention skills.

Table 5.2*:* Teachers and TAs taking part on the interviews, from the mainstream and special school.

Mainstream school (3 different classrooms)	**Special school** (same classroom)
3 teachers (MT1, MT2, MT3)	1 teacher (ST) 2 teaching assistants (TA1, TA2)

Prior to the start of the study, it was briefly explained to teachers and TA's what the project consisted of (i.e. rationale, duration and timeline). They were asked about their expectations from the project and asked to describe how they perceived the children in school: social aspects, personal skills, academic performance, attention and concentration in class. The same questions about the children were asked a week after the end of training (see Appendix 1 for a blank copy of the interview schedule). Interviews were recorded using an audio recorder and with written notes. Written consents were obtained for the audio recordings.

Data analysis

A two-way repeated measures ANOVA using time (pre vs post) as within subject factor and group (training vs control) as between subjects factor was used to analyse pre and post data. Significance level was set at $p<0.05$. Effect sizes are reported as partial eta squared (n_p^2) for ANOVAs and Cohen's *d* (same group size) or Hedges *g* (different group size) for t-tests. All data are reported as mean ± standard error of the mean (across subjects) (SEM). CARS was reported using total scores; Raven's CPM was reported and analysed using standard scores; maths and reading were reported in accuracy (percentage correct out of total questions); copying was reported and analysed using copying rate (the average number of words copied per minute). The qualitative data from the interviews was analysed using thematic analysis (Braun & Clark, 2006). Thematic analysis is a widely used method to identify, analyse and report patterns in qualitative data, organising and describing the data in detail, providing flexibility for interpretation of many aspects of the research (Braun & Clark, 2006). This study utilized both quantitative and qualitative data, although the qualitative data was categorised and turned into quantitative data and analysed using a chi-square test of independence to verify significant differences between the groups. A mixed method analysis combines quantitative and qualitative data in order to come to conclusions about human behaviour and effectiveness of interventions, complementing and enhancing the credibility of the research findings (Hesse-Biber, 2010).

Results

Baseline measures

Scores were distributed normally in all pre and post measures, apart from the maths pre-test (Shapiro-Wilk; control group: $p=0.039$; CPAT group: $p=0.044$). Importantly, the groups did not differ in any of the assessments prior to the commencement of the intervention (Table 5.3: CPM: $t_{(13)}$=-0.730, p=0.48, g_{s}=0.35; maths accuracy: $t_{(13)}$=-1.14, p=0.27, g_{s}=0.56; reading accuracy: $t_{(13)}$=-0.78, p=0.45, g_{s}=-0.38; copying rate: $t_{(13)}$=-1.40, p=0.18, g_{s}=0.68; CARS: $t_{(13)}$=1.02, p=0.32, g_{s}=-0.5). School membership (whether children were attending the mainstream or the special school) also did not affect pre-intervention baseline measures (CPM: $t_{(13)}$=-0.01, p=0.99; maths: $t_{(13)}$=1.39, p=0.19, reading: $t_{(13)}$=0.97, p=0.35 or copying: $t_{(13)}$=-0.13, p=0.99), although CARS scores were higher in the mainstream (33.07±2.06) in comparison to the special school (26.62±1.01; $t_{(13)}$=2.92, p=0.012). See table 5.3 below.

Table 5.3: Data (means ± SEM) for the pre-intervention assessments: CPM, maths, reading, copying and CARS. Scores are presented across all participants, as well as separately for the control and CPAT groups.

Groups	All	Control	CPAT training
CARS	29.6 ± 1.3	28.1 ± 1.3	30.9 ± 2.2
CPM	89.3 ± 4.4	92.8 ± 5.8	86.2 ± 6.7
Maths	37 ± 8.6	47.4 ± 14.1	27.8 ± 10.1
Reading	35.8 ± 4.6	31.9 ± 7.3	39.3 ± 6.2
Copying	3.5 ± 0.6	4.3 ± 1.1	2.7 ± 0.4

Pre vs. post intervention analyses

CARS

A two-way ANOVA was carried out on CARS scores with time (pre vs post training) as a within subject factor and group (CPAT vs. control) as a between subject factor. There were no significant main effects nor interaction with groups. Thus, as expected, it appears that CARS scores were not affected by training or control groups ($F_{(1,13)}$=1.43, p=0.252, n_p^2=0.1) or the passing of time in general ($F_{(1,13)}$=0.71, p=0.415, n_p^2=0.052).

CPM standard score

CPM scores varied in our sample, ranging from extremely low to average, high average and superior, in both control and training groups. A two-way ANOVA was carried out on CPM scores with time (pre vs post training) as a within subject factor and group (CPAT vs. control) as a between subject factor. There was a main effect of time ($F_{(1,13)}$=7.08, p=0.020, n_p^2=0.353), where pre CPM scores were significantly lower (89.55±4.53) in comparison to the post CPM scores (97.5±5.17). The interaction between group and time was marginally significant ($F_{(1,13)}$=3.78, p=0.074, n_p^2=0.225). Further analysis of simple effects revealed a significant increase in the CPM scores from pre to post assessment for the CPAT group (pre=86.25±6.73; post=100±5.98; $t_{(7)}$=-3.67, p=0.008, *Cohen's* d_s=-1.32), but no significant difference for the control group (pre=92.86±5.86; post=95±8.72; $t_{(6)}$=-0.45, p=0.67, *Cohen's* d_s =.011;see Figure 5.2A).

Academic assessments

Maths

There were no significant differences in the number of answered questions between the pre- and post-tests, and across CPAT and training group (average of 10 questions attempted out of the total 11). Data analysis was conducted over the percent correct (correctly answered questions out of total test questions) for each participant. One child (CH7) from the control group was excluded from the following maths data analysis since she failed to complete the test in the post assessment.

A two-way ANOVA was carried out on maths accuracy with time (pre vs post training) as a within subject factor and group (CPAT vs. control) as a between subject factor. There was a main effect for time ($F_{(1,12)}$=13.92, p=0.003, n_p^2=0.537), showing that post-test scores were generally higher than pre-test scores (pre: 38.92±9.17 and post: 53.13±8.92). More importantly, there was a significant interaction between time and group ($F_{(1,12)}$=6.43, p=0.026, n_p^2=0.349). There was a significant improvement in math scores for the CPAT group (pre=27.84±10.14; post=51.71±9.98; $t_{(7)}$=-4.52, p=0.003, d_s=-1.60), but not for the control group (t(5)=-0.866, p=0.426, d_s=-0.18; see figure 5.2B).

Reading comprehension

There were no significant differences in the number of attempted answered questions between pre and post assessment or groups from the total 17 questions in the reading test (average of 10 questions answered out of 17). Analysis was carried out on the accuracy rates (% correct out of the total 17 questions in the test).

A two-way ANOVA was carried out on reading accuracy with time (pre vs post training) as a within subject factor and group (CPAT vs. control) as a between subject factor. Again, there was a main effect of time ($F_{(1,13)}$=8.54, p=0.012, n_p^2=0.397), showing that post training reading scores were generally higher than pre training scores (pre: 35.63±4.74 and post: 47.45±5.15). Again, the interaction between time and group approached significance ($F_{(1,13)}$=3.95, p=0.068, n_p^2=0.233). There was a significant improvement in reading scores for the CPAT group (pre=39.34±6.19; post=59.19±5.34; $t_{(7)}$=-4.28, p=0.004, $d_{s=}$-1.53) but not for the control group ($t_{(6)}$=-0.553, p=0.60, d_s=-0.17), figure 5.2C.

Copying

There were a total of 143 words to be copied in 10 minutes. Word copying performance was analysed by calculating the copying rate (words copied per minute). One participant (CH7) from the control group was excluded from the analysis as he did not participate in the post assessment. The copying rate was submitted to a two-way ANOVA on copied words per minute with time (pre vs post training) as a within subject factor and group (CPAT vs. control) as a between subject factor. There was a main effect of time ($F_{(1,12)}$=7.78, p=0.016, n_p^2=0.393), showing that post-training scores were generally higher than pre-training scores (pre: 3.7±0.6 and post: 4.6±0.5). More importantly, there was a significant interaction between time and group ($F_{(1,12)}$=11.97, p=0.005, n_p^2=0.499). For the CPAT group there was a significant improvement in copying rate as a function of time (pre=2.7±0.46; post=4.9±0.59; $t_{(7)}$=-7.37, p<0.001, *d*=-1.6). In contrast, there was no evidence for improvement in the copying rate for the CG group (pre=4.6±1.2; post=4.4±0.9; t(5)=3.29, p=0.755, *d*=0.09; See figure 5.2D.

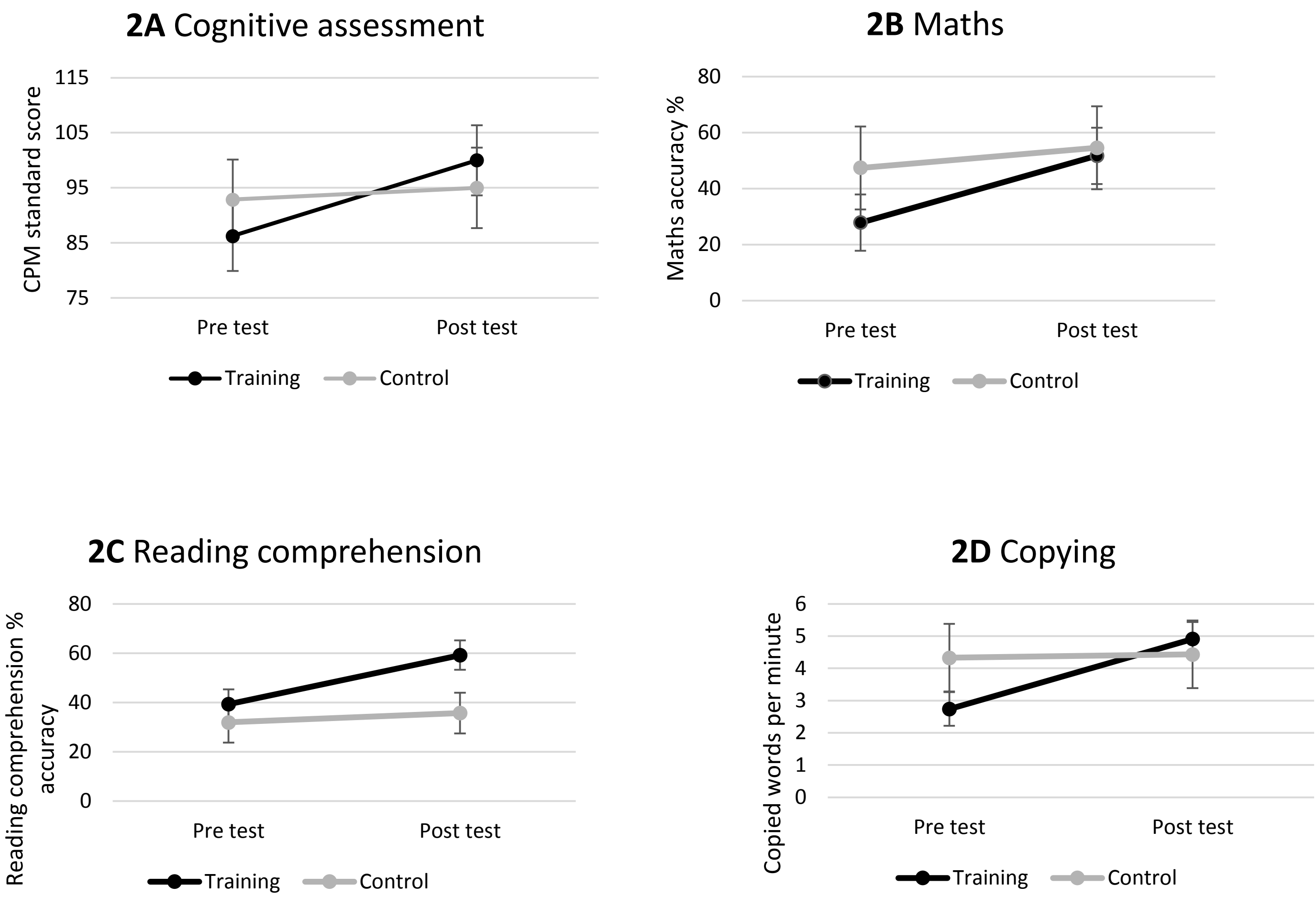


Figure 5.2. 5.2A: Standard scores from the cognitive assessment (CPM) for pre- and post-intervention tests, for the CPAT (black) and control groups (grey). Figure **5.2B:** Scores (accuracy) from the maths assessment for pre- and post-intervention tests, for the training (black) and control group (grey). Figure **5.2C**: Scores (accuracy) from the reading assessment for pre- and post-tests, for the training (black) and control group (grey). **Figure 5.2D:** Number of copied words per minute (copying rate) from the copying assessment for pre-and post-tests, for the training (black) and control group (grey).

Interviews

A thematic analysis of the pre-intervention interviews shows that before training, teachers reported difficulties in social interactions, learning academic skills and concentration for all children who participated in the study (both for control and CPAT groups). In the post-intervention interviews for both control and CPAT groups, teaching staff noted improvements in confidence and independence, increased social interactions and generally improved mood and enthusiasm. In order to investigate potential changes following the intervention, teachers' and TAs' accounts were subjected to thematic analysis (Braun & Clarke, 2006) meaning that they were organised and divided in themes covering different topics and patterns from the interviews, and compared between CPAT and control groups. Specifically, the common themes were identified and grouped into improvements in: attention (including concentration), academic and behavioural changes. The PR was the interviewer and coder, and teachers and TAs were blind towards group allocation. Quotes from the interviews can be found in Appendix 2.

CPAT group

Generally, teachers perceived children who took part in the CPAT program as showing academic progress in maths and English, and as being able to concentrate in tasks for longer periods of time, requiring less prompting (included under the attention improvements). They were also perceived to be more confident and independent, although this was not unique to the CPAT group. Some teachers and TAs also noted more 'seeking' behaviours where children seemed to look more for social interactions following training. Behavioural changes were coded from the post intervention interview transcripts with school staff. Results from the pre- and post-intervention assessments, and fragments from the interviews were organised in recurrent themes (attention, academic and behavioural changes) individually and summarized in Table 5.4 below. Some extracts from the interviews can be found in Table 5.4 but a more detailed account of the staff quotations can be found in Appendix 2.

Table 5.4: Pre- and post-intervention assessment measures for all children from the CPAT group. M: male; F: female. SS: special school; MS: mainstream school. Improvements in attention, academic skills and behaviour were based on interview extracts for each child.

Children (age, gender, school)	CPM standard (pre/post)	Maths accuracy (pre/post)	Reading accuracy (pre/post)	Copying words/min (pre/post)	Examples from the interview passages	Improvements in: Attention	Academic performance	Behaviour
***CH1* (9, F, MS)**	75/95	32/59	50/65	3.9/4.5	"G*reater academic achievement. More focus and attention to the task* (MT2)*"*	Yes	Yes	Yes
***CH3* (7, M, MS)**	75/90	14/32	32/47	2.7/5.2	*"Progress in numeracy, improved focus and concentration (MT1)"*	Yes	Yes	Yes
***CH5* (10, M, S)**	120/120	91/91	74/79	3.1/5.2	"*Academic progress; can concentrate in tasks for longer (MT3)"*	Yes	Yes	No
***CH6* (8, M, MS)**	85/100	0/14	26/38	1.1/2.5	"*Some academic progress; inconsistent. Lower levels of learning (MT1)"*	No	Yes	Yes
CH11 (7, M, SS)	75/85	9/32	21/56	3.1/6	*"Improved in maths (ST). It is easier to get him to work on tasks, attention has improved (TA1)"*	Yes	Yes	Yes
***CH12* (8, M, SS)**	110/115	32/82	50/62	4.9/8.1	*"Improved concentration and attention skills. Maths, English improved (ST)"*	Yes	Yes	Yes
CH14 (8, F, SS)	65/75	9/32	26/47	1.6/3.8	*"Improved in maths (ST). Seems more attentive and interested in doing the tasks (TA1)"*	Yes	Yes	Yes
***CH16* (8, M, SS)**	85/120	36/73	35/79	1.5/4	"*Making progress in maths, better concentration.(ST)"*	Yes	Yes	Yes
Number of children who improved	7/8	7/8	8/8	8/8		7/8	8/8	7/8

Control group

Overall, teachers noted positive changes in behaviour, confidence, independence and some progress in academic areas for some of the children in the control group. The same improvements in attention and concentration were not commonly found in the reports from teachers for the control group. Some quotes from the interviews are listed in Table 5.5 below:

Table 5.5: Pre- and post-intervention assessment measures for all children from the control group. M: male; F: female. SS: special school; MS: mainstream school. Improvements in attention, academic skills and behaviour were based on interview extracts for each child.

Children (age, gender, school)	CPM standard (pre/post)	Maths accuracy (pre/post)	Reading accuracy (pre/post)	Copying words/min (pre/post)	Examples from the interview passages	Improvements in: Attention	Academic performance	Behaviour
CH4 **(8, M, MS)**	95/90	86/77	35/35	3/2.6	*"Difficulties with shapes and words. Still needs prompting, problems concentrating" (MT1)*	No	No	Yes
CH8 (10, M, MS)	90/95	91/100	62/82	8.2/5.2	*"Needs prompting. Progressing academically in maths"(MT3)*	No	Yes	Yes
CH9 **(8, M, SS)**	85/90	9/14	35/15	2.6/4.6	*"Still needs prompting to pay attention. Same academic performance"(ST)*	No	No	Yes
CH10 **(8, M, SS)**	110/120	23/50	41/26	4.9/3.9	*"Always been good. (TA1). Progressing in maths, English, good concentration"(ST)*	Yes	Yes	Yes
CH13 **(8, M, SS)**	70/50	9/5	9/9	1/ 2.1	"*Improved behaviour (TA1). Not major progress academically"(ST)*	No	No	Yes
CH15 **(7, M, SS)**	115/115	82/82	35/47	8.3/8.2	*"Always been good (TA1). Can concentrate in maths. Keeps good academic progress not major jump"(ST)*	Yes	No	No
Number of children who improved	3/6	3/6	2/6	2/6		2/6	2/6	5/6

As detailed in Tables 5.4 and 5.5, the interviews revealed that improvements in academic skills were more frequently noted for participants in the CPAT group. Improvements in attention and concentration in tasks were also more frequently reported for children from the CPAT group, even though all evaluators believed that all children were taking part in an attention-training program. Positive changes were reported in both control and CPAT groups concerning personal skills such as confidence, independence and motivation. To verify this, a chi-square test of independence was performed to examine the relation between attention improvements and group (CPAT and control), academic improvements and group, and behavioural improvements and group. The relation between attention improvement and group was marginally significant, with more improvements in attention within the CPAT group (87.5%, 7 out of 8) in comparison to the control group (33.3%, 2 out of 6; Pearson Chi-Square x^2= 4.38, df=1, p=.036; Fisher's exact test p=.091). The relation between academic improvement and group was significant (Pearson Chi-Square x^2= 7.47, df=1, p=.006; Fisher's exact test p=.015). Children who underwent CPAT training had significantly more reports of improved academic performance (8 out of 8, 100%) in comparison to controls (2 out of 6, 33.3%). Behavioural improvement was not significantly different between the two groups (p>.999); teachers noted similar improvements in behaviour in children from both groups.

Discussion

Previous studies have shown that children with ASD are characterized by atypical attention performance, and as attention functioning is thought to be linked to academic performance, in the present study we attempted to train attention in school children with ASD using a previously developed attention training protocol (CPAT; Shalev et al., 2007). We assessed the potential efficacy of CPAT in improving academic attainment of children with

ASD by obtaining measures of non-verbal cognition, academic skills, ASD symptomatology as well as semi-structured interviews with teachers before and after the training protocol was employed in two schools (one mainstream and one special). Importantly, the functions we measured were not trained within the intervention protocol, which only included simple visual attention tasks (sustained-, selective-spatial- and executive attention). Furthermore, we also included an active control group of children with ASD that underwent a similar protocol of intervention with readily available computer games, using the same format and the same length and frequency of sessions (as well as a one-to-one interaction with an experimenter). This enabled us to verify that any changes we observe following attention training could not be attributed to the mere passage of time or to the children involvement in an engaging computer-based activity during the school day. Overall, the data indicated promising comprehensive improvements for the children in the CPAT intervention group, which were over and above any improvements obtained in the control group.

Particularly, improvements in the CPAT, but not the control group were evident in a variety of academic tests including maths, reading comprehension and copying speed. Following the CPAT intervention, children with ASD were able to score higher in a time-limited maths test, were more successful in performing a time-limited reading comprehension test (albeit only approaching significance in the ANOVA) and were also able to increase their copying rate (words per minute) of a given text. Furthermore, scores on a non-verbal cognitive assessment (Raven's CPM) also improved for the CPAT group following training (although approaching significance). All these improvements were significant in the simple effects analysis. Findings in this study give further support to the growing body of interventions utilizing technology in order to improve or teach new skills to children with ASD, including academic, social and cognitive abilities (Bernardini et al., 2012; Bosseler & Massaro, 2003;

Chabani & Hommel, 2014; Ganz, Boles, Goodwyn & Flores, 2014; Golan et al., 2010; Hetzroni & Shalem, 2005; Hilton et al., 2014; Knight, McKissick & Saunders, 2013; Vries et al., 2015).

While clear academic and cognitive improvements were observed following the attention training, we found no evidence of change in ASD symptomatology. Total scores from the CARS did not change from the pre- to post-intervention assessment and remained equivalent across the two groups (CPAT and control). It is worth noting that the CARS is designed to be used by trained clinicians while in this study it was used by class teachers in the two schools, who were not able to strictly follow the pre- and post-intervention timeline due to busy schedules. It was also the case that overall CARS scores were relatively low for children with ASD, even more so in the special school. We hypothesise that scores were lower in the special school and higher in the mainstream school because teachers were biased considering their environment, so teachers from the mainstream school had neuro typical children as a comparison and the teacher from the special school had other ASD children as a comparison baseline. Nevertheless, the lack of change in ASD symptomatology may also be related to the dissociation between attention atypicality in autism and core symptoms (similarly to Eaves & Ho, 2004) who did not find any differences in CARS scores post-intervention) so that while attention improvement can benefit academic performance it did not affect ASD symptoms.

The academic and cognitive improvements we observed were also reflected in the thematic analysis of the semi-structured interviews we conducted with teachers and TAs in the two participating schools. The teachers' and TAs' reports indicated improvements in attention and academic performance, which were more frequently noted with respect to children in the CPAT group. Teachers' evaluations from the interviews match quite closely the academic tests results in maths and english (reading and writing) for both the CPAT and control group (in the CPAT group teachers reported consistent academic improvements for all children whereas such improvement was reported only for one third of the children in the computer-games group).

Teachers attributed attentional improvements to children from the CPAT more frequently than for the control group, although attention improvements were also noted in the control group. This may represent a placebo effect as staff in the schools were informed that all children were taking part in an attention training program. Nevertheless, close examination of the interview reports may suggest some degree of improvement in sustained attention for the CPAT group, which is not consistently mentioned for the control group. For example, behaviours mentioned for children in the CPAT (but not the control) group include improved concentration in tasks and in the classroom, being able to concentrate for longer periods of time and showing more self-regulation (less prompting needed) when completing routine classroom tasks.

It is also worth noting that the thematic analysis of the interviews did highlight some behavioural changes (albeit in both groups). In particular, teachers' and TAs' noted that children in both groups seemed more confident, showed high self-esteem and even demonstrated more socially oriented behaviour. Indeed, these behavioural changes may be attributed to the general aspects of the intervention protocol (across both groups); namely, the participation in a special activity with a dedicated member of staff on a regular basis as a tool for engagement and interaction (Blatchford, Bassett, Brown & Webster, 2009). Interestingly, while the CARS score did not change the indication that children in the study were showing more socially oriented behaviour may point to an improvement in social interactions, but perhaps not substantial enough to be indicated by the CARS.

The improvements found in maths, reading, copying and non-verbal intelligence following the attention training, are in accordance with previous reports using the CPAT with children with ADHD (Shalev et al., 2007), children with foetal alcohol spectrum disorder (Kerns et al., 2010) and adult stroke patients (Sampanis et al., 2015), where trained attention skills showed transfer effects for non-trained abilities. When used with children with ADHD and with children with foetal alcohol spectrum disorder, the CPAT brought improvements for non-trained academic skills (reading, maths and copying; Kerns et al., 2010; Shalev et al., 2007). Similarly, when the CPAT intervention was utilised with sub-acute stroke patients, improvements were documented in a range of non-trained cognitive domains (e.g., language, memory and number skills; Sampanis et al., 2015). Our results are also in accordance with findings regarding improvement in school performance following a different computerized attention-training program, when used with TD children (Rabiner et al., 2010). Thus, the improvements we report in academic skills and cognitive ability following attention-training support the notion that cognitive training of attention has direct impact on learning and general cognition, and can therefore transfer beyond the trained attentional skills.

In a recent study that has used the CPAT (Sampanis et al., 2015), the authors noted that improvement in sustained attention following the intervention was specifically evident. It was therefore postulated that improved sustained attention might serve as a domain-general approach to training that can transfer to performance in a variety of cognitive domains. While we have not assessed attention performance directly in our cohort (other than the increased level of difficulty reached in all training tasks within the CPAT tasks), improved sustained attention in the CPAT group could be deduced from the thematic analysis of the teachers and TAs reports. Indeed, if children are able to sustain attention for longer periods of time in routine classroom activities and also throughout the academic tests, this will have obvious benefits for learning processes in the classroom, enabling children to improve performance when responding to academic and cognitive tests.

However, it may still be the case that improvements were obtained across various attention functions (sustained, selective and executive attention) but such improvements are harder to note without specialised assessment tools (i.e., it is possible for a teacher to note a child is taking part in a class activity for longer periods of time but not that their selective spatial attention works more efficiently when processing a piece of text). Indeed, the different attention skills trained can directly relate to performance improvements in academic tasks. For example, when reading, children need to ignore surrounding words in a paragraph and select the relevant ones to answer a question using selective-spatial attention. At the same time, they need to focus on local (small) letters, putting them together to form words, while inhibiting outer distracting information, switching from different words or paragraphs, using executive attention, as well as sustaining attention throughout test completion.

Nevertheless, attention improvement might not have been exclusively limited to sustained attention in the CPAT group. Sustained attention may well have a clear impact on performance in maths and reading comprehension tests, but it would be expected that such improvement will also be manifested by increased number of questions attempted within the same amount of time. However, we found no difference in this number before and after training across tests and groups. We therefore suggest that the academic improvements we documented are more likely associated with attention improvement across the different functions (sustained, selective and executive), and possibly improved reactive attention control which was also trained across the CPAT tasks in advanced levels.

Similarly, training these attention functions together may have facilitated performing a cognitive test of fluid intelligence, when logical thinking, inference, sustained attention, attention to details and inhibition or selection of stimuli are required, culminating in the improved cognitive scores (CPM) found in this study for the CPAT group. Transfer effects to fluid intelligence have also been documented following working memory training (e.g., Jaeggi, Buschkuehl, Jonides & Perrig, 2008) and there too, were attributed (at least in part) to enhanced control of attention.

The current study was structured utilising positive feedback and rewards across the two groups, promoting engagement and motivation for both CPAT and control groups. Improvements in children's independence and self-esteem, as well as high motivation to participate in the program were noted by all class teachers and TA's in the interviews with respect to children in both groups. Previous studies utilising CPAT have highlighted the importance of the tight schedule of online feedbacks embedded within the program which helps the participant to associate the effort they make and the impact it has on performance as well as driving motivation (Geurts, Luman & Van Meel, 2008; Kerns et al., 2010; Shalev et al., 2007). Motivation is an important prerequisite of successful interventions, as motivational incentives tap into reward mechanisms that can aid attentional control (Padmala & Pessoa, 2011). Interestingly, in ASD, evidence points to reduced socially-driven motivation, with non-social reward playing a more effective role (Chevallier, Kohls, Troiani, Brodkin & Schultz, 2012; Mundy, 1995). In our study a combination of social and non-social motivational tools were used, such as on-screen feedbacks and points acquired, verbal praise, reward games and stickers, making it difficult to discern what type of motivational tool was more effective in this population. Nevertheless, high motivation or the type of feedback in itself could not explain improvements found in the training group, as these were similar across the CPAT and the control groups.

Importantly, our findings also support the notion that using CPAT as an intervention within a school setting is feasible. Parsons et al. (2013) and Kasari & Smith (2013) highlighted the importance of the implementation of intervention programs for ASD in "real world" settings, such as schools. While the CPAT intervention was challenging to implement due to school breaks, children missing classroom time, need of trained staff and private and quiet training rooms, it was still successfully conducted in the two participating schools. Frequent one or two week breaks took place in both schools (i.e. half term/ Christmas holidays), which required a break in training sessions. Still, children did not show any major differences in performance on the tasks after the breaks, and their motivation and engagement did not alter either. Moreover, we have found no differences in performance (and outcome) across the mainstream and the special school. This further supports the feasibility of the implementation of CPAT in varied school contexts.

In terms of limitations, it is important to note, however, that the present study investigated a relatively small-sized cohort (8 and 7 children for the CPAT and control, respectively). Also, long term effects of training were not investigated. Future studies are therefore needed in order to investigate a larger cohort as well as the long term effects of training. Another factor that should be considered is utilizing a double-blind design to avoid any possible bias scoring post-tests, although all possible measures were taken to ascertain children from both groups were treated equally, experimenters in this study (PR and research assistants) were aware of the group assignment at the end of training. Parents' evaluations should also be considered for future research, in order to investigate if the effects of training are limited within the school setting or if training and transfer effects are also noted at home.

In conclusion, the results found in this study regarding the application of a computerized progressive attention training program (CPAT) in a school setting are promising. Not only in terms of its effective use in a mainstream and special school, but also the near- and far-transfer of attention training to academic and non-verbal cognitive performance of children with autism. At the same time, the program was engaging and motivating for the children, bringing improvements in a personal level for both the CPAT and control groups due to highly structured routine and use of rewards and positive feedback.

Chapter 6

General Discussion

In the general discussion, I will summarize the main findings of each chapter, offer further interpretation and discussion of the results, linking this to the current literature, also discussing limitations, future directions and general conclusion.

Summary of chapters

Attentional differences are found in ASD and the BAP from the first year of life (Elsabbagh et al., 2009; Zwaigenbaum et al., 2005) and associated with life-long atypicalities found in this disorder (Keehn et al., 2013, Sacrey et al., 2014). Being able to attend to salient visual information (bottom-up) and guide attention, selecting and suppressing pieces of salient or non-salient information that are relevant depending on the context (top-down) is a crucial ability in daily activities. There are accounts of altered bottom-up and top-down processing in ASD and the BAP that might be dependent on the nature of the stimuli, with accounts of difficulties processing social information (Adolphs et al., 2006; Behrmann et al., 2006a, 2006b; Bird et al. 2006) but also enhanced abilities such as discrimination and visual search (O'Riordan et al., 2001; O'Riordan, 2004) or local processing (Koldewyn et al., 2013; Mottron & Belleville, 1993; Plaisted et al., 1999; Wang et al., 2007). The context under which advantages or disadvantages in visual processing appear were further investigated in this thesis. It was also checked if differences were dependent on 1. Type of stimuli used; 2. Perceptual or attentional differences; 3. Whether these atypicalities were present not only in individuals with an ASD diagnosis, but also within the BAP and 4. Across visual and motor domains; and finally, I attempted to employ an attention training program in children with ASD in order to evaluate possible cognitive and generalized benefits to children with autism in school settings.

In the first experimental chapter, the ability to suppress distractors mediated by high and low traits of autism was measured. Specifically, using two different visual tasks it was investigated if suppression was modulated by the aspects of stimuli: global vs local and faces vs scenes. It was found that participants with more traits of autism showed improved suppression of the irrelevant distractor regardless of the nature of the stimuli, as seen in a smaller difference between congruent and incongruent conditions in the global-local task, and better distractor filtering for scenes and face target identification. No differences were found in the neutral conditions (when distractors were not present) and a small correlation between attention to details and the congruency difference was found. It is therefore suggested that this visual processing atypicality is related to enhanced distractor suppression rather than to perceptual differences.

This hypothesis was further investigated in the third chapter, where a more rigorous test of perceptual capacity was used. Thus, a face discrimination task was employed without distractors (to test for perceptual capacity differences), as well as with a distractor (measuring the contrast threshold of the distractor). Furthermore, it was also tested whether the enhanced distractors suppression I reported in the previous chapter might be linked to the mode of attentional control the task may require. The previous tasks used here tapped only a preparatory (proactive) mode of control, and it is therefore possible that such preparatory suppression of distractors is enhanced in participants with high expression of autistic traits, but that this is not the case for more reactive suppression processes when control is employed on-the-go. The results indicated no difference in performance between autism groups in low-level perception of faces (without the need to ignore distractors), but an advantage was evident for high AQ in suppressing the distracting scene as this group showed higher contrast thresholds suppressing the irrelevant scenes while discriminating between male faces. Interestingly, enhanced performance was only present in the proactive (morph-face) task, but not when reactive control was prompted in the search task. In this task high rates of autistic traits were detrimental to participants' ability to reactively respond to the occurrence of a salient distractor and use it for their benefit. These findings therefore suggest a dissociation in the effect high AQ has on attentional control, with improved preparatory (proactive) suppression but impaired reactive (dynamic) suppression.

In the fourth chapter, the relationship between visual-attentional and motor distractor suppression was tested in a simple reaching task. Participants with more autistic traits showed increased reaction times (preparation) in comparison to people with less autistic traits, before the initiation of reaching, even when a distractor was not present and appeared in an unexpected fashion during the distractor trials. Such findings are in accord with research on motor control in ASD and chapter 3, where the group with more autistic traits showed atypical performance in the reactive condition. Finally, with the addition of distractors, people with more autistic traits exhibited increased difference in reaction time between having online vision vs no vision of movement, which was driven by longer reaction times when no visual feedback was available, in the most demanding task condition (same colour distractor further away from target). Also, Δerror correlated with the autism subscale "attention to details" in this task, which indicated that improved performance in reaching movement is associated with attentional differences, particularly detail-oriented processing. It is hypothesized that enhanced attention to details, e.g. to target and distractor position, could have aided participants performance when reaching for the target whilst ignoring distractors. Results show that increased attention to details benefited performance when reaching for the target and ignoring the distractor in the proactive (no vision) condition for participants with higher autistic traits. This suggests that benefit in proactive control can also affect motor performance, and attention and motor abilities are closely related.

Lastly, the effects of a Computerized Progressive Attention Training (CPAT) program on cognitive and academic performance of children with autism were investigated, in a mainstream and special school. Fifteen children with autism were assessed pre- and post-intervention, on the Childhood Autism Rating Scale, Raven's Coloured Progressive Matrices and academic tests of maths, reading comprehension and copying. Teachers' impressions were also evaluated using semi-structured interviews. Eight children received CPAT sessions twice a week in a total average of 13 sessions, while seven children were assigned to the active control group, playing computer games for the same frequency, length and format. The results show that after training, the CPAT children showed significant improvement in cognitive scores and academic tests (albeit interaction approached significance for the Raven and reading). Teachers' reports are in accordance with test results, showing improvements in academic and attention skills for the CPAT but not similarly in the control group. This demonstrates that improvements were due to the CPAT and not merely playing computer games. Therefore, improvements are attributed to enhancement of the attention functions trained within the CPAT and transfer effects to non-trained abilities. Interestingly, all children had reports of improved behaviour after training, attributed to positive interactions with the experimenters, based on clear program structure, and positive feedbacks and rewards, all promoting motivation and engagement. This suggests that the CPAT is a feasible instrument to be used in a school setting with children with autism in order to train attention and improve cognitive and academic performance, as well as behaviour.

Perceptual and attentional atypicalities in autism and the BAP

In this section, I will discuss the findings from previous chapters in light of perceptual vs attentional alterations accounts found in the ASD and the BAP literature. Previous research in autism and the BAP has highlighted different impairments in low-level perception of stimuli (e.g. faces; Klin et al., 2002) but also in top-down control (Hill, 2004), while other accounts have shown opposite results, highlighting enhanced perception of stimuli in autism (Mottron, Dawson, Soulieres, Hubert & Burack, 2006) and superior high-level abilities such as visual search and inhibition (O'Riordan et al., 2001). In chapter 2, I attempted to test if differences in visual attention performance within the BAP were in fact due to perceptual alterations - would the high AQ group show enhanced performance when responding to the local level, or impairments in face identification? Are there any differences when differentiating between two faces or scenes? At the same time, I tested if in fact performance differed when attentional selection was utilized, specifically when high salient distractors had to be suppressed, assessing attentional and not perceptual alterations. Findings in chapter 2 show in fact superior attentional ability when it comes to distractor filtering, and no initial indications for perceptual alterations.

To further test this assumption, in chapter 3 the difference between perception and attention was critically assessed in experiment 1, with a first task measuring perceptual discrimination, and a second task looking at distractor suppression, both utilizing the same set of faces. As adults with high AQ showed no difference in performance when differentiating between faces on a morph-continuum, perceptual alterations were then ruled out, contradicting suggestions of enhanced perceptual functioning (EPF – Mottron et al., 2006) often linked to ASD. Importantly, enhanced performance in participants with higher autistic rates was only seen when suppressing an irrelevant scene and responding to less familiar male faces. Findings in the two first experimental chapters support the notion of intact perception (but not enhanced) discrimination of stimuli, in accordance with some findings in the literature using socially relevant stimuli such as faces (Adolphs et al., 2006; Humphreys et al., 2007). Most importantly, results show improved distractor filtering within the BAP, related to attentional and not perceptual abilities. Kaldy, Giserman, Carter & Blaser (2016), in a recent review paper, also suggest that enhanced visual search abilities are related to differences in attention modulation, and not perception of stimuli, developed from attentional alterations present since the first year of life in ASD and the BAP (e.g. Elsabbagh et al., 2009) culminating in atypical attention modulation (over-focus). Further support for this idea comes from Milne (et al., 2013) who found that a late ERP component (P3b) within the BAP, predicted enhanced search ability in a visual attention task, while earlier components that relate to perceptual processes did not. Findings from previous chapters and broader considerations regarding conflicting findings in literature are discussed below, within a theoretical framework that distinguishes between different modes of attentional control, which could account for the enhanced but also impaired performance found in the BAP.

Dual Mechanism of Control (DMC) theory

In chapters 2, 3 and 4 in this thesis, adults with high autistic traits exhibited atypical (enhanced) performance in non-spatial visual attention experiments (chapters 2 and 3), and in motor inhibition (chapter 4, related to the AQ subscale attention to details), specifically when distractor suppression was required. This indicates improved top-down control and no differences in low-level perception of stimuli in the BAP. One possibility of explaining these findings is to consider them within Braver's dual model of cognitive control (Braver, 2012). Previous studies (Abu-Akel et al., 2016; this thesis), suggest a link between this approach and the discrepancies in performance found in ASD research: while individuals with autism and the BAP might show an advantage in tasks relying on proactive (preparatory) control of attention, difficulties are apparent when reactive (online) control is required. This is in accordance with findings in this thesis, where enhanced performance was only seen when participants relied upon proactive control (chapter 2, chapter 3 experiment 1, chapter 4 no vision condition), but when reactive control was available to benefit performance, the expression of more autistic traits had opposite effects, which I attribute to difficulties in the reactive control of attention.

Braver (2012) proposed a Dual Mechanism of Control (DMC) theory to explain the variations of performance in cognitive control for different tasks and those related to different populations and changes in brain function (between-groups). In this account, proactive control is associated with sustained and anticipatory activation of the lateral prefrontal cortex (PFC), responsible for maintaining task goals and serving as a source to activate optimal top-down processing in anticipation of demanding task goals. Reactive control would then utilize transient PFC activation and a range of additional brain regions, being influenced by bottom-up processing (Braver, 2012).

The presence of a salient distractor can elicit proactive or reactive control, depending on task demands. For example, evidence supporting the preparatory nature of a proactive control mechanism in the global-local experiment (chapter 2 experiment 1) was found using transcranial magnetic stimulation (TMS) over the parietal cortex (intraparietal sulcus) either before or after stimuli presentation (Mevorach et al., 2009). This study reported effects of TMS only when it was applied before the onset of the visual information, affecting participants' performance when suppressing a previously known distractor (Mevorach et al., 2006b, Chang et al., 2014). This further supports the notion of enhanced proactive suppression underpinning the smaller congruency difference in the global-local task (chapter 2).

In the second chapter, participants with higher autistic traits exhibited enhanced performance when filtering through distractors in a proactive manner. In the third chapter, I used two tasks, the morph-face task tapping proactive control, and a visual search task that elicited reactive control. Performance of participants with high autistic traits was only improved when suppressing distractors in a proactive (chapter 3 experiment 1), but not reactive manner (chapter 3 experiment 2). When the salient distractor is context relevant, it can act as an anti-cue (non-target), facilitating attention towards the target and eliciting reactive control, as shown in chapter 3 experiment 2. In support of this idea, in an fMRI study the salient non-target facilitated participants' performance, prompting faster and more accurate responses when compared to a similar non-target. The left temporal parietal junction (TPJ) and inferior frontal gyrus (IFG) were both active when the salient anti-cue was present, indicating a key role when reactive control is involved (DiQuattro & Geng, 2011), pointing to which brain atypicalities might also underlie behavioural difficulties in reactive control found in adults with more autistic traits.

This evidence strongly supports my hypothesis that adults with higher autistic rates show a bias towards a proactive mode of cognitive control, reflected in enhanced performance in distractor suppression documented in this thesis, and various visual attention tasks in literature (e.g. Joseph et al., 2009; Kemner et al., 2008; O'Riordan et al., 2001; O'Riordan, 2004; Remington et al., 2009), whilst difficulties when changing performance "on-the-go" or spontaneously orienting attention could be attributed to problems in reactive control of attention (e.g. Freeth et al., 2011; Goldberg et al, 2002; Kawakubo et al., 2004, 2007, Klin et al., 2002; Landry & Bryson, 2004; Riby and Hancock, 2009). For instance, in regards to conflicting findings in top-down control, in Joseph et al. (2009), participants with ASD performed a search task, looking for a letter target and suppressing surrounding distractors in both static and dynamic tasks, showing better performance in comparison to controls in both conditions, and shorter fixations on distractors. In this study, participants had practice blocks and performance feedback before each task, instructions and knowledge of the task ahead was clear before initiation. Therefore it could be said that participants relied on proactive control of attention to achieve enhanced performance. Contrarily, in Landry & Bryson (2004) for example, deficits in attention disengagement were found in children with ASD, when instructions were simply to "look at the screen". As no clear task instructions were given, participants with autism could not rely on proactive control to guide attention, consequently showing problems disengaging from the initial image.

In this framework, longer reaction times before movement initiation found in motor tasks in participants with autism could be attributed to over reliance on proactive control, where individuals would need more time to plan their movements (Rinehart et al., 2001; Sachse et al., 2013), showing similar performance to controls in end error (which is overall similar to the findings I report in chapter 4). Within the same account, problems reprograming, self-developing strategies and utilizing online vision to guide movement after initiation could also be related to difficulties in reactively correcting performance (Glazebrook et al., 2008; Glazebrook et al., 2009; Nazarali et al., 2009). Although no deficits in reactive motor control were found in chapter 4 (except for a larger difference between proactive and reactive conditions when the task was more demanding, driven by longer time needed in the proactive -no vision condition), it could be the case that in the reactive (visual feedback) condition, participants with high AQ were still able to rely on proactive control, simply not utilizing the online feedback to guide movement. On the other hand, when only proactive control was available (no visual feedback), enhanced attention to details benefited performance, showing a link between attention and motor control in the BAP.

The conceptualization of discrepancies in attention control in ASD and the BAP being a consequence of improved proactive and impaired reactive control has important implications for the development of tools and programs to aid individuals with autism in various settings. As such, advantage in proactive control provides support for the development of highly structured activities with a set of clear rules and directives, with enough time for preparation, for children and adults with ASD in a variety of settings, as this seems to be beneficial to visual attentional and motor performance. The CPAT in this case is a program that could aid both proactive and reactive control in training attention in children with autism, making use of both proactive and reactive processes.

Reactive control is of extreme importance in daily situations, as the naturalistic "real world" environment is not completely controlled, and non-planned events often occur and are an intrinsic part of learning and living in society, where proactive and reactive control are both simultaneously utilized. In this sense, the CPAT is also an adequate program to be utilized in order to train the attention of children with ASD as it begins, in the early levels, with "games" utilizing proactive attention control. For example, participants know they need to look for the global level (big smiley face), having visual information available and knowing where it will appear in the first level of the Shift Stroop-like Task. In further levels, as participants progress and achieve good levels of accuracy and speed, the task becomes more complex and reactive control is then introduced for training. For example in higher levels in the same task, a cue appears (big or small smiley face) right before each individual trial, telling participants which level should be attended next, eliciting "on-the-go" responses. Thus, it could be said that reactive, as well as proactive control were further trained with the CPAT, and therefore this might also be responsible for the improvements in non-trained abilities found in this study. The benefit the CPAT and structured control games brought to the behaviour of children with autism can be attributed to positive feedback, verbal praise, rewards and highly structured and clear activities proposed to the children, under individual supervision. The combination of high motivation due to positive feedback, proactive and reactive attention training combined with the various attentional functions being trained with the CPAT make it a suitable program to be further utilized with children with autism in order to bring generalized improvements as such processes are intrinsic to daily activities that are a part of learning.

Having said this, the DMC theory might not be the only explanation for findings in this research. In the reactive visual search task utilized in chapter 3 experiment 2, problems in the disengagement of attention could also account for the lack of advantage utilizing the anti-cue. If adults with autism and in the BAP have difficulties disengaging and shifting attention between items (e.g. Landry & Bryson, 2004), then it could be hypothesized that the salient anti-cue could have been processed and due to problems disengaging, individuals with more autistic traits were not able to reorient attention towards the target as rapidly as adults with less autistic scores. This possibility needs further investigation, as this was the only visual spatial experiment; results from this thesis cannot provide a certain answer at this stage. Nevertheless, one could suggest that disengagement can also be manipulated in a proactive manner using clear task instructions and providing enough time, or in a reactive manner with the sudden need to reorient attention after task initiation. In this case, the experiment used in chapter 3 to measure reactive control elicited reactive disengagement as the appearance of a more salient distractor was not known in advance. Similarly, in Kikuchi et al. (2011), explicit instructions to gaze towards a specific face location before task initiation reversed previous findings in attention disengagement, and children with ASD then exhibited the same performance as TD.

The type of stimuli used could also be related to the findings in this thesis. In the first 3 experimental chapters, the stimuli employed were static, grey-scale simple pictures and objects. Research looking at dynamic stimuli has previously shown atypical performance in top-down regulation from ASD participants (Greenaway & Plaisted, 2005), whereas the use of static, neutral grey-scale pictures of faces elicited intact gaze towards eyes as well as disengagement (Bar-Haim et al., 2006). It could be hypothesized that dynamic stimuli would more naturally elicit reactive regulation, whereas static stimuli would be easily processed in a proactive manner, as long as time and instructions were provided. This is further supported by Greenaway and Plaisted (2005) as the insertion of a dynamic cue brought less benefit to ASD participants as well as no distraction, whereas a colour (static) cue and distractor elicited typical cueing effects.

Limitations and future directions

Another important point to be considered relates to the difference between stimuli used in this research and more naturalistic real-life settings. Hanley, McPhillips, Mulhern and Riby (2013) highlight the importance of utilizing more realistic stimuli to measure responses towards social information in ASD. Participants with ASD, for instance, exhibited typical eye-gaze towards static pictures of faces viewed in isolation, but less attention towards the eyes was present when faces were viewed as part of social scenes (Hanley et al., 2013). Thus, maybe if the faces utilized in the first two experimental chapters were inserted in more realistic settings, different atypicalities in selection might have been present. Therefore, findings pointing to enhanced distractor filtering in a proactive fashion are thus far seen specifically in static stimuli and non-spatial and social tasks. It would be interesting to test if these findings extrapolate to spatial, dynamic and more naturalistic experiments.

Two other limitations worth consideration from the first three experimental chapters in this thesis have been mentioned in chapter 2. They concern the predominant university, female gender in this sample, as well as the use of the AQ to measure autistic traits in participants. Although gender did not affect the findings, if an equal gender or male dominant sample was tested, it could even be hypothesized that the effects found would be stronger, as autism is more prevalent in males (Baron-Cohen et al., 2014). Also, the AQ score range in all chapters was equivalent to those found in previous reports from the general population. Future studies could benefit from the use of different measures to ascertain the presence of autism, such as the Social Responsiveness Scale-Adult (SRS-A; Constantino & Todd, 2005). As autistic traits are present in the typical population to varying degrees, results found in the three first experimental chapters are thought to extrapolate to the clinical ASD population.

Although the CPAT has proven successful in children with ASD in school settings, the cohort is still limited in size. I suggest that larger studies are needed to verify its efficacy in autism, with the development and application of appropriate measures to evaluate specific attentional changes responsible for the improvements seen in cognition and academic performance. Although all possible measures were taken to avoid bias from experimenters, teachers and children, the implementation of double-blind design in future research would also be beneficial to rule out any possible bias. Long-term effects of training should also be tested, to verify if changes in cognition endure the passage of time. Parental reports would also be useful to verify if transfer effects were also noted at home and not only in the school setting where training took place.

Finally, further investigation of the neural underpinnings of proactive and reactive control in the BAP is needed, such as the involvement of the parietal cortex (intraparietal sulcus) in proactive control and the enhanced performance in people with more autistic traits (Mevorach et al., 2009) and the left temporal parietal junction (TPJ) and inferior frontal gyrus (IFG) role in reactive control (DiQuattro & Geng, 2011) and if this is indeed impaired in the BAP and ASD.

Conclusion

In conclusion, this thesis makes a relevant and innovative contribution to the current literature, both in terms of the use of a new theoretical model (DMC) to explain discrepancies in performance of persons within the BAP in visual attention and motor tasks, and in the successful application of a computerized attention training program in children with ASD. Adults with more autistic traits exhibited better distractor suppression in three proactive, non-spatial attention experiments involving global, local, faces and scenes stimuli. In contrast, this effect was reversed when reactive control was available to benefit performance, evidencing a bias towards proactive control and impairments in reactive control in this population. In the final experimental chapter, the application of the CPAT in different school settings brought improvements in academic, cognitive and, according to interviews, attentional skills of children with ASD, as well as behavioural improvements in the training and control groups. Results from the application of the CPAT with ASD children has positive implications for future research and for the application of the CPAT in school settings as a tool to improve attention, to aid cognition and academic learning in children with autism.

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Appendix 1

Interview with teachers

Preamble
Talk about:

- Quickly about project – aimed at improving basic attentional processes involved in school activities

- Academic assessment (content they are seeing in class – math, reading, writing and copying)

- CARS

- Preferences for break activities

Pre interview

- What do you think are their difficulties regarding academic, social, attentional and personal domains?

- What are your expectations from the training?

Post interview

- How are they doing academically, socially, personally now?

- How is their attention in the classroom?

- Any other comments about the project?

Appendix 2

Quotes from the interviews:

CPAT

"*CH11. and CH14 improved in maths, one level up since the beginning of the project"* (ST). *CH11. is better at doing tasks, it is easier to get him to work on tasks, and attention has improved"* (TA1). *"He pays attention to details a lot more"* (TA2). *"CH14. shows improvement in work boxes, she used to flip, but now seems more attentive and more interested in doing the tasks."* (TA1).

"CH16. still shows some disruptive behaviours, not as much after the project. Making progress in maths, better concentration but still needs some prompting sometimes. Can do more now on his own" (ST). "*CH16 has improved; it's easier to get him to focus in activities"* (TA1).

"CH12 has improved concentration and attention skills, he used to get distracted. Maths improved, numbers, English improved, he is progressing really well" (ST). *"He is aware of his own behaviour, and is showing better listening skills now"* (TA2).

"CH3 is more confident and independent… He does things by himself now. CH3 is showing progress in numeracy, improved focus and concentration but still has good and bad days" (MT1).

"CH1 shows greater academic achievement; more likely to go and talk to people; more focus and attention to the task. More independent and confident, can do tasks on her own and asks questions, better communication and social interactions" (MT2).

"CH5 is concentrating in tasks a bit more, for longer. CH5 is making academic progress; he can concentrate in tasks in class for longer, before it used to be 2 minutes" (MT3).

"CH6 made some academic progress, just not as much as one could possibly hope for. He's not quite there yet, so inconsistent, some days are better than others. Lower levels of learning,

numbers need to keep going back to adding, taking away, and number recognition. Talks to himself more. Has many social interactions, but always on his terms". (MT1)

Control

"CH8 is more participative in class, still shows difficulties in doing tasks independently and needs prompting. He is progressing academically in maths but not so much in literacy" (MT3). *"CH4 understands pure maths but has difficulties with shapes and meaning of words and mathematical problems. He is more confident and independent. Shows more stereotyped behaviours, has problems concentrating and still needs prompting to do tasks"* (MT1).

"CH9 still needs prompting to pay attention… Same academic performance" (ST). *"Attention slips a bit"* (TA1). *"He gained a lot of confidence, good computer skills, important for life: learning to interact with the computer"* (TA2).

"CH10 and CH15. have always been good" (TA1). *"CH10 shows good behaviour, progressing in maths, English, good concentration"* (ST). *"CH15's behaviour got worse, he is expressing more, communicating more (started to hit). Can concentrate in maths, English not so much, depends on the task needs prompting. Keeps good academic progress not major jump"* (ST).

"CH13 improved behaviour in activities, completely different during activities" (TA1). *"He can sit and work through tasks but not major progress academically"* (ST).

Across groups

Interestingly, there was a direct comparison between two boys, one from the CPAT and one from the control group, who were from the same classroom, according to MT3: *"CH5 is concentrating in tasks a bit more, for longer…. CH5 (CPAT) is more focused than CH8 (control). CH8 gets more distracted, still needs prompting and has difficulties in doing tasks independently. CH5 is making academic progress, he can concentrate in tasks in class for* *longer, before it used to be 2 minutes".* In particular, TA2 mentioned that all children were showing "*smiles on their faces: children have been very enthusiastic to participate*" (TA2).