

Running Head: Effortful Control, Attention, and Executive Functioning in ASD

Effortful Control, Attention and Executive Functioning in the Context of Autism Spectrum Disorder

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List of Abbreviations

| | |
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| ACC | Anterior Cingulate Cortex |
| ACSENT | Applied Cognitive Science and Experimental Neuropsychology Team |
| ADI-R | Autism Diagnostic Interview-Revised |
| ADHD | Attention Deficit and Hyperactivity Disorder |
| ADOS-2 | Autism Diagnostic Observation Schedule, Second Edition |
| ANT | Attention Network Test |
| ASD | Autism Spectrum Disorder |
| CBQ-VSF | Children's Behaviour Questionnaire – Very Short Form |
| CMS | Children's Memory Scale |
| COMT | Catechol-o-methyl Transferase |
| DRD4 | Dopamine Receptor |
| DSM | Diagnostic and Statistical Manual of mental Disorders |
| EATQ-R | Early Adolescent Temperament Questionnaire, Revised |
| ERN | Error Related Negativity |
| FHS HREC | Faculty of Health Science Human Research Ethics Committee |
| FSIQ-4 | Full Scale Intelligence Quotient |
| MAOA | Monoamine Oxidase A |
| NEPSY-II | Developmental Neuropsychological Assessment, Second Edition |
| SES | Socio-Economic Status |
| SPSS | Statistical Package for the Social Sciences |
| Std | Standardised |
| ToM | Theory of Mind |
| UCT | University of Cape Town |
| WASI | Wechsler Abbreviated Scale of Intelligence |
| WCED | Western Cape Education Department |

Abstract

Autism Spectrum Disorder (ASD) involves a broad presentation of symptoms classified along continuum of severity, with core deficits in Social Affect and Restricted, Repetitive Behaviours required for formal diagnosis (American Psychiatric Association, 2013; Lauritsen, 2013). The development of particular cognitive, behavioural and interpersonal difficulties seen in ASD is of great interest. Temperament offers particular value given that it influences the development of social behaviours, emotionality and self-regulation (Shiner et al., 2012). The self-regulatory temperament factor, effortful control, is known to be diminished in ASD (Garon et al., 2009, 2016) and is theorised to be related to attention and executive functioning (Rothbart & Rueda, 2005). This link is of particular interest, given that attention and executive function deficits are prominent in ASD (Craig et al., 2016; Lai et al., 2017; Sanders, Johnson, Garavan, Gill, & Gallagher, 2008). To date, however, a thorough literature search failed to yield a study which has investigated whether effortful control, attention and executive functioning are concurrently associated with ASD symptomatology. Moreover, the relationship between effortful control, attention and executive functioning is not as unambiguous as previously theorised in typical development, with little investigation into these relationships in ASD. To elucidate the association effortful control, attention and executive functioning have with ASD symptomatology, the relationship between effortful control and these cognitive variable needs to be better established empirically. Therefore the current investigation's aims were twofold. Study One investigated the relationship of effortful control with attention and executive functions in neurotypical and ASD samples. Study Two explored the association between effortful control, attention, executive functions and core ASD deficits (i.e. Social Affect and Restricted, Repetitive Behaviours). A sample of 38 ASD and 38 neurotypical boys (aggregate-matched on key demographic factors), aged 6 – 15, and their primary caregivers were recruited. Study One considered both groups ($n=76$) and featured both quasi-experimental and relational investigations. Study Two focused only on the ASD sample ($n=38$) and used a purely relational design. Neurocognitive measures were used to assess two attention domains (i.e. attention span and sustained attention), and three executive functions (i.e. working memory, inhibition and switching). Effortful control was measured using a parent-report questionnaire and ASD core deficits were examined using the Autism Diagnostic Observation Schedule, Second edition (ADOS-2; Lord, Luyster, Gotham, & Guthrie, 2012). Results of Study One revealed effortful control was a significant predictor of attention span, working memory and inhibition, with ASD participants

performing significantly more poorly on these cognitive domains and rated significantly more poorly on effortful control. Study Two's results indicated that Social Affect was significantly correlated with inhibition and the interaction effect between effortful control and working memory. Furthermore, only effortful control, attention span and their interaction effect were significantly associated with Restricted Repetitive Behaviours. Specifically, effortful control was found to moderate this relationship. At high levels of effortful control, increased attention span was associated with less Restricted, Repetitive Behaviours. These findings may aid efforts to establish a predictive model for ASD core deficits on the basis of temperament and cognitive difficulties.

Keywords: Autism Spectrum Disorder (ASD), Effortful Control, Attention, Executive Functions, Social Affect, Restricted Repetitive Behaviours

Autism Spectrum Disorder (ASD) involves a broad presentation of symptoms classified along a continuum of severity, with the presence of Social Affect impairments and Restricted and Repetitive Behavioural patterns and interests required for formal diagnosis (American Psychiatric Association, 2013; Lauritsen, 2013). Social Affect deficits comprise of language difficulties, diminished social-emotional reciprocity, impaired joint attention as well as abnormal eye contact, facial expressions and gestures (American Psychiatric Association, 2013). Consequently, individuals with ASD struggle to understand social interactions and to develop and maintain relationships. Restricted, Repetitive Behaviours includes stereotyped motor movements (e.g. hand-flapping), repetitive use of objects and speech (e.g. echolalia), fixated interests, ritualised behaviour patterns, extreme adherence to routine, and hyper- or hypo-interests to sensory input (American Psychiatric Association, 2013).

Although these core diagnostic features present in a heterogenous phenotype, they mark out a highly recognisable group of individuals. While the incidence of ASD within South Africa is unknown, 1 in 160 children worldwide are thought to have the disorder (World Health Organization, 2017). Despite the high incidence, the exact aetiology of ASD remains unknown. The cause is thought to be neurodevelopmental and while there is much investigation into its aetiology, the development of particular cognitive difficulties, behavioural styles and interpersonal interactions seen in ASD are of great interest too.

Considering that temperament influences the development of social behaviours, emotionality and self-regulation (Shiner et al., 2012), and a specific abnormal temperament profile has been identified in ASD (Garon et al., 2009, 2016), the association between ASD symptomatology and temperament is of particular interest. The self-regulatory temperament factor, effortful control, is theorised to be related to attention and executive functioning (see, Rothbart and Rueda, 2005). Attention and executive function difficulties are common in ASD (Craig et al., 2016; Lai et al., 2017; Sanders et al., 2008) and consequently investigation into these impairments is of great importance to further understanding their link to core ASD deficits.

However, while effortful control, attention and executive functioning are known to be impaired in ASD (Craig et al., 2016; Garon et al., 2016; Lai et al., 2017; Sanders et al., 2008), their role in the development of core ASD deficits (i.e. Social Affect and Restricted, Repetitive Behaviours) and their impact on symptom severity is not well established (Macari, Koller, Campbell, & Chawarska, 2017). To date, a thorough search of literature has failed to yield a study which has investigated whether effortful control, attention and executive functioning are concurrently associated with ASD symptomatology. Rather the influence of

each variable has been studied in isolation. Furthermore, no clear consensus regarding each variable's association with ASD features has emerged. Specifically, there is conflicting support for prominent ASD theories which propose that cognitive impairments of attention and executive functioning underpin symptomatology (for review see Happé and Frith, 2006 and Sanders et al., 2008). Limited research also exists regarding the effect of effortful control on ASD features (see Konstantareas and Stewart, 2006, Macari et al., 2017 and Samyn et al., 2011). Additionally, many studies are correlational in nature, impeding the ability to make causal inferences.

Nonetheless, one cannot truly begin to elucidate the concurrent role effortful control, attention and executive functioning play in ASD until the theorised relationship between effortful control, attention and executive functioning is better established empirically. While effortful control has historically been argued to be related to attention and executive functioning (Rothbart & Rueda, 2005), such associations are not as unambiguous as previously theorised. Research has predominantly focused on effortful control's association with the 'executive attention network' in neurotypical samples. Yet evidence reveals this network demonstrates interdependence with other attention networks thus complicating and confounding interpretation of its link to effortful control (Keehn, Lincoln, Muller, & Townsend, 2010; Macleod et al., 2010; Redick & Engle, 2006; Samyn, Roeyers, Bijttebier, & Wiersema, 2017). Moreover, studies investigating effortful control's association to separate distinct domains of attention and executive functions in typical development remain few, with one study demonstrating contradictory relationships (Friedman, Miyake, Robinson, & Hewitt, 2011). Additionally, the range in the types of attention and executive functions examined hampers the interpretation and comparison of results across studies. Notably, and of particular importance to this study, few studies have endeavoured to explore these relationships in ASD, and the results remain equivocal (see Samyn, Roeyers, Bijttebier, Rosseel and Wiersema, 2015, Samyn, Roeyers, Bijttebier, and Wiersema, 2017 and Samyn et al., 2014).

Given the ambiguous relationship between effortful control, attention and executive functioning, this study endeavours to explore these variables in both neurotypical and ASD samples. Effortful control, attention and executive functioning are known to be impaired in ASD and examining the relationship between these variables may further inform our understanding of their association with core ASD symptoms. Thus this study further seeks to investigate the relationship between effortful control, attention, executive functioning and ASD core deficits (i.e. Social Affect and Restricted, Repetitive Behaviours). In the review

below the existing knowledge on effortful control, attention and executive functioning and their proposed relationships will be described, considering both neurotypical and ASD literature. Thereafter, the association these variables have with the core deficits of ASD will be explored.

Temperament

A factor known to play a crucial role in the development of child psychopathology is temperament (Murriss & Ollendick, 2005). However, the role of temperament in ASD is not well understood (Macari, Koller, Cambell & Chawarska, 2017). An enduring definition of temperament was that of Rothbart & Derryberry (1981; as cited in Rothbart & Rueda, 2005), which describes it as the unique difference in one's biological and behavioural reactivity and the self-regulation (at neural and behavioural levels) of such reactivity. Temperament is considered to have a biological basis, with temperament characteristics being recognised and measured in both fetuses and newborns (Rothbart, 2007). Although rooted in the biological/genetic make-up of an individual, temperament is further influenced by the child's experience and cultural values (Rothbart, 2007).

Previously, temperament was considered to stem from biological factors at birth and be subsequently influenced by experiential factors over development. However, current perspectives emphasize that continual interaction between these biological and experiential factors influence temperament over the course of development (Shiner et al., 2012). The multi-faceted nature of temperament and the varying spheres of influence on it, prompted research in numerous domains, including genetic, physiological, behavioural and cognitive sciences. Following these multi-disciplinary efforts, an updated definition of temperament was proposed, describing it as dispositional traits in activity, emotionality, attention and self-regulation, which are innate but influenced throughout development by the intricate interactions between biological and experiential factors (Shiner et al., 2012). Thus the measurement of temperament can potentially serve as an early endophenotype which essentially provides genetic, cognitive and psychological markers to assist in identifying individuals with a given disorder. This offers particular value in the study of ASD given the disorder has a complex inheritance (Miles, 2014) and a broad spectrum of presentations (American Psychiatric Association, 2013; Lauritsen, 2013). Furthermore, considering temperament is an enduring feature of behaviour (Rothbart, 2007) and influences the development of social behaviours, emotionality and self-regulation (Shiner et al., 2012), it is also meaningful to assess its impact on individual functioning and ASD symptom severity across development.

Indeed, infants at high risk of developing ASD (i.e. infants of siblings who have ASD and are themselves later diagnosed with ASD), are shown to have a specific temperament profile of low surgency and effortful control, and higher levels of negative affectivity (Garon et al., 2009, 2016). Surgency, negative affectivity and effortful control are the three broad factors of temperament which are widely accepted throughout the literature to date. Surgency consists of approach behaviours, activity level and positive anticipation (Rothbart, 2007). Negative affectivity, broadly speaking, is comprised of negative emotions, as well as physical discomfort and poor ability to soothe (Putnam, Ellis, & Rothbart, 2001; Rothbart, 2007). Lastly, effortful control, a form of self-regulation, consists of emotion regulation, attention modulation, inhibitory control, and perceptual sensitivity (Rothbart & Rueda, 2005). Surgency and negative affectivity, which develop earlier than effortful control (Putnam, Ellis, & Rothbart, 2001; Rothbart, 2007; Rothbart & Rueda, 2005), are reactive factors of temperament and thus relatively automatic (Rothbart, Sheese, & Posner, 2007). Historically, research focused on these reactive elements which suggested individuals' responses were limited by their dispositions for approach and avoidant-behaviours (Posner & Rothbart, 2009). However, the identification and conceptualisation of effortful control shed new interest on the ability of individuals to regulate their behaviour and gained particular relevance in research fields investigating the development and persistence of internalising and externalising problem behaviours in disorders like ASD.

Effortful Control

Effortful control is thought to emerge within the second or third year of life, although some studies suggest it could appear before the age of one (Rothbart, 2007; Rothbart, Ellis, Rueda, & Posner, 2003). It continues to develop markedly over preschool and school years and may continue developing into adulthood (Rothbart, 2007; Rothbart et al., 2003). The development of effortful control plays a crucial role in the development of Theory of Mind (ToM) and socialisation (Rothbart & Rueda, 2005). Deficits in ToM have consistently been illustrated in ASD (Hill & Frith, 2003) and as mentioned above, social impairment (which encompasses social-decision making; see Rilling and Sanfey, 2011) is a core ASD deficit (American Psychiatric Association, 2013). Thus effortful control's association with these factors which are known to be atypical in ASD, suggests that effortful control itself may play a role in the emergence and severity of core ASD symptoms and accompanying impairments.

Indeed effortful control is associated with prosocial functioning as individuals high in effortful control are typically more socially competent, displaying a greater capacity for

prosocial responsiveness (Eisenberg, Smith, Sadovsky, & Spinrad, 2004). It is thought that effortful control may provide the flexibility to understand how one's actions will influence others and relate the perceived consequences to feelings of responsibility (Posner & Rothbart, 2000). Furthermore, effortful control may support empathy by providing the mental capacities needed for one to attend to both their own and others' emotions without becoming overwhelmed by such feelings (Rothbart, 2007). Specifically, self-regulation enables the control of emotion, affect and motivation, which is particularly important for empathy (Decety, 2011). Hence, the involvement of effortful control in prosocial functioning is likely attributable to the attentional, emotional and behavioural regulatory processes underlying it.

The self-regulatory processes of effortful control permit individuals to modulate their emotions and behaviour in a socially appropriate manner, rather than merely acting on impulse (Posner & Rothbart, 2000). This is because effortful control comprises of both attentional and inhibitory aspects, permitting one to voluntarily modulate their attention (i.e. shift or focus) and regulate their emotions and/or behaviours (i.e. activate or inhibit) when necessary (Muris & Ollendick, 2005). For instance, when experiencing negative emotions individuals may try distract themselves, ultimately shifting and focusing their attention elsewhere (Eisenberg et al., 2004). Likewise, one may employ inhibitory processes to regulate the expression of negative emotions like frustration or fear for example (Eisenberg et al., 2004). Through the regulation of attention, emotions and behaviour, mental capacity becomes available for higher-order functions, like planning, error detection and the integration of multiple sources of information, allowing one to make more careful decisions about their behavioural responses (Diamond, 2013; Eisenberg et al., 2004).

Given that effortful control pertains to capabilities involved in regulating attention, emotion and behaviour, many argue that it demonstrates a strong theoretical link to the cognitive processes of attention and executive functioning (Rothbart & Rueda, 2005). Considering attention and executive functioning are also impaired in children with ASD (Craig et al., 2016; Lai et al., 2017; Sanders et al., 2008), further investigation into their apparent associations with effortful control may further our understanding of the role these variables play in ASD symptomatology. However, the association between effortful control, attention and executive functioning has not been widely investigated in ASD. Rather research has predominantly focused on these associations in neurotypical children.

Association between Effortful Control, Attention and Executive Functions in Typical Development

The recognition that effortful control may be related, in theory, to attention and executive function processes has led researchers to investigate this assumption empirically. Studies on attention and executive functions thought to underlie effortful control have predominantly centred on Posner-type paradigms, which have focused primarily on what they term the executive attention network (Rothbart & Rueda, 2005). The executive attention network comprises of inhibitory control, conflict resolution, planning and cognitive flexibility, all which bring about top-down attention regulation (Diamond, 2013; Keehn et al., 2010; Posner & Fan, 2008). Executive attention is typically measured by the conflict task of the Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002) or adapted versions thereof (Callejas, Lupiáñez, Funes, & Tudela, 2005; Rueda et al., 2004; Samyn et al., 2017). Studies have revealed a link between the ANT conflict tasks and effortful control questionnaires. For instance, Simonds et al. (2007), demonstrated that parent-report measures of effortful control (but not self-report measures) were related to executive attention in neurotypical children between the ages of 7 – 10 years. A similar relationship was demonstrated in adolescents, with executive attention difficulties being associated with lower effortful control (Ellis, Rothbart, & Posner, 2004).

Furthermore, researchers have tried to determine a physical basis for effortful control and executive attention respectively, and in so doing have attempted to identify the anatomical links between them. The Anterior Cingulate Cortex (ACC) is of particular importance in effortful control and executive attention, with studies evidencing it as the possible underlying neural link. For instance, Whittle et al. (2008) demonstrated a positive association between self-report measures of effortful control and the size of the dorsal regions of the ACC. Additionally, the ACC has repeatedly been shown to activate during conflict tasks measuring executive attention (Fan, Fossella, Sommer, Wu, & Posner, 2003; Posner & Fan, 2008). Thus the role of the ACC in both effortful control and executive attention suggests it may act as an anatomical link between them.

In understanding the potential neural networks underpinning effortful control and the executive attention network, researchers have endeavoured to map the underlying genetic correlates. Dopamine genes have been of particular interest given the high concentrations of this neuromodulator in the ACC (Posner & Fan, 2008). More specifically, dopaminergic genes have been investigated to determine whether they influence the effectiveness of the executive attention network and ultimately effortful control. For instance, a gene involved in

dopamine metabolism, namely catechol-o-methyl transferase (COMT) gene, has been associated with executive attention in toddlers, children and adults (see Posner and Rothbart, 2009 for review). Furthermore, dopamine- and serotonin-related genes have also been related to performance in executive attention (see Rothbart et al., 2007 for review). Fan and colleagues (2003), who previously evidenced strong associations between the efficiency of conflict resolving tasks and polymorphisms in Dopamine receptor (DRD4) and Monoamine Oxidase A (MAOA) genes (Fossella et al., 2002), further revealed that individuals with polymorphisms associated with better conflict resolution have a greater activation of the ACC compared to those whose polymorphisms were associated with poorer conflict mediation.

However, studies investigating the relationship between effortful control and executive attention may not indicate as clear a link as initially anticipated. This is in part due to the interdependent nature of the executive attention network with the two other attention networks (i.e. orienting attention network and alerting attention network) measured by the ANT (Keehn et al., 2010; Macleod et al., 2010; Redick & Engle, 2006; Samyn et al., 2017). This interdependence complicates interpretation of results and thus an argument has been made in favour of examining attention and executive functions individually. This argument is further supported by the fact that the term ‘executive attention’ appears too broad a definition and has prompted much confusion within the literature (Diamond, 2013). Consequently, given the concern over the theoretical and psychometric properties of the ANT (see Macleod et al., 2010 for review), as well as the confusion engendered by the term ‘executive attention’, other researchers have endeavored to examine separate domains of attention and executive functions to try limit interaction effects and permit a more disentangled interpretation of results.

Nonetheless, attention and executive functions are interdependent, making it difficult to define and subsequently study them in isolation. Indeed, no single definition of attention or executive function has yet been agreed upon within the literature. For instance, in terms of attention, while some earlier theorists proposed fixed or flexible capacity attention models which define the allocation of attentional processes based on task requirements, others suggested multiple resource theories which conceptualised attention into ‘resource pools’ each capable of mediating different types of information (Williams, Davids, & Williams, 1999). Most recent models consider attention to consist of separate components, each with distinct neuroanatomical regions, which interact together to form an integrated neural system (Anderson, Northam, Hendy, & Wrennall, 2001). However, there are various researchers who

have suggested different attention networks, including Posner whose work was mentioned above (Anderson et al., 2001; Williams et al., 1999). Within the developmental context, sustained attention is consistently recognised as a separate, yet interdependent component of attention and refers to the ability to concentrate over time (Anderson, 2010). Other attentional domains are also consistently recognised, including focused/selective attention (i.e. attend to a task amidst distractors), shifting attention (i.e. efficiently change focus between different aspects of a task), and divided attention (i.e. distribute attention across concurrent tasks; Anderson, Northam, Hendy, & Wrennall, 2001). Additionally, there is attention span, an aspect of short-term memory, which refers to the capacity of how much information one can consciously hold in mind (Cowan, 2008; Diamond, 2013). The amount of information one can actively hold in a readily available state is limited, with attention span capacity increasing with age (Gathercole, 1999). Attention span is related to working memory, which refers not only to how much information one can consciously hold in mind but also to the ability to consciously work with that information (Cowan, 2008). However, working memory is generally classified under executive functioning rather than attentional domains.

A review by Diamond (2013), argues that a hierarchical relationship exists between attention and executive functions, with attention span developing first. Diamond (2013), identifies three core executive functions, which appear to be the most widely adopted within developmental research (Moriguchi, Chevalier, & Zelazo, 2016). These three core executive functions are, *working memory*, *inhibition* (including self-control, cognitive inhibition and selective attention) and *switching* (i.e. shift between mental tasks; also known as cognitive flexibility). Higher-order mental processes, like planning, reasoning and problem solving, are considered to be built on from these three core executive functions.

Given the difficulty in defining, isolating and examining the attentional and executive functions theorised to be related to effortful control, differing results relating to different aspects of these cognitive functions have emerged throughout the literature. This was particularly evidenced by Friedman, Miyake, Robinson, and Hewitt (2011), who argued that the strength and direction of the relationship between effortful control and executive functioning would depend upon the components of executive functions studied. This follows their somewhat inconsistent results where “Common EF” (a latent variable which statistically extracted variance common to working memory, inhibition, and shifting) showed a strong positive association with early self-restraint, while the Shifting-specific variable (which was created after having statistically separated out the variance shared with “Common EF”), showed a negative relationship. This contrasting directionality remains perplexing and further

investigation into the relationship of effortful control with separate executive functions is required to elucidate these associations. To date, however, it appears that no other investigators have further examined effortful control's association with these three core executive functions.

Apart from these three core executive functions, the relation of effortful control to other aspects of executive functioning has not been widely investigated. Furthermore, there is little research exploring effortful control's association with separate components of attention. Of the few studies that were readily identified in the literature, one of the earliest investigations illustrated a positive association between conflict resolution and parent-reports of attentional self-regulatory abilities (i.e. shifting, focused and sustained attention) in 30- and 36-month old children (Gerardi-Caulton, 2000). Other studies focusing on attention domains have identified sustained attention as having a strong association with effortful control. For instance, Verstraeten et al. (2010) revealed a significant positive relationship between a sustained attention measure of the Test of Everyday Attention for Children (i.e. Score!; Cohen, 1997) with parent-report measures of effortful control in 8 – 17 year olds. Additionally, Johansson et al. (2015) demonstrated that a one year-old's ability to sustain their attention positively predicts their capacity for effortful control a year later.

As detailed above, the range in the types of attention and executive functions studied hampers the interpretation and comparison of results across studies. This necessitates further examination of attention domains and executive functions to assist in determining whether certain relationship patterns with effortful control endure across studies. Furthermore, as previously mentioned, the ambiguity over effortful control's relationship with attention and executive functions impedes our ability to understand their role in ASD. This is particularly relevant, given effortful control, attention and executive functions are known to be impaired in ASD (Craig et al., 2016; Garon et al., 2009, 2016; Lai et al., 2017; Sanders et al., 2008) and are thought to be associated with social functioning (Anderson et al., 2001; Eisenberg et al., 2004; Rothbart, 2007). However, the relation of effortful control, attention and executive functioning to ASD symptoms cannot be truly elucidated until the relationship between effortful control, attention and executive functioning is better understood. There remains a limited number of studies that have investigated this relationship in ASD samples.

Association between Effortful Control, Attention and Executive Functions in ASD

Seemingly only Samyn and colleagues (2014, 2015 & 2017) have focused on the association between effortful control, attention and executive functioning in ASD.

Specifically, they investigated this association in neurotypical, ASD and Attention-Deficit/Hyperactivity Disorder (ADHD) groups. ADHD is highly comorbid with ASD and evidences impairment in effortful control, attention and executive function (American Psychiatric Association, 2013; Craig et al., 2016; Simonoff et al., 2008).

Samyn, Roeyers, Bijttebier, Rosseel, and Wiersema (2015) argued that the inclusion of these clinical groups allows for the unique opportunity to examine whether the theoretical links between effortful control, attention and executive functioning translate into tangible measures of the same underlying construct. Given the conceptual overlap between effortful control and attention and executive functioning, Samyn et al. (2015) presumed the variables referred to the same underlying construct and hypothesised that the temperament and neuropsychological measures should in turn be interchangeable. However, such an assumption is misguided, as having constructs be related to each other does not necessarily mean they are interchangeable and represent the same construct. Unsurprisingly, the Confirmatory Factor Analyses they conducted revealed that while the effortful control questionnaire variables showed significant loading onto the latent effortful control factor, neuropsychological tests of executive function did not. While such findings prove that the measures and constructs are not interchangeable, they provide little clarification over the degree to which effortful control, attention and executive functions are related to each other. Other studies by Samyn and colleagues sought to directly examine these associations.

In 2014, Samyn et al. investigated effortful control's relationship to executive attention as measured by neuropsychological tasks and ACC physiological indicators. The physiological indicators were event related potentials, specifically, N2 (which reflects response inhibition, and/or conflict monitoring), P3 (shows response inhibition or the monitoring of inhibitory outcomes) and Error Related Negativity (ERN; indicates error detection system activation). Only ERN was related to effortful control self- and parent-report measures in the ASD, ADHD and neurotypical groups respectively. Interestingly, across all three groups effortful control was not associated with executive attention performance on the neuropsychological measure (a modified version of Eriksen Flanker paradigm (Eriksen & Eriksen, 1974)). Similarly, Samyn et al. (2017) found no association between effortful control (using self- and parent-reports) and executive attention performance (on a modified version of the ANT) in ASD, ADHD and neurotypical groups, even when controlling for general intelligence. Such findings are in contrast to previous executive attention studies whose samples consisted only of neurotypical groups (e.g. Ellis et al., 2004 and Simonds et al., 2007).

Findings regarding the association between effortful control, attention and executive functions in ASD are equivocal. Furthermore, given executive attention's association with effortful control has predominantly been studied, there remains a gap in knowledge concerning effortful control's relation to separate domains of attention and executive functions in ASD. A clearer understanding of these relationships is imperative to further elucidate the association effortful control, attention and executive functioning have with ASD core deficits. Such information is essential given that the potential role of effortful control, attention and executive functions in the emergence of ASD symptoms is not well established (Macari et al., 2017).

ASD Core Deficits: The Role of Effortful Control, Attention and Executive Function

To date, a thorough search of literature has failed to yield a study which has investigated whether effortful control, attention and executive functioning are concurrently associated with ASD severity. ASD severity is based on impairments of the primary diagnostic characteristics, namely, Social Affect and Restricted, Repetitive Behaviours (American Psychiatric Association, 2013). No primary cause or deficit has been identified that is capable of wholly explaining both Social Affect and Restricted, Repetitive Behaviours (Happé, Ronald, & Plomin, 2006; Visser, Rommelse, Geven, & Buitelaar, 2016). Although a neurobiological basis is widely accepted, a lack of consensus exists between differing research traditions.

The study of temperament offers potential insight into understanding the development of ASD symptoms as temperament itself is considered to be neurobiologically based (Rothbart, 2007) and influences the development of social behaviours, emotionality and self-regulation (Shiner et al., 2012). Furthermore, considering a specific abnormal temperament profile is identified in ASD (Garon et al., 2009, 2016), the association between autistic traits and temperament is of particular interest. Attention and executive function difficulties are also common in ASD (Craig et al., 2016; Lai et al., 2017; Sanders et al., 2008), with prominent ASD theories proposing cognitive impairments of attention and executive functioning underpin symptomatology (for review see Happé and Frith, 2006 and Sanders et al., 2008). Effortful control, attention and executive functioning facilitate everyday tasks (Allen & Courchesne, 2001; Diamond, 2013; Eisenberg et al., 2004) and thus improving such self-regulatory abilities may aid individuals with ASD to better adapt and function in everyday settings. Thus investigation into effortful control, attention and executive function's concurrent association with core ASD deficits holds great potential value within intervention

settings. However, throughout the literature these potential predictors tend to be studied in isolation. Given that the function of these potential predictors in ASD has not been investigated in unison, the evidence of each variable's role in ASD will be discussed separately.

Attention's and executive function's association with ASD. Attention and executive function impairments are prominent within ASD. However, a specific phenotype detailing the exact attentional and executive function deficits is not apparent. This is in keeping with the characteristic broad spectrum of presentations seen in ASD, with symptoms classified along a continuum of severity (American Psychiatric Association, 2013; Lauritsen, 2013). Additionally, as described earlier, the cognitive processes of attention and executive functioning are multi-faceted in nature and no universal definition/classification exists. Task complexity and assessment setting (i.e. lab vs real-life environments) further influences evaluation and interpretation of attention and executive functioning abilities (Gardiner et al., 2017). Consequently, varying results about numerous domains of attention and executive functioning have emerged throughout the literature.

While impaired attention is not a core diagnostic feature of ASD, the high comorbidity rates with ADHD (American Psychiatric Association, 2013; Simonoff et al., 2008), suggest attention difficulties are virtually characteristic of ASD. Consequently, attention has become of particular interest to understanding ASD impairments, with different researchers investigating different aspects of attention. Originally, visuospatial orienting attention was thought to be impaired in ASD (Keehn et al., 2010; Sanders et al., 2008), however, a recent study (Samyn et al., 2017) failed to replicate such results. Evidence also reveals poor divided attention in ASD, which is thought to underly characteristic impaired joint attention (Boxhoorn et al., 2018). Specific studies on basic attention span have received little focus, however, children with ASD have been shown to have poorer visual and auditory attention spans in comparison to neurotypical children (Mayes & Calhoun, 2007). Studies on sustained attention in ASD have yielded conflicting results. A review by Allen and Courchesne (2001), found that, while sustained attention was mostly intact when individuals with ASD were required to focus on a single location, they demonstrated poor sustained attention when provided with social reinforcement (e.g. told "good job" during the task). Furthermore, a review by Sanders et al., (2008) suggested that sustained attention in ASD was mostly found to be intact, however, some studies have demonstrated impaired sustained attention in ASD on cognitive testing (see Corbett, Constantine, Hendren, Rocke, and Ozonoff, 2009 and Schatz, Weimer, and Trauner, 2002). Additionally, recent brain imaging studies have shown

disorder-specific brain functioning abnormalities in ASD during sustained attention tasks (Christakou et al., 2013). Moreover, abnormalities in functional brain maturation of sustained attention networks between the age of 11 – 35 years in ASD individuals were associated with impairments in sustained attention (Murphy et al., 2014).

In terms of executive functions, working memory and cognitive flexibility difficulties are common in ASD, however, studies of inhibition have yielded conflicting results (Craig et al., 2016; Lai et al., 2017; Sanders et al., 2008). In a meta-analysis on children with high-functioning ASD, cognitive flexibility was shown to be impaired while inhibition was not (Lai et al., 2017). Similarly, Lopez, Lincoln, Ozonoff, and Lai (2005), replicated findings of intact inhibitory functioning in children with ASD. Yet, a review by Craig et al. (2016), concluded prominent inhibitory difficulties were indeed present in ASD. Interestingly, while Kana, Keller, Minshew, and Just (2007) saw no difference between neurotypical controls and ASD groups in performance scores on response inhibition tasks, brain imaging revealed atypical activation and less synchronicity in inhibitory neural networks of children with ASD.

The mounting evidence revealing attention and executive function deficits in ASD has led to the suggestion that such deficits may be central to the emergence of the core diagnostic features. For instance, Keehn et al., (2010) found that decreased efficiency of alerting attention network (which permits increased sensitivity to incoming information), was correlated with increased socio-communicative deficits. Keehn et al. (2010) thus suggested that socio-communicative difficulties may stem from impaired attention modulation, which is thought to assist in navigating dynamic social interactions. Yet, associations remain unclear as more recently Hendry et al. (2018) asserted that executive attention does not act as a predictor to the ASD phenotype.

Indeed, some prominent ASD theories propose cognitive impairments underpin symptomatology. For example, the Weak Central Coherence Theory postulates that individuals with ASD focus intensely on detail, rather than seeing the gestalt (Frith & Happé, 1994; Hill & Frith, 2003). Consequently, information is processed in a piecemeal manner rather than contextualised into a meaningful whole, with individuals struggling to reflexively attend to and integrate information in everyday settings (Frith & Happé, 1994; Hill & Frith, 2003). However, empirical evidence suggests that the Weak Central Coherence Theory describes one aspect of social cognition deficits rather than acts as a primary predictor (for review see Happé and Frith, 2006). Additionally, the Weak Central Coherence Theory fails to explain Restricted, Repetitive Behaviours in ASD (South, Ozonoff, & McMahon, 2007).

Restricted, Repetitive Behaviours appear to be accounted for by the Executive Dysfunction Hypothesis, another prominent theory in ASD (Hill & Frith, 2003; Sanders et al., 2008). The Executive Dysfunction Hypothesis postulates that impairment of executive control processes accounts for behavioural characteristics of ASD (Hill & Frith, 2003; Sanders et al., 2008). Specifically, working memory, response inhibition and cognitive flexibility have demonstrated an association with Restricted, Repetitive Behaviours (Lopez et al., 2005; South et al., 2007). Executive dysfunction has also been associated with social impairment. Specifically, parent report measures on executive processes of behavioural regulation (inhibition, shifting and emotional control) and metacognition (initiation, working memory, planning, and monitoring) have been shown to be predictive of social functioning (Leung, Vogan, Powell, Anagnostou, & Taylor, 2016). However, conflicting support of these two theories is demonstrated throughout the literature and it appears that each attempts to explain an aspect of ASD symptomatology rather than wholly account for the profile (Sanders et al., 2008). Furthermore, within a South African sample, results revealed partial support for the Executive Dysfunction Hypothesis and no support for the Weak Central Coherence theory (Daniels, 2008). Thus, such neuropsychological theories are insufficient in wholly accounting for ASD core deficits.

Association between Effortful Control and ASD. Effortful control plays a significant role in emotional, behavioural and cognitive development, and is ultimately associated with social competence and adjustment across childhood and older ages (Eisenberg et al., 2004). Given that effortful control allows one to regulate attention (i.e. shift or focus), emotions and behaviour (i.e. inhibit inappropriate responses or persist with tasks), it further enables one to act adaptively and appropriately in everyday settings (Schwartz et al., 2009). Thus children with high effortful control have an increased capacity for prosocial responding and fewer negative internalising and externalising behaviours (Eisenberg et al., 2004). Indeed, lower levels of effortful control place one at greater risk for developing childhood psychopathologies, specifically by playing an important role in the development and persistence of internalising and externalising problem behaviours (Eisenberg et al., 2004; Muris & Ollendick, 2005; Rothbart, 2007). Although temperament's role in child psychopathologies is well understood, it's possible influence in the emergence of ASD symptoms is not well understood (Macari et al., 2017).

The self-regulatory temperament factor, effortful control, is known to be compromised in ASD, with individuals having lower levels of effortful control than neurotypical groups (Garon et al., 2009, 2016; Macari et al., 2017; Samyn et al., 2011).

Lower levels of effortful control have been associated with increased severity of ASD symptoms in both younger children and adolescents (Konstantareas & Stewart, 2006; Samyn et al., 2011). Interestingly, in a recent longitudinal study, negligible associations between effortful control and both core ASD diagnostic domains were revealed at the initial time point in toddlers between the ages of 16 – 36 months. However, data collected at the second time point indicated that a decline in effortful control between 24 – 42 months of age predicted poorer adaptive functioning and hence greater ASD symptom severity (Macari et al., 2017). Similar findings were evidenced by Garon et al. (2016), who found that lower IQ at 12 months combined with poorer effortful control at 24 months were associated with more ASD symptoms at 36 months in toddlers at high risk of developing ASD, (i.e. infants of siblings who have ASD). These findings suggest that effortful control may have an influence on ASD over the course of development rather than being implicated in initial causation. However, research on the predictive nature of effortful control on ASD phenotypes remains limited, with inadequate discussion over effortful control's link to Social Affect and Restricted, Repetitive Behaviours.

Rationale

The exact aetiology of ASD remains unknown (Happé et al., 2006; Miles, 2011). Effortful control is thought to play a role in the emergence of symptoms (Konstantareas & Stewart, 2006; Samyn et al., 2011). Furthermore, prominent ASD theories suggest that cognitive impairments in attention and executive functioning underpin certain core ASD features. Given effortful control comprises of attentional and behavioural regulatory processes (Muris & Ollendick, 2005; Rothbart & Rueda, 2005; Samyn et al., 2014), it is thought that the cognitive processes of attention and executive functioning are related to effortful control (Rothbart & Rueda, 2005). Thus investigation into effortful control and the cognitive functions associated with it may further inform our knowledge regarding the emergence and severity of ASD symptoms. Yet our current understanding of how effortful control is related to attention and executive functioning remains limited and inconsistent. Such ambiguity further limits our understanding of the association of effortful control, attention and executive functioning with Social Affect deficits and Restricted, Repetitive Behaviours in ASD.

In considering the limitations of previous research, the current study endeavoured to investigate the relationship of effortful control with attention and executive functions within neurotypical and ASD groups. Such research is essential as it will assist in further elucidating

the relationship between effortful control and the cognitive domains of attention and executive functioning. In addition, this study further intended to explore the relationship of effortful control, attention, and executive functioning with core ASD deficits (i.e. Social Affect and Restricted, Repetitive Behaviours). This focus is relevant as it will not only extend our theoretical understanding but may also have practical implications for targeted interventions that assist ASD individuals to adapt and function better in everyday environments.

Aims and Hypotheses

Study One: effortful control's relationship with attention and executive functions. The primary aim of Study One was to examine the association of effortful control with attention domains and executive functions in neurotypical and ASD children. I expected that neurotypical and ASD children would differ significantly on effortful control, attention and executive functioning¹. Based on these expected group differences, I then explored whether effortful control acts as a predictor of aspects of attention and executive functioning respectively. Thus the following specific hypotheses were tested:

Hypothesis 1. Neurotypical children will be rated to have significantly better effortful control than ASD children.

Hypothesis 2. Neurotypical children will perform significantly better than ASD children on attention tasks. This significant group difference was expected in both attention span (Hypothesis 2.1) and sustained attention (Hypothesis 2.2).

Hypothesis 3. Neurotypical children will perform significantly better than ASD children on executive function tasks. This significant group difference was expected for working memory (Hypothesis 3.1), inhibition (Hypothesis 3.2) and switching tasks (Hypothesis 3.3).

Hypothesis 4. Effortful control will emerge as a significant predictor of attention. This relationship was expected for both attention span (Hypothesis 4.1) and sustained attention (Hypothesis 4.2).

Hypothesis 5. Effortful control will emerge as a significant predictor of executive functioning. This relationship was expected across working memory (Hypothesis 5.1), inhibition (Hypothesis 5.2), and switching (Hypothesis 5.3).

¹ Most recent APA guidelines encourage writers to use first person pronouns when describing their research rather than write in passive voice as was previously done (American Psychological Association, 2013, p. 69).

Study Two: Association between effortful control, attention and executive functioning in relation to ASD core deficits. The primary aim of Study Two was to determine whether effortful control, attention and executive functioning are associated with ASD core deficits, namely Social Affect and Restricted, Repetitive Behaviours. Specifically, I explored whether effortful control moderates the relationship between attention/executive functions and ASD core deficits. The following hypotheses were therefore tested:

Hypothesis 6. Effortful control will moderate the relationship between attention domains and Social Affect. This interaction was expected for both attention span (Hypothesis 6.1) and sustained attention (Hypothesis 6.2).

Hypothesis 7. Effortful control will moderate the relationship between attention domains and Restricted, Repetitive Behaviours. This interaction was expected for both attention span (Hypothesis 7.1) and sustained attention (Hypothesis 7.2).

Hypothesis 8. Effortful control will moderate the relationship between executive functions and Social Affect. This interaction was expected across working memory (Hypothesis 8.1), inhibition (Hypothesis 8.2), and switching (Hypothesis 8.3).

Hypothesis 9. Effortful control will moderate the relationship between executive functions and Restricted, Repetitive Behaviours. This interaction was expected across working memory (Hypothesis 9.1), inhibition (Hypothesis 9.2), and switching (Hypothesis 9.3).

Methods

Research Design and Setting

The current research is subsumed under a larger investigation performed by the University of Cape Town's (UCT) Autism Research Group. The larger project sought to examine the biological basis of social deficits in ASD. The current sub-study focused on a subset of measures, examining temperament, cognitive domains and ASD symptomatology. The protocol consisted of two studies. The first was both quasi-experimental and relational in nature. It considered two groups of participants, first establishing whether group differences existed between neurotypical and ASD children on effortful control, attention and executive functioning. Subsequently, it examined whether effortful control was related to attention and executive functions. The second study used a purely relational design, examining the association the temperament and cognitive factors have with ASD core deficits (i.e. Social Affect and Restricted, Repetitive Behaviours). Purposive sampling was employed and child

participants of varying ages, belonging to different neurodevelopmental groups (i.e. neurotypical versus ASD), were included.

Participants

Overall, 38 male children (6 – 15 years) with ASD and their primary caregivers were recruited through autism-specific and special needs schools within the Western Cape. Participants were also recruited through the UCT ASD database which included families involved in previous studies who indicated they would like to be contacted for future research. ASD participants were then aggregate-matched to neurotypical controls on their age and their caregivers' monthly household income. The control group of 38 male neurotypical children and their parents were recruited via local mainstream schools.

Post-hoc power analyses were conducted using *G*Power* 3.1.9.3 (Faul, Erdfelder, Buchner, & Lang, 2007) for both Study One and Two. For Study One, data from the regression analyses were used in the calculation as they were most sensitive to sample size. Because four different regression analyses were conducted, only the model containing the most predictor variables (i.e. three), and for which effortful control emerged as a significant predictor was chosen for the post-hoc power calculations. Effortful Control was considered the tested predictor and therefore its R^2 change value of .038 (see Table 5, p. 50) was used to calculate the effect size ($f^2 = .04$). The alpha level was set to convention at $\alpha = .05$ and the total sample was used ($n=76$). A power ($1 - \beta$) value of .40 emerged, indicating that Study One was under-powered and would only be able to detect large effects.

For Study Two, again the regression analyses were the focus of post-hoc power calculations. While it was originally anticipated that three different moderation analyses would be conducted, ultimately only one was done. Four predictors were included in the calculations, including the interaction effect. The interaction effect was considered the tested predictor and its R^2 change value of .087 (see Table 17, p. 66) was used to calculate the effect size ($f^2 = .10$). The alpha level was set to convention at $\alpha = .05$ and given only the ASD group was considered in Study Two, the sample size was 38. A power ($1 - \beta$) value of .46 emerged, demonstrating that Study Two was under-powered and would only be able to detect large effects.

Recruiting large numbers of a participants in clinical groups is often challenging resulting in clinical studies struggling to obtain adequate power (see Ing, 2011 and Samyn et al., 2017, 2014). This limitation is further discussed below (see p. 87).

Inclusion and exclusion criteria. ASD participants had their existing diagnosis

confirmed by an Autism Diagnostic Observation Schedule, Second edition (ADOS-2; Lord et al., 2012) assessment, conducted by a specially trained doctoral team member who is certified as both clinically and research reliable. Participants were required to be proficient in English (i.e. have English as their home language or be schooled in English). The ADOS-2 (Lord et al., 2012) was originally created in English and has not been formally translated and validated for other South African languages (Western Psychological Services, 2018). Furthermore, ADOS-2 administration rules do not permit use of a translator (Lord et al., 2012), as this would change the nature of the social dynamic during assessment.

The ADOS-2 (Lord et al., 2012) was further used to determine the expressive language/verbal ability of participants. Given the neurocognitive tests required participants to comprehend instructions and respond verbally, only verbal children were considered for the current sub-study. Therefore children with ASD who used little to no verbal language completed Module 1 of the ADOS-2 and were excluded from this sub-study. Children who could complete Module 2 or 3 of the ADOS-2 demonstrated expressive language ability and underwent further screening to assess their ability to comprehend instructions. The Comprehension of Instruction subtest of A Developmental Neuropsychological Assessment, Second Edition (NEPSY-II; Korkman, Kirk, & Kemp, 2007) further informed the inclusion/exclusion criteria for language ability. Verbal ASD children who could consistently follow two-stage commands were included in this sub-study.

Only males were included in this study. The ratio of boys diagnosed with ASD in comparison to girls is 4:1 (American Psychiatric Association, 2013), although a recent review indicates that ratio may be closer to 3:1 (Loomes, Hull, & Mandy, 2017). It appears girls with ASD are more likely to go unnoticed, may be misdiagnosed, or receive a diagnosis later in life (Loomes et al., 2017). There is thus dispute over possible diagnostic gender biases, with arguments made for the possible existence of female-specific ASD phenotypes. Considering the potential confounding factors in the female ASD population, only males were recruited.

ASD and neurotypical participants with any history of head injury, psychiatric disorders, or other neurological/neurodevelopmental conditions were excluded as these conditions were expected to confound the relationships between the variables under investigation. However, ASD participants with ADHD were not excluded. Given ASD and ADHD are highly comorbid (American Psychiatric Association, 2013), exclusion of these participants would have resulted in an incomplete representation of the ASD spectrum. Furthermore, excluding ASD children with known attention difficulties would have limited this study's ability to fully investigate attention.

Parents/ caregivers were required to live with the participating child and be considered the primary caregiver. Given the prescribed age ranges on cognitive measures, only children between the ages of 6 – 15 years were recruited.

Measures

Socio-demographics form. The demographics survey (Appendix A) contained questions regarding the child's and parent's age, sex, and socio-economic status (SES). Such data was collected to assist in matching ASD participants with neurotypical controls. To inform exclusion criteria, the survey asked if the child had a history of head injury, psychiatric disorders and/or neurological/neurodevelopmental conditions.

Verbal ability and ASD core deficits. The use of the ADOS-2 (Lord et al., 2012) was threefold. Firstly, it was administered to all ASD participants to confirm and validate their diagnosis. Secondly, it was used to inform the inclusion/exclusion criteria regarding expressive language ability. Thirdly, it was utilized to obtain a measure of ASD participants' Social Affect and Restricted, Repetitive Behaviour.

This standardized measure is regarded as the “gold standard” for observation, assessment and diagnosis of Social Affect and Restricted, Repetitive Behaviours in ASD (McCrimmon, 2014). The ADOS-2 is semi-structured and consists of five modules which are each structured according to age (12 months through to adulthood) and language ability. Only Modules 1 – 3 were utilized in the current study as they are suitable for children and young adolescents (\pm 16 and younger). Either Module 1, 2 or 3 was administered depending on the participant's verbal ability. Module 1 is designed for individuals who are non-verbal or lacking in flexible phrase speech. Module 2 is designed for individuals who are not verbally fluent but engage in phrase speech (i.e. demonstrate expressive language ability typical of 4-year old children). Module 3 is designed for verbally fluent children/adolescents. Children who completed Module 2 or 3 were considered as potential participants and underwent further screening (i.e. Comprehension of Instruction of NEPSY-II; Korkman et al., 2007) to confirm if they could be included in the sample. Subsequently, of the children who met the inclusion criteria, their Social Affect and Restricted Repetitive Behaviour scores were analyzed in Study Two. Note, a higher score denotes greater impairment in Social Affect or Restricted, Repetitive Behaviour.

Administration of the ADOS-2 was completed by a clinically and research certified member of the UCT Autism Research Group. To obtain certification, the doctoral candidate

team member completed a course with an accredited trainer and participated in post-course administration and coding; achieving at least 80% agreement with the trainer.

The ADOS-2 is a reliable measure with moderate and high internal consistency values for the Restricted, Repetitive Behaviour (.51 – .66) and Social Affect domains (.87 – .92) respectively (McCrimmon, 2014). In terms of test-retest reliability, Social Affect, Restricted, Repetitive Behaviour, and overall total severity scores demonstrated correlations ranging from .68 – .92 (McCrimmon, 2014). Additionally, correlations ranging between .79 – .98 for all three domains were revealed when examining inter-rater reliability (McCrimmon, 2014). Lastly, investigations evidenced acceptable content and construct validity, with Social Affect and Restricted, Repetitive Behaviour domains each showing independent contributions toward predicting diagnosis and the overall severity score holding the highest predictive value (McCrimmon, 2014). The ADOS-2 has been shown to be an effective diagnostic tool within South African research (Hoogenhout, 2016). Furthermore, translated and adapted versions of the ADOS-2 for use with young isiZulu-speaking and Afrikaans-speaking Coloured children from low – high SES backgrounds have proved useful and somewhat culturally-appropriate in detecting ASD (Chambers et al., 2016; Smith, Malcolm-Smith, & de Vries, 2017). However, given such adapted and translated versions had not been validated at the time of the current study, only the English version was utilized.

Verbal comprehension. The Comprehension of Instruction subtest of the NEPSY-II (Korkman et al., 2007) was used to assess verbal comprehension ability. The Comprehension of Instruction evaluates the ability of a child between ages 3 – 16 years to follow one-, two- and three-stage commands of increasing syntactic complexity. The child must point to relevant stimuli on a page following verbal instruction by the examiner. Children who completed Module 2 or 3 of the ADOS-2 were administered this task to establish if comprehension difficulties that could undermine performance on neurocognitive tests were present. Children with ASD who could consistently follow two-stage commands were included in the current study's sample.

The NEPSY-II demonstrates good psychometric properties with Comprehension of Instruction being one of the subtests with the highest reliability coefficients (i.e. between .62 – .88; Korkman et al., 2007). Further evidence indicates adequate test-retest reliability (.71 – .82) as well as internal reliability coefficients of $r = .80$ or higher in clinical samples (Brooks, Sherman, & Strauss, 2009). The Comprehension of Instruction was used successfully in the South African context to assess the comprehension abilities of both ASD and neurotypical children (Hoogenhout & Malcolm-Smith, 2014). Further evidence concerning the application

of the NEPSY-II in both ASD and South African samples is discussed below under cognitive assessments on page 35.

General intelligence. The Weschler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) is suitable for ages 6 – 89 years and was administered to determine Full Scale Intelligence Quotient (FSIQ-4) for participants. The FSIQ-4 was derived from the Verbal and Performance Scales. The Verbal Scale which measures crystalized skills, consists of the *Vocabulary* subtest, examining expressive verbal knowledge, and the *Similarities* subtest, assessing abstract verbal reasoning. The Performance Scale is comprised of *Block Design*, which assesses visuo-spatial perception and organization, and *Matrix Reasoning*, which examines nonverbal fluid reasoning.

The WASI is recognised as an effective tool for brief cognitive assessment and determining FSIQ-4 quotients (Stano, 2004; Wechsler, 1999). It has good psychometric properties with reliability coefficients ranging between .81 – .97 for children (Stano, 2004). Furthermore, evidence of content and construct validity is presented within the WASI manual (Wechsler, 1999). The WASI can be used across ethnically diverse populations, however, language and cultural factors must be considered when interpreting results (Razani, Murcia, Tabares, & Wong, 2007). This was also demonstrated in a local investigation studying the suitability of the WASI with English and Afrikaans children in the Western Cape (van Wyhe, 2012). The WASI is suitable for use within clinical populations (Wechsler, 1999) and has been used regularly in local ASD and ADHD research (e.g. Daniels, 2008; Hoogenhout & Malcolm-Smith, 2014; Ing, 2011; Wilson, 2014).

Cognitive assessments of attention and executive functioning.

Attention span and working memory. The Children's Memory Scale (CMS; Cohen, 1997), administered to children aged 5 – 16 years, is comprised of three domains, one of which is Attention/Concentration. A core subtest of the Attention/Concentration domain is *Numbers*, which is divided into two tasks. The *Forwards* task assesses attention span, requiring children to recall number sequences of increasing length. The *Backwards* task, which examines working memory, requires the individual to repeat number sequences backwards. The CMS is a useful measure as it provides scores for both the *Forward* and *Backward* tasks respectively. These sub-scores are of particular importance in this study as they permit the examination of separate domains of attention, limiting interaction effects and allowing for a more disentangled interpretation of results. Consequently, participants' Scaled Score Equivalents of the Supplemental Raw Scores from the *Forwards* and *Backwards* task were used in the analyses to represent attention span and working memory respectively.

The CMS Numbers subtest acts as an accurate measure with the Attention/Concentration Index having a reliability coefficient of .87 and a high correlation (.74) with the Working Memory Index of the Wechsler Intelligence Scale for Children, fourth edition (Drozdick, Holdnack, Rolfhus, & Weiss, 2008; Wechsler, 2003). The CMS was designed for administration with children known to have learning difficulties (Vaupel, 2001). Moreover, the CMS is considered to have utility in cross-cultural environments and has been used within the South African context in studies with clinical and developmentally vulnerable samples of English, Afrikaans and isiXhosa speaking children (Ferrett, Carey, Thomas, Tapert, & Fein, 2010; Lanesman, 2015; Malgas, 2010).

Sustained attention, inhibition and switching. The Inhibition Subtest of the NEPSY-II (Korkman et al., 2007) was administered to assess sustained attention, inhibition and switching. The Inhibition subtest is comprised of three tasks, *Naming*, *Inhibition* and *Switching*.

Naming measures one's ability to sustain attention whilst naming shapes or the direction of arrows. Sustained attention was determined using the Naming Total Errors scores. Within the NEPSY-II scoring manual, the Naming Total Errors score is given as a range in percentile ranks (i.e. <2, 2-5, 6-10, 11-25, 26-50, 51-75, >75). The Scaled Scores for each participant were subsequently derived from the median value of these Total Error Percentile Ranks ranges.

Inhibition evaluates the child's ability to inhibit automatic responses so as to allow the opportunity to provide new responses. The Inhibition Combined Scaled Score was used in analyses to represent participants' Inhibition performance.

Switching assesses the ability to switch between response sets. The Switching Combined Scaled Score was used in analyses.

Note, while *Naming* and *Inhibition* tasks can be administered to children aged 5 – 16 years, the *Switching* task may only be administered to children between the ages of 7 – 16 years.

The NEPSY-II Clinical and Interpretative Manual presented reliability coefficients as high as .96 amongst the three tasks across the varying age groups (Korkman et al., 2007). Furthermore, the Inhibition subtest is shown to have consistent moderate relationships with a similar neuropsychological measure, the Delis-Kaplan Executive Function System Word Colour Inference subtest (Korkman et al., 2007). The NEPSY-II is evidenced to detect cognitive deficits within clinical subgroups, including ASD, ADHD, language disorders and Intellectual Disabilities (Brooks et al., 2009). Specifically, the Inhibition subtest has been

used successfully in ASD research with a recent study using it to examine relations between executive functions and social competence in Western ASD children (see Berard, Loutzenhiser, Sevigny, & Alfano, 2017). In terms of cross-cultural use of the NEPSY-II, evidence from a pilot study in Zambia, suggests this measure was ideal for use within South Africa. This study, based on the original Western-normed NEPSY, revealed the measure is fairly resistant to language and cultural differences which are typically thought to undermine the applicability of such tests in non-western settings (Mulenga, Ahonen, & Aro, 2001).

Effortful control. The very short form of the Children's Behaviour Questionnaire (CBQ-VSF; Putnam & Rothbart, 2006) and the Early Adolescent Temperament Questionnaire, Revised (EATQ-R; Ellis & Rothbart, 2001) are parent-report measures which were used to examine child temperament. These questionnaires are equivalent measures, with the CBQ-VSF aimed at parents of children aged 3 – 8 years (Putnam & Rothbart, 2006) and the EATQ-R for parents of children aged of 9 – 15 years (Ellis & Rothbart, 2001). The questionnaires ask parents to rate how true a specific characteristic or reaction is for their child. The CBQ-VSF consists of a 7-point Likert scale while the EATQ-R contains a 5-point Likert scale. These two questionnaires provide scores for the three factors of temperament, with only the effortful control factor being examined in this study. The Total Effortful Control scores from the CBQ-VSF and EATQ-R were converted into *Z*-values for analyses, to allow for comparison of effortful control across all ages.

The CBQ-VSF was developed from the standard CBQ (Rothbart, Ahadi, Hershey, & Fisher, 2001) to provide researchers with an efficient measure to obtain scores for just the three broad factors (i.e. surgency, negative affectivity and effortful control; Putnam & Rothbart, 2006). All three factors demonstrate good internal consistency, with the effortful control scale having alpha coefficients ranging from .62 – .78 (Putnam & Rothbart, 2006).

The EATQ-R is a revision of the 1992 measure (Capaldi & Rothbart, 1992), with improvements made in assessing self-regulatory aspects of temperament (Ellis & Rothbart, 2001). Both parent- and self-report measures exist, with the two versions being identical except for items being rephrased to either the parent/child's perspective (e.g. "my child likes being sung to" vs. "I like being sung to"). Considering there is no self-report version of the CBQ-VSF, only the parent-report version of the EATQ-R was employed. This preference of parent-report measures over self-report measures permitted the examination of all participants recruited maximizing the size of the limited sample of the current sub-study. Furthermore, in the context of the ASD sample, a parent-report measure offered greater strength over a self-report measure as individuals with intellectual disability may have

difficulty comprehending and responding to abstract and socially reflexive questions (Finlay & Lyons, 2001), which is particularly relevant to the temperament questionnaires. The EATQ-R has acceptable psychometric properties, with scale reliability coefficients ranging from .65 to .86 (Ellis & Rothbart, 2001). Furthermore, the EATQ-R is considered a valid measure given its relation to personality and psychopathology assessments (Muris & Meesters, 2009).

The CBQ and EATQ-R are predominantly used in temperament research (Muris, Meesters, & Blijlevens, 2007; Verstraeten et al., 2010; Whittle et al., 2008; Zentner & Bates, 2008). Consequently, such report-based measures were chosen so as to allow for more suitable comparison with previous temperament research reported in the literature. The effortful control scale of these measures is useful in differentiating those with ASD from neurotypical children (Konstantareas & Stewart, 2006; Samyn et al., 2011, 2014). A thorough search of literature failed to yield studies utilizing the CBQ-VSF and EATQ-R within local South African contexts. However, studies with low and middle-income families have demonstrated the utility of the CBQ (Harris, Robinson, Chang, & Burns, 2007; Martini, Root, & Jenkins, 2004). These findings suggest the questionnaires are appropriate to use within low and middle income Countries like South Africa.

Procedure

Once ethical approval was obtained (see Appendices B, C, D) and permission granted by local autism-specific, special needs and mainstream schools, information packs were sent to the parents/caregivers of ASD and neurotypical children who attended the respective schools. These information packs contained an information sheet (Appendix E), consent form (different forms were created for parents of ASD (Appendix F) and neurotypical children respectively (Appendix G)), and a socio-demographic survey (Appendix A). If parents were interested in participating, they completed the relevant forms and returned them to the researcher via the school. Parents of children with ASD were also recruited through the UCT Autism Research Database. They were contacted telephonically or via email and if interested, completed and returned the forms provided in the information pack.

Once the parent/caregiver's consent was obtained, testing sessions with the child were then arranged at their school. Before commencement of the first session, the study and its various tasks were explained to the children in language they could understand, and assent was obtained. Additionally, children were asked before commencement of each remaining session if they wanted to continue participating. Children were assessed in a quiet room, free

from distraction. They were typically seen three to four times, depending on their level of ability. Over these testing sessions, measures for both the current sub-study and the larger investigation (which subsumed various other research protocols) were administered. These testing sessions were one-on-one and typically lasted 30 – 40 minutes depending on the child's attention capacity. Children with ASD had an extra session in comparison to neurotypical participants, which was always scheduled prior to other sessions. In this additional first session, children with ASD were administered the ADOS-2 (to confirm their diagnosis, assess their expressive language ability and examine their social deficits) and the Comprehension of Instruction of the NEPSY-II (to assess their ability to comprehend instructions). This session was conducted by the specially trained doctoral candidate, and typically took 40 – 60 minutes.

Parents of participating children were contacted to set up interviews at a time most convenient to them. During these interviews, the CBQ-VSF/EATQ-R was administered as well as other parent-report measures utilized in the larger investigation. Interviews were conducted over two sessions (typically 30 – 60 minutes each in duration) at the parent/caregivers' home or performed telephonically, depending on their preference.

Ethical Considerations

The larger study within which the current investigation is nested, received ethical approval from the UCT Faculty of Health Sciences Human Research Ethics Committee (FHS HREC; Appendix B), Western Cape Education Department (WCED; Appendix C) and UCT Department of Psychology Research Committee (Appendix D). Permission to recruit families was also obtained from participating schools' principals. All study procedures were conducted in accordance with the Declaration of Helsinki (World Medical Organisation, 2013) and UCT guidelines for research involving human subjects.

Consent, voluntary participation and confidentiality. Once informed of the research study, and given the opportunity to ask questions, parents provided informed consent (Appendices F and G). Participation in the study was voluntary. Upon commencement of each session participants were asked if they would like to participate and reminded they could withdraw from the study at any time without repercussions. Participants were assured that all data collected throughout the study would remain confidential and be accessed solely by members of the research team. Participants were assigned a unique code in place of their name, which was placed on all record forms used during testing or interview sessions. The completed record forms were subsequently stored in locked filing cabinets, in

an access controlled room within UCT Psychology Department. Data was inputted electronically on to password-protected computers. Again the participants' unique codes were used on the electronic datasheet in place of their names.

Risks. There was minimal risk to participating in this study as participants did not perform any potentially harmful tasks. Furthermore, neurocognitive tasks that were designed specifically for the use with children were selected. It was recognised that participating children, particularly those with ASD, may have felt anxious interacting with an unfamiliar person or having changes made to their school day. In an attempt to allay such feelings, testing sessions were planned in advance, with the child being informed and reminded of the testing day. The children were also introduced to the researcher by their school teacher or school psychologist (i.e. a familiar person). Furthermore, all members of the research team received training on how to appropriately administer the tasks to children and before each session would ask the participants if they wanted to partake. Only when the child assertively agreed, would the session begin. If the child became distressed during a task, the session was terminated and rescheduled if permitted. Sessions were also ended and rescheduled if the participant became fatigued. However, to mitigate this, tasks were spread out over a number of sessions on different days and frequent breaks were taken during the assessment.

Parent interviews were scheduled at times convenient to the parent and due care was taken to ensure they felt comfortable answering the questions. Furthermore, parents were allowed to take breaks during the sessions and could decline to answer a particular question if they preferred.

Benefits. Children with ASD received an ADOS-2 assessment (Lord et al., 2012). The ADOS-2 (Lord et al., 2012) is an internationally acclaimed ASD diagnostic tool. However, within South Africa this assessment is typically only offered in private practice at high cost, and many families are placed on long waiting lists when seeking the service via state hospitals. By participating in the study, children were offered the assessment free of charge and parents were provided with an individualised report detailing the child's strengths and limitations on the ADOS-2 (Lord et al., 2012). The child's performance on the WASI (Wechsler, 1999) was also summarised. This report could then be used to further inform parents, and parents could, if they chose, give the report to clinicians and educators involved in the child's care.

Parents of neurotypical children also received a report on their child's strengths and weaknesses on the WASI (Wechsler, 1999) and the UCT ToM Battery (Hoogenhout & Malcolm-Smith, 2014), which was administered within the larger study.

Cost. Participants incurred no costs. There were no additional travel costs to parents as sessions were arranged at the participants' schools during school hours and parent interviews were conducted at their homes or telephonically, depending on their preference. If telephonic interviews were requested, the research team would call using the study telephone.

Statistical Analyses

Data analyses were performed using IBM SPSS Statistics 25.0. Significance was set at $p < .05$ and effect sizes were reported for all analyses. The measures were scored based on rules detailed in the respective test manuals. The data were scrutinized for potential bias and examined to confirm whether assumptions of the independent samples t -tests and regression analyses were met.

ASD and neurotypical groups were aggregated-matched on age and SES. Two-tailed independent group t -tests were conducted in preliminary analyses to confirm no significant group differences existed on these two demographic variables. The age of the child was converted into months and entered as a continuous variable; however age was converted back into years post-analysis for reporting purposes. SES was indicated by annual Total Family Income (TFI), and entered as a continuous variable. Preliminary analyses further involved examining sample characteristics for FSIQ-4, a known predictor of the outcome variables in Study One and Two (i.e. attention, executive functions and ASD symptomatology; Bishop, Richler, & Lord, 2006; Passer et al., 2009; Zillmer, Spies, & Culbertson, 2008). The mean, standard deviation and range were calculated and a one-tailed independent sample t -test was conducted to determine whether the neurotypical children obtained a significantly higher FSIQ-4 than the ASD group.

Study One analysed the relationship between effortful control, attention and executive functions. However, rather than investigating effortful control's relationship to attention and executive function in general, in order to gain a more nuanced understanding of these relationships, effortful control's association with each aspect of attention (i.e. attention span and sustained attention) and executive functioning (i.e. working memory, inhibition and switching) was explored individually. I regarded this approach as appropriate given the inconsistent findings within the literature over effortful control's relationship with various aspects of attention and executive function.

In stage one of Study One's main analyses, independent sample t -tests were performed to determine whether groups differed significantly on effortful control, attention span, sustained attention, working memory, inhibition and switching. Given neurotypical

children were hypothesised to obtain significantly higher scores than the ASD children on all variables of interest, these independent sample *t*-tests were all one-tailed.

Variables established to differ significantly between neurotypical versus ASD participants were subsequently used in stage two of Study One's main analyses. Here zero-order correlations and Hierarchical Multiple Regression Analyses (MRAs) were conducted using the entire sample grouped together². Firstly, zero-order correlations between the predictors and outcome variables were conducted. Effortful control was the main predictor variable of interest while attention domains and executive functions were the outcome variables. Age, SES and FSIQ-4 are known predictors of attention and executive functioning (Anderson et al., 2001; Hackman & Farah, 2009; Hackman, Farah, & Meaney, 2010; Passer et al., 2009) and were thus also included in the initial zero-order correlation analyses. It was expected that all predictors (i.e. age, SES, FSIQ-4 and effortful control) would have a positive relationship with each outcome variable (i.e. attention domains and executive functions). Thus one-tailed significance tests were used.

Based on the zero-order correlations, it was established which relationships between predictor (i.e. age, SES, FSIQ-4 and effortful control) and outcome variables (i.e. attention domains and executive functions) were worth further investigation³. Consequently, Hierarchical MRAs were built individually based on the strength and significance of the zero-order correlations as well as on the hypothesized effects. Results were also scrutinized to ensure MRA assumptions of linearity and normality of residuals and multicollinearity were not violated and that there was no potential bias within the models.

Study Two examined whether effortful control, attention and executive functions are associated with ASD core deficits (i.e. Social Affect and Restricted, Repetitive Behaviours)

² Regression analyses are particularly sensitive to sample size, with a limited number of predictor variables permitted to be entered into a model when the sample size is relatively small. Therefore, I decided to conduct the regression using the entire sample grouped together ($n=76$), rather than perform separate regressions on each group (i.e. neurotypical and ASD). However, the variable 'group' was expected to be strongly correlated with most predictors. Thus it could not be entered into the model in order to limit multicollinearity. Therefore, effortful control and the cognitive variables were to be considered along a spectrum, with the neurotypical and ASD groups representing the upper and lower bounds respectively. Hence, I conducted independent sample *t*-tests to determine whether neurotypical participants scored significantly higher than ASD participants. Overall, where group differences existed, and effortful control emerged as a predictor, inferences over the relationship between effortful control and attention domains and/or executive functioning could be drawn across groups.

³ Given the sample size, the number of variables entered into the model needed to be limited. Therefore the zero-order correlations were used to help further inform which relationships were worth further investigation and hence which variables were to be included in the Hierarchical Multiple Regression Analyses. Thus the models were built on the notion of significance and hence to some degree were based on chance. It is indeed possible that some of the non-significant zero-order correlations may have proved influential when multiple correlations were considered simultaneously in the model, but given the very small correlation coefficient values, this was not very likely.

and thus analyses were conducted only on the ASD sample. Specifically, Study Two investigated whether effortful control moderated the relationship between attention/executive functioning and ASD Symptomatology. Only the attention and executive function variables for which effortful control emerged as a significant predictor in Study One were considered in Study Two.

Considering Study Two included only ASD participants, the sample size was relatively small ($n=38$), and hence the number of variables to be entered into the proposed regression analyses needed to be strictly limited. Therefore, preliminary analyses were conducted to determine if a composite “Cognitive Variable” combining the significant variables from Study One could be created. Zero-order correlations were scrutinised to determine to what extent these cognitive variables were interrelated; as positive associations were expected, one-tailed significance tests were used. No significant relationships emerged and hence a composite was not created.

Rather than potentially entering all three cognitive variables into one model, these were instead considered separately, thus reducing the number of variables entered into each model. First zero-order correlations were scrutinized between each cognitive variable (the predictor variables of interest), effortful control (the moderator variable) and the two outcome variables (i.e. Social Affect and Restricted, Repetitive Behaviours). FSIQ-4 and SES were also considered as potential predictors. It was expected that the cognitive variables and effortful control would have an inverse relationship with each outcome variable (i.e. Social Affect and Restricted, Repetitive Behaviours). This is because a higher score for ASD core deficits denotes greater impairment. Thus one-tailed significance tests were used to examine zero-order correlations.

As in Study One, based on zero-order correlations, it was established which relationships between predictor, moderator and outcome variables were worth further investigation. Consequently, if further investigation was warranted, moderation analyses were conducted to determine whether effortful control moderated the relationship between specific cognitive variables and an ASD core deficit (i.e. either Social Affect or Restricted Repetitive Behaviours). Thus models were built individually based on the strength and significance of zero-order correlations as well as on the hypothesized effects. Results were scrutinized to ensure MRA assumptions of linearity and normality of residuals and multicollinearity were not violated and that there was no potential bias within the models.

Results

Sample Characteristics

Firstly the data were scrutinized to assess whether there was potential bias. Three outliers were identified: an ASD participant obtained a very high attention span score, a neurotypical participant obtained a very high inhibition score, and an ASD participant obtained a very high Social Affect score. Note that while high scores on attention span and inhibition are indicative of good performance, a higher score of Social Affect denotes greater impairment. These data points were not excluded from the analyses as they were considered to hold valuable information (as opposed to being random error). For instance, the ASD participant who obtained a high attention span score was known to have severe fixations which in turn allowed him to attend intensely to the task. Considering severe fixations are a typical feature of ASD, exclusion of this participant would have created an incomplete representation of the ASD sample.

In terms of missing data, it was established that one neurotypical child and four ASD children did not complete the *Switching* task of the NEPSY-II Inhibition. The *Switching* task can only be administered to children aged 7 – 16 years (Korkman et al., 2007); these five participants were six years old and thus too young. Consequently, their data was excluded listwise when conducting analyses using the switching variable.

Sample characteristics: Demographic variables. Two-tailed independent sample *t*-tests revealed that neither age nor SES act as covariates – no between group differences were evident (see Table 1). The assumptions of normality and homoscedasticity were upheld. Furthermore, all participating children were English-speaking males. Thus, the neurotypical and ASD groups were successfully aggregated matched.

Table 1
Demographic Characteristics across Groups

| Characteristic | Group | | Significance Across Groups | | Effect size |
|---|---------------------------------|--------------------------|----------------------------------|----------|----------------|
| | Neurotypical (<i>n</i> =38) | ASD (<i>n</i> =38) | <i>t</i> | <i>p</i> | <i>d</i> |
| Age (Years:Months) Range | 6:11 – 13:6 | 6:1 – 13:7 | - | - | - |
| Age (Years:Months) \bar{X} (<i>SD</i>) | 9:9 (1:10) | 9:8 (2:1) | 0.24 | .815 | 0.06 |
| TFI Range (Rands per Year) | 55794 – 550506 | 100794 – 550506 | - | - | - |
| TFI (Rands per Year) \bar{X} (<i>SD</i>) | 412437.00 (163422.90) | 346386.90 (161118.30) | 1.77 | .080 | 0.41 |

Notes. ASD = Autism Spectrum Disorder. TFI = Total Family Income (annual). \bar{X} =Mean. *SD*=Standard deviation.

Sample characteristics: General intelligence. FSIQ-4 is a known predictor of attention, executive functions and ASD symptomatology (Bishop et al., 2006; Passer et al., 2009; Zillmer et al., 2008). Thus WASI FSIQ-4 was considered and controlled for when examining the relationships of the potential predictors of interest with various outcome variables considered in both Study One and Two. The descriptive statistics for each group's FSIQ-4 are indicated in Table 2. One-tailed independent sample *t*-tests were conducted to identify group differences. The assumptions of normality and homoscedasticity were upheld. As anticipated, neurotypical children had significantly higher FSIQ-4 than ASD children. This effect was very large, Cohen's *d* = 1.75 (Cohen, 1988; Rosenthal, 1996).

Table 2

General Intelligence Functioning (FSIQ-4) across Groups

| FSIQ-4 | Group | | Significance | | Effect |
|-------------------------|-----------------------|------------------------|---------------|----------|----------|
| | NT (<i>n</i> =38) | ASD (<i>n</i> =38) | Across Groups | | size |
| | | | <i>t</i> | <i>p</i> | <i>d</i> |
| Range | 87 – 135 | 55 – 119 | - | - | - |
| \bar{X} (<i>SD</i>) | 111.21 (12.30) | 87.39 (14.78) | 7.63 | <.001 | 1.75 |

Notes. FSIQ-4=Full Scale Intelligence Quotient. NT=Neurotypical. ASD=Autism Spectrum Disorder. \bar{X} =Mean. *SD*=Standard deviation.

Study One Stage One Analyses: Investigating Group Differences

I conducted preliminary analyses to determine whether neurotypical and ASD children differed on effortful control, attention domains and executive functioning. Variables established to differ significantly between neurotypical versus ASD participants were subsequently used in stage two analyses, where I explored whether effortful control acts as a potential predictor of attention domains and/or executive functioning.

Group differences on effortful control, attention and executive functioning. I hypothesized that neurotypical children would be rated significantly better than children with ASD on effortful control (Hypothesis 1), and perform significantly better on attention span (Hypothesis 2.1), sustained attention (2.2.), working memory (Hypothesis 3.1), inhibition (Hypothesis 3.2) and switching (Hypothesis 3.3). Consequently, one-tailed independent samples *t*-tests were conducted. The assumptions of normality and homoscedasticity were upheld and results are presented in Table 3.

Table 3

Group Differences for Effortful Control, Attention and Executive Functioning

| Domain | Descriptive Statistics | Group | | Significance Across Groups | | Effect size |
|------------------------|-------------------------|-----------------------|------------------------|----------------------------|----------|-------------|
| | | NT (<i>n</i> =38) | ASD (<i>n</i> =38) | <i>t</i> | <i>p</i> | <i>d</i> |
| Effortful Control | Range | -2.24 – 1.66 | -2.63 – 1.41 | - | - | - |
| | \bar{X} (<i>SD</i>) | .001 (.99) | -.95 (.98) | 4.22 | <.001 | 0.97 |
| Attention Span | Range | 3 – 14 | 2 – 12 | - | - | - |
| | \bar{X} (<i>SD</i>) | 9.61 (2.94) | 5.55 (2.46) | 6.52 | <.001 | 1.50 |
| Sustained Attention | Range | 2 – 16 | 1 – 16 | - | - | - |
| | \bar{X} (<i>SD</i>) | 8.66 (4.67) | 7.76 (5.50) | 0.77 | .224 | 0.18 |
| Working Memory | Range | 5 – 19 | 2 – 14 | - | - | - |
| | \bar{X} (<i>SD</i>) | 10.58 (3.09) | 6.32 (3.09) | 6.01 | <.001 | 1.38 |
| Inhibition | Range | 4 – 19 | 1 – 12 | - | - | - |
| | \bar{X} (<i>SD</i>) | 10.21 (3.27) | 5.76 (3.35) | 5.86 | <.001 | 1.34 |
| Switching ^a | Range | 3 – 19 | 1 – 15 | - | - | - |
| | \bar{X} (<i>SD</i>) | 10.51 (3.41) | 6.68 (4.29) | 4.19 | <.001 | 0.99 |

Notes. NT=Neurotypical. ASD=Autism Spectrum Disorder. \bar{X} =Mean. *SD*=Standard deviation. *Z*=Z score. *SS*=Scaled Score.

^a Five participants were too young to complete this task, therefore *n*=37 for the NT group and *n*=34 for the ASD group.

The Z-values derived from the Total Effortful Control scores of the CBQ-VSF (parents of children aged 6 – 8 years) and EATQ-R (parents of children aged 9 – 15 years), permitted examination of effortful control across all ages. The neurotypical group demonstrated significantly better effortful control than the ASD group, thus supporting Hypothesis 1. A large effect size was indicated, Cohen's *d* = 0.97 (Cohen, 1988). Regarding attention domains, results support Hypothesis 2.1 that neurotypical children have

significantly better attention span than ASD children as measured by the *Forwards* task of CMS; this effect size was very large, Cohen's $d = 1.50$ (Cohen, 1988; Rosenthal, 1996). Unexpectedly, no significant group difference existed for sustained attention performance (measured by the *Naming* task of NEPSY-II Inhibition subtest), with a small effect size indicated, Cohen's $d = 0.18$ (Cohen, 1988). Therefore, Hypothesis 2.2 was not supported. Lastly, as expected, the neurotypical group obtained significantly higher working memory (*Backwards* task of CMS), inhibition (*Inhibition* task of NEPSY-II Inhibition) and switching (*Switching* task of NEPSY-II Inhibition) scores than the ASD group. Very large effect sizes were indicated for working memory (Cohen's $d = 1.38$) and inhibition (Cohen's $d = 1.34$), and a large effect size was shown for switching (Cohen's $d = 0.99$; Cohen, 1988; Rosenthal, 1996). Therefore, Hypotheses 3.1, 3.2 and 3.3 were all supported.

Study One Stage Two Analyses: Investigating Effortful Control's Association with Attention and Executive Functions

The primary aim of Study One was to determine whether effortful control has a relationship with attention domains and executive functions respectively. Variables which differed significantly between neurotypical versus ASD participants were subsequently used in the stage two analyses. I built Hierarchical Multiple Regression (MRA) models using the entire sample grouped together ($n=76$), to identify whether effortful control was a predictor of attention domains and executive functions. Subsequently, where group differences existed, and effortful control emerged as a predictor, inferences over the relationship between effortful control and attention domains and/or executive functioning could be drawn across groups.

Associations between predictor and outcome variables: Effortful control and attention. Only attention span was considered in stage two's analyses, as the groups differed only on this attention domain. Thus while Hypothesis 4.1 was explored, Hypothesis 4.2 was not.

Zero-order correlations (see Table 4) indicated that effortful control was significantly correlated with attention span. This association was positive indicating increased effortful control is associated with an increased ability to consciously hold information in mind. SES and FSIQ-4 demonstrated a significant positive association with attention span, while age did not. Additionally, age was not significantly correlated with SES, FSIQ-4 or effortful control, indicating that age is independent of these three variables. Lastly, SES and effortful control were not significantly associated.

Table 4

Zero-Order Correlation Matrix: Attention Span

| | 1 | 2 | 3 | 4 | 5 |
|--------------------------|------|--------|--------|-------|---|
| 1. Age (Months) | - | | | | |
| 2. SES (TFI) | -.19 | - | | | |
| 3. FSIQ-4 | -.05 | .36*** | - | | |
| 4. Effortful Control (Z) | .04 | -.09 | .24* | - | |
| 5. Attention Span (SS) | -.10 | .47*** | .61*** | .28** | - |

Notes. SES=Socio-Economic Status. TFI=Total Family Income (annual).
FSIQ-4=Full Scale Intelligence Quotient. EC=Effortful Control. Z=Z score.
SS=Scaled Score

*. Correlation is significant at the .05 level (1-tailed).

**. Correlation is significant at the .01 level (1-tailed).

***. Correlation is significant at the .001 level (1-tailed).

MRA model building. Based on the zero-order correlations, the relationship between effortful control and attention span (the outcome variable) was worth further investigation. Initially age, SES and FSIQ-4 were all considered as potential predictors. However, because age did not demonstrate a significant relationship with attention span it was excluded from the model. SES and FSIQ-4 were significantly correlated with, and therefore, likely to influence attention span, thus these potential predictors were entered into the model prior to effortful control. As explained in the Statistical Analysis section (see p. 40), the variable ‘group’ was not included in the model to limit multicollinearity as it was expected to correlate strongly with most predictors. Rather, effortful control and attention span were considered according to a spectrum with neurotypical participants scoring significantly higher than ASD participants (see Table 3).

Examination of MRA assumptions and potential bias within model. Examination of Average Leverage values and Mahalanobis and Cook’s distances did not indicate any cases having undue influence. The assumptions of independent errors (Durbin Watson = 2.04), homoscedasticity and normally distributed errors were upheld. Furthermore, the VIF values

were well below 10 and the tolerance statistics well above .02, thus there did not appear to be multicollinearity within the data.

Associations between effortful control and attention span. Based on the zero-order correlations and the hypothesised relationships, SES was entered into the model first, followed by FSIQ-4 and then subsequently effortful control. The overall model was significant, $F(3, 72) = 22.81, p < .001$, explaining 46.6% of the variance as indicated by the adjusted effect size (Table 5). Effortful control made a significant contribution to the model, explaining 3.8% of the variance in the model as indicated by the R^2 change value. Indeed, effortful control acted as a significant predictor of attention span (see Table 6), supporting Hypothesis 4.1. SES and FSIQ-4 also emerged as significant predictors (see Table 6). Overall, standardized beta values indicate FSIQ-4 had the greatest influence on attention span, followed by SES and then effortful control.

Table 5

Predictors of Attention Span: Model Summary

| Model | <i>R</i> | <i>R Square</i> | <i>Adjusted R Square</i> | Std. Error of the Estimate | <i>R Square Change</i> | <i>F Change</i> | <i>df 1</i> | Change Statistics | | <i>Sig. F Change</i> |
|-------|----------|-----------------|--------------------------|----------------------------------|----------------------------|-----------------|-------------|-------------------|--|--------------------------|
| | | | | | | | | <i>df 2</i> | | |
| 1 | .474 | .225 | .215 | 2.99 | .225 | 21.49 | 1 | 74 | | <.001 |
| 2 | .670 | .449 | .434 | 2.54 | .224 | 29.72 | 1 | 73 | | <.001 |
| 3 | .698 | .487 | .466 | 2.47 | .038 | 5.34 | 1 | 72 | | .024 |

Notes.

Model 1: Constant, Socio-Economic Status (SES; Total Family Income (TFI))

Model 2: Constant, SES (TFI), FSIQ-4

Model 3: Constant, SES (TFI), FSIQ-4, Effortful Control

Table 6

Coefficients for Model 3: Attention Span

| Model | Predictors | Unstandardized coefficients | | Standardized | <i>t</i> | <i>p</i> | Collinearity Statistics | |
|-------|------------|-----------------------------|------------|--------------|----------|----------|-------------------------|------|
| | | <i>B</i> | Std. Error | <i>β</i> | | | Tolerance | VIF |
| 3 | (Constant) | -2.96 | 1.67 | | -1.77 | .080 | | |
| | SES (TFI) | 6.820E-6 ^a | 0.00 | .33 | 3.61 | .001 | .84 | 1.93 |
| | FSIQ-4 | 0.08 | 0.02 | .45 | 4.71 | <.001 | .80 | 1.25 |
| | EC (Z) | 0.64 | 0.28 | .20 | 2.31 | .024 | .91 | 1.10 |

Notes. SES=Socio-Economic Status. TFI=Total Family Income. FSIQ-4=Full Scale Intelligence Quotient. EC=Effortful Control. Z=Z score.

^a The B value associated with SES(TFI) is exponentially small due to a large discrepancy between its scale (R17994p.a – R550506p.a) and the scale of the outcome variable (Attention Span: 1-19). However, the β value shows the relative predictive effect.

Associations between predictor and outcome variables: Effortful control and executive functioning. Zero-order correlations (see Table 7) indicated that effortful control is significantly correlated with working memory, inhibition and switching. These associations were all positive, indicating that increased effortful control is associated with increased capacity to hold and manipulate information in mind (i.e. working memory), inhibit automatic responses in preference for another learned response (i.e. inhibition) and ability to shift between mental tasks (i.e. switching). The strongest correlation was between effortful control and inhibition, followed by working memory and switching respectively.

In terms of other possible predictors, FSIQ-4 was significantly and positively correlated with all three executive function variables, while SES only positively correlated significantly with switching. Age did not show a significant association with any of the three executive functions. Furthermore, FSIQ-4 was significantly correlated with SES and effortful control. SES and effortful control were not associated with one another. Moreover, age did not correlate with SES, FSIQ-4 or effortful control, indicating that age is independent of these three variables.

As anticipated, the three executive functions were all significantly positively correlated with one another. Specifically, switching and inhibition demonstrated the strongest correlation, followed by working memory's association with switching and inhibition respectively. This indicates that these variables are indeed measuring the same broader construct of executive functioning.

Table 7

Zero-Order Correlation Matrix: Executive Functions

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--------------------------|------|--------|--------|--------|--------|--------|---|
| 1. Age (Months) | - | | | | | | |
| 2. SES (TFI) | -.19 | - | | | | | |
| 3. FSIQ-4 | -.05 | .36*** | - | | | | |
| 4. Effortful Control (Z) | .04 | -.09 | .24* | - | | | |
| 5. Working Memory (SS) | .02 | .12 | .60*** | .32** | - | | |
| 6. Inhibition (SS) | -.08 | .09 | .67*** | .38*** | .55*** | - | |
| 7. Switching (SS) | -.06 | .22* | .70*** | .21* | .58*** | .62*** | - |

Notes. SES=Socio-Economic Status. TFI=Total Family Income (annual). FSIQ-4=Full Scale Intelligence Quotient. Z=Z score. SS=Scaled Score

*. Correlation is significant at the .05 level (1-tailed).

**. Correlation is significant at the .01 level (1-tailed).

***. Correlation is significant at the .001 level (1-tailed)

Based on the zero-order correlations, the relationship between effortful control with the three executive function variables, namely working memory, inhibition and switching respectively, was worth further investigation. Consequently, I built three Hierarchical MRA models individually, for each aspect of executive function based on the strength and significance of the zero-order correlations in Table 7 as well as on the hypothesized effects. Again, in order to limit multicollinearity the variable ‘group’ was excluded from the models given it was anticipated to be strongly associated with most predictors. Rather, effortful control and the different executive functions were considered according to a spectrum with neurotypical participants scoring significantly higher than ASD participants (see Table 3).

Examination of potential bias within each model. Given the Average Leverage values and Mahalanobis and Cook’s distances were within the appropriate ranges for all three MRA models run, no cases were seen to have undue influence. Furthermore, the assumptions of independent errors, homoscedasticity and normally distributed errors were upheld for each

model. Additionally, the VIF values are well below 10 and the tolerance statistics well above .02, thus there did not appear to be multicollinearity within the data.

MRA model building: Working memory. Age and SES were not significantly correlated with working memory and hence not considered for the hierarchical MRA model. Therefore, FSIQ-4 was entered into the model first, followed by effortful control.

Associations between effortful control and working memory. The overall model was significant, $F(2,73) = 24.25, p < .001$ and the adjusted effect size (see Table 8) showed that the model explained 38.3% of the variance. Effortful control made a significant contribution, explaining 3.4% of the variance in the model as indicated by the R^2 change value in Table 8. Hypothesis 5.1 was supported as effortful control emerged as a significant predictor of working memory (see Table 9). FSIQ-4 was also a significant predictor of working memory and had a greater influence on the outcome variable than effortful control (see Table 9).

Table 8

Predictors of Working Memory: Model Summary

| Model | <i>R</i> | <i>R Square</i> | <i>Adjusted R Square</i> | Std. Error of the Estimate | <i>R Square Change</i> | <i>F Change</i> | <i>df 1</i> | <i>df 2</i> | Change Statistics | |
|-------|----------|-----------------|--------------------------|-------------------------------|------------------------|-----------------|-------------|-------------|----------------------|----------------------|
| | | | | | | | | | <i>Sig. F Change</i> | <i>Durbin Watson</i> |
| 1 | .604 | .365 | .357 | 3.01 | .365 | 42.57 | 1 | 74 | <.001 | |
| 2 | .632 | .399 | .383 | 2.94 | .034 | 4.13 | 1 | 73 | .046 | 1.67 |

Notes.

Model 1: Constant, FSIQ-4

Model 2: Constant, FSIQ-4, Effortful Control

Table 9

Coefficients for Model 2: Working Memory

| Model | Predictors | Unstandardized coefficients | | Standardized coefficients | | | Collinearity Statistics | |
|-------|-----------------------------------|-----------------------------|------------|---------------------------|----------|----------|-------------------------|------|
| | | <i>B</i> | Std. Error | β | <i>t</i> | <i>p</i> | Tolerance | VIF |
| 2 | (Constant) | -2.77 | 1.99 | | -1.39 | .168 | | |
| | FSIQ-4 | 0.12 | 0.02 | .56 | 6.00 | <.001 | .95 | 1.06 |
| | Effortful Control (<i>Z</i>) | 0.65 | 0.32 | .19 | 2.03 | .046 | .95 | 1.06 |

Notes. FSIQ-4=Full Scale Intelligence Quotient. *Z*=*Z* scores.

MRA model building: Inhibition. I built the model based on the zero-order correlations displayed in Table 7 as well as the hypothesized effects. Consequently, age and SES were not included in the model (no significant correlation with inhibition); FSIQ-4 was entered into the model first, followed by effortful control.

Associations between effortful control and inhibition. The overall model was significant, $F(2, 73) = 36.16, p < .001$, accounting for 48.4% of the variance (see Table 10). Effortful control made a significant contribution to the model, and accounted for 5.2% of the variance (see Table 10). Moreover, effortful control emerged as a predictor of inhibition (see Table 11) thus supporting Hypothesis 5.2. FSIQ-4 was also a predictor of inhibition, having a greater influence than effortful control.

Table 10

Predictors of Inhibition: Model Summary

| Model | <i>R</i> | <i>R Square</i> | <i>Adjusted R Square</i> | Std. Error of the Estimate | <i>R Square Change</i> | <i>F Change</i> | Change Statistics | | | <i>Durbin Watson</i> |
|-------|----------|-----------------|--------------------------|----------------------------|------------------------|-----------------|-------------------|-------------|----------------------|----------------------|
| | | | | | | | <i>df 1</i> | <i>df 2</i> | <i>Sig. F Change</i> | |
| 1 | .667 | .445 | .438 | 2.98 | .445 | 59.44 | 1 | 74 | <.001 | |
| 2 | .705 | .498 | .484 | 2.86 | .052 | 7.60 | 1 | 73 | .007 | 1.95 |

Notes.

Model 1: Constant, FSIQ-4

Model 2: Constant, FSIQ-4, Effortful Control

Table 11

Coefficients for Model 2: Inhibition

| Model | Predictors | Unstandardized coefficients | | <i>Standardized coefficients</i> | <i>t</i> | <i>p</i> | Collinearity Statistics | |
|-------|--------------------------------|-----------------------------|------------|----------------------------------|----------|----------|-------------------------|------|
| | | <i>B</i> | Std. Error | β | | | Tolerance | VIF |
| 2 | (Constant) | -4.99 | 1.94 | | -2.58 | .012 | | |
| | FSIQ-4 | 0.14 | 0.02 | .61 | 7.17 | <.001 | .95 | 1.06 |
| | Effortful Control (<i>Z</i>) | 0.86 | 0.31 | .24 | 2.76 | .007 | .95 | 1.06 |

Notes. FSIQ-4=Full Scale Intelligence Quotient. *Z*=*Z* scores.

MRA model building: Switching. Based on the zero-order correlations displayed in Table 7 as well as the hypothesized effects, SES was entered into the model first, followed by FSIQ-4 and then effortful control. Age was not considered as it did not correlate significantly with switching.

Associations between effortful control and switching. The overall model was significant, $F(3, 67) = 21.23, p < .001$, and accounted for 46.4% of the variance (as indicated by the adjusted R^2 value in Table 12). Unexpectedly, effortful control did not make a significant contribution to the model (see Table 13) and hence Hypothesis 5.3 was not supported. Only FSIQ-4 emerged as a predictor of switching (see Table 13).

Table 12

Predictors of Switching: Model Summary

| Model | <i>R</i> | <i>R Square</i> | <i>Adjusted R Square</i> | Std. Error of the Estimate | <i>R Square Change</i> | <i>F Change</i> | Change Statistics | | | Durbin- Watson |
|-------|----------|-----------------|--------------------------|-------------------------------|------------------------|-----------------|-------------------|-------------|----------------------|-------------------|
| | | | | | | | <i>df 1</i> | <i>df 2</i> | <i>Sig. F Change</i> | |
| 1 | .221 | .049 | .035 | 4.21 | .049 | 3.54 | 1 | 69 | .064 | |
| 2 | .698 | .487 | .472 | 3.12 | .438 | 58.05 | 1 | 68 | <.001 | |
| 3 | .698 | .487 | .464 | 3.14 | .000 | .06 | 1 | 67 | .809 | 2.09 |

Notes.

Model 1: Constant, Socio-Economic Status (SES; Total Family Income (TFI))

Model 2: Constant, SES (TFI), FSIQ-4

Model 3: Constant, SES (TFI), FSIQ-4, Effortful Control

Table 13

Coefficients for Model 3: Switching

| Model | Predictors | Unstandardized coefficients | | Standardized coefficients | <i>t</i> | <i>p</i> | Collinearity Statistics | |
|-------|--------------------------------|-----------------------------|------------|---------------------------|----------|----------|-------------------------|------|
| | | <i>B</i> | Std. Error | β | | | Tolerance | VIF |
| 3 | (Constant) | -7.68 | 2.23 | | -3.44 | .001 | | |
| | SES (TFI) | 0.00 | 0.00 | -.06 | -0.63 | .530 | .81 | 1.24 |
| | FSIQ-4 | 0.17 | 0.02 | .71 | 7.12 | <.001 | .76 | 1.32 |
| | Effortful Control (<i>Z</i>) | 0.09 | 0.36 | .02 | 0.24 | .809 | .90 | 1.12 |

Notes. SES=Socio-Economic Status. TFI=Total Family Income. FSIQ-4=Full Scale Intelligence Quotient. *Z*=*Z* score.

Study Two: Investigating the Association Between Effortful Control, Attention and Executive Functioning in Relation to ASD Core Deficits

The primary aim of Study Two was to determine whether effortful control, attention and executive functioning were associated with ASD core deficits, namely Social Affect and Restricted, Repetitive Behaviours. Specifically, I explored whether effortful control moderates the relationship between attention/executive functions and ASD core deficits. Of the cognitive variables, only attention span, working memory and inhibition were considered in Study Two given that effortful control emerged as a significant predictor only of these variables in Study One.

ASD symptomatology characteristics. The range for each ASD deficit was scrutinized to determine whether there was variability in presentation. These descriptive statistics are indicated in Table 14; the presence of variability permits further examination of the relationship these outcome variables (i.e. Social Affect and Restricted, Repetitive Behaviours) have with attention, executive functioning and effortful control.

Table 14

ASD Core Deficit Characteristics

| Descriptive Statistics | Core Deficit | |
|-------------------------|----------------------------------|---|
| | Social Affect (<i>n</i> =38) | Restricted Repetitive Behaviours (<i>n</i> =38) |
| Range | 2 – 18 | 0 – 6 |
| \bar{X} (<i>SD</i>) | 7.29 (3.01) | 2.05 (1.51) |

Notes. ASD=Autism Spectrum Disorder. \bar{X} =Mean. *SD*=Standard deviation.

Consideration of a composite cognitive variable. I explored whether a composite “Cognitive Variable” could be created, incorporating attention span, working memory and inhibition – the smaller sample size (*n*=38) required the number of variables placed into the regression models to be strictly limited. Associations between the cognitive variables were observed in the larger sample, suggesting a composite variable may be viable and useful in Study Two given the sample constraint. Zero-order correlations were therefore scrutinised to explore the relationships between attention span, working memory and inhibition in the ASD sample. It was expected all cognitive variables would have a positive relationship with each other thus one-tailed significance tests were used. However, (see Table 15) none of the

cognitive variables correlated significantly with each other and a composite “Cognitive Variable” could not be created. The difficulty of limiting the number of variables in the model remained. Therefore, attention, working memory and inhibition were considered separately rather than entering all three cognitive variables into one model.

Table 15

Zero-Order Correlation Matrix: Attention, Working Memory and Inhibition (SS)

| | 1 | 2 | 3 |
|-------------------|-----|-----|---|
| 1. Attention Span | - | | |
| 2. Working Memory | .20 | - | |
| 3. Inhibition | .13 | .20 | - |

Notes. SS=Scaled Scores

*. Correlation is significant at the .05 level (1-tailed).

**. Correlation is significant at the .01 level (1-tailed).

***. Correlation is significant at the .001 level (1-tailed)

Main Analyses: Investigating the association between effortful control, attention, executive functioning and ASD core deficits. In the main analyses, I explored the primary aim of determining whether effortful control moderated the relationship between cognitive variables (i.e. attention span, working memory or inhibition) and ASD core deficits (i.e. Social Affect or Restricted, Repetitive Behaviours). Here, zero-order correlations were scrutinized between each cognitive variable (the predictor variables of interest), effortful control (the moderator variable) and the two outcome variables (i.e. Social Affect and Restricted, Repetitive Behaviours). FSIQ-4 and SES were also considered as potential predictors. Zero-order correlations provided indications of which relationships between predictor, moderator and outcome variables were worth further investigation in moderation analyses. This notion of building models based off zero-order correlations aided in further limiting the numbers of variables entered into the regression analyses. Thus models were built individually based on the strength and significance of zero-order correlations as well as on the hypothesized effects.

In moderation analyses, it is commonly recommended that all variables involved in the interaction are centred around the mean so as to reduce multicollinearity (see Field, 2013a, p. 398). In order to centre a variable, the mean is subtracted from each individual score of that variable (i.e. $X_{\text{standardised (std)}} = X - \bar{X}$). Therefore I created new standardised effortful control, attention span, working memory and inhibition variables. The three interaction terms were subsequently created by multiplying the standardised values of effortful control with each respective cognitive variable (i.e. $\text{effortful control}_{\text{std}} * \text{cognitive variable}_{\text{std}}$).

Association between attention span, effortful control and ASD symptomatology.

Firstly, I conducted zero-order correlations on all the relevant predictor and outcome variables of interest (see Table 16).

Zero-order correlation analyses revealed that Social Affect did not demonstrate a significant association with attention span, effortful control or the interaction between attention span and effortful control. Consequently, there was little evidence for further investigation over whether effortful control moderates the relationship between attention span and Social Affect, and so a moderation analysis was not conducted.

Restricted, Repetitive Behaviours, the other outcome variable, was moderately to strongly correlated with $\text{effortful control}_{\text{std}}$, $\text{attention span}_{\text{std}}$ and the interaction term ($\text{effortful control}_{\text{std}} * \text{attention span}_{\text{std}}$). While Restricted, Repetitive Behaviour had a positive association with $\text{effortful control}_{\text{std}}$, it demonstrated a negative relationship with $\text{attention span}_{\text{std}}$ and the interaction term. Based on the zero-order correlations, the relationship between effortful control, attention and Restricted, Repetitive Behaviours was worth further investigation.

Note, given SES and FSIQ-4 emerged as significant predictors of attention span in Study One, they were considered as potential predictors in Study Two. Zero-order correlation analyses revealed that FSIQ-4 was significantly negatively associated with both Social Affect (moderate – large strength) and Restricted, Repetitive Behaviours (moderate strength). However, SES did not correlate significantly with either outcome variable.

Additionally, examination of the relationships between the potential predictors revealed that FSIQ-4 was significantly positively associated with $\text{attention span}_{\text{std}}$, while SES demonstrated a significant relationship with $\text{effortful control}_{\text{std}}$ and $\text{attention span}_{\text{std}}$.

Table 16

Zero-Order Correlation Matrix: Effortful Control and Attention Span's association with Social Affect and Restricted Repetitive Behaviours

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--|--------|--------|-------|---------|--------|-----|---|
| 1. SES | - | | | | | | |
| 2. FSIQ-4 | .13 | - | | | | | |
| 3. EC _{std} | -.41** | -.09 | - | | | | |
| 4. Attention span _{std} | .31* | .45** | -.22 | - | | | |
| 5. EC _{std} * attention span _{std} | .05 | .03 | -.14 | .06 | - | | |
| 6. Social Affect | -.02 | -.40** | -.16 | -.15 | -.19 | - | |
| 6. RRB | -.21 | -.28* | .46** | -.53*** | -.37** | .16 | - |

Notes. SES=Socio-Economic Status. FSIQ-4=Full Scale Intelligence Quotient. EC=Effortful Control. Std=Standardised. RRB=Restricted, Repetitive Behaviours.

*. Correlation is significant at the .05 level (1-tailed).

**. Correlation is significant at the .01 level (1-tailed).

***. Correlation is significant at the .001 level (1-tailed)

Association between attention span, effortful control and Restricted, Repetitive Behaviours. I conducted a moderation regression analysis to determine whether effortful control moderates the relationship between attention span and Restricted, Repetitive Behaviours. Given SES did not correlate significantly with Restricted, Repetitive Behaviours, it was excluded from the model. FSIQ-4 was placed in the model first. Effortful control_{std} and attention span_{std} were entered together into the second level and the interaction between effortful control_{std} and attention span_{std} was entered last.

The assumptions of independent errors, homoscedasticity and normally distributed errors were upheld. The Average Leverage values and Mahalanobis and Cook's distances were within the appropriate ranges. Furthermore, the assumption of multicollinearity did not appear to be violated as the VIF values were well below 10, with the average VIF = 1.17 and the tolerance statistics well above .2.

The overall model was significant $F(4, 33) = 7.89, p < .001$, accounting for 42.7% of the variance as indicated by the Adjusted R^2 value (see Table 17). FSIQ-4 did not emerge as a significant predictor of Restricted, Repetitive Behaviours (Table 18). Keeping the interaction constant, both effortful control_{std} and attention span_{std} emerged as significant predictors of

Restricted, Repetitive Behaviours (see Table 18). The interaction effect was also significant, indicating that moderation was present. Figure 1 illustrates these relationships at high (green line), mean (red line) and low levels (blue line) of effortful control. Post-hoc linear regression analyses were conducted to determine whether attention span emerged as a significant predictor of Restricted, Repetitive Behaviours at these three different levels of effortful control. Given three separate post-hoc linear regression analyses were conducted, a Bonferroni correction was applied and significance was set at $p < .017$ in order to limit Type I error. Results in Table 19 indicate that at low and mean levels of effortful control, attention span does not emerge as a significant predictor. Instead this interaction effect is only significant at high levels of effortful control. Specifically, when effortful control is high (see green line in Figure 1), there is a strong negative relationship between attention span and Restricted, Repetitive Behaviours. Considering lower scores of Restricted, Repetitive Behaviours denotes less impairment, this negative relationship indicates that increased attention span is associated with less impairment in Restricted, Repetitive Behaviours when effortful control is high.

Table 17

Interaction between Effortful Control and Attention Span in Predicting Restricted Repetitive Behaviours: Model Summary

| Model | <i>R</i> | <i>R Square</i> | <i>Adjusted R Square</i> | Std. Error of the Estimate | <i>R Square Change</i> | <i>F Change</i> | Change Statistics | | | Durbin- Watson |
|-------|----------|-----------------|--------------------------|-------------------------------|------------------------|-----------------|-------------------|-------------|----------------------|-------------------|
| | | | | | | | <i>df 1</i> | <i>df 2</i> | <i>Sig. F Change</i> | |
| 1 | .278 | .077 | .052 | 1.47 | .077 | 3.01 | 1 | 36 | .091 | |
| 2 | .634 | .402 | .349 | 1.21 | .325 | 9.24 | 2 | 34 | .001 | |
| 3 | .699 | .489 | .427 | 1.14 | .087 | 5.59 | 1 | 33 | .024 | 1.78 |

Notes.

Model 1: Constant, FSIQ-4

Model 2: Constant, FSIQ-4, Effortful Control (EC)_{standardised (std)}, attention span_{std}Model 3: Constant, FSIQ-4, EC_{std}, attention span_{std}, Interaction (EC_{std}* attention span_{std})

Table 18

Interaction between Effortful Control and Attention Span in Predicting Restricted Repetitive Behaviours: Coefficients for Model 3

| Model | Predictors | Unstandardized coefficients | | <i>Standardized coefficients</i> | | | Collinearity Statistics | |
|-------|---|-----------------------------|------------|----------------------------------|----------|----------|-------------------------|------|
| | | <i>B</i> | Std. Error | β | <i>t</i> | <i>p</i> | Tolerance | VIF |
| 3 | (Constant) | 2.41 | 1.26 | | 1.91 | .065 | | |
| | FSIQ-4 | -0.01 | 0.01 | -.05 | -.36 | .718 | .79 | 1.26 |
| | EC _{std} | 0.49 | 0.20 | .32 | 2.48 | .018 | .94 | 1.07 |
| | Attention Span _{std} | -0.26 | 0.09 | -.42 | -2.92 | .006 | .76 | 1.31 |
| | EC _{std} * Attention Span _{std} | -0.20 | 0.08 | -.30 | -2.36 | .024 | .98 | 1.02 |

Notes. FSIQ-4=Full Scale Intelligence Quotient. EC=Effortful Control. Std=Standardised

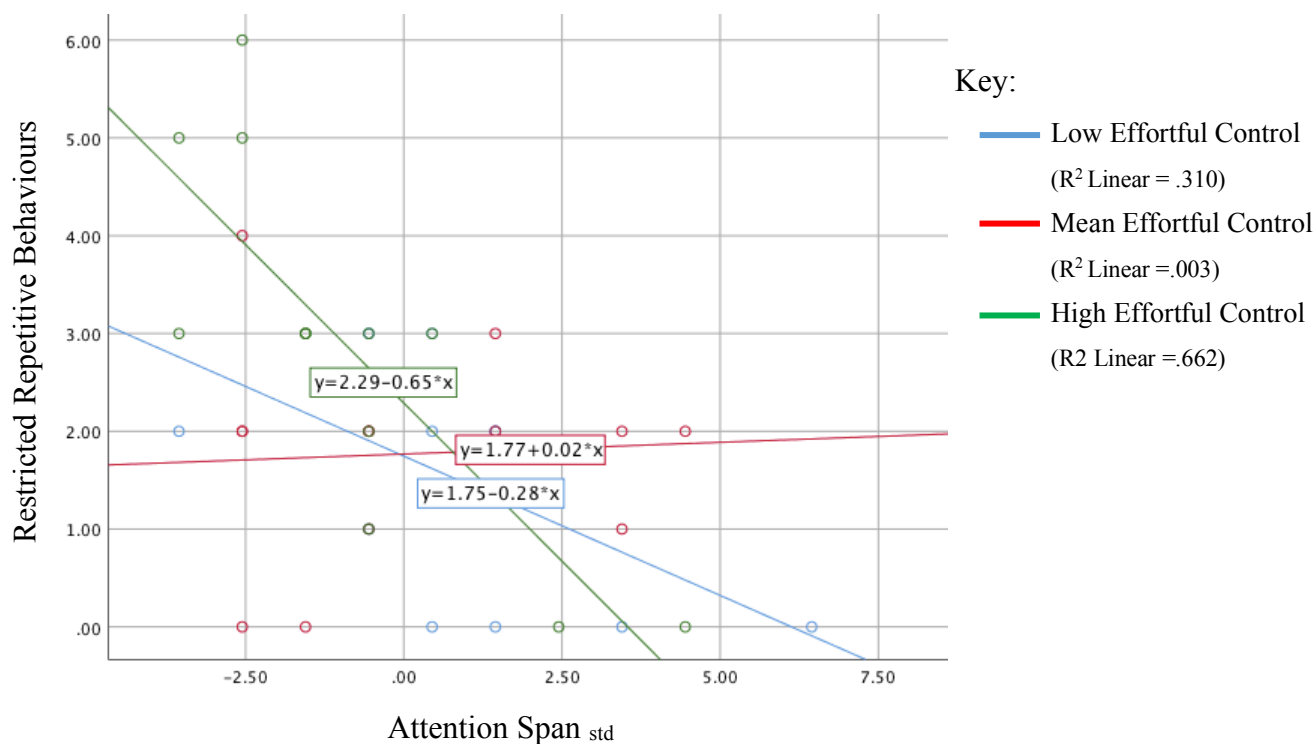


Figure 1. *Restricted Repetitive Behaviours according to different levels of Effortful Control and Attention Span.*

Table 19.

Predicting Restricted Repetitive Behaviours: Coefficients for Attention Span at differing levels of Effortful Control

| Predictor | Level of EC _{std} | Unstandardized coefficients | | Standardized coefficients | <i>t</i> | <i>p</i> |
|-------------------------------|----------------------------|-----------------------------|------------|---------------------------|----------|----------|
| | | <i>B</i> | Std. Error | β | | |
| Attention Span _{std} | Low | -0.29 | 0.13 | -.56 | -2.12 | .060 |
| | Mean | 0.02 | 0.13 | .06 | 0.19 | .857 |
| | High | -0.65 | 0.14 | -.81 | -4.64 | .001 |

Notes. EC=Effortful Control. Std=Standardised

Association between working memory, effortful control and ASD symptomatology. I conducted zero-order correlations on all the predictor and outcome variables of interest (see Table 20).

In terms of Social Affect, zero-order correlation analyses revealed that neither effortful control_{std} nor working memory_{std} were significantly associated with Social Affect. However, the interaction between effortful control_{std} and working memory_{std} was significantly positively associated with Social Affect (moderate strength in relationship) and thus moderation analyses were subsequently considered.

Restricted, Repetitive Behaviours demonstrated a significant positive association with effortful control_{std} (medium – large strength). However, given that neither working memory_{std} nor the interaction effect were significantly correlated with Restricted, Repetitive Behaviours (the outcome variable), further investigation into whether effortful control moderates the relationship between working memory and Restricted, Repetitive Behaviours was not warranted.

Note, given FSIQ-4 emerged as a significant predictor of working memory in Study One, it was also considered as a potential predictor in Study Two. As previously mentioned, zero-order correlation analyses revealed that FSIQ-4 had a significant negative relationship with both Social Affect (moderate – large strength) and Restricted, Repetitive Behaviours (moderate strength). Additionally, examination of the relationships between the various potential predictors revealed that FSIQ-4 and working memory_{std} had a significant moderate-large positive relationship. Furthermore, effortful control_{std} and the interaction effect were significantly moderately associated with each other.

Table 20

Zero-Order Correlation Matrix: Effortful Control and Working Memory's association with Social Affect and Restricted Repetitive Behaviours

| | 1 | 2 | 3 | 4 | 5 | 6 |
|--|--------|-------|------|------|-----|---|
| 1. FSIQ-4 | - | | | | | |
| 2. EC _{std} | -.09 | - | | | | |
| 3. WM _{std} | .42** | .00 | - | | | |
| 4. EC _{std} * WM _{std} | -.10 | -.27* | -.14 | - | | |
| 5. Social Affect | -.40** | -.16 | -.13 | .30* | - | |
| 6. Restricted Repetitive Behaviours | -.28* | .46** | .11 | .03 | .16 | - |

Notes. SES=Socio-Economic Status. FSIQ-4=Full Scale Intelligence Quotient. EC=Effortful Control. Std=Standardised. WM=working memory.

*. Correlation is significant at the .05 level (1-tailed).

**. Correlation is significant at the .01 level (1-tailed).

***. Correlation is significant at the .001 level (1-tailed)

Association between working memory, effortful control and Social Affect. I considered performing a moderation regression analysis to determine whether effortful control moderates the relationship between working memory_{std} and Social Affect. In the proposed model FSIQ-4 was entered first, followed by effortful control_{std} and working memory_{std} in the second level and their interaction effect in the third level.

However, upon examination of residual statistics, several high standardized residuals were identified suggesting that some cases had undue influence on the proposed model (see Table H1 in Appendix H). Furthermore, inspection of the plot of standardised residuals against predicted values indicated that the assumption of homogeneity of variance had been violated (see Figure H1 in Appendix H). Additionally, the Q-Q plots of the interaction between effortful control_{std} and working memory_{std} indicated that the data was positively skewed (see Figure H2 in Appendix H). Such findings evidenced the presence of bias within the data.

Transformation of the data was contemplated but ultimately decided against. For one, there is great controversy over whether transformation of data is appropriate. Specifically,

arguments have been made over whether obtaining more valid probability statements outweighs the cost of the transforming data (Field, 2013b). Moreover, transformations essentially alter the hypotheses being tested as different constructs to the ones originally measured are created and analysed (Field, 2013b). Furthermore, and with particular relevance to the current study, there were concerns over whether the small sample size could bear the weight of such analyses. Additionally, as mentioned above, neither effortful control_{std} or working memory_{std} as separate variables were significantly correlated with Social Affect. Thus it seemed unlikely that the variables would concurrently be associated with Social Affect in a moderation analyses.

Given the points detailed above, I felt performing a moderation analysis on transformed data would not offer me a reliable enough model from which I could confidently draw conclusions.

Association between inhibition, effortful control and ASD symptomatology. Zero-order correlation analyses (see Table 21) revealed that inhibition_{std} was moderately strongly correlated with Social Affect (inverse relationship). However, given that effortful control_{std} and the interaction effect were not significantly associated with Social Affect, there was little evidence for the need of further analyses investigating whether effortful control moderates the relationship between inhibition and Social Affect.

In addition, effortful control_{std} showed a positive relationship (moderate – large strength) with Restricted, Repetitive Behaviours. However, as neither inhibition nor the interaction effect were significantly correlated with Restricted, Repetitive Behaviours, a moderation analysis was not conducted.

Note, given FSIQ-4 emerged as a significant predictor of inhibition in Study One, it was also considered as a potential predictor in Study Two. Zero-order correlation analyses indicated FSIQ-4 had a significant positive association with Inhibition_{std} and, as previously mentioned, a significant negative relationship with both Social Affect and Restricted, Repetitive Behaviours. However, as discussed above, further moderation analyses were not conducted as the primary relationships of interest were non-significant.

Table 21

Zero-Order Correlation Matrix: Effortful Control and Inhibition's association with Social Affect and Restricted Repetitive Behaviours

| | 1 | 2 | 3 | 4 | 5 | 6 |
|--|--------|-------|--------|------|-----|---|
| 1. FSIQ-4 | - | | | | | |
| 2. EC _{std} | -.09 | - | | | | |
| 3. Inhibition _{std} | .62*** | .16 | - | | | |
| 4. EC _{std} * Inhibition _{std} | -.15 | -.18 | -.08 | - | | |
| 5. Social Affect | -.40** | -.16 | -.45** | .19 | - | |
| 6. Restricted Repetitive Behaviours | -.28* | .46** | -.23 | -.15 | .16 | - |

Notes. SES=Socio-Economic Status. FSIQ-4=Full Scale Intelligence Quotient. EC=Effortful Control. Std=Standardised.

*. Correlation is significant at the .05 level (1-tailed).

**. Correlation is significant at the .01 level (1-tailed).

***. Correlation is significant at the .001 level (1-tailed)

Discussion

The purpose of the current study was two-fold: Firstly, I explored the relationship of effortful control with attention and executive functions in neurotypical and ASD children, with some focus on performance differences between the two groups. Secondly, I examined the association between effortful control, attention, executive functions and core ASD deficits (i.e. Social Affect and Restricted, Repetitive Behaviours). Results from Study One will be discussed first, with effortful control's association with each cognitive variable addressed sequentially. Thereafter, Study Two's results will be discussed.

Study One: Performance Differences between Groups

Effortful control. The results from the temperament questionnaires revealed that children with ASD were rated to have significantly lower effortful control than neurotypical children. These results support Hypothesis 1 and are in keeping with previous studies (see Garon et al., 2009, 2016, Macari et al., 2017 and Samyn et al., 2011). Overall, children with ASD were rated to have a poorer ability to self-regulate their attention, emotions and behaviour in comparison to neurotypical children. This suggests attention and executive

functioning may also be implicated when effortful control is compromised. In addition, considering effortful control enables one to be more proficient in adapting and acting appropriately in everyday settings, such findings suggest lower effortful control may in turn be associated with ASD symptoms.

Attention. Children with ASD had significantly poorer attention span abilities than neurotypical children. This finding confirms Hypothesis 2.1, and lends support for previous research (e.g. Mayes & Calhoun, 2007) suggesting that children with ASD have diminished capacity to hold information in mind. Specific studies on basic attention span have received little focus, thus my findings contribute to our knowledge of attention span in ASD. It will be interesting to see whether future studies obtain similar findings.

Unexpectedly, ASD and neurotypical children did not differ significantly on their ability to sustain their attention. These non-significant results did not support Hypothesis 2.2. Throughout the ASD literature there remain inconsistencies over whether sustained attention is impaired. My findings are consistent with studies that found no evidence of sustained attention difficulties on cognitive testing (see Allen & Courchesne, 2001 and Sanders et al., 2008).

An explanation for the non-significant sustained attention finding may be attributable to the measurement tool used. Despite having good psychometric properties (Brooks et al., 2009; Korkman et al., 2007), the NEPSY-II Inhibition subtest is predominantly considered a measure of inhibition and switching abilities. The inclusion of the *Naming* task in the subtest assists examiners in determining whether difficulties on the *Inhibition* or *Switching* tasks are instead attributable to impairments of lower-order functions of sustained attention (as measured by the Naming Total Errors score) or processing speed (represented by the Naming Total Completion Time score). Thus while the NEPSY-II *Naming task* provides some measure of sustained attention, it may not have been sensitive enough to pick up on sustained attention difficulties.

Alternatively, the non-significant group difference may be the product of reduced power. Study one was only sufficiently powered to detect large effects, hence if a small effect was present it may have escaped detection. Given the inconsistent findings throughout the literature over whether sustained attention is impaired in ASD, it will be interesting to see if significant group differences emerge in future studies utilizing a similar sustained attention measure in larger samples.

Executive functioning. The results confirmed Hypothesis 3, as the neurotypical group performed significantly better than the ASD group on the executive function tasks. In

terms of working memory, results suggest that children with ASD have a poorer ability to hold and manipulate information in mind in comparison to neurotypical children. With regards to inhibition, the results reveal that children with ASD are less able than neurotypical children to inhibit automatic responses so as to allow the opportunity to provide new responses. The results also indicate that children with ASD demonstrate a diminished ability to shift between mental tasks. The working memory and switching results are congruent with a body of literature which consistently demonstrates impairments in these domains (Craig et al., 2016; Lai et al., 2017; Sanders et al., 2008). Inhibition, however, has yielded conflicting results throughout the literature, with some studies evidencing intact inhibitory functioning in children with ASD (for review see Lai et al., 2017) while others do not (see Craig et al., 2016). Many argue that inhibition is not a unitary construct but instead comprises of different inhibitory processes (Diamond, 2013; Friedman & Miyake, 2004; Nigg, 2000). Accordingly, varying types of inhibition could be compromised in ASD, while some inhibitory process may be intact. My findings lend support for disordered prepotent response inhibition in ASD.

Study One: Effortful Control's Relationship with Attention and Executive Functioning

The primary aim of Study One was to determine whether effortful control was associated with particular aspects of attention domains and executive functions respectively. Hierarchical MRAs found that effortful control emerged as a significant predictor of attention span, working memory and inhibition across the sample, with ASD participants performing significantly more poorly on these cognitive domains and rated significantly more poorly on effortful control. Effortful control's relationship with each attention and executive function domain will be discussed below sequentially.

Effortful control and attention span. The results indicated that effortful control was significantly positively correlated with attention span. As expected, the MRA revealed that when controlling for SES and FSIQ-4, effortful control significantly predicted attention span. Therefore, increasing levels of effortful control were predictive of longer attention spans, confirming Hypothesis 4.1. Due to the presence of significant between group differences in effortful control and attention span, performance on these domains is understood along a spectrum, with ASD and neurotypical children representing the lower and upper bounds respectively. Consequently, it can be inferred that diminished effortful control in ASD children was associated with poorer attention span.

Such findings support a broad body of literature that theorises effortful control is associated with attention. However, attention is a broad construct with varying types of

attention recognised (Anderson et al., 2001; Williams et al., 1999). Consequently, effortful control's association with several forms of attention has been examined in both typical and atypical development, with no clear relationship patterns having yet emerged. Remarkably, to date a thorough search of literature failed to yield a study which had examined whether effortful control is associated with basic attention span, in both neurotypical and ASD individuals. Thus, the current study's findings provide novel insight into the relationship between effortful control and this specific domain of attention.

The association between effortful control and attention span was anticipated given that effortful control pertains to abilities involved in regulating attention, as well as emotion and behaviour (Rothbart & Rueda, 2005). The role of effortful control in regulating attention is particularly important to prosocial functioning. For instance, when experiencing negative emotions individuals may try distract themselves and focus their attention elsewhere (Eisenberg et al., 2004). This in turn permits one not to become overwhelmed by emotional distress and respond in a more socially appropriate manner. Furthermore, I propose that the unusual attentional features seen in ASD, for example fixation on specific objects or tasks, may perhaps be explained somewhat by a difficulty in regulating what one attends to and consciously holds in mind. Thus considering the predictive model revealed in this current study, the association between low effortful control and poor attention span in ASD may possibly be associated with both their diminished ability for prosocial functioning as well as impairments on non-social tasks. Therefore, the relationship between effortful control and attention span evidenced in the current study further encourages the investigation into whether such functions are related to core ASD deficits.

Effortful control and sustained attention. There were no significant sustained attention differences between neurotypical and ASD children in this sample. Consequently, sustained attention could not be understood according to a spectrum as neurotypical and ASD children did not appear to represent differing bounds of the continuum. As a result, the association between effortful control and sustained attention for these groups was not further investigated.

Effortful control and working memory. Results indicated that effortful control and FSIQ-4 were significantly positively correlated with working memory while age and SES were not. Hierarchical MRA analyses revealed that, when controlling for FSIQ-4, effortful control emerged as a significant predictor of working memory, confirming Hypothesis 5.1. As discussed above, ASD and neurotypical children differ significantly in their effortful control and working memory abilities, thus performance on these domains is understood

along a spectrum. The ASD group represents the lower bound of the spectrum as they were rated more poorly on effortful control and performed more poorly on working memory in comparison to the neurotypical group. Consequently, it can be inferred that diminished effortful control in ASD children was associated with poorer working memory.

Research regarding effortful control's association with working memory remains limited, with only one study being readily identified, which focused only on typical development. This previous longitudinal study found that with differing levels of effortful control at 14 – 36 months of age, the ability of updating working memory when 17 years old appeared to remain similar (Friedman et al., 2011). Such findings are in contrast to the current study's results. The difference in findings may lie in the nature of the two studies. The previous study was longitudinal in design while the current study was cross-sectional. Temperament, although rooted in the genetic make-up of an individual, is influenced over development by biological and experiential factors which constantly interact with each other (Rothbart, 2007; Shiner et al., 2012). Thus, it is possible that an effortful control profile at 14-36 months of age may not be related to working memory abilities at 17 years of age as the child's temperament may have been modified somewhat over time. However, in the current study, the effortful control task characterised temperament based on the child's behaviour within the past six months of assessment. Thus the significant association between effortful control and working memory found in the current cross-sectional study, suggests that the proposed model may only be relevant to effortful control and working memory abilities measured within at least six months of each other.

However, a more likely explanation for the divergence in results between the two studies may be attributed to the previous study's measures. Friedman et al. (2011) argue that their null associations may be ascribed to their effortful control task placing no requirement on the child to continuously update their working memory. In contrast, the effortful control measures employed in the current study did pose questions to parents/primary caregivers regarding their child's ability to hold and manipulate information in mind. For example, parents were asked whether the following statements were true or not for their child within the last six months: "finds it easy to really concentrate on a problem", "is good at keeping track of several different things that are happening around him" or "is good at following instructions." Such tasks tap into working memory ability, for instance the child will need to hold on to the details of the instructions as well as work out what he would need to do to accomplish the specified task/s. Given the effortful control measures in the current study tap

into working memory abilities, it makes sense that they would be associated with the working memory task itself.

As mentioned, the previous study discussed above focused solely on typical development. Notably, the current study appears to be the first to have examined effortful control's association with working memory in ASD. These findings are particularly important as new knowledge over such relationships adds to our understanding of how impaired effortful control and working memory operate in ASD. It is possible that through effortful control's association with working memory, it may support prosocial behaviour by permitting one to attend to other people's emotions while understanding what they mean in relation to one's own emotions and behaviour. Thus perhaps ASD individuals' difficulty in navigating social situations may, in part, be related to their diminished ability to hold in mind and work with various pieces of information in social settings. Such notions support the need for further investigation over effortful control and working memory's association with ASD core deficits.

Effortful control and inhibition. Correlation analyses revealed that FSIQ-4 and effortful control had a strong positive relationship with inhibition. Additionally, the Hierarchical MRA analyses indicated that when controlling for FSIQ-4, effortful control emerged as a significant predictor of inhibition, confirming Hypothesis 5.2. Given the significant group differences on effortful control and inhibition, these variables can be understood along a spectrum. The ASD and neurotypical group represent the lower and upper bounds respectively as the ASD group were rated more poorly on effortful control and performed more poorly on inhibition than the neurotypical group.

Previous studies have predominantly investigated effortful control's association with executive attention, which comprises inhibitory control, conflict resolution and switching. Overall, previous research has consistently evidenced links between effortful control and executive attention in neurotypical samples (see, Ellis et al., 2004 and Simonds et al., 2007). However, the relationship was not replicated in ASD (see, Samyn et al., 2017, 2014). Such findings suggested that inhibitory control processes implicated in executive attention are not associated with effortful control in atypical development. However, this is in contrast to the current study's results which found that when looking at inhibition in isolation, it is associated with effortful control in ASD. Perhaps when looking at inhibition in isolation, we obtain a more clean, disentangled understanding of its relationship to effortful control as opposed to when it is included in a broad factor (i.e. executive attention). Future studies are

needed to determine whether this relationship between effortful control and inhibition is replicated in other ASD samples.

Effortful control and switching. Results indicated that effortful control had a significantly weak – moderate positive correlation with switching. When controlling for SES and FSIQ-4 (which were also significantly correlated with switching), effortful control did not emerge as a significant predictor of switching in the full sample. Hence Hypothesis 5.3 was not supported.

There is limited research examining effortful control's association with switching, particularly in ASD. It seems only Friedman et al. (2011) investigated this relationship and they only considered a neurotypical sample. Furthermore, their results are in contrast to the current study, as Friedman et al. (2011) found a negative relationship between effortful control and switching. Moreover, as mentioned above, studies investigating effortful control's relation to executive attention, which incorporates switching, found positive associations in neurotypical samples but null associations when including an ASD group (see, Ellis et al., 2004, Samyn et al., 2017, 2014 and Simonds et al., 2007). Thus there remains a lack of consensus over this relationship and future ASD studies should focus on effortful control's association with switching specifically to help clarify this relationship across different samples.

In terms of my interpretation of the null association evidenced, I suggest that perhaps effortful control indirectly influences switching ability through its association with working memory and inhibition. Specifically, switching is built on from working memory and inhibition (Diamond, 2013). Thus while working memory, inhibition and switching are considered the three core executive functions, there is a hierarchical relationship between them. Findings from the current study suggest that effortful control acts as a significant predictor of these “lower order” executive functions (i.e. working memory and inhibition) but not the somewhat “higher-order” function of switching. Effortful control allows one to regulate attention (i.e. shift or focus), emotions and behaviour (i.e. inhibit inappropriate responses or persist with tasks), and is thus considered to further enable one to act reflexively and appropriately in everyday settings (Schwartz et al., 2009). Therefore, I propose that rather than effortful control being directly linked to switching ability itself, perhaps it enables reflexive responding indirectly through its association with working memory and inhibition.

Study Two: Association between Effortful Control, Attention and Executive Functioning in Relation to ASD Core Deficits.

Study two investigated whether effortful control moderates the relationship between aspects of attention/executive functions and ASD core deficits (i.e. Social Affect and Restricted, Repetitive Behaviour). Moderation regression analyses revealed that effortful control only moderated the relationship between attention span and Restricted, Repetitive Behaviours. The results of Social Affect's and Restricted, Repetitive Behaviours' relation to effortful control and each cognitive domain will be discussed below.

Effortful control and attention span in relation to ASD symptomatology.

Social Affect. Results revealed that neither effortful control, attention span nor their interaction was significantly correlated with Social Affect. Such findings did not support further investigation into whether effortful control moderates the relationship between attention span and Social Affect. Therefore, Hypothesis 6.1 was not confirmed. These null associations may be attributed to sampling error as the sample ($n=38$) was relatively small reducing the likelihood of having adequately sampled from the total population. Furthermore, given the study is underpowered, small effects may have escaped detection. It will be interesting to see if significant associations emerge in larger samples.

While my results should be interpreted with caution, the current study's findings are in contrast to a previous temperament study which found that lower levels of effortful control are associated with greater severity of ASD core symptoms in toddlers (Garon et al., 2016). Of note, this previous study did not examine effortful control's association with Social Affect in particular, but rather looked at overall symptom severity (which is comprised of both Social Affect and Restricted, Repetitive Behaviours). Thus, it is possible that the true relationship between effortful control and Social Affect was masked by Restricted, Repetitive Behaviours. The fact that effortful control did demonstrate a significant correlation with Restricted, Repetitive Behaviours later in the current study lends further support to this notion. Additionally, Macari et al. (2017) found negligible associations between effortful control and Social Affect in children aged 16 – 36 months.

Specific studies of attention span's association to Social Affect are limited, with the current results providing some new insight into such relationships in ASD. These findings suggest that one's diminished attention span is not necessarily associated with difficulties in understanding social interactions and developing and maintaining relationships as initially suggested in Study One's discussion, but may rather only undermine non-social functioning.

This is further evidenced by the significant association of effortful control and attention span to Restricted, Repetitive Behaviours which is subsequently discussed.

Restricted Repetitive Behaviours. Correlation analyses indicated that FSIQ-4, effortful control, attention span, and the interaction between effortful control and attention span, were significantly correlated with Restricted, Repetitive Behaviours. Regression analyses revealed that effortful control moderated the relationship between attention span and Restricted, Repetitive Behaviours, confirming Hypothesis 7.1. Post-hoc analyses revealed that this relationship was significant at high levels of effortful control. Specifically, increased attention span was associated with less impairment in Restricted, Repetitive Behaviours at high levels of effortful control.

It is understandable that better attention span is associated with fewer Restricted, Repetitive Behaviours at high levels of effortful control. We know effortful control permits individuals to modulate their attention, emotions and behaviours in a socially appropriate manner (Posner & Rothbart, 2000; Rothbart & Rueda, 2005). Thus, I propose the interaction between one's ability to self-regulate and increased attention span, may assist in allowing one to deliberately focus their attention more appropriately rather than become fixated on one task or behaviour. This ability to regulate attention more efficiently may in essence result in less Restricted, Repetitive Behaviours.

Such findings are unique to the literature as no study to date has investigated whether effortful control and attention span are concurrently associated with Restricted, Repetitive Behaviours. While interpretation of the results must be tentative, one can have some confidence in the findings given a meaningful effect emerged despite the study being underpowered and after having applied a stringent correction the post-hoc investigations. Therefore, results lend support for future studies to continue investigating the possible development of a predictive model for Restricted, Repetitive Behaviours of ASD on the basis of temperament and attention span difficulties and suggest interventions and education plans targeting self-regulation in ASD may be helpful .

Effortful control and working memory in relation to ASD symptomatology.

Social Affect. Results indicated that effortful control and working memory as separate variables were not significantly correlated with Social Affect. However, Social Affect was significantly associated with the interaction between effortful control and working memory and therefore I explored whether further moderation analyses could be conducted. However, following the identification of bias in the data and the concern over conducting transformations (as discussed under the Results section on page 70), a regression analysis

investigating whether effortful control moderated the relationship between working memory and Social Affect was ultimately not conducted. In particular, I felt performing a moderation analysis on transformed data would not offer me a reliable enough model from which I could confidently draw conclusions. Consequently, Hypothesis 8.1 was not supported.

Results should be interpreted with caution considering the low power and potential sampling error encountered with small sample size. While it appears that no previous studies have investigated effortful control and working memory's concurrent association with Social Affect, earlier theories do suggest effortful control and working memory may be associated with empathy. Specifically, effortful control is thought to support empathy by enabling one to attend to others' negative emotions as well as attend to their own feelings evoked by the other person and not be overcome by such distress (Rothbart, 2007). The attentional flexibility described here echoes working memory. Empathy is important for prosocial functioning. Thus, while the current findings indicate that effortful control and working memory may not be directly associated with Social Affect in ASD, they may indirectly undermine prosocial functioning through their involvement with empathy. However, further investigations into such hypothesised relationships are required as it's possible the null associations may instead be a product of low power and sampling error.

Restricted Repetitive Behaviours. Only FSIQ-4 and effortful control were significantly correlated with Restricted, Repetitive Behaviours. Working memory and the interaction effect were not, and consequently moderation analyses were not carried out. Hypothesis 9.2 was not confirmed. To date, no previous studies have investigated whether the interaction between effortful control and working memory is related to Restricted, Repetitive Behaviours. However, previous research did find significant associations between working memory and Restricted, Repetitive Behaviour (e.g. Lopez et al., 2005; South et al., 2007), which is in contrast to the current results. Again the null finding may be a product of the small sample size, with the true relationship in the total population not being detected due to sampling error or reduced power.

The direction of effortful control's relationship with Restricted, Repetitive Behaviours is perplexing, providing further indication that sampling error may be at play. The positive association implies that an increased ability to self-regulate attention, emotions and behaviour is associated with more Restricted, Repetitive Behaviours. This finding is inconsistent with a broad body of literature which asserts that higher effortful control is associated with fewer ASD symptoms (Garon et al., 2016; Konstantareas & Stewart, 2006; Macari et al., 2017; Samyn et al., 2011). However, comparison with earlier research is not easy given findings are

based on overall ASD severity with little consideration of each core deficit. Thus, further research with larger samples is required to better understand these associations, as the true relationship may be under- or over-represented in this small sample.

Effortful control and inhibition in relation to ASD symptomatology.

Social Affect. Correlation analyses demonstrated inhibition had a significant negative association with Social Affect. However, effortful control and the interaction effect between effortful control and inhibition were not significantly correlated with Social Affect. Therefore, further moderation analyses were not conducted, and Hypothesis 8.2 was not confirmed.

These null associations may be attributed to the small sample size, with the relationship in the total population not being truly represented due to sampling error or reduced power. Throughout the literature, the functions of these potential predictors in ASD have not been investigated in unison but rather tend to be studied in isolation, with previous research mainly focused on inhibition's relation to ASD severity in general (e.g. Leung et al., 2016). The current study thus had the potential to contribute a more nuanced understanding; but was limited by the difficulty in recruiting a larger ASD sample.

While results should be interpreted with caution, the inverse relationship between inhibition and Social Affect revealed in the current study suggests that a poor ability to inhibit your immediate impulses is associated with an increased difficulty with social communication and interaction. Since higher-order mental processes, like planning, reasoning and problem solving, are built on from inhibition (Diamond, 2013), it is possible that a child with ASD who has difficulty inhibiting their immediate response in social settings is less capable of engaging these higher order mental processes and acting more reflexively. For instance, perhaps whilst having a disagreement with a classmate, a child who is unable to refrain from physically acting out is less proficient in determining other more suitable ways to respond.

Self-regulatory processes of effortful control permit individuals to modulate their emotions and behaviour in a socially appropriate manner, rather than merely acting on impulse (Posner & Rothbart, 2000). Therefore, it is an unusual finding that effortful control does not correlate significantly with Social Affect or feature in the relationship between inhibition and Social Affect. Hence it is thought that this null association may be the product of small sample size, with the true relationship being under- or over-represented. Future studies are encouraged to investigate these associations in larger samples.

Restricted Repetitive Behaviours. Results revealed that effortful control was significantly positively correlated with Restricted, Repetitive Behaviours. However, inhibition and the interaction effect were not. Regression analyses to further investigate whether effortful control moderates the relationship between inhibition and Restricted, Repetitive Behaviours were not carried out; Hypothesis 8.2 was not supported.

The null association between inhibition and Restricted, Repetitive Behaviours is in contrast to previous findings (e.g. Lopez et al., 2005; South et al., 2007). Furthermore, the current findings do not lend support for the Executive Dysfunction Hypothesis which theorises that impairment of executive control processes accounts for behavioural characteristics of ASD (Hill & Frith, 2003; Sanders et al., 2008). However, as the risk of incurring sampling and Type II error was high the current study's results should be interpreted with caution.

As mentioned above, the directionality of the relationship between effortful control and Restricted, Repetitive Behaviours remains perplexing and may be the result of sampling error. Future research focusing on effortful control's relationship to specific core deficits (as opposed to overall severity) is needed to determine whether this positive relationship is replicated in other larger ASD samples.

Effortful control and switching in relation to ASD symptomatology. Given effortful control did not emerge as a significant predictor of switching, further analyses investigating whether effortful control moderates the relationship between switching and Social Affect were not conducted. Thus, Hypotheses 8.3 and 9.3 were not explored.

The Role of Demographic Factors and Intelligence in Study One and Two

Age. Results revealed that age did not significantly correlate with attention span, working memory, inhibition or switching in Study One, therefore it was not considered in Study Two's analyses.

These null associations were expected given that the Scaled Scores were used in the analyses as opposed to raw scores; Scaled Scores provide a standardised measure of performance across age ranges. These norms are required given that attention and executive functions develop markedly over childhood and adolescence, with individuals becoming more competent in such cognitive abilities as they mature (Anderson et al., 2001). Thus the measures used are designed to be developmentally sensitive, with scoring tables constructed and presented according to age (i.e. norms are based on what is typically expected of a child at that specific age in development). Therefore, the null associations were seen because age

had already been accounted for when initially scoring the attention span, working memory, inhibition and switching performances.

Socio-economic status. As anticipated, SES demonstrated a significant positive correlation with attention span and switching abilities. This relationship means that higher SES is associated with improved attention span and switching. Furthermore, Hierarchical MRAs revealed that SES emerged as a stronger predictor of attention span than effortful control. Unsurprisingly, SES was also significantly positively related to FSIQ-4. This is in keeping with findings from a local study by Bray, Gooskens, Kahn, Moses, and Seekings (2010), who examined three different communities within the Western Cape region of South Africa. Their results consistently revealed that the SES of the child's family and neighbourhood strongly correlated with school performance.

Unexpectedly, SES did not correlate with working memory or inhibition. These null associations are in contrast to previous findings which indicate that SES has a moderate effect on executive functions, particularly working memory and cognitive control (Hackman & Farah, 2009; Hackman, Farah, & Meaney, 2010). Attention span, working memory inhibition and switching exist within a hierarchal arrangement, with attention span representing the "lower order" function and switching the "higher order" function (Diamond, 2013). Therefore, it is unusual that in the current study, SES demonstrated a very selective association with some but not all of these cognitive variables. Again the relatively small sample size may have undermined these findings, with the true relationships being under- or over-represented due to the higher risk of sampling and Type II errors. Future studies considering SES' association to specific aspects of attention and executive functioning are required to further inform whether such selective relationships are seen in larger local samples.

Moreover, in Study Two SES did not correlate significantly with the outcome variables Social Affect or Restricted, Repetitive Behaviours. Within the United States, the prevalence of ASD appeared to be greater in higher SES populations (Thomas et al., 2012). However, such findings do not specifically indicate that SES is associated with increased severity of ASD symptoms but may rather be a product of ASD children from low SES background being under diagnosed. For instance, children from low SES families likely have limited access to health care and special needs services and consequently are not readily assessed/diagnosed by a qualified health professional. Indeed research in Sweden found that lower SES was associated with greater risk for developing ASD (Rai et al., 2012). The disparity in the current study's findings in comparison to previous research could perhaps be

explained by the fact that the current study's ASD sample was recruited through autism-specific and special needs schools. Therefore, although some families came from a lower SES background, they did have access to special needs facilities which in turn may have offered intervention strategies or education plans that aided in improving ASD core symptoms. Therefore, the current ASD sample may be unrepresentative of the low SES population, specifically of families who do not have access to such facilities. The suggestion that disparity in health care may better explain the difference in ASD symptoms rather than SES is strengthened by findings from a previous epidemiological study in Denmark (Larsson et al., 2005). This study found that where access to health care was free and equal to the population, SES had no association with risk for developing ASD.

General intelligence. In Study One, FSIQ-4 demonstrated significant positive associations with attention span, working memory, inhibition and switching. Furthermore, FSIQ-4 emerged as a stronger predictor of these cognitive domains than effortful control. This finding was anticipated given that performance on WASI subtests relies to a great extent on attention and executive function abilities. For instance, FSIQ-4 can be divided into *crystallised* and *fluid intelligence* (Passer et al., 2009). *Crystallised intelligence* refers to knowledge previously acquired, while *fluid intelligence* involves the cognitive ability to solve novel information for which one cannot draw from personal or cultural experience (Passer et al., 2009). The ability to work with information from long-term memory (i.e. *crystallised intelligence*) as well as to problem-solve and think deductively (i.e. *fluid intelligence*) relies on efficient attention span, working memory, inhibition and switching. Thus these variables, although distinct, are interrelated. Although there was no issue of multicollinearity between these variables during the statistical analyses, some may suggest to rather statistically partial out FSIQ-4's shared variance with these cognitive variables so as to obtain a more nuanced understanding of effortful control's relationship with attention and executive functioning. However, I argue that given the intertwined nature of FSIQ-4, attention and executive functioning, separating out such shared variance would result in a somewhat artificial construct.

Regarding the results from Study Two, FSIQ-4 had a significant inverse relationship with Social Affect and Restricted, Repetitive Behaviours. Such findings are consistent with a broad body of literature (Nowell, Goin-Kochel, McQuillin, & Mire, 2017; Zillmer et al., 2008), indicating that higher general intelligence is associated with less severe ASD symptoms. Interestingly, in the current study however, FSIQ-4 did not emerge as a significant predictor of Restricted, Repetitive Behaviours in the regression analyses. A review

by Nowell et al. (2017), found that only Bishop et al. (2006) had investigated the association between Restricted, Repetitive Behaviours and intelligence. Bishop et al. (2006) found that non-verbal IQ was associated with Restricted, Repetitive Behaviours and that the direction of the relationship was contingent upon the type of Restricted, Repetitive Behaviour studied (e.g. circumscribed interest vs. repetitive movements). Bishop only reported on nonverbal IQ rather than FSIQ-4. This suggests that ASD core deficits may have selective associations with subcomponents of IQ. Future research is required to better establish ASD core deficits' relationship with different aspects of intelligence.

General Discussion

Results from Study One indicated effortful control emerged as a significant predictor of attention span, working memory and inhibition, with ASD participants performing significantly more poorly on these cognitive domains and rated significantly more poorly on effortful control. I suggest the association between low effortful control and poor attention span, working memory and inhibition undermines ASD individuals' ability for social and/or non-social functioning. Specifically, ASD individuals may struggle in social settings or on non-social tasks to self-regulate what information is attended to and consciously worked with in mind as well as modulate their emotions and behaviour rather than acting on impulse. Given the relatively small sample size and low power it will be interesting to see whether these patterns of associations occur in future studies involving larger samples. Overall, findings from Study One indicated that investigation into the concurrent association of effortful control, attention and executive functioning with core ASD deficits (i.e. Social Affect and Restricted, Repetitive Behaviours) was warranted.

Results from Study Two indicated that Social Affect was significantly associated with inhibition and the interaction between working memory and effortful control. In terms of Restricted, Repetitive Behaviours, its relationship with attention span was moderated by effortful control. This interaction indicated that at high levels of effortful control, increased attention span was associated with less Restricted, Repetitive Behaviours. The null associations seen between the remaining predictor variables and ASD core deficits may be a product of sampling error and reduced power, with the true relationships being under- or over-represented in this small sample. This may also be the case regarding effortful control's confusing positive relationship with Restricted, Repetitive Behaviours. Therefore, future studies are encouraged to explore these associations in larger samples to help provide further insight over these relationships in the larger population.

In addition, FSIQ-4 emerged as a stronger predictor than effortful control of attention span, working memory, inhibition and switching; this was anticipated given the interrelated nature between FSIQ-4, attention and executive functioning. SES demonstrated a significant relationship with attention span and switching. These findings may be a result of the small sample size and further research is required to determine whether this selective association emerges in the larger population. Furthermore, FSIQ-4 was significantly associated with Social Affect and Restricted Repetitive Behaviours while SES was not. Access to health care and special needs services, rather than low SES, may act as more suitable predictor of ASD severity, however future studies are required to provide more insight.

Results lend support for the possibility of developing predictive models for ASD core deficits on the basis of temperament and cognitive difficulties. Moreover, such findings may help guide the advance of more nuanced intervention strategies or education plans targeting impaired self-regulation abilities that facilitate daily tasks, potentially enhancing the ability of ASD individuals to adapt and function better in everyday environments.

Limitations and Considerations for Future Research

Sample size. Post hoc power analyses indicated that the sample sizes for both Study One ($n=76$) and Study Two ($n=38$) were not adequate to achieve a high level of power and thus only large effects could be detected. Furthermore, given the relatively small sample there was a higher risk for sampling error. Thus it is highly possible that the sample sizes were not big enough to adequately allow for the generalisation of the results to the larger population as the true relationships may have been under- or over-represented in the current sample. This is particularly pertinent for Study Two's findings as analyses were only conducted on the ASD sample. Therefore, results should be interpreted with caution.

The limitation in sample size can be attributed to difficulty in recruiting ASD participants. Firstly, given the neurocognitive tests required participants to comprehend instructions and respond verbally, only verbal ASD children were included. However, a large proportion of ASD children have language impairments and are non-verbal (American Psychiatric Association, 2013; Mody et al., 2013), therefore increasing the difficulty of recruitment efforts in finding eligible verbal ASD participants. Furthermore, participants could only be recruited from the surrounding Western Cape region due to time and financial constraints. Thus the research team had to recruit a very specific group within a relatively confined area. Additionally, ASD is comorbid with several neurological and psychiatric conditions (American Psychiatric Association, 2013) which would be confounded with the

relationships between the variables under investigation. Therefore, ASD children with neurological and/or psychiatric comorbidities (except ADHD; see Methods section on page 31) had to be excluded, further limiting the number of eligible participants.

Exclusion of non-verbal ASD children. As mentioned, the cognitive measures required participants to comprehend verbal instructions and respond verbally. Therefore, non-verbal ASD children were excluded from the sample. Consequently, the current findings do not provide a comprehensive understanding of the full spectrum of ASD presentations. Such a limitation was unavoidable given many of the existing cognitive assessments, including general intelligence tests, are verbally loaded with several reliant solely on verbal abilities. While I could have attempted to utilise measures requiring non-verbal responses, for example choosing to assess visual attention span and working memory, I would still have been faced with difficulty of ascertaining whether the participants truly understood the non-verbal instructions. This remains a very real limitation within ASD research (see Ing, 2011 and Samyn et al., 2017, 2014) and future investigators are encouraged to develop practical and affordable ways of empirically assessing various non-verbal aspects of attention and executive functions.

Matching. The neurotypical and ASD group were aggregate-matched on the children's age and caregivers' monthly household income. Due to time constraints, this matching technique was preferred over case matching. While *t*-tests revealed that neither demographic variable acted as a covariate, case matching does offer greater control over potential confounding variables and future studies should aspire to use this technique to enhance comparability between groups.

Measures.

ASD core deficits. The ADOS-2, although a "gold standard" measure for assessment and diagnosis of core ASD deficits (McCrimmon, 2014), only provides a once-off observation of Social Affect and Restricted, Repetitive Behaviours. Therefore, although observations were made by a clinically and research certified team member, the scores obtained essentially only represent the child's functioning on that particular occasion. The ADOS-2 does not provide a longstanding indication of the child's Social Affect and Restricted, Repetitive Behaviours, and results are vulnerable to being influenced by random everyday factors. For instance, if the participant was having a particularly bad day, such unpredictable factors could have negatively influenced the participant's score. The Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003), which comprises of questions to parents about their child's ASD symptoms across development, offers

reporting and evaluation of ASD symptoms over a longer time period. However, the ADI-R is a parent report measure which comes with its own limitations. Therefore, it would be advantageous for future studies to include both parent-report and clinical assessment measures of ASD core deficits, in order to provide a comprehensive evaluation of ASD symptomatology.

Effortful Control. Within the current sub-study, the CBQ-VSF and EATQ-R were utilised to examine effortful control. Such measures are report-based and the limitation of the social desirability influencing participants' reporting must be acknowledge. However, the CBQ and EATQ-R are predominantly used in temperament research (Muris, Meesters, & Blijlevens, 2007; Verstraeten et al., 2010; Whittle et al., 2008; Zentner & Bates, 2008) with little to none performance-based measures presented. Consequently, these report-based measures were chosen so as to allow for more suitable comparison with previous temperament research reported in the literature. However, future resources should be dedicated to developing and validating performance-based measures of effortful control in temperament research so as to establish a variety of techniques to investigating temperament.

A further perceived limitation regarding the effortful control measures may be related to the measures being parent-report rather than self-report. However, considering individuals with intellectual disability struggle to understand and answer questions regarding emotions and behaviours in hypothetical situations (Finlay & Lyons, 2001), as posed by the temperament questionnaires, parent-report measures were deemed more suitable for the current study's clinical sample. Furthermore, while the EATQ-R is available in both self- and parent-report versions, the CBQ-VSF is only presented as a parent-report measure. Given the challenges in recruiting ASD participants, opting for the parent-report measure permitted the recruitment and inclusion of participants over a broader age-range. Future studies with large samples of ASD participants aged of 9 – 15 years the could include both parent- and self-report measures, however, due care should be taken in ensuring ASD participants are able to competently complete the questionnaires.

Attention. As mentioned, numerous aspects of attention are recognised throughout the literature (Anderson et al., 2001; Williams et al., 1999). Within the current study, only attention span and sustained attention were investigated, two attention domains that are consistently recognised within the developmental context. Given the current study was nested in a larger investigation which subsumed various other research protocols, there were a great number of measures which needed to be administered over the limited number of testing sessions. Thus the addition of multiple measures of the same attention domain or measures of

other attention domains, although desirable for this sub-study, would have jeopardized the practicality of the data collection. Future studies should endeavor to incorporate measures assessing various types of attention, to obtain a more widespread understanding of attention's relationship with effortful control and ASD core deficits.

Age range. The current sample consists of participants between the ages of 6 – 15 years. The reason for the wide age range stems from the logistical constraints of obtaining a reasonable sample size (as discussed above on page 87). However, this broad age range may potentially confound the variation in attention and executive function performance amongst participants of varying ages. This being because attention and executive functioning develop markedly over the ages of 6 – 15 years (Anderson, Northam, Hendy, & Wrennall, 2001). Therefore, some participants' attention and executive function abilities may have been more mature/developed in comparison to other participants. In order to limit such influences, the current study sought to use developmentally sensitive measures. Furthermore, scaled scores (rather than raw scores) obtained from age-appropriate norm tables of the scoring manuals were used in all statistical analyses. Additionally, age was controlled for as a potentially influential demographic variable through aggregate matching. However, in order to further mitigate the possible undue influence of age, it is suggested that future studies recruit participants within a narrow age range. Such improvements may enable a more nuanced understanding of attention and executive functions' relationship with effort control and core ASD deficits of various age cohorts.

Administration and Scoring. There were a number of researchers on the larger investigation and consequently the administration and scoring of the measures was not completed by the same person. The research team received suitable training on the administration and scoring of the various tests and standardized testing procedures were upheld. Future studies involving research teams could incorporate site checks to maintain assessment fidelity, and assign a specific team member to conduct quality control over all scored measures.

Statistical analyses and model construction. Regression analyses are sensitive to sample size, with fewer predictors permitted to be entered into models when the sample size is relatively small. Therefore, the size of the sample influenced the decisions I made regarding how I built the various models.

For instance in Study One, I opted to conduct the regression analyses on the entire sample ($n=76$) rather than perform separate regressions on each group (i.e. $n=38$ for neurotypical and ASD group respectively). This permitted me to add all relevant predictors

into the model. However, in order to limit multicollinearity, the variable 'group' could not be entered into the model. Rather performance on effortful control, attention and executive functioning was considered along a spectrum, with the ASD group representing the lower bound on the performance continuum. Hence, I needed to conduct independent sample *t*-tests for evidence that ASD participants scored significantly lower on the temperament and cognitive variables than neurotypical participants. However, carrying out these numerous analyses may have increased the chance of incurring Type I error. Yet, given the study was underpowered, making alpha more stringent would have further increased the risk of incurring Type II error. Furthermore, no study had previously investigated the relationships explored in this current study, and thus I was more concerned over missing possible effects than potentially obtaining false positive results. Therefore, I chose to leave $\alpha=.05$. This study could be regarded as exploratory and smaller alpha values can be applied in future studies with larger samples once the empirical basis is better established.

Furthermore, in both Study One and Two while the construction of the models was informed, to some extent, by the literature, I also used zero-order correlations to further inform which variables were worth further investigation in Hierarchical MRAs. In using results from zero-order correlations, the models were built on the notion of significance and hence to some degree were based on chance. It is possible that some of the non-significant zero-order correlations may have proved influential when multiple correlations were considered simultaneously in the model, although given the very small correlation coefficient values, this was not very likely. However, where feasible future studies should make every effort to recruit a relatively large sample so as to minimize potential restrictions placed on data analysis and interpretation.

Conclusion

Effortful control emerged as a significant predictor of attention span, working memory and inhibition, with ASD participants performing significantly more poorly on these cognitive domains and rated significantly more poorly on effortful control. Interestingly, only inhibition and the interaction effect between effortful control and working memory correlated significantly with Social Affect. At a high level, effortful control significantly moderated the relationship between increased attention span and less Restricted, Repetitive Behaviours. Thus while inhibition and the interaction between effortful control and working memory appear to be associated with diminished social functioning in ASD, the interaction between attention span and effortful control is linked to non-social impairments. Additionally, FSIQ-

4, but not SES, was significantly associated with Social Affect and Restricted, Repetitive Behaviours.

This research offers a foundational basis for future studies exploring the concurrent role of effortful control, attention and executive functions in ASD symptomatology.

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Appendix A

Socio-Demographics Survey

Your name: _____ Date: _____
 Child's name: _____ School: _____
 Age: _____ Date of Birth: _____
 Number(s) to contact you on for parent interview: _____

Child's Sex: *Male* *Female*
 Ethnicity: *White* *Black* *Indian* *Coloured*
 Asian *Other* *If other, please specify: _____*

Home Language: _____
 Handedness (circle one): *Left* *Right* *Ambidextrous*

Number of siblings: _____

Number of **older** siblings: _____

Has your child ever been diagnosed with Autism Spectrum Disorder (ASD)? YES/NO

If yes, please specify: _____

Has your child ever been diagnosed with a disruptive, impulse-control, or conduct disorder, such as conduct disorder or oppositional defiant disorder (ODD)? YES/NO

If yes, please specify: _____

Has your child ever had a communication disorder? (For example: Having problems with understanding or producing speech, slow vocabulary development, difficulties recalling words or problems with producing sentences appropriate for his age). YES/NO

If yes, please specify: _____

Has your child ever experienced learning difficulties such as dyslexia or attention-deficit/hyperactivity disorder (ADD/ADHD)? YES/NO

If yes, please specify: _____

Has your child ever experienced a head injury? (e.g., being hit on the head and losing consciousness as a result). YES/NO

If yes, please specify: _____

Has your child ever experienced any of the following medical conditions:

Neurological problems (e.g., epilepsy, meningitis, cerebral palsy, encephalitis, Tourette's syndrome, brain tumour, other)? YES/NO

If yes, please specify: _____

Depression? YES/NO

If yes, please specify: _____

Memory problems? YES/NO

If yes, please specify: _____

Problems with their vision? YES/NO

If yes, please specify: _____

Problems with their hearing (e.g., difficulty hearing, hearing aids, grommets)? YES/NO

If yes, please specify: _____

Is he currently taking any prescription medication? YES/NO

If yes, please specify: _____

Parent/ Guardian Information

Please indicate here if child is adopted: YES NO

Who is the child's primary caregiver? _____

What is your relationship to the child (e.g., mother, father, etc.)? _____

Please note that information on the primary caregiver is required. If the primary caregiver is not the biological or adoptive mother or father, please place their information under "Guardian."

What is the total monthly income of your household? (Tick appropriate block):

| | | | |
|---|-------------------|-------------------|----------------------|
| 0 – R2999 | R3000 – R6299 | R6300 – R 10 499 | R10 500 – R 14599 |
| R14 600 – R18 799 | R18 800 – R22 999 | R23 000 – R26 999 | R27 000 – R31 299 |
| R31 300 – R35 499 | R35 500 - R39 499 | R39 500 – R43 750 | more than R43 750 |
| What is the estimated value of your total monthly household income: R | | | |

[NOTE: This should be total household income, not personal income]

| Highest level of education completed for... (please circle number): | Mother | Father | Guardian |
|--|--------|--------|----------|
| 1) 0 years (Never went to school) | 1 | 1 | 1 |
| 2) Grade 1 | 2 | 2 | 2 |
| 3) Grade 2 | 3 | 3 | 3 |
| 4) Grade 3 / Standard 1 | 4 | 4 | 4 |
| 5) Grade 4 / Standard 2 | 5 | 5 | 5 |
| 6) Grade 5 / Standard 3 | 6 | 6 | 6 |
| 7) Grade 6 / Standard 4 | 7 | 7 | 7 |
| 8) Grade 7 / Standard 5 [Completed primary school] | 8 | 8 | 8 |
| 9) Grade 8 / Standard 6 | 9 | 9 | 9 |
| 10) Grade 9 / Standard 7 | 10 | 10 | 10 |
| 11) Grade 10 / Standard 8 | 11 | 11 | 11 |
| 12) Grade 11 / Standard 9 | 12 | 12 | 12 |
| 13) Grade 12 / Standard 10 [Matric] | 13 | 13 | 13 |
| 14) Tertiary education: Higher education certificate | 14 | 14 | 14 |
| 15) Tertiary education: Diploma received | 15 | 15 | 15 |
| 16) Tertiary education: Bachelor's degree received | 16 | 16 | 16 |
| 17) Tertiary education: Post graduate degree received | 17 | 17 | 17 |
| 18) Don't know | 18 | 18 | 18 |

| Parental employment (Please circle appropriate number): | Mother | Father | Guardian |
|--|--------|--------|----------|
| 1) Higher executives, owners of large businesses, major professionals (e.g., doctors, lawyers) | 1 | 1 | 1 |
| 2) Business managers of medium sized businesses, professions like nurses, opticians, pharmacists, social workers, teachers, accountants | 2 | 2 | 2 |
| 3) Administrative personnel, managers, owners/ sole proprietors of small businesses (e.g., decorator, actor, reporter, travel agent) | 3 | 3 | 3 |
| 4) Clerical and sales, technicians (e.g. bank teller, bookkeeper, clerk, draftsman, timekeeper, secretary) | 4 | 4 | 4 |
| 5) Skilled manual – usually having had training (e.g., baker, barber, chef, electrician, fireman, machinist, mechanic, welder, police, plumber, electrician) | 5 | 5 | 5 |
| 6) Semi-skilled (e.g., hospital aide, painter, bartender, bus driver, cook, garage guard, checker, waiter, machine operator) | 6 | 6 | 6 |
| 7) Unskilled (e.g., attendant, janitor, construction helper, unspecified labour, porter) | 7 | 7 | 7 |
| 8) Homemaker | 8 | 8 | 8 |
| 9) Student, disabled, no occupation | 9 | 9 | 9 |

| Which of the following items, in working order, does your household have? | Yes | No |
|--|-----|----|
| 1. A refrigerator or freezer | Yes | No |
| 2. A vacuum cleaner or polisher | Yes | No |
| 3. A television | Yes | No |
| 4. A hi-fi or music centre (radio excluded) | Yes | No |
| 5. A microwave oven | Yes | No |
| 6. A washing machine | Yes | No |
| 7. A video cassette recorder or DVD player | Yes | No |



| Which of the following do you have in your home? | Yes | No |
|---|-----|----|
| 1. Running water | Yes | No |
| 2. A domestic servant | Yes | No |
| 3. At least one car | Yes | No |
| 4. A flush toilet | Yes | No |
| 5. A built-in kitchen sink | Yes | No |
| 6. An electric stove or hotplate | Yes | No |
| 7. A working telephone / cellular phone | Yes | No |

| Do you personally do any of the following? | Yes | No |
|---|-----|----|
| 1. Shop at supermarkets | Yes | No |
| 2. Use financial services such as a bank account, ATM card or credit card | Yes | No |
| 3. Have an account or credit card at a retail store | Yes | No |

Thank you for your participation!

Appendix B

Ethical Approval from UCT Faculty of Health Sciences Human Research Ethics Committee

| | | |
|--|--|---|
|  | <p>UNIVERSITY OF CAPE TOWN Faculty of Health Sciences Human Research Ethics Committee</p> |  |
| <p>Room E53-46 Old Main Building Groote Schuur Hospital Observatory 7925 Telephone (021) 406 6492 Email: sumayah.arietdien@uct.ac.za Website: www.health.uct.ac.za/fhs/research/humanethics/forms</p> | | |
| <p>20 October 2017</p> | | |
| <p>HREC REF: 346/2017</p> | | |
| <p>Dr S Malcolm-Smith Psychology Department Upper Campus UCT</p> | | |
| <p>Dear Dr Malcolm-Smith</p> | | |
| <p>PROJECT TITLE: THE BIOLOGICAL BASES OF SOCIAL DEFICITS: THE POSSIBLE ROLES OF THE MU-OPIOID RECEPTOR AND THE SEROTONIN TRANSPORTER PROMOTER LENGTH POLYMORPHISM IN SOCIAL MOTIVATION AND THEORY OF MIND IN AN AUTISM SPECTRUM DISORDER SAMPLE-PhD-candidate-K Hamilton</p> | | |
| <p>Thank you for your response letter dated 13 October 2017, addressing the issues raised by the Human Research Ethics Committee (HREC).</p> | | |
| <p>It is a pleasure to inform you that the HREC has formally approved the above-mentioned study, including the following documentation: -</p> | | |
| <ol style="list-style-type: none"> 1. PI Generated Synopsis Instruction version date 23 July 2014 2. Research Protocol version date 16 April 2012 3. Information Sheet and Parent Consent Form 4. Child Assent Form 5. Parent Questionnaire: ASCQ 6. Ethical Approval: Psychology Ethics Board, UCT 7. Ethics Approval: Science Faculty Ethics Board, UCT 8. Permission to approach schools: Western Cape Education Department 9. Budget Summary 10. Form A: Version 19, dated February 2015 11. Research Protocol for Phase Two: DNA Component of Study 12. Consent Form for Phase Two: DNA Component of Study 13. Assent form for Phase Two: DNA Component of Study | | |
| <p>Approval is granted for one year until the 30 October 2018.</p> | | |
| <p>Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period. (Form forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)</p> | | |
| <p><i>We acknowledge that the student: Katie Hamilton will also be involved in this study.</i></p> | | |
| <p>Please quote the HREC REF in all your correspondence.</p> | | |
| <p>HREC 346/2017</p> | | |

Appendix C

Ethical Approval from Western Cape Education Department



Directorate: Research

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20150422-46598

ENQUIRIES: Dr A T Wyngaard

Ms Kate Hamilton
PO Box 1694
Milnerton
7435

Dear Ms Kate Hamilton

RESEARCH PROPOSAL: THE BIOLOGICAL BASES OF SOCIAL DEFICITS: THE POSSIBLE ROLES OF THE MU-OPIOID RECEPTOR (OPRM1) AND THE SEROTONIN TRANSPORTER PROMOTER LENGTH POLYMORPHISM (5-HTTLPR) IN SOCIAL MOTIVATION AND THEORY OF MIND IN AN AUTISM SPECTRUM DISORDER (ASD) SAMPLE

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **24 April 2015 till 30 September 2017**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

**The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000**

We wish you success in your research.

Kind regards.

Signed: Dr Audrey T Wyngaard

Directorate: Research

DATE: 22 April 2015

Lower Parliament Street, Cape Town, 8001

tel: +27 21 467 9272 fax: 0865902282

Safe Schools: 0800 45 46 47

Private Bag X9114, Cape Town, 8000

Employment and salary enquiries: 0861 92 33 22

www.westerncape.gov.za

Appendix D

Ethical Approval from UCT Psychology Department Ethics Review Committee

UNIVERSITY OF CAPE TOWN



Department of Psychology

University of Cape Town, Rondebosch 7701 South Africa
Telephone: (021) 650 3414
Fax No.: (021) 650 4104

13 April 2015

Mr K. Hamilton
Department of Psychology
University of Cape Town
Rondebosch

Dear Ms Hamilton,

This is to confirm that ethical clearance has been given by an Ethics Review Committee of the Faculty of Humanities for your study, *The Biological Bases of Social Deficits*. The reference number is PSY2014-024.

I wish you all the best for your study.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Johann Louw'.

Johann Louw PhD
Professor
Chair: Ethics Review Committee

Appendix E

Study Information Sheet



UCT Autism Research

Brief Overview of Psychology Doctoral Study

The Biological Bases of Social Deficits: The possible roles of two candidate genes in social motivation and social ability in Autism Spectrum Disorder

Dear Parents

You and your child are invited to participate in my study! I am a PhD Psychology student with a history in Neuropsychology (MA Clinical Neuropsychology, 2014), and am a member of the University of Cape Town Autism Research Group (uctautism.com). I am investigating the social difficulties in Autism Spectrum Disorders (ASD) and I am inviting children with ASD and without ASD to participate. I am interested in general social ability, and specifically in social motivation and Theory of Mind. Theory of Mind refers to the ability to understand other people's thoughts, beliefs, and emotions, and to understand that these are different from one's own. For example, the ability to understand jokes and the ability to understand that when you know something, everyone else doesn't automatically know it too, are forms of Theory of Mind. I am interested in two candidate genes as one may be involved in whether children look for social interaction (the mu-opioid receptor, OPRM1), and the other may be involved in how well children understand social interaction and other people's behaviours (the serotonin transporter promoter length polymorphism, 5-HTTLPR). In order to conduct my study, I have recruited children with ASD and I am now inviting children who do not have ASD to participate. This will enable me to make comparisons and improve our understanding of how children with ASD may differ from other children.

Who can participate?

In order to participate, your son must be between 4-16 years old and must understand English. Children can participate as long as they do not have a diagnosed Autism Spectrum Disorder and their home language or the language their teachers use with them is English. You as the parent must also be fluent in either English as I will need to interview you about your son.

Must my child and I participate?

No, not at all – this study is completely optional. There are no negative consequences if you choose not to participate. Also, if you decide to participate and then change your mind, you can just let me know that you are withdrawing and you don't even need to provide a reason. If this happens, you and your son will not be penalised in any way.

What will happen if we take part?

If you decide to participate in the study, I will ask you to sign a consent form and complete a demographics form. The demographic forms asks about your son's medical history and your family income and education. I understand that this is personal information, so as soon as I receive it I will remove your name and record the information under a confidential participation number. This information will not be shared with anyone else. We need this personal information for two reasons: first, we need the medical information to establish whether anything else could explain the relationships we are exploring, in which case we may not be able to include your son in the study, and second, we need the financial information to make sure that this research recruits children from all backgrounds and is therefore representative of the South African population.

Myself or someone in my team will then call you to arrange a time to interview you. The interview will consist of two parts, each 30-60 minutes, and can be done telephonically or we can meet and conduct the interview in person.

I will then meet with your son at his school. At the start of every session I will ask your son if he is willing to play the games with me that day, and if he isn't then we won't have a session. I will meet each child for 2 sessions of approximately 40 minutes, where we will complete several tasks all designed to measure different aspects of social and cognitive ability. All the tasks are designed to appear as games for the children, so they are all toy or story based.

What will happen to the information I give you and the information from seeing my son?

All information is recorded under a confidential participant number, and your privacy will be maintained at all times. I will not share this information with others, and if any data is shared it will be the kind of information that does not reveal who you are (for example, when I send the lab samples I may give them the age and sex of you son, but not his name, school, or anything else). Therefore, your name, income information, son's medical information, and all other information will not be shared with anyone. All information will be securely stored so that no one else can access it, and the data is coded so that your name and your son's name are removed. Any DNA that is unused will be destroyed.

What will happen with the results of this study?

At the end of this study I will provide you with a personalised report explaining what I learnt about your son. You can keep this report, and you can choose to share it with schools or any clinical professional involved in your son's care (for example, psychologists, GPs, speech therapists, etc.). I am also always available to discuss anything about the research and to answer any questions.

If I publish my findings from this study, you and your son will never be identified personally. I will be delighted to share the results with you as soon as they are available.

Who has approved this study?

This study has received ethical approval from the Western Cape Education Department, the UCT Psychology Department Ethics Board, and the UCT Faculty of Science Ethics Board.

Who is responsible for this study?

I am the Doctoral Candidate who is conducting the study, and can be contacted at any time with any questions. My supervisor, Dr Susan Malcolm-Smith, is a senior lecturer and

Neuropsychologist at UCT can also be contacted if you have any queries or complaints that you would rather address to her. Or, alternatively you can address these issues to Rosalind Adams, the administrative assistant for the Psychology Department Ethics board. All contact details are included at the end of this letter.

How to participate?

Thank you for considering participating in my study! In order to join the study, please sign the attached consent form, complete the demographic form and return these forms to your school. Please feel free to call me with any questions or for help submitting these forms.

I look forward to hearing from you!

Katie Hamilton
PhD Psychology
Candidate
Department of Psychology,
UCT
082 463 8335
kate@hamilton.co.za

Dr Susan Malcolm-Smith
Senior Lecturer
Department of Psychology,
UCT
021-650-4605
susan.malcolm-smith@uct.ac.za

Rosalind Adams
Admin. Assistant: Ethics
Committee
Department of Psychology, UCT
021-650-4104
rosalind.adams@uct.ac.za

Appendix F

Consent Form: ASD Sample

Consent Form

The study has been explained to me, and my questions have been answered. I understand that participation in this study is voluntary, and that I may withdraw my child at any point. I understand that my child will not be identified except by an initial, and that this anonymity will be maintained throughout the study and when the research is published.

I consent to participate and to allow my child to **participate** in this study.

Child's name: _____

Signature of parent/ guardian: _____

Date: _____

I hereby give consent for **DNA** samples to be collected from my child using cheek swabs. I understand that this DNA will only be used for research purposes. I give consent for this DNA to be stored at the Department of Molecular and Cell Biology or the Department of Psychology, UCT, and to be used in later research.

Signature of parent/ guardian: _____

Date: _____

Please indicate below if you would like to be notified of future research conducted by our research group:

Yes, I _____ (initial) would like to be added to your research participation pool and be notified of research projects in which I or my child might participate in the future.

Phone number: _____

Cell phone number: _____

E-mail address: _____

{Parent/guardian} _____ has been informed of the purpose, procedures, and any possible risks of this study. He / she has been given time to ask any questions, and these questions have been answered to the best of my ability. He / she understands that participation is voluntary.

Researcher: _____

Signature & Date: _____

Appendix G

Consent Form: Neurotypical Sample

Consent Form

The study has been explained to me, and my questions have been answered. I understand that participation in this study is voluntary, and that I may withdraw my child at any point. I understand that my child will not be identified except by an initial, and that this anonymity will be maintained throughout the study and when the research is published.

I consent to participate and to allow my child to **participate** in this study.

Child's name: _____

Signature of parent/ guardian: _____

Date: _____

Please indicate below if you would like to be notified of future research conducted by our research group:

Yes, I _____ (initial) would like to be added to your research participation pool and be notified of research projects in which I or my child might participate in the future.

Phone number: _____

Cell phone number: _____

E-mail address: _____

{Parent/guardian} _____ has been informed of the purpose, procedures, and any possible risks of this study. He / she has been given time to ask any questions, and these questions have been answered to the best of my ability. He / she understands that participation is voluntary.

Researcher: _____

Signature & Date: _____

Appendix H

Diagnostic Statistics for Proposed Model Investigating the Relationship between Effortful Control, Working Memory and Social Affect

This appendix contains table and figures illustrating the diagnostic statistics which evidences the presence of bias within the model proposed to investigate whether effortful control moderates the relationship between working memory and Social Affect.

Table H1.

Casewise Diagnostics of Problematic Residuals for Model investigating the interaction between Effortful Control_{std} and Working Memory_{std} in Predicting Social Affect

| Case Number | Mahalanobis Distance ^a | Leverage Value ^b | Covariance Ratio ^c | Absolute DFBeta | Standardised Residuals. |
|-------------|-----------------------------------|-----------------------------|-------------------------------|--------------------|-------------------------|
| 1 | 17.92 | .48 | 2.31 | | |
| 2 | | | 1.64 | | |
| 5 | | | 1.39 | | |
| 9 | | | | >1.00 ^e | 6.63 |
| 10 | | | 1.37 | | |
| 17 | 17.13 | .46 | 2.28 | | |
| 19 | | | 1.42 | | |
| 30 | | | 1.37 | | |
| 32 | | | | >1.00 ^f | 6.25 |

Notes. Only values that violated the relevant assumptions were included in the table. Fields (2013c, p. 345 – 350) was used to inform values at which cases may be problematic.

^a Values should not be above 15 in a sample of 50 participants or less

^b Values should not be above .32

^c Values should not be above 1.32

^d Two out of four DF Beta values were >1.00

^e One out of four values were >1.00

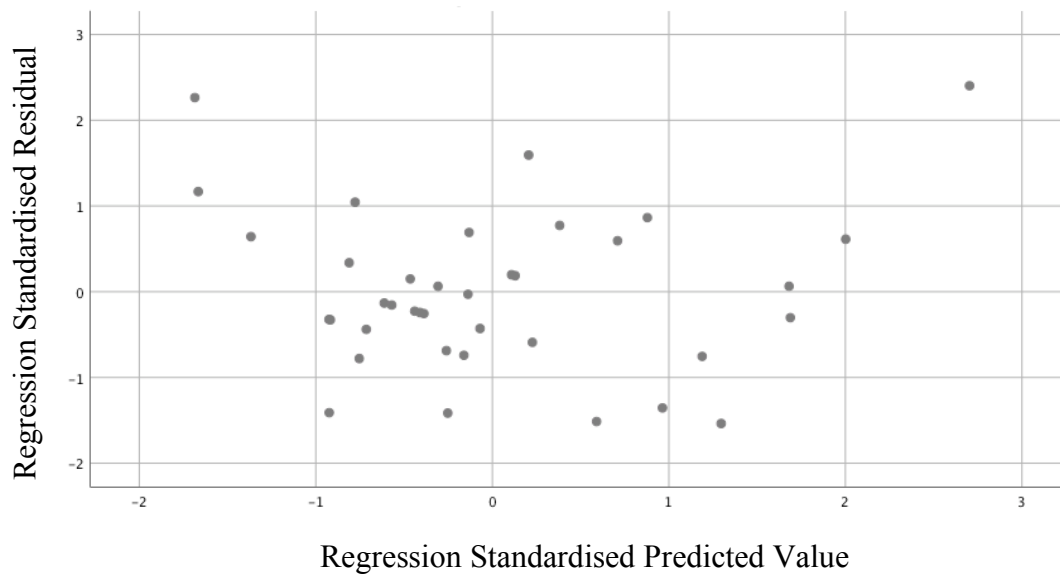


Figure H1. *Plot of Regression Standardised Residuals against Regression Standardised Predicted values for the Outcome Variable Social Affect*

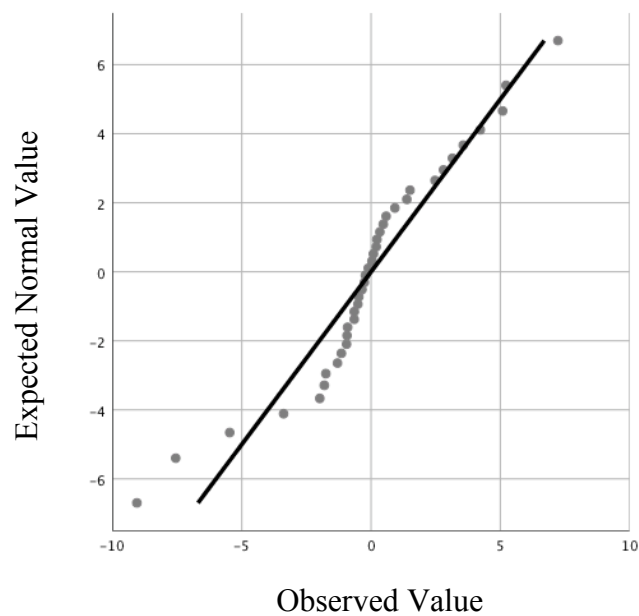


Figure H2. *Q-Q Plot Representing the Quantiles of the Interaction Effect between Effortful Control_{std} and Working Memory_{std}*