The overlap between Attention-deficit/hyperactivity disorder and Autism Spectrum Disorder symptoms and their association with reading skills and social cognition ability

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Thesis Summary

ADHD and ASD are both associated with social cognition and literacy deficits in childhood. Although ADHD and ASD are highly comorbid conditions, few studies have sought to examine to the role that co-occurring diagnoses has on these important life skills.

This thesis aimed to address this lack of research by first investigating the effect of ASD traits on reading comprehension performance in a large scale sample of children with ADHD, together with an examination of the full profile of literacy ability in ADHD. Results revealed that basic reading was an area of strength for some children with ADHD, while reading comprehension represented the largest literacy deficit. However, additional ASD trait severity was not shown to exacerbate this reading comprehension deficit.

Secondly, the effect of ASD symptoms on the social cognition abilities of adolescents with ADHD was investigated. Each social cognition ability (facial emotion recognition, empathy and theory of mind) were explored in turn with differing results. Social cognition was tested using behavioural tasks, and both FER and empathy were also examined using eye tracking technology. Results showed that ASD symptoms were not found to affect the facial emotion recognition ability of children with ADHD, or alter their eye looking patterns. However, ASD symptoms were shown to have a significant effect on cognitive empathy for fear, alongside reducing the amount of time children spent looking at the eyes and increasing the amount of time spent looking at the face of a character experiencing fear.

In the investigation of theory of mind, co-occurring conduct disorder symptoms were also investigated alongside ASD symptoms, as a gap in the literature was identified. Results showed that theory of mind was impaired in children with ADHD compared to controls, and that conduct disorder symptoms seemed to be driving this deficit. ASD symptoms, on the other hand, had no additional effect on performance.

Thirdly, the relationship between reading comprehension and social cognition was explored in relation to a sample of adolescents with ASD and typically developing peers. Participants with ASD were found to be impaired in reading comprehension, facial emotion recognition and cognitive empathy compared to controls. In addition, the association between ASD diagnosis and reading comprehension was shown to be mediated by cognitive empathy.

Taken together, these results provide a valuable insight into the dimensional overlap between ADHD and ASD, and suggest that practitioners should take co-occurring ASD and conduct disorder symptoms into account when choosing appropriate interventions for young people with ADHD. The findings from our ASD sample additionally indicate that interventions which focus on improving both reading comprehension and social cognition simultaneously could be viable, and should be considered for future implementation into schools to support the learning of individuals with ASD.

Contribution to data collection and analysis

The data presented in this thesis originate from three separate studies; (1) Study of ADHD genes and environment (SAGE), (2) the longitudinal follow up of a subset of SAGE participants, called the ADHD study, (3) data from a sample of adolescents collected mainly from secondary schools, but also from colleges and community centres across South Wales, called the school study. Study 2 represents a later stage of data collection using participants that were originally recruited as part of study 1. The third study involved data collection from a new sample of participants, mainly recruited from secondary schools. This section will highlight my roles and responsibilities regarding the collection and analysis of the data used in this thesis.

The first study, SAGE, was a large scale study that recruited over 700 participants with clinical diagnoses of ADHD to take part in a battery of different cognitive tasks and assessments. The data collection took place from 2007-2011, and was complete before I began my PhD study in 2014. I was interested in the literacy skills and autistic traits of the participants, so I created reading ability-achievement scores for each participant using their IQ scores, and used the social communication questionnaire (SCQ) as a measure of autistic traits. I developed the aims and hypotheses to address the questions I was interested in, before analysing the data.

I had a primary role in the data collection and analysis of the data for the ADHD study. Alongside another PhD student, I conducted the testing at the University and collected data from the 70 adolescents that took part in the study. The testing consisted of a large battery of tasks, and I shared responsibility for entering and analysing the data for all of the tasks used in the study. I developed the aims and hypotheses to address the questions of this thesis. In accordance with this, I chose to add an additional task to the test battery, the Frith-Happé triangles animations task as a measure of theory of mind. I was interested in all three social cognition tasks used in the study; facial emotion recognition, empathy film clips, and the triangles task. I assisted in entering the data for the facial emotion recognition task, and I entered, scored and analysed all the data for the empathy film clips and triangles tasks. The other PhD student involved in this study was investigating the effect that an additional diagnosis of conduct disorder has on emotion recognition and empathy.

Finally, in the school study, I independently recruited and tested 59 participants from secondary schools, colleges and community centres across South Wales. I was responsible for all aspects of this study. The social cognition tasks were the same as those used in the ADHD study, but I chose to make alterations to the design of the facial emotion recognition task and the film clips used in the empathy task. I developed the aims and hypotheses for the study, and I entered and analysed all the task data from the study, including transcribing and scoring the triangles task. I additionally used Tobii eye tracking software to analyse the eye movements of participants during the empathy film clips and facial emotion recognition tasks.

CHAPTER 1

1.0 Introduction

Attention-deficit/hyperactivity disorder (ADHD) and Autism Spectrum Disorder (ASD) are among the most common childhood neurodevelopmental disorders. ADHD and ASD are two distinct, yet highly comorbid conditions. However, the nature of this comorbid relationship has not been fully explored. Research has shown that children with ADHD or ASD often have difficulties with social cognition and literacy (Asberg Johnels, Kopp, & Gillberg, 2014; Nation, Clarke, Wright, & Williams, 2006; Nijmeijer et al., 2008; Ricketts, Jones, Happé, & Charman, 2013). What is unknown is how the interplay between ADHD and ASD at diagnostic and symptom level affects these two abilities in childhood. This thesis seeks to understand the relative contribution of ADHD and ASD symptoms to social cognition and reading comprehension, to ultimately determine the extent to which these abilities are associated.

1.1.1 What is attention-deficit / hyperactivity disorder?

Attention-deficit / hyperactivity disorder (ADHD) is the most common neurodevelopmental disorder in childhood, with a worldwide prevalence rate in children of between 5.29 and 7.1 % (Polanczyk, De Lima, Horta, Biederman, & Rohde, 2007; Willcutt et al., 2012). The disorder has a strong genetic basis, with a heritability estimate of 76% (Faraone et al., 2005). A diagnosis of ADHD according to the Diagnostic and Statistical Manual, 5th edition (DSM-5; APA, 2013), is dependent on difficulties with either attention or hyperactivity/impulsivity or both. Inattention refers to difficulties with sustaining focus and completing tasks to deadline, as well as a tendency to lose possessions and a failure to organise daily activities. An inability to engage in activities quietly and keep still are typically features of hyperactivity/impulsivity, alongside a propensity to interrupt others. A diagnosis of ADHD in DSM-5 is dependent on the presence of a significant number of symptoms (six out of nine) for either inattention or hyperactivity/impulsivity or both, several of which must have occurred before the age of 12 years. ADHD symptoms must also impact on daily living across more than one setting (e.g. home and school) to receive a diagnosis (APA, 2013).

It is the social difficulties that often co-occur with ADHD diagnosis that are often viewed as the most debilitating characteristic of ADHD (For a review, see Nijmeijer et al., 2008). As noted above, children diagnosed with ADHD present with a number of symptoms, which may include the tendency to interrupt others or fail to take turns, which refers to a clear difficulty with social interaction. These hyperactive/impulsive symptoms are believed to be related to rejection from peers (Wheeler & Carlson, 1994). Inattention symptoms that form ADHD diagnosis, such as not listening and getting easily distracted, are also thought to contribute to peer rejection. For example, Wheeler et al., (2000) found that children with ADHD predominantly inattentive type were socially passive and impaired in social knowledge, which was shown to predict lower social status amongst peers. Overall, Nijmeijer et al., (2008) found in their review that studies frequently reported that children with ADHD have fewer friendships, are less liked by peers and have more difficult relationships when they do have friends.

ADHD is frequently diagnosed in childhood. While the majority of children with ADHD are educated in mainstream schools, their learning and that of their classmates can be adversely affected by their ADHD symptoms (Kristoffersen, Krægpøth, Nielsen, & Simonsen, 2015;

Mannuzza & Klein, 2000). Compared to their peers, children with ADHD score lower on standardised tests and are more likely to be excluded from school (Fleming et al., 2017; Mannuzza & Klein, 2000; Watts, 2018). Older adolescents with ADHD are also more likely to take part in risky behaviour such as smoking (Elkins et al., 2017; Kollins, McClernon, & Fuemmeler, 2005; Osland, Hirsch, & Pringsheim, 2017), alcohol abuse and drug use (Barkley, Fischer, Smallish, & Fletcher, 2004; Elkins et al., 2018).

ADHD is known to persist into adulthood, affecting 3.4 % of adults cross-nationally (Fayyad et al., 2007), symptoms are not necessarily stable and have been shown to change and recede across the lifespan (Willcutt et al., 2012). However, having childhood ADHD has been shown to increase the likelihood of involvement in criminal activity as young adults (Watts, 2018). Elevated ADHD symptoms have been associated with an increased risk in taking part in crime such as robbery, selling drugs or being arrested, even when factors such as low family income and parental education are taken into account (Fletcher & Wolfe, 2009). ADHD symptoms are also associated with unemployment (Fleming et al., 2017). The social difficulties that often co-occur alongside ADHD diagnosis have been viewed as primarily responsible for the link between ADHD and these poor adolescent and adult outcomes (Wehmeier, Schacht, & Barkley, 2010). In addition, the role of the highly comorbid conditions of autism spectrum disorder (ASD) and conduct disorder (CD) should also be taken into account, as both these disorders have been shown to have social cognition difficulties (Baron-Cohen, Leslie, & Frith, 1985; Oliver, Barker, Mandy, Skuse, & Maughan, 2011). It could be the case that co-occurring ASD or CD symptoms/diagnoses in those with ADHD are responsible for social cognition deficits. In view of this, it is also vital to consider the role of ASD and CD in shaping the social difficulties of children with ADHD.

1.1.2 What is autism spectrum disorder?

ASD has an estimated worldwide prevalence of 0.76% across all ages (Baxter et al., 2015) and UK prevalence of approximately 1.56 to 1.7% (Baron-Cohen et al., 2009; Russell, Rodgers, Ukoumunne, & Ford, 2014) in childhood. Autism is a highly heritable neurodevelopmental disorder, with heritability estimates in excess of 80% (Lichtenstein, Carlström, Råstam, Gillberg, & Anckarsäter, 2010). First described by Kanner (1943), under the current DSM-5 diagnostic criteria (APA, 2013), autism is characterised by a dyad of impairments; a social domain consisting of social communication and social interaction difficulties, and restricted and repetitive behaviour. The social domain of difficulty includes three areas of difficulty: (1) deficits in social-emotional reciprocity such as failing to respond to social interactions, (2) difficulties in non-verbal communication, including a lack of integrated facial expressions or gestures, and (3) deficits in developing and understanding relationships. Restrictive and repetitive behaviours refer to four areas of difficulty: (1) the presence of stereotyped or repetitive movements, (2) insistence of sameness that includes an inability to cope with changes to routines and the environment, (3) restricted and intense interests, and (4) hyper or hypo-reactivity to sensory aspects of the environment. To obtain a diagnosis, symptoms must be identified from all three social difficulties and two of the four restrictive and repetitive behaviours. These symptoms must have been present since early childhood and cause significant impairment to daily functioning.

ASD is recognised as a lifelong condition that affects early relationships and academic progress in school. Although IQ has been found to predict school attainment in the general population, it is not a reliable indicator of achievement in those with ASD, with one study finding that 78% of autistic adults with average or above IQ did not achieve any formal qualifications (Howlin, Goode, Hutton, & Rutter, 2004). High unemployment levels in adulthood are common (Shattuck et al., 2012). For example, a study sent to UK families of adults with autism found that only 14% of respondents were in full time paid employment (Eaves & Ho, 2008). The social difficulties that form part of an ASD diagnosis are often found to have the greatest impact on adult outcomes (Hendricks, 2010), contributing to a lack of independent living, few friendships (Barnard, Harvey, Potter, & Prior, 2001) and fewer employment opportunities (Hillier et al., 2007). Howlin, Mawhood and Rutter (2000) also found that the social functioning of adults with autism was related to their early language development, suggesting that children with language difficulties are more at risk of greater social difficulties as adults. In addition to language difficulties, the overlap between ASD and ADHD is also believed to aggravate social difficulties (Oerlemans et al., 2014), and this will be examined later in this thesis.

1.1.3 Comorbidity between disorders: ADHD and ASD

ADHD and ASD are highly comorbid conditions, with a review finding that between 20 to 50% of children diagnosed with ADHD meet criteria for ASD, whilst estimates for children with ASD meeting diagnostic criteria for ADHD are between 30 and 80% (Rommelse, Franke, Geurts, Hartman, & Buitelaar, 2010). In addition, individuals with either ADHD or ASD are significantly more likely to have elevated traits of either disorder than those without ADHD or ASD (Ronald, Simonoff, Kuntsi, Asherson, & Plomin, 2008). The overlap between these disorders has been found to have a genetic basis in childhood and adolescence (Stergiakouli et al., 2017), with twin studies finding that monozygotic twins are significantly more likely to have a dual diagnosis than dizygotic twins (Lichtenstein et al., 2010).

However, before the DSM-5 (APA, 2013) was published, it was not possible to have a concurrent diagnosis of both ASD and ADHD, with ASD taking precedence over ADHD. As a result, children would often move from one diagnosis to the other dependent on subsequent assessments (Miodovnik, Harstad, Sideridis, & Huntington, 2015). This rule can also in part account for the historic lack of research studies into, for example, the social skills and reading abilities of children with both disorders. This was because research studies frequently included the same exclusion criteria as the diagnostic manuals and therefore had samples where either those with dual diagnoses were excluded or only one disorder was assessed (Thapar, Cooper, & Rutter, 2017). Research that has looked at the impact of a dual diagnosis of ASD and ADHD has found that these children tend to have a more severe clinical profile than those with a single diagnosis (Tye et al., 2014). For example, Thomas et al., (2015) investigated whether children with a dual diagnosis had greater difficulties through using parent and teacher questionnaires. Results showed that children with both ASD and ADHD were reported as having a poorer quality of life, as identified by greater psychosocial and physical health problems, as well as greater emotional, behavioural and peer difficulties in comparison to children with a diagnosis of ADHD only.

Even traits of ASD or ADHD in children with a single diagnosis can increase the likelihood of more severe difficulties. Indeed, it is increasingly recognised that exploring the dimensional overlap between disorders is important to identify individuals with subthreshold symptomology for a developmental disorder that nevertheless experience impairments associated with meeting diagnostic criteria for the disorder (Thapar et al., 2017). For instance, Cooper et al., (2014) found that ASD traits in children with ADHD are associated with a more complex presentation of difficulties with behaviour, increased anxiety and greater cognitive difficulties. Evidently, having both disorders or elevated traits, leads to greater difficulties in childhood, although further research into the specific nature of these difficulties is needed.

1.1.4 Other comorbid disorders: Oppositional defiant disorder and conduct disorder in those with ADHD

Oppositional defiant disorder (ODD) and conduct disorder (CD) are the most frequent comorbidities in those with an ADHD diagnosis, with an estimated overlap with ADHD of 30 to 50% (Biederman, Newcorn, & Sprich, 1991). Symptoms of ODD and CD are the most common reasons why children are referred to child and adolescent mental health services (CAMHS) in the UK (Nice, 2013). The UK prevalence of both disorders is estimated at 5% among children aged between 5 to 15 years (ONS, 2004).

ODD is a behavioural disorder with an estimated worldwide prevalence of 3.3% (Canino, Polanczyk, Bauermeister, Rohde, & Frick, 2010). ODD is diagnosed on the basis of a persistent angry/irritable mood (e.g. losing temper), argumentative/defiant behaviour (e.g. arguing with authority figures and/or refusing to comply with requests) and vindictiveness (e.g. spiteful behaviour). This behaviour pattern has to have lasted at least six months and occurs in relation to social interactions that are not confined to sibling relationships alone (APA, 2013).

Conduct disorder (CD) refers to severe antisocial behaviour shown in childhood or adolescence, and has an estimated worldwide prevalence of 3.2% (Canino et al., 2010). CD is defined as a specific pattern of behaviour, defined through the presence of at least three out of 15 anti-social behaviour criteria in the last 12 months, with at least one criterion occurring within the last six months (APA, 2013). These 15 criteria are encompassed by four categories: aggression to people and animals; destruction of property; deceitfulness or theft and serious violation of the rules. For example, symptoms of aggression include bullying, fighting and using weapons. CD often occurs alongside callous-unemotional traits, which are described as a lack of remorse and unconcern for the wellbeing of others (DSM-5). Overall, CD has a substantial adverse effect across the lifespan. Children with CD are more likely to leave school without qualifications, suffer from drug dependency and have a criminal record in adulthood than unaffected peers (Fergusson, John Horwood, & Ridder, 2005).

Studies often merge ODD and CD diagnoses under the heading of ‘Conduct Disorders’ or ‘Disruptive Behaviour Disorders’ and consider them as disorders with the same behavioural features (Rowe, Maughan, Pickles, Costello, & Angold, 2002) with CD as a more severe behavioural presentation. This has meant that ODD is often portrayed as a stepping stone to CD diagnosis. However, as their different diagnostic criteria referred to earlier (DSM-5) demonstrates, these are distinct but overlapping disorders. While children with a diagnosis of ODD do often later receive a diagnosis of CD, this is not the case for all children, with an estimated 40% of those with ODD later receiving a diagnosis of CD (Angold, Costello, &

Erkanli, 1999). In addition, the differences between comorbid ODD or CD remain clinically distinct for children with ADHD. Children with a diagnosis of ADHD alone, ADHD + ODD and ADHD + CD have been found to have different difficulties in regards to delinquency, aggression and ADHD symptom severity, with the ADHD+CD group demonstrating the most profound difficulties (Connor & Doerfler, 2008). However, despite the proposed additive negative effect of ODD and CD on behaviour in children with ADHD, the overlap between these disorders and the effect on social development in childhood and adolescence is not often studied.

1.2 Literacy skills

Learning to read is viewed as one of the most important skills to acquire during childhood education (Bigozzi, Tarchi, Vagnoli, Valente, & Pinto, 2017), and as a result, a great amount of time and resources are spent on both teaching children to read and monitoring their progression. Acquiring the ability to read competently at an early age appears to be vital; children who show early difficulties tend to struggle to catch up with their peers. For example, Claessens et al., (2009) found that children's reading skills in the early years predicted their later reading skills. The magnitude of the differences between poor and proficient readers have also been shown to increase with age (Morgan, Fuchs, Compton, Cordray, & Fuchs, 2008). Reading has also been shown to be of paramount importance to successful adult outcomes. Currie and Thomas (1999) examined the outcomes of 17,000 children as adults, and found that their reading scores at age seven predicted their educational attainment, level of employment and salary at ages 22 and 33 years, when other factors such as social economic status were taken into account. A further study supports this by finding that reading skills were significantly associated with the level of educational attainment and choice of vocational versus academic further education routes (Savolainen, Ahonen, Aro, Tolvanen, & Holopainen, 2008).

In research, literacy skills tend to be split into three main skills: basic reading, spelling and reading comprehension. Basic reading can be defined as word recognition or decoding, “the ability to rapidly derive a representation from printed input” (Hoover & Gough, 1990, p.130). Spelling on the other hand can be defined as the ability to reproduce (orally or through writing) the letters of words in the correct order according to standard orthography (Tainturier & Rapp, 2001). Reading comprehension is viewed as the most complex of these three skills, and involves extracting meaning from text through accessing background knowledge and forming inferences (Ricketts, 2011). Reading comprehension is considered to be the ultimate goal of reading (Ricketts, 2011), and deficits in reading comprehension have also been associated with poor educational attainment. For example, Ricketts, Sperring and Nation (2014) found that children who were identified as poor comprehenders at age nine years had significantly poorer educational attainment at age 11 compared to controls, and at both age 11 years and 16 years compared to national performance levels.

In addition, reading comprehension has been identified in the general population as requiring distinctive cognitive processes to other literacy skills. For instance, Oakhill, Cain and Bryant (2003) carried out a longitudinal study looking at the development of word reading and reading comprehension, and found that word reading skills did not account for a significant amount of variance in reading comprehension over time. Similarly, a longitudinal study by Nation et al. (2010) found that children who were identified as poor comprehenders at age eight years were more likely to have early comprehension difficulties at age six years, even where their reading accuracy, fluency and phonological skills were within the normal range at both ages. This distinction between reading comprehension and other literacy skills has often been explored in autism research, while reading research in ADHD has been less specific. In the following sections research into literacy skills in childhood will be discussed, first in relation to ADHD and then ASD diagnoses.

1.2.1 Literacy skills in children with ADHD

Reading disability is a heterogeneous developmental disorder that is characterised by difficulties with fluent or accurate word recognition, spelling and/or decoding skills, which is frequently found to be the result of phonological processing deficits (Fletcher et al., 1994; Ghelani, Sidhu, Jain, & Tannock, 2004). Reading disability is classed as difficulties with word reading, spelling and/or reading comprehension (Lyon, Shaywitz, & Shaywitz, 2003) and is considered to be the most commonly occurring learning difficulty in those with ADHD (Dunn & Kronenberger, 2003; Maughan & Carroll, 2006), affecting up to 45% of children diagnosed with ADHD (Kouichi Yoshimasu et al., 2012). While the proportion of children with reading disability that meet criteria for ADHD is estimated to be between 15 to 35% (Shaywitz, Fletcher, & Shaywitz, 1995; Willcutt, Pennington, & DeFries, 2000).

Reading disability in ADHD has been viewed as the result of executive function (EF) difficulties (Biederman et al., 2004; Jacobson et al., 2011). EFs are defined as processes that effect goal-directed behaviour, and broadly include inhibition/impulsivity, working memory, processing speed and set shifting/cognitive flexibility (Crippa et al., 2014). Specifically, reading difficulties in ADHD are believed to originate from working memory and processing speed deficits that reduce reading fluency and slow down word decoding ability (Kofler et al., 2019). The casual role of EF in reading disability can be implicated by a study by Bental and Tirosh (2007), which found that there was a relationship between reading accuracy and EFs in children with ADHD, that was not found in typically developing children. In addition, several studies have found that children that have both ADHD and reading disability have greater EF impairments than children with ADHD alone (Bental & Tirosh, 2007; Horowitz-Kraus, 2015; Willcutt et al., 2001).

Interestingly, a study (Horowitz-Kraus, 2015) also found that eight weeks of cognitive training to improve EFs had a subsidiary effect in improving the reading ability of children with ADHD. The level of improvement was also found to be greater for the comorbid group ADHD and RD compared to those with ADHD alone. Therefore, there appear to be multiple research studies that support the executive function theory of reading deficits in ADHD.

In spite of the considerable overlap between ADHD and reading disability, studies have tended to only investigate literacy deficits using cut-off scores to identify those with difficulties (e.g. Del'Homme, Kim, Loo, Yang, & Smalley, 2007; Wadsworth, DeFries, Willcutt, Pennington, & Olson, 2015), rather than looking more in depth at each of the three main literacy skills. This has meant that actual performance ability has rarely been explored for each skill. Da Silva et al., (2015) conducted one of the few studies that have looked at the skills separately, although only word reading and spelling were investigated. They compared the reading and spelling scores of children with and without ADHD across years 3, 5 and 7 in primary school. Results showed that children with ADHD were significantly less likely to meet the benchmark scores (minimum national standard score needed to progress) for both reading and spelling at each time point. For instance, 24% of children with ADHD did not meet the benchmark score for reading in year 7, compared to 12% of children without ADHD. Other studies support these findings by also demonstrating specific reading and spelling deficits in ADHD (Asberg, Kopp, Berg-Kelly, & Gillberg, 2010; Asberg Johnels et al., 2014).

In contrast to these studies consistently finding word reading and spelling deficits in those with ADHD, the small number of studies that have investigated reading comprehension skills have had mixed results. Martinussen et al., (2015) found than children with ADHD had significantly lower reading comprehension scores than children without ADHD, when word reading skills were matched across groups. Some other studies that have looked at reading comprehension in those with ADHD have also found deficits (Asberg et al., 2010; Brock & Knapp, 1996; Mayes & Calhoun, 2006; McIntyre et al., 2017). On the other hand, Ghelani et al., (2004) found that the reading comprehension scores of adolescents with ADHD did not differ from controls, and are supported in this finding by further studies (Gremillion & Martel, 2012; Miller et al., 2013). Evidently, greater research into the nature of reading comprehension deficits is needed to provide clarity to the previous findings.

Although some studies discussed here have examined different literacy skills separately in those with ADHD, it is important to note that very few of these studies have directly compared performance across all three literacy skills or controlled for IQ. Without controlling for IQ, it is difficult to establish whether there is a true deficit in literacy skills. There is one exception to this, Mayes and Calhoun (2006) controlled for IQ when examining the word reading, spelling, and reading comprehension skills of children with developmental disorders. They found that children with ADHD and IQ> 80 had significantly lower scores than expected based on their IQ. However, the study focused on reading impairment, and did not look at children that may have performed better than expected. Consequently, it seems that the full profile of literacy skills in children with ADHD has not been investigated.

1.2.2 Literacy skills in children with ASD

Unlike ADHD, the full profile of literacy skills has been explored in children with ASD. Jones et al., (2009) looked at peaks and dips in the literacy skills of a large sample of 100 children with ASD. Reading peaks and dips in the study referred to either significantly higher, or lower scores than expected based on IQ. The authors found that a large proportion of children (38%) had a dip in reading comprehension, compared to 14% and 13% for basic reading and spelling respectively. Of those children with a reading comprehension dip, 70% had a deficit in this skill alone. This suggests that reading comprehension impairments are frequently found in children with ASD, and tend to be a specific impairment, with intact basic reading and spelling skills. There is also evidence for basic reading being a particular area of strength in those with ASD (Huemer & Mann, 2009). Indeed, researchers have suggested that children with ASD are often adept at the skills which enable word reading, such as strong visual memory and developed phonological skills (Newman et al., 2007).

Although there is much heterogeneity in literacy skills within those with autism (Nation et al., 2006), the predominant profile demonstrated in research studies concurs with Jones et al.'s (2009) finding of intact basic reading and spelling, with impaired reading comprehension (Nation et al., 2006; Newman et al., 2007; Asberg et al., 2008; Huemer et al., 2010). Reading comprehension deficits in ASD may be viewed as intrinsic to the social skills symptoms that form ASD diagnosis. Jones et al., (2009) found that the reading comprehension scores (relative to IQ) of adolescents with ASD were significantly associated with their social and communication scores as measured by the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). Adolescents with ASD who had low reading comprehension discrepancy scores tended to have greater social and communication impairments, implying that ASD symptom severity goes hand in hand with reading comprehension deficits. These findings have been replicated by a recent study (McIntyre et al., 2017). The contrast between the consistent findings regarding reading comprehension difficulties in those with ASD and the inconsistent findings in the field of ADHD research are of interest. Considering the substantial overlap between ADHD and ASD and the tendency of research studies to either exclude those with a dual diagnosis or not to assess both disorders (Thapar et al., 2017), the inconsistent reading comprehension findings in ADHD studies could be partly due to the effect of overlapping ASD symptoms that have not been taken into account. This hypothesis needs to be investigated.

The exacerbating effect of ASD symptoms on reading comprehension in those with ADHD can be supported further by a study by Asberg et al., (2017). Asberg and colleagues found that children with ADHD and poor reading comprehension in their study had elevated autistic symptoms, compared to children with intact reading comprehension. This was the first study to investigate this, and demonstrates that ASD symptoms alone may be sufficient to have an additional effect on reading comprehension performance. However, the sample of poor comprehenders numbered only 10 children, so further studies are needed to determine the effect of overlapping ASD symptoms in those with ADHD.

In summary, it is clear from previous research that reading difficulties are often found in individuals with both ADHD and ASD. Whilst ASD difficulties tend to be specific to reading comprehension skills, children with ADHD are often impaired in basic reading and spelling. However, no studies to date have fully explored the literacy profile of children with ADHD, and only a few studies have investigated reading comprehension skills, with inconsistent results. Due to the overlap between ADHD and ASD, and previous studies (Asberg Johnels et al., 2017; Jones et al., 2009) it is important to investigate the effect that ASD symptoms can have on the literacy skills performance of children with ADHD.

1.3 Social cognition

Social cognition refers to understanding the social world; it is fundamentally the ability to identify and interpret the emotions, thoughts and behaviour of other people, and is foremost in creating successful social interactions (Staub & Eisenberg, 1981). Social cognition is underpinned by three key skills; (1) emotion recognition (this thesis will focus on facial emotion recognition, rather than auditory or body language recognition), (2) empathy, and (3) theory of mind. This section will explore each skill in turn before discussing the research on these skills in the context of children with ADHD and ASD.

1.3.1 What is facial emotion recognition and how is it assessed?

Facial emotion recognition (FER) is the ability to identify emotions from facial expressions alone, without any contextual knowledge to support recognition, and it is a skill that typically developing people begin to acquire from birth (Odom & Lemond, 1982). Studies with new born babies have found that we are born with a face bias, and naturally orient our gaze to human faces or face like shapes (DiGiorgio et al., 2011 & 2012). Six basic emotions have been identified: happiness, sadness, anger, fear, surprise and disgust (Odom & Lemond, 1972) and by four to seven months of age, infants begin to be able to discriminate between these different facial expressions (Serrano, Iglesias, & Loeches, 1992; Walker-Andrews, 1998). Mondloch, Geldart, Maurer and Le Grand (2003) found that by the age of 10 years, typically developing children are able to reliably identify the six basic emotions, with a level of accuracy that is not different to adults. The early development of facial emotion skills speaks to their importance in our understanding of and interaction with the world.

The six basic emotions are those that are typically tested in FER studies. The Ekman photographs (Ekman & Friesen, 1976), which are black and white images of males and females displaying these emotions, are commonly used in studies, and typically developing children and adults have consistently been found to be able to identify the emotions portrayed in the photographs. Another popular task that arguably measures emotion recognition is the reading the mind in the eyes test (RMET; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). The task involves viewing black and white photographs of the eye region of faces and choosing which mental state or emotion is portrayed from the four options given. In this respect it is very similar to facial emotion recognition tasks. Although originally designed to measure theory of mind ability (interpreting the mental states of others, see section 3.3 for further discussion), researchers have increasingly argued that within the RMET it is difficult to disentangle facial emotion recognition skills from theory of mind skills (Jarrold, Butler, Cottington, & Jimenez, 2000; Johnston, Miles, & McKinlay, 2008).

Similarly to traditional FER tasks, the RMET provides participants with facial indicators of emotion, rather than providing any contextual background information, which is vital to theory of mind and provided for in other tasks (e.g. White, Hill, Happé, & Frith, 2009).

In support of this argument, Oakley, Brewer, Bird and Catmur (2016) investigated the use of RMET as a theory of mind task with a sample of children including 14 with alexithymia. Children with alexithymia (a personality trait that involves an inability to recognise their own emotions; Parker, Bagby, & Taylor, 1991) have been shown to be impaired in emotion recognition, but have intact theory of mind (Grynberg et al., 2012). Results revealed that children with alexithymia scored significantly worse in RMET, but performed at the same level as controls in an alternative theory of mind test. In addition, Brent et al., (2004) investigated the links between three different theory of mind tasks. They found that while the scores of children with ASD for the strange stories test and cartoons task were correlated, performance in RMET was not related to either task. In addition, some studies have found that RMET has failed to differentiate between those with and without ASD, even when theory of mind impairments have been demonstrated across other tasks (Couture et al., 2010; Roeyers, Buysse, Ponnet, & Pichal, 2001; Spek, Scholte, & Van Berckelaer-Onnes, 2010). Consequently it seems that RMET may not measure theory of mind, and instead reflects emotion recognition ability, and therefore the RMET task will be referred to within this thesis as a facial emotion recognition task.

Facial emotion recognition is also tested using eye tracking technology that monitors eye movements. Eye movements have been found to be vital to the understanding of facial expressions (Bal et al., 2010; Kirchner, Hatri, Heekeren, & Dziobek, 2011), and have been shown to be the most effectual in identifying certain emotions such as fear (Morris & Dolan, 2002), sadness and anger (Eisenbarth & Alpers, 2011). As such, typically developing individuals are found to concentrate more on the eye region of faces when interpreting them (Schwarzer, Huber, & Dümmler, 2005). Consequently, studies that use a FER task in conjunction with eye tracking are able to identify both FER ability and the underlying reasons for this capability. If a FER impairment is identified, then a lack of gaze to the eye region would suggest that difficulties lie at this initial viewing stage, while finding typical eye gaze would suggest that there is an impairment in identifying the emotion itself (Serrano, Owens, & Hallowell, 2015, see FER in ASD (1.4.1) for a more in depth discussion).

1.3.2 What is empathy and how is it assessed?

Empathy is a skill that extends from identifying other people's emotions, to affectively feeling that emotion yourself (Decety, Michalska, Akitsuki, & Lahey, 2009). This is often achieved by drawing on personal experiences to imagine the emotions felt by the other person, and in this way is distinct from sympathy. For example, if a friend's pet died you may be sympathetic, and feel sorry for that person. Alternatively you could think about how sad you were when a similar event happened to you and feel sad because your friend is sad. This would be classed as empathy. Empathy has been shown to develop between 2-3 years of age (Knafo, Zahn-Waxler, Van Hulle, Robinson, & Rhee, 2008; Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992) and is believed to affect how we behave towards other people as well as our perceptions of morality (Decety & Cowell, 2014). Eisenberg and Miller (1987) found in their meta-analysis that empathy was positively related to prosocial and altruistic behaviour, while a lack of empathy has been associated with bullying in childhood (Van Noorden, Haselager, Cillessen, & Bukowski, 2015; Zych, Ttofi, & Farrington, 2016).

Empathy has also been shown to inhibit antisocial behaviour (Jolliffe & Farrington, 2004; Miller & Eisenberg, 1988; Strayer & Roberts, 2004), and facilitate the resolution of conflicts (Strayer & Roberts, 2004).

Historically, defining empathy for research purposes has led to extensive debate, with some researchers referring to empathy as a cognitive mechanism or as perspective taking (Deutsch & Madle, 1975; S. Shamay-Tsoory, Tomer, Yaniv, & Aharon-Peretz, 2002), while others defined empathy affectively in terms of taking on the emotion of another person (e.g. Eisenberg & Miller, 1987). Current studies, however, have incorporated both definitions of empathy. Following on from Feshbach (1978) and Strayer et al.,(1987), empathy is now widely perceived as comprising two separate dimensions: cognitive empathy (understanding the emotion of another) and affective empathy (experiencing the emotion of another). Baron-Cohen (2002) expanded this view by incorporating both dimensions into the empathy process; perceiving cognitive empathy as stage one, "identify[ing] another person's emotions and thoughts" and affective empathy as stage two "respond[ing] to these [emotions and thoughts] with an appropriate emotion" (p. 248).

Studies of empathy in typically developing children can support this view. For example, in a study by Dadds et al. (2008), over 2000 parents completed a 23 item measure asking questions about their child's empathic behaviour and how often it occurred. Factor analysis revealed that two clusters were found, the first comprised questions about understanding other people's behaviour (labelled cognitive empathy) and the second questions about feeling emotions after perceiving another's emotion (labelled affective empathy). Interestingly, these clusters were not found to correlate, demonstrating further the distinct nature of these two empathic processes. It has also been argued that cognitive and affective empathy occur in different parts of the brain. Shamay-Tsoory et al., (2009) found that the inferior frontal gyrus was involved in affective empathy, while the ventromedial prefrontal cortex was used for cognitive empathy. This suggests that they are two separate systems. Empathy, then, involves separate skills of identifying and feeling the emotions of other people, within a particular situation or social context.

Empathy, both cognitive and affective, is often assessed using questionnaire measures, in which self-report questionnaires and/or parent questionnaires are utilised to ask direct questions or situation based questions (e.g. Dadds et al., 2008; Marton, Wiener, Rogers, Moore, & Tannock, 2009; Pijper et al., 2016). For example, Hundry and Slaughter (2009) provided mothers with situational based questions, such as how their child reacted when someone was ill. Other studies, including Jones et al., (2008) have used vignettes that require children to imagine how they would feel following different events. However, these studies have been perceived as lacking in ecological validity as they require participants to recall or imagine reactions to specific scenarios or simply to state feelings and do not create the more complex social environment that is needed to elucidate empathic feeling (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). A few studies investigating empathy have instead opted to use video-taped recordings of empathic scenes in a bid to provide a more naturalistic measure of both cognitive and affective empathy. For example, Schwenck et al., (2012) used nine film clips of emotional situations that involved different characters. Participants then had to describe their own emotions and the characters' emotions after watching the clips. Arguably, having this greater contextual background within which to assess empathy is more representative of real-life situations. Indeed, the need for contextual background information differentiates empathy from other social cognitive abilities such as emotion recognition, which can occur in isolation and may involve facial expressions alone.

1.3.3 What is theory of mind and how is it assessed?

Theory of mind is considered to be the most complex social cognitive ability as it involves interpreting the mental states of other people, which allows the prediction of future behaviour (Korkmaz, 2011). It is distinct from emotion recognition and empathy, as it involves interpreting what is not visible, the feelings, beliefs and desires of others (mental states), within the context in which they occur. This ability is termed mentalising. Theory of mind is the last of the three social cognition skills that children acquire, and although there is evidence of understanding intentions in early infancy (Woodward, Sommerville, Gerson, Henderson, & Buresh, 2009) more complex belief understanding has not been shown to be present until three to four years of age in typically developing children (Frith & Frith, 2003; Perner & Lang, 1999).

Early studies testing theory of mind have focused on the concept of false belief, which is the understanding that other people may have feelings, beliefs and desires that are different to their own. False belief is considered to be an important developmental milestone, indicating a different outlook on the world in which people are understood to have perceptions which can be discordant with reality (Wellman, 1992). False belief tests are often either first order (knowing what another person believes) or second order (knowing what a person believes about another person's beliefs). Other more advanced studies of theory of mind focus on testing the use of mental state language to describe the actions of others (Abell, Happé &Frith, 2000). For a more in-depth discussion of theory of mind tasks, see sections 1.4.3 and 1.5.3 that explore theory of mind in ASD and ADHD, respectively.

Theory of mind in childhood is vital to understanding the social world. The ability is essential to the development of friendships and communicating effectively with others including understanding jokes and sarcasm (Korkmaz, 2011). For example, Slaughter et al., (2002) found that theory of mind ability predicted how popular young children were considered to be by their peers, and this association increased with age. In contrast, those children with low theory of mind scores were more often rejected by peers. Theory of mind has also been found to be associated with morality and trusting others (Wellman & Miller, 2008). Deficits in theory of mind can lead to continuing difficulties in social settings, which can include an increased risk of becoming involved in bullying (Shakoor et al., 2012) (Shakoor et al., 2011) and a greater likelihood of behaviour problems (Hughes & Ensor, 2006).

1.4 Social cognition in children with ASD

Social cognition difficulties are typically associated with ASD (Korkmaz, 2011) and are viewed as commensurate with the social interaction and communication difficulties that make up the dyad of impairments needed to receive ASD diagnosis (White et al., 2009). There are many prominent theories of ASD that view social cognition impairments as integral to the disorder. The EF hypothesis, as discussed previously in relation to ADHD and reading ability, is one theory that has been implicated in the exploration of social cognition difficulties in ASD. The theory assumes that EF difficulties, such as problems with working memory, cognitive flexibility and inhibition, reduce the social cognition capabilities of children with ASD. Whereas the theory of mind hypothesis of autism (Baron-Cohen et al., 1985; Baron-Cohen, Tager-Flusberg, & Cohen, 1994) states that autism is fundamentally defined by this inability to interpret the mental states of others. Other researchers have termed ASD a disorder of empathy (Gillberg, 1992) and have sought to differentiate ASD from other disorders by focusing on this empathy deficit (Smith, 2009). An alternate theory has focused on a behavioural hypothesis that individuals with autism lack social motivation, and have impaired social cognition because they do not attend to social stimuli in their environment (Mathersul, McDonald, & Rushby, 2013). However these social cognitive difficulties are believed to arise, it has nevertheless been established that social cognition deficits are a characteristic of ASD diagnosis, regardless of age and IQ (Carter, Davis, Klin, & Volkmar, 2005). The following sections will discuss all three social cognition skills in relation to ASD.

1.4.1 Facial emotion recognition in children with ASD

Historically, studies investigating facial emotion recognition in ASD have had mixed findings, with some studies finding children with ASD were impaired across all the basic emotions (Lozier et al., 2014), others finding deficits in a single or a few specific emotions (Pelphrey et al., 2002; Jones et al., 2011) and some finding no deficits at all (Castelli, 2005; Grossman, Klin, Carter, & Volkmar, 2000). However, summarising the evidence, a recent meta-analysis (Lozier et al., 2014) found that children with ASD are impaired in recognising all six basic emotions, with the greatest impairment found in the recognition of fear, sadness and disgust. The study also found that emotion recognition deficits increased with age, but were not related to IQ. Consequently it appears that children with ASD have a general rather than specific emotion recognition deficit and do not catch up with typically developing peers as they grow up.

As well as investigating facial emotion recognition behaviourally in children with ASD, studies have also utilised eye tracking technology to investigate whether there is also a fundamental deficit in the visual processing of faces in individuals with ASD. Papaginannopoulou et al., (2014) carried out a meta-analysis of 14 eye tracking studies that used emotional and/or neutral faces as stimuli. The authors found that children with ASD looked significantly less at the eyes of faces in comparison to controls. A number of studies included in the meta-analysis also found that children with ASD look significantly more at the mouth region of the face, but due to variation between studies this finding did not reach statistical significance.

There appears to be a clear relationship between eye looking and emotion recognition ability in the general population. For example, one eye tracking study of typically developing adults, utilising a static facial recognition task, found that participants spent 70% of the time looking at the eyes out of the time spent looking at faces (Walker-Smith, Gale, & Findlay, 1977). It seems evident that looking at the eye region of faces facilitates emotion recognition. This corroborates with the findings of Dadds et al., (2006), which demonstrated that adolescents with psychopathic symptoms were impaired in their recognition of fearful faces, but that instructing them to focus on the eyes of fearful faces significantly increased their ability to recognise fear. This association has also been found in the autistic population. For example, Jones et al., (2008) found that two year old children with ASD were found to look significantly less at the eyes of an actress initiating activities with them compared to control children. This lack of time spent looking at the eyes was also found to determine the extent of social difficulties (as measured by the ADOS) in the ASD group.

Additionally, for a FER task specifically, investigating eye gaze patterns can reveal whether children with ASD are impaired because they do not view the relevant areas of the face (as appears to have been the case in the Dadds et al., study) or whether difficulties are the result of misinterpreting the emotion shown on the face (Black et al., 2017; Serrano et al., 2015). If difficulties are found to lie at viewing relevant areas of the face, then this could suggest that interventions that involve encouraging participants to look at the eyes could improve emotion recognition problems. This seems to have been the case with the study by Dadds et al., (2006) of children with psychopathic traits. Alternatively, if the deficit appears to be unrelated to eye looking patterns then this suggests that a deficit exists in identifying emotions themselves from facial features. If this is the case then interventions that focus on understanding and interpreting facial cues would be more appropriate.

Evidently, using eye tracking technology is particularly beneficial as it provides more information about the cause of facial emotion recognition deficits as well as guiding future interventions. Despite this advantage of combining emotion identification and eye tracking, most ASD studies have tended to investigate either facial emotion recognition using a response task alone (e.g. Buhler, Bachmann, Goyert, Heinzel-Gutenbrunner, & Kamp-Becker, 2011; Dyck, Ferguson, & Shochet, 2001) or just examined visual attenuation to faces with eye tracking technology (de Wit, Falck-Ytter, & von Hofsten, 2008; Van Der Geest, Kemner, Verbaten, & Van Engeland, 2002). Few studies have combined a response task with eye tracking to provide a more comprehensive investigation of facial emotion recognition in ASD.

Indeed, a recent review of eye tracking studies in autism (Black et al., 2017) refers to only four studies of children with ASD that use both a FER response task and eye tracking in their study design. Two of the studies were conducted by the same authors (Bekele et al., 2014; Bekele et al., 2013), and both aimed to examine the use of a virtual reality programme to test FER using avatar faces telling emotional stories. This story telling was followed by the avatar making a story appropriate emotional expression (enjoyment, sadness, fear, anger, surprise, disgust or contempt) for five seconds, in which participants were instructed to name the emotion while the eye movements were tracked. In both studies, participants with ASD looked significantly more at the forehead and significantly less at the mouth when identifying the emotion compared to controls. No difference was found for the time spent looking at the eyes. As previous studies have found that individuals with ASD preferentially look less at the eyes and more at the mouth region, this is an unexpected finding which may be accounted for by the design of the avatar faces. For instance, as the authors noted, the forehead and mouth regions altered the most across the different emotions, and the eye region was small. This suggests that contrary to typical faces, looking at the forehead and mouth regions may prove more effectual in decoding the facial emotion in this specific task. This can be supported by the finding that emotion naming accuracy did not differ between the groups, and both participants with ASD and typically developing individuals looked more at the mouth region when they correctly identified the target emotion. Consequently, it does seem that using these avatar faces with different feature proportions and emotional reactions might not be appropriate when investigating facial emotion recognition. This calls into question the findings of the two Beleke and colleagues' studies included in the meta-analysis (Black et al., 2017).

The other two studies included in the Black et al., (2017) meta-analysis used human faces, and so were more in line with previous literature on facial emotion recognition. Bal et al., (2010), used photos of neutral faces slowly morphing into each of the six basic emotions as stimuli. They found that elevated ASD symptoms were associated with less accurate emotion recognition, particularly regarding recognition of anger. A tendency for reduced gaze to the eye region of faces and increased gaze to the mouth region or the rest of the face was also identified in ASD participants. However, this difference in eye gaze did not reach statistical significance, perhaps due to the small sample size of 12 children with ASD who had eye tracking data. Similarly, McCabe et al., (2013) found that ASD participants spent significantly less time looking at emotional faces (photographs of the six basic emotions) and had lower emotion accuracy scores than controls. Consequently, the initial evidence based on these two studies of human faces suggests that eye movements do impair the emotional processing of faces in autism. However, these studies involved small ASD sample sizes (between 12 and 17 participants with ASD in each study) and did not explore whether eye gaze was directly related to emotion recognition accuracy. Therefore, it seems that further investigation into the relationship between eye looking patterns and emotion recognition is needed in ASD research.

1.4.2 Empathy in children with ASD

Empathy deficits in those with ASD have long been considered as characteristic of the disorder (Baron-Cohen, 2002; Gillberg, 1992), and prominent theories of autism have emerged from these findings (Baron-Cohen, 2002; Smith, 2009). One theory is the empathy imbalance hypothesis, proposed by Smith (2009). This theory incorporates both facets of empathy, and states that most children with autism have reduced capacity for cognitive empathy, while their affective empathy is intact or even heightened.

Numerous studies have supported this hypothesis. Demurie et al., (2011) investigated cognitive empathy in children using an empathic accuracy task. The accuracy task involved looking at short video clips of naturalistic interactions between five adolescents. The adolescents in the clips had been asked to state their own emotions during the recorded interaction, and participants in the study were asked what they thought these emotions were. Scores were based on accuracy, and results revealed that children with ASD had significantly lower scores than typically developing peers. The study also used the Interpersonal Reactivity Index (Davis, 1983), a questionnaire measure that tested different aspects of empathy including perspective-taking (understanding other's feelings) and personal distress (feeling upset in reaction to the emotion of others). The questionnaire was answered by both the child and their parent separately. Combined parent and child scores showed that children with ASD had significantly lower scores than children with ADHD and controls across all aspects of empathy, however if only parent scores are compared, children with ASD are rated as having the lowest levels of perspective taking (which roughly corresponds to cognitive empathy) but similar levels of personal distress (a feature of affective empathy) as the rest of the sample. Overall, studies do suggest that children with ASD have impaired cognitive empathy.

Other studies have investigated affective empathy in children with ASD. Jones et al., (2010) tested affective empathy in children using a self-report measure formed of vignettes. The vignettes comprised of stories of negative behaviour towards peers, and children were asked to imagine that they themselves had caused the harm, and how they would feel as a result. The study found that children with ASD did not differ in affective empathy scores to typically developing children. Similarly, Hundry and Slaughter (2009) investigated affective empathy by providing situational based questionnaires that asked mothers to imagine how their child might react, such as how they would behave if another child fell and cried. Again empathic responses were rated as occurring to the same extent in both children with ASD and IQ matched controls. Another study (Sigman et al., 2003) measured the heart rate and visual fixations of children with ASD and controls as they watched videos of a baby crying or happily playing. Results showed that children with ASD showed evidence of affective empathy through changes in heart rate and visual fixations similarly to controls.

Studies investigating empathic ability in adults with ASD have shown the same pattern of results (e.g. Kirchner et al., 2011). For example, Dziobek et al., (2008) tested both cognitive and affective empathy using the Multifaceted Empathy Test (MET) in adults with ASD and controls. The test involves presenting photographs of people in emotionally charged situations, for which participants were required to explain the person's emotion (cognitive empathy) and their own emotion (affective empathy) while viewing the photos. Results were in line with the empathy imbalance hypothesis; adults with ASD were impaired in cognitive empathy but affective empathy was intact.

Only one study, Schwenck et al. (2012), has directly tested both cognitive and affective empathy using behavioural tasks in children with ASD. The study tested the empathic abilities of male adolescents with ASD using a video sequences task. Children watched nine video clips and were asked to state the emotion of the protagonist and why (cognitive empathy) as well as how they felt after watching the clips (affective empathy). Results were in line with the empathy imbalance hypothesis; children with ASD were impaired in cognitive empathy but affective empathy was intact. Consequently it seems that referring to ASD simply as an empathy disorder is misleading; deficits appear to lie solely in understanding the emotions of others and the reasons why. Children and adults with ASD have been shown to feel as much care and concern for the emotions of others as typically developing children and adults.

An understanding of participants' eye movements when taking part in empathy tasks may be particularly useful in understanding whether information avoidance or misinterpretation of emotions causes cognitive empathy difficulties. However, to my knowledge there are no studies that examine empathy in children with ASD that have used eye tracking technology. Smith's empathy imbalance theory (2009) seems to suggest that studies that use eye tracking may be particularly valuable in finding out more about this social cognitive ability in an ASD population. As previously discussed, Smith's theory states that while individuals with ASD have impaired cognitive empathy, their affective empathy is intact or even heightened. Smith further elaborates his theory to suggest that children with autism may suffer from an excess of affective empathy due to over arousal. A study by Capps et al., (1992) supports this view, finding that children with ASD expressed more empathic facial affect while looking at emotion inducing photos of children compared to controls. This could mean that children with ASD find more intense emotions difficult to process as they feel more distressed. This view can be supported by findings from facial emotion recognition studies that, whilst impairment is shown across all emotions, children with ASD find fear and anger the most difficult emotions to identify (Lozier et al., 2014). This could also account for the tendency for children with ASD to look less at the eyes and more at the mouths of faces

(Papagiannopoulou et al., 2014). Consequently, investigating empathy using eye tracking may help to uncover the reasons for impaired cognitive empathy in those with ASD.

1.4.3 Theory of mind in children with ASD

There have been many studies that have identified theory of mind as an ability that is often impaired in individuals with ASD (for a review, see Frith, 2012). False belief is perhaps the most frequently used paradigm to test theory of mind. In contrast to typically developing children who seem to unequivocally pass false belief tasks by age five years (Callaghan et al., 2005) children with ASD seem to be significantly less likely to pass these until they reach the age of 13 years or a verbal mental age of nine years (F. G. Happé, 1995). For example, one popular false belief test is the Sally-Anne task, which is often acted out by experimenters using puppets or dolls to demonstrate a sequence of events where an object is moved from the place Sally left it in by Anne, out of the view of Sally. Participants are then asked where Sally would look for the object. Studies found that children with ASD more frequently incorrectly stated Sally would look for the object where Anne had placed it, than children without ASD (e.g. Baron-Cohen et al., 1985). Recently, a computer version of the Sally-Anne task has been created which minimises the need for social interaction with the experimenter in order to engage successfully in the task (Carlsson, Miniscalco, Gillberg, & Johnels, 2018). Results revealed that children with autism continued to be impaired in comparison to typically developing peers. More complex false belief tasks such as the three stories: the ice cream van, the coat and the puppy birthday present (Perner & Wimmer, 1985; Tager-Flusberg & Sullivan, 1995), require children to show what a character thinks about another character. This is an example of a second order false belief task, and children with ASD have also been shown to find these tasks more difficult than typically developing children (e.g. Norbury et al., 2005).

Studies have shown that older children and adults with ASD who have average or above IQ are often able to pass false belief tasks (Bowler, 1992; Ozonoff, Rogers, & Pennington, 1991). These findings could suggest that non-theory of mind based strategies can be used to pass theory of mind tasks, as these children still present with social difficulties (F. G. Happé, 1993). As a direct result of these findings, more advanced theory of mind tasks were developed that appear to represent a more naturalistic complex understanding of mental states. One such advanced task is the Strange Stories Test (F. G. Happé, 1994). Participants are required to read a series of vignettes in which characters say something that is not really true. Participants then have to explain why characters have made these incorrect statements. For example, achieving full marks for one of the questions involves understanding that a character is telling a white lie to spare another character's feelings. These mental state stories are used in conjunction with physical state control stories, which do not involve mental states to provide a comparison. Results have revealed that children with ASD are impaired in interpreting mental state stories compared to typically developing children, while their performance in the control stories was intact (F. G. Happé, 1994; Mazza et al., 2014).

The Strange Stories Test was revised with alterations to the original stories as well as the addition of animal and nature stories and unlinked sentences (White et al., 2009). These additional story elements are intended to differ in their mentalising components, from the mental state stories that elicit the greatest degree of mentalising, to the unlinked sentences which require no mentalising. All stories used are also now carefully controlled for difficulty. Using these revised versions of the Strange Stories Test, White and colleagues (2009) found children with ASD had significantly lower scores than typically developing children when answering the mental, human and animal stories, with the greatest level of impairment found for the mental state stories and the least for the animal stories. In addition, children with ASD that passed first and second order false belief tasks (Sally-Anne, the Ice Cream van, Birthday Puppy and Coat stories) were still impaired compared to controls when answering questions in the Strange Stories Test. Consequently, this task emerges as more sensitive to theory of mind impairments than false belief tasks and therefore more suitable for children and adults with autism who have average and above intellectual ability.

Another more advanced and sensitive theory of mind task is the Frith-Happé triangles animations (Abell, Happé & Frith, 2000; See Chapter 3, section 3.3.1 for further information on this task). These are animated cartoon clips of two triangles shapes moving around, that last approximately 40 seconds each. The clips either demonstrate theory of mind interaction between the triangles, or merely goal directed actions or random movements that do not elicit mentalising. Participants are asked to state what the triangles are doing in the clips. Importantly, these triangles do not have faces (see Figure 3.3.1), and as a result facial emotion recognition difficulties (see Introduction section 1.3.1 and chapter 3.1) do not interfere with the participants' responses. Simply asking participants what the triangles are doing, rather than asking a specific question like the Strange Stories Test, also facilitates a more naturalistic, free-flowing response that determines if individuals with ASD will use mental state language without being specifically directed to do so. An eye tracking theory of mind study (Freeth et al., 2010) found this free viewing technique elicited natural responses from their ASD participants in their static scene watching task.

The triangles task has frequently been used to test theory of mind ability in young people and adults with ASD, with all studies finding that children and adults have significantly lower scores than typically developing individuals for the theory of mind clips, whereas scores for goal directed and/or random clips are not different (Abell, Happé & Frith, 2000; Castelli, Frith, Happé & Frith, 2002; Schwenck et al., 2012; Ricketts et al., 2013; Salter et al., 2008). The sensitivity of the triangles task to finding true theory of mind difficulties was also explored (Abell, Happé & Frith, 2000) and similarly to the Strange Stories Test (White et al., 2009), children with autism who passed false belief tests were impaired when describing the theory of mind clips.

Evidently, children with ASD often have theory of mind deficits. However, as previously discussed, the reasons for this impairment have been debated by competing theories. One theory, the EF hypothesis describes domain-general cognitive difficulties in ASD that reduce theory of mind ability through affecting skills such as working memory and inhibition (Hill, 2004; Russell, 1997). This can be supported by previous studies finding that there is an association between theory of mind and EF in children with ASD (Kimhi, Shoam-Kugelmas, Ben-Artzi, Ben-Moshe, & Bauminger-Zviely, 2014; Ozonoff, Pennington, & Rogers, 1991; Pellicano, 2007).

However, implicit social cognition tests that involve measuring spontaneous looking patterns and require very limited EFs have still identified social cognition deficits in children with ASD compared to controls. For example, in one study (Schneider, Slaughter, Bayliss, & Dux, 2013) childrens' eye looking patterns were measured used eye tracking software while they watched a number of film clips portraying false-belief interactions. Children also completed standard explicit false-belief tasks. Results showed that children with ASD demonstrated theory of mind deficits as they did not show any evidence of tracking the false-belief interactions, while controls were able to do this successfully. Their explicit false-belief scores, on the other hand, were not different to controls. In support of this, a recent study of over 100 adolescents with ASD (Jones et al., 2018) found that although performance on a theory of mind task correlated with EF measures, there was no direct association between EFs and parent reported ASD symptomology. Whereas theory of mind scores were directly associated with ASD symptoms. Consequently, it appears that although EFs are related to theory of mind performance, they do not emerge as the primary candidate for theory of mind difficulties in children with ASD.

Alternatively, the theory of mind hypothesis is in direct opposition to the EF hypothesis, as it proposes that theory of mind deficits represent a core feature present in ASD, and are responsible for the all the social interaction and communication impairments associated with autism in childhood (Baron-Cohen et al., 1985). The numerous studies finding theory of mind impairments in ASD, as discussed in this section, could be perceived as evidence for this theory. However, studies have questioned the utility of the theory of mind hypothesis, as autism diagnosis includes restricted and repetitive behaviours, which are not explained by the theory (for a review see Tager-Flusberg, 2007). In addition, as discussed in this section, there are two other distinct social cognitive skills, empathy and FER, and deficits in these tend to be found before theory of mind has developed in childhood (Frith & Happé, 1994; Klin, Volkmar, & Sparrow, 1992). Ultimately, this section has shown that however they arise, theory of mind deficits are common, and are found across different tasks. Overall this section on ASD and social cognition has discussed evidence that children with ASD are often impaired in facial emotion recognition, cognitive empathy and theory of mind in comparison to typically developing children. Task design has been shown to be paramount in creating naturalistic stimuli to test social cognitive abilities and through the use of eye tracking technology to uncover the reasons surrounding deficits.

1.5 Social cognition in children with ADHD

Unlike the diagnostic criteria for ASD, social cognition deficits are not part of the diagnostic criteria for ADHD (APA, 2013). However, social dysfunction is frequently viewed as a feature of ADHD (Barkley, 1998; Nijmeijer et al., 2008; Uekermann et al., 2010) and arguably the most incapacitating characteristic of the disorder (Nijmeijer et al., 2008). Early studies found that children with ADHD demonstrate a reduced understanding of social information (Dodge & Newman, 1981) and have difficulty in interpreting the cues of social interaction (Cunningham & Siegel, 1987). As a result, children with ADHD are often found to have few friends, and have problems with maintaining friendships (Becker et al., 2006; Meltzer, Gatward, Goodman, & Ford, 2003). Not all children with ADHD demonstrate difficulties with social cognition, for example, Greene (1996) found that 22% of children diagnosed with ADHD in their study had social functioning deficits. Whereas other studies have estimated that around 50% of children with ADHD have social difficulties (Barkely et al., 2006).

Social cognition difficulties in those with ADHD are often believed to arise from executive dysfunction, which is often considered to be a characteristic of ADHD (Nijmeijer et al., 2008; Buhler et al., 2011, Crippa et al., 2014) and has previously been discussed regarding reading difficulties in ADHD (see 1.2.1). A strong relationship between theory of mind and EFs has also been suggested; poor inhibitory control, cognitive inflexibility and poor working memory seem to hinder the development of social cognition (Yang et al., 2009; Korkmaz, 2011). This is because holding stimuli in working memory and making considered (rather than impulsive) decisions are paramount to all three social cognitive abilities (Charman et al., 2001). Brain imaging studies have lent support to this view by demonstrating that lesions to the orbitofrontal cortex region of the brain, an area that is implicated in socially appropriate behaviour, have also been found to be linked to executive dysfunction (Uekermann et al., 2010).

This may not, however, be the full story. Research has suggested that although executive dysfunction contributes to deficits in social cognition, there may also be an underlying social processing deficit in ADHD (Bora & Pantelis, 2015; Graziano & Garcia, 2016; Uekermann et al., 2010). For example, Yuill and Lyon (2007) found that children with ADHD continued to be impaired in an emotion recognition task after an inhibitory scaffolding procedure was introduced, which prevented children from identifying emotions without first considering the emotional response options. Interestingly, the children were no longer impaired in a matched non-emotional recognition task, implying a specific emotional deficit. A study by Kofler et al., (2011) that investigated EF and social problems in children with ADHD can provide further support for this, as the study found no direct link between EFs and parent reported social problems (defined as difficulties across social domains and social functioning and behaviour). Results instead revealed that social problems were indirectly related to EFs through inattentive and hyperactive-impulsive symptoms that seemed to constrain EFs, particularly working memory. Consequently, as EF deficits cannot fully account for the social difficulties that are often experienced by children with ADHD, this does suggest that there could be an underlying social processing deficit in ADHD. However, it should be noted that in some studies the concept of a social processing deficit in ADHD has been linked to comorbid CD symptoms and diagnosis (Nijmeijer et al., 2008). Some researchers also question whether social difficulties in those with ADHD are intensified by the presence of other developmental disorders, such as ASD, although this has not been sufficiently investigated (Nijmeijer et al., 2008; Bora & Pantelis, 2015). This overlap will be explored later in the introduction.

Social dysfunction has been referred to as particularly important in determining the outcomes of children with ADHD (Greene et al., 1996). Indeed, social difficulties in children with ADHD have been found to be related to later substance abuse (Greene et al., 1999). Ying et al., (2016) additionally found that emotion dysregulation in children with ADHD predicted poorer educational outcomes such as a greater number of suspensions from school in adolescence. The difficulties individuals with ADHD have in creating and maintaining friendships, (Buhrmester, Whalen, Henker, MacDonald, & Hinshaw, 1992; Erhardt & Hinshaw, 1994; Grenell, Glass, & Katz, 1987; Pelham & Bender, 1982) adjusting to higher education (Shaw-Zirt, Popali-Lehane, Chaplin, & Bergman, 2005) and staying in employment (Barkley et al., 2004) have also been suggested to originate from difficulties with social dysfunction (Nijmeijer et al., 2008). Consequently, the impact of social dysfunction on the prognosis of those with ADHD is manifest. However, as not all individuals with ADHD have such deficits (Barkley et al., 2006; Greene et al., 1996) it is important to identify those that may be at risk of social cognition deficits.

1.5.1 FER in children with ADHD

Studies investigating facial emotion recognition in children with ADHD have shown that deficits compared to controls are common. For example, Aspan (2014) found that adolescent boys were impaired in their recognition of sadness and fear compared to typically developing boys. Other studies have also reported impairments in recognising sadness and fear (Pelc et al., 2006) or found deficits across all six basic emotions (Justye et al., 2017; Da Fonesca et al., 2009).

It has been suggested that emotion recognition deficits in those with ADHD are related to the ADHD specific symptoms of inattention and/or impulsivity (Ibanez et al., 2011; Uekermann et al., 2010). It does seem logical that mistakes are made by a failure to pay attention to the faces used in these tasks, or simply through choosing an emotion without considering the options. In support of this argument, Sinzig et al., (2008) found that performance in sustained attention and inhibition tasks was associated with emotion recognition accuracy. In addition, Miller et al., (2011)found that the number of errors made when identifying sadness positively correlated with self-reported inattention symptoms.

Despite evidence of an association between ADHD symptoms and social cognitive difficulties, evidence suggests that these ADHD symptoms cannot completely account for FER task difficulties. Yuill and Lyon (2007) tested participants using two FER tasks; one with emotional faces and the other with non-emotional faces. Results revealed that children with ADHD were similarly impaired compared to controls in both tasks. However, after repeating the experiment with an inhibitory scaffolding procedure, which ensured participants made informed decisions when identifying the facial expressions, children with ADHD were only impaired in the emotional faces FER. This suggests that there is an underlying social processing deficit in children with ADHD. This can be supported by studies by Kats-Gold et al., (2007) and Pelc et al., (2006) finding that the emotion recognition abilities of children at risk of ADHD and children diagnosed with ADHD were found to be negatively associated with their social functioning and interpersonal problems.

As with studies of individuals with ASD that explore FER, eye tracking has also been used to understand emotion recognition in children with ADHD, although such studies are rare. Monitoring of visual attention using eye tracking technology is also valuable through helping to determine the extent to which inattention to stimuli can effect emotion recognition ability. Serrano et al., (2015) used a FER task in conjunction with eye tracking to test adolescents with and without ADHD. Results revealed that children with ADHD who were faster to respond or made more fixations to the eye and mouth regions of the faces were better at emotion recognition. However, the authors found that although teacher rated inattention symptoms were related to response times, there was no relationship between inattention and fixations to the eye and mouth regions. Instead, hyperactive-impulsive symptoms were related to both response times and fixations; children with higher symptoms took longer and made less fixations. Notably, this study did not use an inhibitory scaffolding procedure to manage impulsive responding. Taken together, the results of Yuill and Lyon (2011) and Serrano and colleagues (2015) indicate that although inattention and impulsivity symptoms do appear to aggravate FER ability, these symptoms cannot fully account for FER deficits. This does suggest that children with ADHD could instead have an underlying emotion processing deficit. However, Yuill and Lyon (2007) and Serrano and colleagues (2015) did not look at the comorbid ASD or CD symptoms of the participants in their studies, both of which are often associated with impaired FER (Lozier et al., 2014, Sully et al., 2015). This thesis is therefore an important extension of such work.

Ultimately, as with ASD literature on FER, it seems that looking at both eye tracking and FER response tasks can tell us more about emotion recognition in ADHD, but studies exploring this are rare, with only a single published study looking at the combination of emotion recognition and eye tracking simultaneously. The impact of ASD and CD should be taken into account to gain a greater understanding into the interplay between disorders and facial emotion recognition. This is explored fully in the overlap section of this introduction.

1.5.2 Empathy in children with ADHD

To my knowledge, there are only four studies that have investigated empathy in children with ADHD that utilised a control group to compare performance. The lack of research in this area has been noted by reviewers of ADHD literature (Uekermann et al., 2010). Of these four studies, two investigated the role of ADHD in cognitive empathy skills only. Dyck, Ferguson and Shochet (2001) tested children's performance on a number of social cognitive tests, including a comprehension test that measured the children's ability to understand character's emotions in specific emotional situations (cognitive empathy) such as finding out their bike had been stolen. Children with ADHD were not found to differ in performance to children without psychological disorders. Demurie et al., (2011) also tested empathic accuracy (cognitive empathy) in children with ADHD as well as testing children with ASD, and found that scores of children with ADHD were at an intermediate level, and did not differ significantly from children with ASD or typically developing children.

Researchers have also examined affective empathy performance in children with ADHD. Marton et al., (2009) used a parent reported questionnaire of their children's responses to other people's distress (affective empathy) to measure empathy in children with and without ADHD. They also used a self-report questionnaire, again assessing affective empathy, where the child considered their own emotional reaction to situations such as "[i]t makes me sad to see a boy who can't find anyone he can play with". The study revealed that while children's accounts of their own empathy did not differ between groups, the parents of children with ADHD rated them as less empathetic than those without ADHD.

In addition, Braten and Rosen (2000) investigated affective empathy by telling children eight stories with accompanying photos of the character (with blanked out faces) in the situation depicted by the story. Children were asked what emotion the character felt, and then what emotion they felt themselves; this was the match task and was scored for the extent of match between the two emotions identified. The second part of the task required children to explain why the character made them feel the way they did. This was scored in terms of interpretation; a higher score indicated a more character focused explanation. Results showed that children with ADHD had significantly lower match and interpretation scores than typically developing controls. Consequently, the opposite profile to ASD emerges, it appears that there is some evidence to suggest that children with ADHD have intact cognitive empathy while their affective empathy is impaired. However, as few studies have investigated the role of empathy in children with ADHD, this conclusion requires further explanation.

1.5.3 Theory of mind in children with ADHD

Individual research studies have had mixed findings as to whether theory of mind impairments are typical for children with ADHD (Bora & Pantelis., 2015). Buitelaar et al., (1999), in an often cited study, tested children's theory of mind ability using first order tasks such as Sally-Anne and second order tasks including the false belief ice cream story. Results showed that children with ADHD performed at a similar level to those with ASD and were impaired compared to controls. Similarly, Buhler et al., (2011) found that the performance of children with ADHD in the Heider and Simmel animated shapes task (Heider & Simmel, 1944) did not differ from that of children with ASD, implying a similar deficit. Other studies, such as Caillies et al., (2014), also identified theory of mind deficits. The researchers found that children with ADHD were impaired in their scores for both a second order false belief task and understanding ironic stories compared to controls.

Conversely, Charman, Carroll and Sturge (2001) investigated the performance of boys with and without ADHD on the Strange Stories Test, and found that scores did not differ between the groups. Dyck et al., (2001) using the same task, found that children with ADHD were not found to have theory of mind deficits. One reason for these differences across the studies could be the tasks used. Tasks designed for autistic participants, such as false belief tasks may not always be suitable for children with ADHD who are often found to problems with EFs and attention (Buhler et al., 2011; Crippa et al., 2014) or reading difficulties (McIntyre et al., 2017; Sexton, Gelhorn, Bell, & Classi, 2012). Consequently, using an appropriate task is important to ensure that poor theory of mind task scores in children with ADHD are not simply just a reflection of poor reading, executive dysfunction and inattention (see Chapter 3, section 3.3.1 for further discussion).

Summarising across different studies, a meta-analysis by Bora and Pantelis (2015) found a significant association with a medium effect size for theory of mind studies, suggesting that children with ADHD do seem to have theory of mind deficits across studies. The majority of these theory of mind studies used false belief tasks or the strange stories task, which, as previously discussed, could be inappropriate for children with ADHD. In addition, although this meta-analysis found a greater level of impairment in children with ASD compared to ADHD, they were not able to examine the effect of co-occurring ASD symptomology as this was not examined in any of the studies they reported. Consequently, potentially unsuitable theory of mind tasks, as well as overlapping disorders such as ASD and CD could account for some of the differences found in individual ADHD theory of mind studies (See Chapter 3.3 an exploration of these views).

1.6 Social cognition and the overlap between disorders

Despite the high level of comorbidity between ADHD and ASD (Rommelse et al., 2010), previous literature examining the overlap in relation to social cognition in childhood has been sparse. In contrast, research examining the overlap between ADHD and CD has increased in recent years, although there continues to be a noticeable lack of studies examining the overlap of ADHD and CD in relation to theory of mind specifically.

The few studies that have investigated the overlap between ADHD and ASD have been FER studies. For example, when using the reading the mind in the eyes (RMET) task to examine the neurological profile of children with both disorders, Colombi and Ghaziuddin (2017) found that children with both ADHD and ASD had significantly lower scores than children with a diagnosis of ASD alone. Similarly, Oerlemans et al., (2014) found that children with ASD and ADHD had a poorer performance overall on an FER task compared to children with ASD alone. Sinzig et al., (2008) was the only study that compared four groups, those with ASD and ADHD alone, controls and those with ASD + ADHD. Surprisingly, Sinzig et al., (2008), found that while the ADHD and comorbid group were impaired compared to controls, this was not the case for the ASD alone group, suggesting that ADHD symptoms are driving FER difficulties. All these studies demonstrate that the presence of comorbid diagnoses have a detrimental effect on FER ability. However, none of these studies are able to account for these deficits as they have not utilised eye tracking technology to determine whether the deficit lies in the initial processing stage or in interpreting the emotions. As previously discussed in this introduction, the use of eye tracking in ASD alone and ADHD alone studies has provided a more in-depth account of atypical eye looking patterns when viewing faces (Papagiannopoulou, Chitty, Hermens, Hickie, & Lagopoulos, 2014; Serrano et al., 2015). Research studies combining both FER tasks and eye tracking are rare in studies of individuals with ASD or ADHD alone, and to date there are no FER studies investigating the role of comorbid ADHD and ASD.

An eye tracking study by Groom et al., (2017) suggests that using eye tracking to examine the overlap between these disorders may be particularly enlightening. The authors investigated attenuation to neutral faces and the overlap between ASD and ADHD using electroencephalography and eye tracking. Results revealed that children with ADHD had a similar pattern of face viewing and eye gaze to typically developing controls, whereas children with ASD or comorbid ASD + ADHD had different gaze patterns. This provides evidence that FER ability in ADHD may be affected by ASD diagnosis and that eye tracking technology can be effective in investigating this. Evidently, studies that consider the overlap between ADHD and ASD are needed that utilise FER task that tests different emotions while also monitoring eye movements.

Eye tracking could also be a fruitful area of research for empathy studies in children with comorbid ASD and ADHD. To my knowledge, there have been no studies that have investigated the effect that overlapping ASD and ADHD symptoms have on empathy ability, with or without eye tracking technology. As with FER studies, when using laboratory tests to study empathy, an understanding of participants' eye movements could help to determine whether avoidance or inattention, rather than a lack of understanding of character's emotions, accounts for any observed cognitive or affective empathy deficits. For example, Klin et al., (2002) used six emotional video clips from the film "Who's afraid of Virginia Woolf" to test eye movements. Adults with ASD were found to follow the expected pattern of looking less at the eyes and more at the mouth. However, the task did not include a verbal response from participants, so it was not clear if their eye movements affected their empathic reasoning. It would also be interesting to determine whether ADHD symptoms affected viewing patterns. Co-occurring ADHD symptoms could further reduce eye gaze due to inattention or an emotional processing deficit. Consequently, investigating empathy using eye tracking in conjunction with verbal reports may be the most useful paradigm to understand the empathic ability of children with ASD as well as ADHD.

Literature examining theory of mind in relation to the overlap between ADHD and ASD has also been extremely limited. To date, only two studies have sought to investigate this comorbidity. First, Buhler et al., (2011) looked at performance in the Heider and Simmel animated shapes task (Heider & Simmel, 1944) between participants with ADHD or ASD or both disorders. Results found no difference in performance between the groups, suggesting all participants were similarly impaired. However, results were hampered by a number of methological limitations, including the lack of a control group, the large age range of five to 22 years, only exploring results diagnostically, and the fact that some participants in the ADHD group had a diagnosis of CD, which may have affected group comparisons. The second study by Colombi and Ghaziuddin (2017) had similar results, finding no difference in the scores of the strange story task between a group of children with ASD compared to a comorbid ASD + ADHD group. Like the first study, this study also did not have a control group, and only looked at the groups diagnostically. The lack of control groups to compare scores meant that these studies were not able to determine whether theory of mind deficits were present. Investigating the groups only diagnostically rather than looking at symptoms could mean that the true effect of elevated symptoms could have been missed. As a result, further research needs to be carried out to investigate the role of the overlap between ASD and ADHD in relation to theory of mind ability.

In contrast, the overlap between ADHD and CD in relation to empathy and facial emotion recognition has received greater attention from researchers. Although there are limited studies investigating empathy in children with ADHD, it does appear that CD may be driving reported affective empathy deficits. Several studies have found that children with CD have a reduced affective empathy ability (Kostić, Nešić, Stanković, Žikić, & Marković, 2016; Pijper et al., 2016; Schwenck et al., 2012). This also corroborates with Smith's empathy imbalance theory (Smith, 2009) in which people with CD are described as having the opposite empathy profile to those with ASD; intact cognitive empathy and impaired affective empathy.
Marton et al., (2009) can provide further support for this finding in their study of the role of

CD symptoms on parent and self-report empathy questionnaires. Although finding that children diagnosed with ADHD were rated by their parents as demonstrating lower levels of affective empathy compared to controls, this group difference was revealed to be accounted for by comorbid CD symptoms. Two studies using the same task can provide further evidence for this (Airdrie, Langley, Thapar, & Van Goozen, 2018; Van Goozen et al., 2016). These studies used film clips to test cognitive and affective empathy in children with ADHD, some of whom also had CD. Results from both studies revealed that affective empathy scores were associated with CD symptoms alone, not ADHD severity, and that those with a combined diagnosis of ADHD and CD had a greater impairment than ADHD alone. Overall, this suggests that CD has an additional effect on the affective empathy performance of children with ADHD.

CD has also been found to contribute to FER deficits in ADHD. Two studies (Airdrie et al., 2018; Van Goozen et al., 2016) tested participants on their recognition of emotions using Ekman faces (Ekman & Friesen, 1976) and found that adolescents with ADHD and CD were impaired in the recognition of fear compared to participants with ADHD alone. This difficulty with interpreting fear has frequently been found in previous studies of children with CD (Fairchild, Van Goozen, Calder, Stollery, & Goodyer, 2009; Martin-Key, Graf, Adams, & Fairchild, 2018) and together with this recent research it seems that FER difficulties in ADHD are aggravated by the presence of CD. This can also in part account for the mixed findings in FER studies in ADHD populations (Bora & Pantelis, 2015), as the role of CD is not often taken into account.

On the other hand, the relative contribution of CD symptoms to theory of mind ability in children with ADHD has not been examined. Theory of mind is often regarded as intact in those with CD, while affective empathy and FER are impaired (Bowen & Dixon, 2010; Decety et al., 2009; Fairchild et al., 2009; Jones et al., 2010). However, some studies have identified theory of mind difficulties in children with CD using parental report (Green, Gilchrist, Burton, & Cox, 2000; F. Happé & Frith, 1996; Oliver et al., 2011) and a faux pas task (Arango Tobón, Rosa, Restrepo Tamayo, & Puerta Lopera, 2018). Few studies examining ADHD and theory of mind have considered the role of CD (Bora & Pantelis, 2015) and even studies of theory of mind in children with CD alone are sparse (Nijmejer et al., 2008) with some finding that children with CD are impaired (Oliver et al., 2011; Green et al., 2000; Happé & Frith, 1996) and others not (Charman, Carroll, & Sturge, 2001; O'Nions et al., 2014; Schwenck et al., 2012). Shuai et al., (2011) as far as I am aware, is the only study to directly compare children with ADHD to children with both ADHD and CD whilst investigating theory of mind. This study found that both groups of children had significantly lower scores in a false belief task than controls. However, the study only examined the groups diagnostically, and the ADHD plus CD group included children with comorbid CD or oppositional defiant disorder (ODD), making it difficult to assess the unique contribution of CD to theory of mind difficulties. Consequently, further research is needed to discover whether CD per se has an additional negative effect on the theory of mind performance of children with ADHD.

Finally, as research has shown that both children with ASD and ADHD have social cognition deficits (White et al., 2009; Bora & Pantelis, 2015), it is plausible to believe that having a diagnosis or elevated symptoms of both disorders increases the risk of having more pronounced social cognition impairment across all three skills. There is some evidence for this; Taylor et al., (2013) found in a large scale twin study that traits of ADHD at age eight years predicted ASD traits at age 12 years, as well as a greater level of social communication difficulties. Factor et al., (2017) found that children with ASD and heightened ADHD symptoms had higher scores on a parent reported questionnaire of social difficulties for both the social communication and social awareness subscales than children with ASD alone. Consequently, research that focuses directly on the role of ADHD and ASD on each social cognitive ability, while taking CD into account, could help to determine those sub-groups that are at the greatest risk of specific social cognition deficits in order to target interventions effectively.

1.7 Literacy skills and social cognition and the overlap between disorders

The studies presented in this introduction have demonstrated that specific reading comprehension deficits and social cognition deficits across facial emotion recognition, empathy and theory of mind are common in autistic people. In contrast, research into those with ADHD has tended to find basic reading and spelling impairments alongside social cognition deficits, although fewer studies have been conducted and identified impairments have not been found to be consistent. Studies that investigate the overlap between these disorders are rare, and no studies have investigated the links between literacy skills and social cognition while exploring the relative contribution of ASD and ADHD symptomology.

Investigating the relationship between reading comprehension and social cognition in ASD is important for the development of efficacious interventions. Many previous studies have utilised a variety of interventions to help to improve social cognition in children with ASD (for a review, see Ke, Whalon, & Yun, 2018), and other studies have focused on improving literacy skills (for a review, see El Zein, Solis, Vaughn, & McCulley, 2014). However, if a relationship is found to exist between these two skills in ASD, then interventions could be tailored to support progression in both skills simultaneously. There is some support for the existence of this relationship. Although not testing reading comprehension ability, Capps et al., (2000) found that children with ASD (N=13) gave poorer explanations of a wordless picture book story than typically developing children. The researchers were investigating the children's narrative ability, and found that children with ASD made fewer references to the characters' feelings and gave fewer reasons for their emotions. Within the ASD group, narrative ability was also found to correlate with scores from theory of mind tasks. Consequently, it does seem plausible that reading comprehension and social cognition skills are connected (see Chapter 4 for more detail).

However, in ASD research, only one study has directly investigated the relationship between reading comprehension and social cognition. Ricketts et al., (2013) used two theory of mind tasks, the strange stories test and triangles animation task, to measure social cognition in a large sample of 100 adolescents with ASD. Results revealed that combined social cognition scores predicted reading comprehension when oral language and basic reading were taken into account. This suggests that real world difficulties with mentalising also affect performance in reading comprehension tasks. However, Ricketts et al., (2013) did not have a control group in their study, which meant that it was not possible to ascertain whether this relationship between social cognition and reading comprehension is specific to ASD or found more generally.

Additionally, the authors only looked at two theory of mind tasks to test social cognition ability, and did not explore facial emotion recognition or empathy. As previously discussed in this section, the three main social cognitive abilities represent distinct skills, which demonstrates that an investigation of all three skills is necessary to explore social cognition. Ricketts et al., (2013) also did not examine the role of ASD symptoms in the relationship between reading comprehension and social cognition or take ADHD symptoms into account. As we have already seen, ADHD is also associated with social cognitive difficulties and is highly comorbid with ASD, consequently the role of additional ADHD symptoms should not be overlooked. Therefore, further studies are needed to identify the relationship between reading comprehension and social skills in ASD. If social skills are found to have a significant impact on reading comprehension performance then it follows that interventions can be effectively targeted to support both skills in children with ASD.

1.8 Summary, rationale and questions

This chapter has highlighted previous research into reading and social cognition abilities in children with ADHD or ASD. Children with ASD have been shown to often have difficulties with reading comprehension while basic reading skills are intact. Children with ADHD on the other hand often have basic reading and spelling deficits, while reading comprehension difficulties have not been conclusively associated. In fact, the full profile of literacy in ADHD has not been fully investigated, taking into account the role of IQ or in trying to identify specific strengths as well as deficits in literacy ability.

When research studies have investigated social cognition in those with ASD or ADHD, deficits in facial emotion recognition, empathy and theory of mind are found for both disorders. However, the results of social cognition studies in ADHD are often mixed, and this section has sought to suggest that difficulties could be driven or exacerbated by the presence of overlapping disorders such as ASD and CD.

The research discussed here has additionally demonstrated the need to explore reading comprehension and social cognition with specific consideration of the methodologies used. The efficacy of utilising eye tracking technology to establish where deficits lie in FER and empathy studies has also been discussed. Previous theory of mind research studies have shown that task selection is important to ensure it can differentiate between reading problems and attention, in order to specifically measure theory of mind ability.

Finally, what ultimately emerges from this introductory section is the limited number of studies investigating how the overlap between ADHD and ASD affects reading comprehension and social cognitive ability. When the high level of comorbidity between these disorders is considered, alongside FER literature suggesting that dual diagnosis leads to greater deficits, it becomes necessary to explore the relative contribution of ASD and ADHD at both symptom and diagnostic level. This will then assist in identifying the children that are at greatest risk of developing difficulties in these vital skills. Additionally determining whether there is a unique relationship between reading comprehension and social skills in children with ASD would prove particularly valuable in guiding school based interventions. Consequently, this thesis aims to address this lack of research through exploring the following three questions.

1. What is the profile of literacy skills in children with ADHD and are autistic traits associated with the reading comprehension performance of children with ADHD? (Chapter 2)

This will be investigated by examining basic reading, spelling and reading comprehension skills using a continuous measure of ASD symptoms in a sample of children with ADHD. This data comes from the first wave of an ADHD cohort study (the SAGE study). Due to a lack of previous literature examining the full literacy profile of children with ADHD, this will also be addressed.

2. Are autistic symptoms associated with social cognitive ability of adolescents with ADHD? (Chapter 3)

This will be investigated by examining each of the three social cognitive abilities in a sample of children with ADHD. First facial emotion recognition (3.1), then empathy (3.2) and finally theory of mind (3.3) will be investigated. This data comes from the second wave of the SAGE ADHD study. Alongside behavioural tasks, both the FER and empathy tasks will include eye tracking to measure eye looking patterns.

3. Are social cognitive skills associated with the reading comprehension ability of adolescents with ASD? (Chapter 4)

This final question will be investigated by examining both the reading and social cognition abilities of children with ASD compared to typically developing controls. The role of ADHD symptoms will also be examined. This will be investigated in a newly acquired sample which involved the collection of data from adolescents attending secondary schools across South Wales.

CHAPTER 2

Reading ability in ADHD and the effect of autistic traits

2.1 Introduction

Although not part of the diagnostic criteria, literacy difficulties are often experienced by children with ADHD (Semrud-Clikeman et al., 1992). As outlined in chapter 1, there is a high level of comorbidity between reading disability and ADHD (Willcutt et al., 2000; K. Yoshimasu et al., 2010) with between 15-45 % of children selected for ADHD in studies using community and clinical samples meeting diagnostic criteria for reading disability (Sexton et al., 2012). Impaired reading skills have been shown to have a lasting impact on exam performance and employment prospects (McLaughlin, Speirs, & Shenassa, 2014). Moreover, research has shown that reading scores in childhood can predict adolescent exam performance, as well as wages in adult employment (Currie & Thomas, 1999; Hardy et al., 1997). The considerable effect of literacy impairments on learning and future employment opportunities highlights the need for early interventions to support children that demonstrate difficulties.

Although there have been a number of studies reporting the literacy skills of children with ADHD, studies have tended to focus on the presence of reading disability. This focus means that studies have used literacy scores only to classify reading disability (de Jong et al., 2009; Del'Homme et al., 2007; Wadsworth et al., 2015) rather than individual investigation of the three main literacy skills of basic reading (word recognition), spelling (orthography) and reading comprehension (interpreting meaning from text) Children can be diagnosed with reading disability if their performance in reading, spelling and/or reading comprehension is significantly lower than expected for their chronological age and their IQ (APA, 2013; Willcutt et al., 2000).

As a result of this focus on reading disability classification, the profile of literacy ability in ADHD has tended to be overlooked in previous research. As discussed in chapter 1, the few studies that have examined the individual literacy skills of basic reading, spelling and reading comprehension (Asberg et al., 2010; Asberg Johnels et al., 2014; D. Silva et al., 2015) have found general deficits in reading and spelling in children diagnosed with ADHD. However, the relationship between ADHD and reading comprehension skills has been less consistent, with some studies finding impairments in performance compared to controls (Asberg et al., 2010; Brock & Knapp, 1996; Martinussen & Mackenzie, 2015) and others not (Ghelani et al., 2004; Gremillion & Martel, 2012; Miller et al., 2013). Further, although these few studies have examined the three different literacy skills separately, these studies have tended to report only the mean reading score for each literacy skill without controlling for IQ. As ADHD has been associated with lower IQ (e.g. Kuntsi et al., 2004), this is an important issue.

A more in depth study by Mayes and Calhoun (2003) controlled for IQ by examining negative ability-achievement discrepancies in all three literacy skills in a sample of children aged 6 to 16 years with clinical disorders. They found that mean achievement scores for all literacy skills in 453 children with ADHD were lower than predicted by the mean IQ. Basic reading had the largest ability-achievement discrepancy, with a mean score of 18 points lower than expected. This study highlights the importance of considering the role of IQ when investigating the relationship between ADHD and reading difficulties, however the study did not seek to identify groups of children that may have performed better than expected. Martinussen and Mackenzie (2015) reported that although adolescents with

ADHD performed more poorly overall than IQ matched typically developing children in reading comprehension tests, 50% of the ADHD group were identified as good comprehenders. This demonstrates that the full profile of literacy skills in ADHD can be obscured by focusing on mean scores, and provides some preliminary evidence that there might be some children with ADHD who perform better than expected. To my knowledge, the proportion and characteristics of children with ADHD that perform well above or below that expected by their IQ in basic reading, spelling and reading comprehension have not been examined.

Whilst limited research has explored the profile of literacy skills in those with ADHD, this has been examined more thoroughly in ASD. This research has shown that reading comprehension is the most commonly identified area of impairment and tends to be an isolated deficit (Nation et al., 2006; Newman et al., 2007; Åsberg, Dahlgren, & Dahlgren Sandberg, 2008). Unlike ADHD, the full profile of peaks (overachievement) and dips (underachievement) in reading performance has been studied in ASD. Jones et al., (2009) investigated 100 14-16 year old autistic adolescents and identified those who had basic reading, spelling or reading comprehension scores that were significantly discrepant from their intellectual ability. The authors identified small groups (10-16 %) with either a peak or dip in basic reading or spelling compared to their IQ. In contrast, 38% of the sample presented with a dip in reading comprehension, and this dip was an isolated discrepancy for 70% of the subgroup. This shows that reading comprehension deficits can be dissociated from other reading impairments in those with ASD, which might suggest that autistic symptomology drives difficulties with reading comprehension in an ASD population.

In ASD research, one process linked to the profile of impaired reading comprehension is social cognition. Ricketts and colleagues (2013) using the same sample as Jones and colleagues (2009) found that measures of social cognition and social behaviour predicted reading comprehension scores after controlling for word recognition and oral language. This suggests that reading comprehension impairments may be directly related to social cognition impairments in adolescents with ASD. It appears that the difficulties children with autism have in understanding the intentions of other people are also apparent when interpreting the intentions and actions of characters in a text. For example, a study by White and colleagues (2009) found that children with autism were significantly impaired when making inferences about human actions and behaviour in stories, compared to age and IQ matched control participants. Crucially, the autistic children that exhibited this mentalising impairment showed intact performance when making inferences about natural events. This implies that their reading comprehension difficulties were specifically linked to mentalising, rather than indicating general difficulties with text comprehension. Consequently, it seems that the social cognition deficits observed in those with ASD may explain the association between reading comprehension and ASD symptoms.

ASD commonly occurs with ADHD, with a recent review concluding between 20 to 50% of children diagnosed with ADHD meet criteria for ASD, whilst estimates for children with ASD meeting diagnostic criteria for ADHD are between 30 to 80% (Rommelse et al., 2010). Overlap between ASD and ADHD is also found at symptom level in children referred to paediatric clinics and in the subclinical population (Grzadzinski et al., 2011; Ronald et al., 2008). Furthermore, children with a diagnosis of either disorder are more likely to have elevated symptoms of the other compared to the general population (Hattori et al., 2006;

Mulligan et al., 2009; Reiersen, Constantino, Volk, & Todd, 2007). Although there has been research into reading comprehension in ADHD and ASD separately, there are a surprising lack of studies exploring the overlap between these highly comorbid disorders and reading ability at the diagnostic and symptom level. The few studies that have explored ADHD and reading comprehension have tended to exclude individuals with an ASD diagnosis, and have not measured autistic traits (Brock & Knapp, 1996; Ghelani et al., 2004; Miller et al., 2013). It is possible that the mixed findings of previous studies in relation to associations between ADHD and reading comprehension are due to the overlap between the disorders; children with ADHD demonstrating impaired reading comprehension may be those that also have high ASD traits as these are known to be related to reading comprehension difficulties. The difference between studies may therefore be due differing proportions of individuals with high ASD traits in each sample.

As far as I am aware only two studies, using the same sample, have investigated whether reading comprehension difficulties in children with ADHD and ASD are underpinned by similar mechanisms (Asberg et al., 2010; Asberg Johnels et al., 2017). Asberg et al. (2010) found that ASD symptoms may drive reading comprehension difficulties in children with ADHD. The study examined the reading comprehension abilities of Swedish children aged eight to 17 years with a diagnosis of ADHD or ASD and typically developing children. The researchers found that autistic symptoms across the whole sample were negatively associated with reading comprehension performance after scores in word decoding, oral language and non-verbal ability were controlled for. However the sample was small, 20 children in the ASD group and 36 in the ADHD group, all of whom were female. In addition, this negative association was no longer significant when ADHD symptoms were taken into account. Asberg and colleagues (2017) looked again at this sample of participants to identify those in the ADHD group who had poor reading comprehension and those whose reading comprehension was intact. Results revealed that the group of poor comprehenders had significantly more autistic symptoms than the intact comprehenders group. This finding does provide some evidence that additional ASD symptoms can have an effect on the reading comprehension of children with ADHD. However, the poor comprehenders group numbered only 10 participants, and their reading comprehension scores, though lower, were not significantly different from those of the intact reading comprehenders. Therefore, further investigation is needed to explore the effect of ASD traits on reading comprehension in children with ADHD.

2.1.1 Rationale and aims

Building upon previous literature, the current study had two main aims. The first was to explore the literacy profile of children with ADHD by looking at peaks and dips in performance on the Wechsler Objective Reading Dimensions (WORD; Wechsler, 1993) subtests of basic reading, spelling and reading comprehension. Secondly, the study aimed to build upon previous research to examine the impact of ASD traits on the reading comprehension ability of children with a clinical diagnosis of ADHD. To our knowledge, no previous study has examined reading comprehension ability in a large sample of children with a clinical diagnosis of ADHD and comorbid autistic traits. Based on Asberg et al. (2010) we hypothesised that the higher the level of autistic traits, the lower the reading comprehension score for children with ADHD.

2.2 Method

2.2.1 Participants

The sample was taken from the Study of ADHD Genes and Environment (SAGE) based in Cardiff, UK. In this study, children with a suspected or confirmed diagnosis of ADHD were recruited through child psychiatry and paediatric outpatient clinics in Great Britain. Children were able to participate in this study if they met criteria for a research diagnosis of ADHD (DSM-III-R or DSM-IV (3rd ed., rev.; DSM–III–R; APA, 1987; 4th ed.; DSM–IV; APA, 1994) and were excluded if they had a current clinical diagnosis of ASD, schizophrenia, epilepsy or another neurological disorder. If families were happy to participate in the research, then children completed a battery of tasks and assessments during a home visit from trained psychologists, that took approximately two to three hours. Breaks were provided as necessary. One psychologist administered the assessments with the child while the other concurrently interviewed the parent about their child. This data collection took place from 2007 to 2011.

The sample explored in the first stage of this study investigating the literacy profile of children with ADHD, focused on participants that had completed the WORD (Wechsler, 1993). This sample consisted of 548 participants, 14.8 % were female and all had a full scale IQ score of 70 or above. The ages of participants ranged from 5 to 15 years and the mean age was 9 years (SD=2.0). The second stage of the study involved also looking at autistic traits and participants without this data were removed from the analysis, leaving 340 participants. The missing data occurred because the autistic trait measure was included in the protocol part way through the study. The mean age and age range remained the same, and 17.1 % were female. Ethical approval was received from NHS ethics, and parents provided written consent, while children provided written assent. For further details about the full sample, see Stergiakouli et al., (2012). .

2.2.2 Measures

DSM-IV symptoms and research diagnoses of ADHD were assessed using the parent version of the Child and Adolescent Psychiatric Assessment (CAPA; Angold & Costello, 2000), a semi-structured diagnostic interview. The interviews were conducted by trained psychologists and cases were discussed for reliability with a child psychiatrist on a weekly basis. The CAPA has been found to have high construct validity and test-retest reliability (Angold & Costello, 2000).

ASD traits were assessed as a continuous measure using the Social Communication Questionnaire (SCQ; Rutter, Bailey, Lord & Berument, 2003), a 40 item questionnaire which was completed by the parents. Scores range from 0 to 39, as item 1 is a language screening score that is removed from the total score. In addition to the total score the items were divided into three subscales of autistic symptoms: social functioning, communication and restricted and repetitive behaviour.

The measure used to assess full scale IQ (FSIQ) was the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2003). All 10 core subtests were administered to calculate the FSIQ. The three subsets of the Wechsler Objective Reading Dimensions (WORD; Wechsler, 1993) were used to assess literacy skills. The WORD has a mean of 100 and a standard deviation of 15. The Basic Reading subtest required participants to read parts of words or complete words that become increasingly difficult. The Spelling subtest involved spelling words of increasing complexity and the Reading Comprehension subtest required participants to read short paragraphs aloud or silently and then answer one question on each paragraph, which required literal or inference-based responses. In accordance with administration instructions, no feedback or help was given regarding their reading accuracy or fluency.

Parents were asked to withhold ADHD medication 24 hours prior to their children completing the standardised assessments. All assessments were conducted by trained psychologists.

2.2.3 Data analyses

To address the first aim, the literacy profile of participants (N=548) was explored by examining peaks and dips in reading performance. This method enabled us to identify individuals whose reading abilities were significantly higher or lower than would be expected based on their intellectual ability.

In accordance with previous studies (Jones et al., 2009) groups were created by identifying participants whose discrepancies between full scale IQ and WORD standard scores were in the 10th percentile of population norms in either direction (Wechsler, 1993). This resulted in three groups for each literacy skill: peak, not different to IQ and dip. Individuals in the peak group had reading scores that were substantially higher than expected based on IQ; scores that were within the range expected were identified as not different to IQ; dip reading scores were substantially lower than expected by IQ. The cutoff points for discrepancy scores in the 10th percentile for each WORD subset were taken from the WORD manual. A basic reading standard score of 14 points or more lower than IQ was used to classify a basic reading dip. The cutoff for spelling was 16 points, and reading comprehension was 13 points (see Wechsler, 1993, p.135, Table C.9). Following Jones and colleagues (2009), we also used these cutoffs to identify peak groups (i.e. a basic reading peak score would be a basic reading standard score of 14 or more points higher than IQ), as there was no normed data for ability-achievement discrepancies where WORD standard scores were higher than IQ. The discrepancy groups were then compared to examine the profile of reading performance across each area of reading proficiency.

To assess the second aim, the data of participants with SCQ scores (N=340) was examined to measure the association between autistic traits and the different WORD scores. For this analysis, the SCQ total score was used. As well as the standard WORD scores, the ability-achievement discrepancy scores were calculated so that the association between social communication and degree of discrepancy could be directly measured (Jones et al., 2009). These scores were calculated following the manual (Wechsler, 1993) by subtracting each WORD standard score from the total IQ score for each participant, creating three discrepancy scores. A univariate regression was performed, with reading comprehension ability-achievement discrepancy score as the dependent variable. In the case of a significant association between reading comprehension and the SCQ score, multiple regression analysis would control for basic reading, spelling and ADHD symptoms.

2.3 Results

2.3.1 Descriptive statistics

Table 2.1 shows the characteristics of the sample. The mean scores for each reading skill are all within the average range for the WORD subtests (Wechsler, 1993). Table 2.2 shows the proportion of individuals in the peak, not different and dip groups for each reading skill. Altogether, 20.8 % of participants were identified as having at least one reading peak and 30.3% had at least one reading dip. More participants were identified as having a dip in reading comprehension (23.2%) compared to basic reading (14.8%) and spelling (15%), a difference that was statistically significant using Cochran's Q test ($p = < 0.001$). When examining the literacy profile of these children with a reading comprehension dip, 56.7% were found to have a dip in at least one other reading skill.

Table 2.1 Sample characteristics (N=548)

		Mean	SD	Range
WISC	Full scale IQ	88.1	11.0	70.0 – 122.0
WORD Basic Reading	Standard score	88.6	13.7	58.0 – 143.0
WORD Spelling	Standard score	85.3	12.2	61.0 – 154.0
WORD Reading Comprehension	Standard score	84.7	13.5	43.0 – 129.0
ADHD	Hyperactivity	4.5	0.9	0.0 – 5.0
	Impulsivity	3.4	0.9	0.0 – 4.0
	Inattention	7.3	1.7	0.0 – 9.0
	Total symptoms	15.1	2.4	7.0 – 18.0
SCQ	Social	6.0	3.5	0.0 – 17.0
	Communication	3.7	2.0	0.0 – 9.0
	Repetitive behaviour	2.4	2.0	0.0 – 8.0
	Total symptoms	12.6	6.2	0.0 – 29.0

Note: ADHD= Attention-deficit/hyperactivity disorder, SCQ= Social and Communication Questionnaire, SCQ data only available for (N=340)

Table 2.2 also shows that participants were more likely to present with reading dips than peaks, with the exception of basic reading, where 15.7% were identified as having a peak in comparison to 14.8% with a dip. A Cochran's Q test revealed that significantly more participants had a peak in basic reading compared to spelling and reading comprehension (p= < 0.001). Of those with a basic reading peak, just over half (55.8%) had a peak in at least one more reading skill. Overall, multiple reading peaks and dips were common (see Figures 2.1(a) and 2.1(b) for an illustration of this overlap). Half of the children (50.6%) that were identified as having a reading dip, were affected in more than one area of performance. Similarly, 42.1 % of children with a reading peak had at least 2 reading peaks.

Table 2.2 The number of cases with WORD scores higher than, lower than, or not different to full scale IQ, based on discrepancy criteria (N=548)

WORD	**Higher than FSIQ -Peak** **N (%)**	**Not different from FSIQ** **N (%)**	**Lower than FSIQ -Dip** **N (%)**
Basic Reading	86 (15.7)	381 (69.5)	81 (14.8)
Spelling	40 (7.3)	426 (77.7)	82 (15.0)
Reading comprehension	49 (8.9)	372 (67.9)	127 (23.2)

Table 2.3 shows the descriptive statistics for the sample for each of the three areas of literacy skills, separated into their discrepancy groups. The peak groups each demonstrate below average mean IQ scores, while the three WORD subtests scores are within the average range. For example, in Table 2.3, the mean basic reading ability of the reading peak group was in the average range (M=104.1, SD= 11.1), while IQ was below average (M=83.1, SD= 9.1).

In contrast, the dip groups present with average IQ scores and below average reading subtype scores. For example, in the basic reading dip group, the mean scores of all three reading subtests were below average, 77.7 (SD= 9.5) for basic reading, 78.1 (SD= 9.5) for spelling and 78.0 (SD=13.4) for reading comprehension, and they were not significantly different ($p > 0.05$). There was more variation between the mean literacy skills scores in the spelling and reading comprehension dip groups (Table 2.3), with the dip score being approximately 8 points lower than the other subtest scores in both groups. In both groups, this difference was significant (both ps < 0.05).

In addition, there was no difference in the mean total ADHD symptom score between each reading group for each of the literacy skills. This remained the case when looking at the separate ADHD symptom dimensions of hyperactivity/impulsivity and inattention.

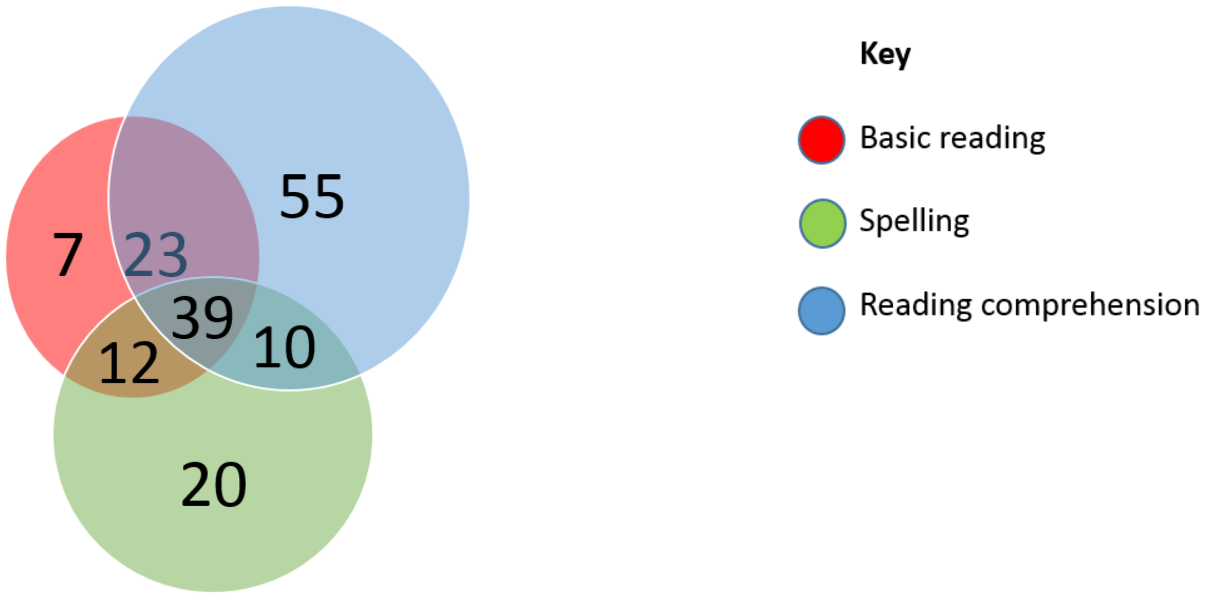
Table 2.3 Descriptive statistics for IQ, standard WORD, ADHD and SCQ scores based on basic reading (BR), spelling (SP) and reading comprehension (RC) full scale IQ discrepancies (N=548)

		Peak	*Not different*	*Dip*	*Peak*	*Not different*	*Dip*	*Peak*	*Not different*	*Dip*
		BR			**SP**			**RC**		
		Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
WISC	Full Scale IQ	83.1 (9.1)	87.3 (10.6)	96.6 (10.1)	81.9 (10.8)	86.7 (10.1)	98.1 (9.6)	82.8 (9.4)	87.0 (10.5)	93.2 (11.1)
WORD	Basic Reading	104.1 (11.1)	87.4 (11.9)	77.7 (9.5)	101.8 (13.0)	88.3 (13.3)	83.6 (11.7)	98.6 (11.2)	89.9 (13.0)	80.8 (12.8)
	Spelling	95.3 (12.4)	84.6 (11.3)	78.1 (9.5)	103.7 (13.2)	85.2 (10.8)	76.9 (8.7)	91.4 (10.9)	86.2 (11.8)	80.4 (12.5)
	Reading comprehension	92.0 (11.4)	84.5 (13.1)	78.0 (13.4)	91.1 (11.0)	84.4 (13.3)	82.8 (14.8)	101.4 (11.4)	86.3 (11.0)	73.6 (12.0)
ADHD	Total symptoms	15.3 (2.5)	15.2 (2.4)	14.8 (2.5)	15.3 (2.5)	15.1 (2.4)	15.1 (2.4)	15.5 (2.3)	15.0 (2.5)	15.2 (2.3)
SCQ	Total score	12.2 (6.7)	13.0 (6.3)	11.4 (5.2)	13.1 (6.3)	12.8 (6.3)	11.4 (5.6)	11.3 (6.3)	13.3 (6.4)	10.8 (5.1)
	Social	5.8 (3.9)	6.2 (3.4)	5.5 (3.0)	6.0 (4.0)	6.1 (3.5)	5.7 (2.9)	5.8 (3.8)	6.3 (3.6)	5.2 (2.8)
	Communication	3.5 (2.0)	3.9 (2.1)	3.3 (1.8)	3.7 (1.6)	3.8 (2.0)	3.3 (1.9)	3.4 (2.2)	3.9 (2.0)	3.3 (1.9)
	Repetitive behaviour	2.4 (2.2)	2.4 (2.0)	2.2 (2.0)	2.7 (2.3)	2.4 (2.0)	1.9 (1.8)	1.9 (2.0)	2.5 (2.1)	2.0 (1.9)

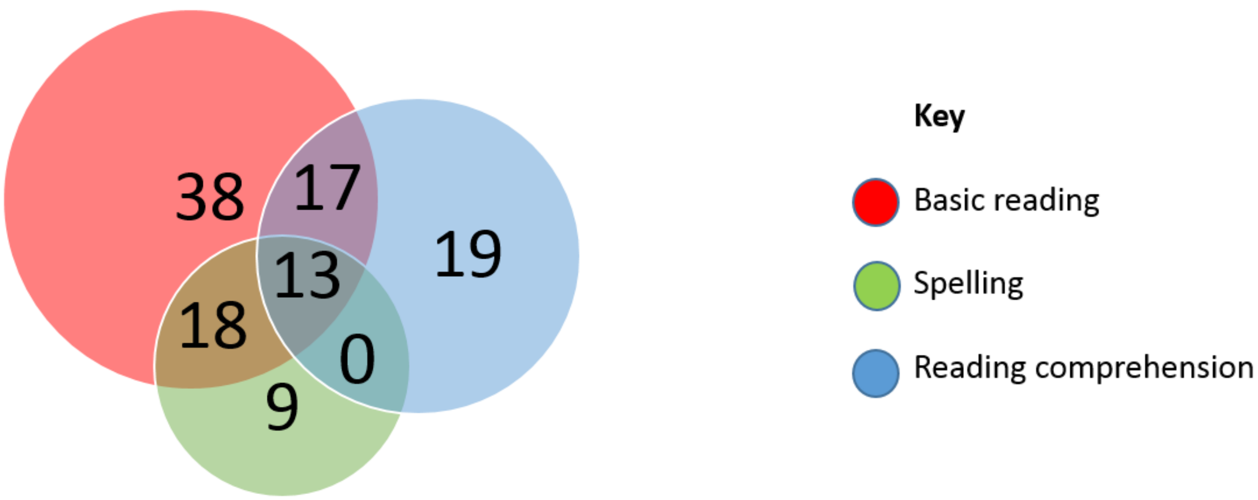
Note: ADHD= Attention-deficit/hyperactivity disorder, SCQ= Social and Communication Questionnaire, SCQ data only available for (N=340)

Figure 2.1 Venn diagrams showing (i) the number of participants with a dip in each reading skill **(ii)** the number of participants with a peak in each reading skill. Measurements obtained using the Wechsler Objective Reading Dimensions (WORD; Wechsler, 1993)

(i)



(ii)



2.3.2 Association between the SCQ and reading scores

The sample characteristics of the 340 participants with SCQ data were not significantly different to those of the full sample (See Appendix 1).

Correlations demonstrated that gender, socioeconomic status and age were not associated with WORD scores, total SCQ and total ADHD scores. Further, no significant correlations were found between any of the standard scores or ability-achievement scores of the WORD and the total SCQ score. However, a significant positive relationship was found between the reading comprehension ability score and the social subscale of SCQ (See Appendix 2 for the correlations table).

Univariate regression analyses with reading comprehension ability-achievement discrepancy score as the outcome variable, showed that reading comprehension was significantly associated with spelling and basic reading (see Table 2.4). The association with ADHD symptoms was non-significant. Additionally there was no significant association between the reading comprehension ability-achievement discrepancy score and autistic traits as measured by the SCQ total score. This positive but non-significant relationship between autistic traits and reading comprehension suggests that higher autistic traits do not lead to a reduction in reading comprehension (relative to IQ) in children with a clinical diagnosis of ADHD. Separate regressions with the three subscales of the SCQ and the reading comprehension ability-achievement discrepancy score showed a similar pattern of findings, with no evidence of an association with reading comprehension.

Table 2.4 Multiple regression analysis table showing associations between spelling and basic reading ability-achievement discrepancy scores, autistic traits and ADHD symptoms with reading comprehension ability-achievement discrepancy score (N=340)

	Univariate		
Variables	**B (S.E)**	**β**	***p***
Basic Reading	0.71 (0.04)	0.74	< 0.001
Spelling	0.61 (0.04)	0.60	< 0.001
Autistic traits	0.18 (0.11)	0.09	0.11
ADHD symptoms	-0.19 (0.28)	-0.04	0.50

-DV= reading comprehension ability-achievement discrepancy score

Note: ADHD= Attention-deficit/hyperactivity disorder

2.4 Discussion

The current study examined the literacy profiles of a large sample of 5-15 year old children with ADHD (N= 548). We focussed on relative peaks and dips in basic reading, spelling and reading comprehension performance compared to intellectual ability. Overall we found that 20.8% of children had a reading peak and 30.3% of children had a least one reading dip, this level of impairment was expected based on the previous literature investigating literacy in ADHD (see Chapter 1, section 1.2.1) and the high level of comorbidity with Reading Disability (Sexton et al., 2012). For example, Mayes and Calhoun (2006) found that 33% of their sample with ADHD were identified as having a basic reading impairment. We also identified a tendency for relative reading impairments to co-occur, with 50.6% of children with a reading dip experiencing difficulty in more than one area of reading. Similarly 42.1% of children with a reading peak excelled in at least one other reading skill.

An unexpectedly high number of children, 15.7 %, had a peak in Basic Reading compared to a dip. A Cochan's Q test found that significantly more children had a peak in basic reading compared to one in spelling or reading comprehension. This demonstrates the efficacy of looking at peaks and dips as opposed to mean scores, as this area of strength would otherwise have been missed.

Significantly more children were identified as a having a dip in reading comprehension, (23.2%) compared to children with dips in spelling (15%) or basic reading (14.8%). This is in contrast to some previous studies of ADHD populations that have not found a deficit in reading comprehension (e.g. Ghelani et al., 2004). When examining the literacy profile of the children with a reading comprehension dip (23.2%) we found that over half (56.7%) of these children had concomitant difficulty with basic reading and/or spelling. This profile differs to Jones and colleagues' (2009) study of 100 adolescents with ASD where 70% of participants with a single dip in reading comprehension did not have another area of significant difficulty.

Additionally, while Jones et al. (2009) found that there was an 18 point difference between the standard reading comprehension scores of the dip group and the other reading scores, our study found only a seven point difference. Taken together, these results indicate that those with a dip in reading comprehension are different in the two clinical groups. Individuals with ASD show, on average, poorer reading comprehension, and this is an isolated deficit in almost 4/5ths of affected individuals. In contrast, individuals with ADHD who struggle with reading comprehension do not show such a distinct deficit and have a much higher chance of having another area of reading weakness. This has important implications for literacy interventions, as it suggests that while specific reading comprehension interventions may be more suitable for children with ASD, more general literacy interventions may be best suited to those with ADHD.

The relationship between symptoms of ADHD with literacy skills was also examined. ADHD symptoms, including both total symptom score and subtests were not associated with ability-achievement discrepancies.

The second aim of our study was to examine the effect of autistic traits on reading comprehension performance. Counter to our hypotheses, ASD symptoms were not found to differ across each reading dip group. This is at odds with previous research which has found that children and adolescents with ASD are frequently impaired in reading comprehension (e.g. Jones et al., 2009; Nation et al., 2006). Further analysis revealed that autistic traits, measured by the SCQ, did not significantly predict reading comprehension ability.

Although we found that significantly more children had a reading comprehension dip in comparison to other literacy skills, the proportion of individuals with reading comprehension difficulties identified in studies of individuals with ASD are frequently greater than that found in our study. Only 23.2% of our sample of children with ADHD had a reading comprehension dip, in contrast to 37% of adolescents with ASD reported in Jones et al., (2009). Other studies looking at the number of autistic children with significantly low reading comprehension scores also found evidence of relatively high levels of impairment. For example, Ricketts et al. (2013) found that 60% of children with ASD in their study had a reading comprehension problem. Nation and colleagues (2006) found a similar figure, with

65% of children with ASD demonstrating impaired reading comprehension performance. However, these comparisons need to be interpreted with caution, as different criteria were used to identify reading comprehension deficits. Our findings suggest that having elevated autistic traits in an ADHD population is not sufficient to lead to the specific reading comprehension deficit that ASD studies have identified.

The reason that ASD traits did not have an influence on reading comprehension in children with ADHD is unclear. One strong possibility is that variability in reading comprehension is primarily driven by other factors, making the influence of autistic symptomology hard to detect. Indeed, in Ricketts et al. (2013) word recognition and oral language were much stronger predictors of reading comprehension performance than social cognition and behaviour. In the current study, co-occurring dips in reading performance were common. Consequently, it could be because literacy skills in general are impaired in our sample, ASD traits do not have an additional effect on reading comprehension skills.

The participants in this study did not have a diagnosis of autism; another possible explanation for the lack of an association between ASD symptoms and reading comprehension ability may be because ASD symptoms did not reach diagnostic level. Ricketts et al. (2013) found the severity of social and communication difficulties (measured by the ADOS) predicted performance on the WORD reading comprehension subtest in their sample of autistic adolescents. We did not find this graded sensitivity in our ADHD sample using the SCQ. In my sample, the mean score on the SCQ was 12.6, which is higher than the average for typically developing children (Mulligan et al., 2009), as would be expected on account of the high rates of comorbidity between ADHD and ASD at the symptom level (Grzadzinski et al., 2011). However, 15 is considered to be the screening cut off for potential ASD and a score of 24.4 is average for an individual with ASD (Berument, Rutter, Lord, Pickles, & Bailey, 1999); perhaps the mean of 12.6 demonstrates a level of autistic traits that is too low to have a marked effect on reading comprehension performance.

In summary, the results of our study seem to suggest that children with ADHD often have multiple and overlapping reading deficits. However, the peak in basic reading demonstrates that there can be areas of reading strength that may have been overlooked in studies focusing on mean scores. We found that significantly more children had a reading comprehension dip, although for most this was not a specific deficit. This considerable reading comprehension deficit relative to IQ could not be accounted for by an association with autistic traits. As reading comprehension impairments have been shown to be related to poor educational attainment and employment opportunities (McLaughlin et al., 2012; Savolainen et al., 2008), it is important to know the children with ADHD that are at risk for reading comprehension difficulties. This would then allow for the provision of early interventions and indicate the need for resources. While this chapter indicated that ASD traits were not associated with the reading comprehension performance of children with ADHD, the next chapter will attempt to determine whether ASD symptoms effect the social cognition abilities of children with ADHD. The final chapter in this thesis will then revisit literacy skills to determine more explicitly the role of mentalising in reading comprehension performance.

CHAPTER 3

The effect of ASD symptoms on the social cognitive ability of children with ADHD

3.0 Overview

This chapter investigates the role of additional ASD symptom severity on the social cognition performance of a sample of children diagnosed with ADHD. In this chapter, all three social cognitive abilities, and the effect of ASD symptom severity on these skills, are explored in turn. First facial emotion recognition performance is investigated, followed by cognitive and affective empathy, and finally theory of mind. In the case of theory of mind, additional CD symptom severity and diagnosis was investigated alongside ASD symptom severity.

In section 3.1 (FER) and section 3.3 (Theory of mind), it was possible to compare data to the control sample from the school study (Chapter 4). This was not the case for section 3.2 (empathy) as the empathy film clips task used alternative clips in the school study.

In this sample, 42.6 % of children reached criteria for a research diagnosis of CD. The role of CD symptoms were not the primary aim of this thesis, however it was necessary to consider the role of these symptoms (see Introduction 1.1.4). Consequently, CD symptoms were statistically controlled for in sections 3.1 and 3.2 (when looking at Facial Emotional Recognition and empathy), although further analysis was not undertaken because these data were examined in this sample by colleagues (Airdrie et al., 2018). This also meant that the effect of CD symptom severity on the FER and empathy abilities of children with ADHD had already been investigated. In section 3.3, on the other hand, the role of CD symptoms on the theory of mind ability of those with ADHD was investigated as this relationship has not been explored using this sample or in previous research (see section 1.6 for a full explanation).

3.1 FACIAL EMOTION RECOGNITION

3.1.1 Introduction

Facial emotion recognition (FER) refers to the ability to identify a person's emotional state by observing their facial expressions alone. Studies have shown that typically developing infants are born with a face bias, and naturally orient their gaze to faces (Simion, Di Giorgio, Leo, & Bardi, 2011). Facial emotion recognition ability begins at this early stage, and by four to seven months of age infants are able to discriminate between the six basic emotions (Ekman & Friesen, 1976; Serrano et al., 1992; Walker-Andrews, 1998). FER is therefore one of the earliest social cognitive skills that children develop. Yet the significance of this early skill should not be overlooked; studies have found that FER is associated with social skills in typically developing children, with impaired FER predicting early academic difficulties (Izard, 2001) and lower social competence (Miller et al., 2005).

In children with ADHD, FER deficits are associated with social dysfunction, which frequently accompanies ADHD diagnosis (Nijmeijer et al., 2008). For example, Pelc et al., (2006) investigated the identification of four emotions (sadness, anger, joy and disgust) and found that children with ADHD were impaired in the recognition of sadness and anger compared to controls, and that poor recognition was associated with greater interpersonal problems. While some studies have found that children with ADHD were impaired in their recognition of all six emotions (Da Fonseca, Seguier, Santos, Poinso, & Deruelle, 2009; Jusyte, Gulewitsch, & Schonenberg, 2017), others have found no deficits compared to controls (Berggren, Engstrom, & Bolte, 2016; Demurie, De Corel, & Roeyers, 2011). The differences found in these individual studies could be in part due to comorbid ASD or CD symptoms, (see Introduction 1.6), which is explored in more detail later in this section. Overall, however, it does seem that children with ADHD have FER deficits; Bora and Pantelis (2015), in their meta-analysis of 18 studies, found that children with ADHD had significantly impaired emotion recognition accuracy, and that the greatest impairment was for the recognition of anger and fear.

Recent research has suggested that it may be comorbid CD sub-clinical symptoms or clinical diagnoses that are driving FER deficits in children with ADHD (Nijmeijer et al., 2008). Studies of children with CD alone have typically found impairments in FER tasks compared to controls (Fairchild et al., 2009; Sully, Sonuga-Barke, & Fairchild, 2015). One study examined the role of CD on FER in children with ADHD (Airdrie et al., 2018). The study used the Ekman faces stimuli (Ekman & Friesen, 1976) and found that children with ADHD who also met criteria for CD were significantly impaired in their recognition of fear and neutral faces compared to those with ADHD alone. Therefore it does seem that CD contributes to FER problems in children with ADHD, particularly with regard to fearful and neutral faces. It is therefore necessary to account for CD symptoms or diagnoses in analyses of associations between ADHD and FER.

In addition, there is some evidence to suggest that a comorbid diagnosis of ASD results in greater FER deficits in those with ADHD alone. Children with ASD are often found to be impaired in emotion recognition, (Uljarevic & Hamilton, 2013, see Introduction 1.4.1) with a meta-analysis finding that children with ASD are impaired in their recognition of all six basic emotions compared to controls (Lozier, Vanmeter, & Marsh, 2014). Several studies have directly addressed the effect that a comorbid ASD diagnosis has on FER performance in those with ADHD. Sinzig et al., (2008) compared FER performance in four groups of participants; those with ADHD, ASD, ADHD+ASD and controls. Sinzig and colleagues (2008) found that both the ADHD alone and ADHD+ASD groups demonstrated impairment compared to controls. There was no significant difference between the scores of the ASD alone group and all other groups. Similarly, Colombi and Ghaziuddin (2017) found that children with both ADHD and ASD had significantly lower scores on a facial recognition task than children with a diagnosis of ASD alone. These findings suggest that children with both ADHD and ASD have the greatest risk of FER impairment, although previous studies have not looked dimensionally at the contribution of ASD symptoms to FER ability in ADHD. The importance of exploring the dimensional overlap between disorders is receiving greater recognition in research (Thapar et al., 2017, see Introduction 1.1.3). Notably, there is evidence that ASD symptoms in ADHD are associated with a more severe clinical presentation (Cooper et al., 2014), yet the relationship between this dimensional overlap and social cognition is unknown. Consequently, identifying whether there is a subtype of children with ADHD and elevated ASD symptoms who are at greater risk of FER impairment would expand upon previous diagnostic overlap research, and also be particularly beneficial in targeting interventions for those with ADHD.

In addition, although the contribution of a comorbid diagnosis of ASD to FER ability in ADHD has previously been investigated, what yet remains to be known are the reasons behind this deficit. Eye tracking technology has proved to be beneficial at indicating visual processing patterns that may contribute to FER deficits (Karatekin, 2007). Looking at the eyes in photographs of faces has been shown to result in the more accurate emotion identification in typically developing individuals (Baron-Cohen, Wheelwright, & Jolliffe, 1997; Eisenberg & Morris, 2002). If children's eye movements do not focus on key areas of the face such as the eyes, this suggests that emotion recognition deficits relate to fundamental differences in visual processing. Conversely, if eye movements are typical then this suggests that a lack of understanding of emotional facial expressions may be at the heart of poor emotion recognition. Understanding where this deficit lies would be extremely beneficial for interventions, as training could focus on encouraging viewing of optimal face regions or training based on what different expressions mean. As a result, studies that combine a response based task (such as FER) alongside eye tracking technology (or neuroimaging) are now considered to be the ideal method for exploring social cognition deficits (Black et al., 2017; Boraston & Blakemore, 2007; Harms, Martin, & Wallace, 2010; Serrano et al., 2015). For example, Bal et al.,(2010) tested children with ASD on their recognition of emotions using photos that slowly merged from a neutral facial expression to one of the six basic emotions. Results showed that ASD symptom severity was associated with poorer emotion recognition accuracy and less time spent looking at the eyes of the faces. This suggests that in ASD, children demonstrate impaired FER through atypical eye movements that result in a lack of attention to key areas of the face that facilitate emotion recognition. Therefore, the efficacy of a study paradigm that includes both a response FER task and eye tracking is evident.

Research examining the overlap between ADHD and CD and how this effects emotion recognition has utilised eye tracking technology in conjunction with a response task to explore FER deficits (Airdrie et al., 2018). As previously mentioned, Airdrie et al., (2018) found that adolescents with ADHD and CD were impaired in their recognition of fear. They also found that this dual diagnosis group looked significantly less at the eyes of fearful faces and fearful faces as a whole compared to children with ADHD alone. However, eye tracking technology has not been used together with FER response tasks in studies exploring the overlap between ASD and ADHD, meaning that it is not possible to clarify the role that an additional ASD diagnosis or elevated symptoms has in reducing FER ability in children with ADHD. Based on previous ASD eye tracking literature (Bal et al., 2010) and studies looking at the overlap between ASD and ADHD (Colombi & Ghaziuddin, 2017; Sinzig et al., 2008) it seems viable to suggest that elevated ASD symptoms in those with ADHD leads to greater FER deficits as a result of reduced attention to the eye region of faces.

3.1.1.1 Aims and rationale

Following the evidence discussed, it seems that children with ADHD tend to have FER deficits, and that this deficit is exacerbated in those with co-occurring conditions such as ASD. Identifying at what stage FER deficits manifest (at the perceptual level or decision making stage) is important to inform future interventions and eye tracking within a traditional FER task makes this possible. Therefore, the aim of the analyses in this chapter was to explore the relative contribution of ASD symptoms to the FER ability of children with ADHD through utilising both a traditional FER response task alongside eye tracking technology. Based on previous literature, I expected that children with greater ASD symptoms would demonstrate poorer FER accuracy across all emotions studied, and that this would be explained by reduced time spent looking at the eye region of the faces.

3.1.2 Method

3.1.2.1 Participants

The sample in this study consisted of 65 participants that had taken part in an FER eye tracking task, 26.2% were female. The ages of participants ranged from 10 to 18 years and the mean age was 14.2 years (SD= 2.1). All children had a childhood clinical diagnosis of ADHD. The participants in this study had previously taken part in the research study SAGE study (for further details of the SAGE study, see Chapter 2, section 2.2) and were invited back to take part in the follow-up ADHD study. Families were tested at a Cardiff University laboratory. Children completed a battery of tasks and assessments that took approximately 5 to 6 hours in total. Parents were interviewed concurrently about their child. Breaks were provided as and when required. (see p.xiii for more details). Ethical approval was received from NHS ethics, and parents provided written consent, while adolescents provided written assent.

3.1.2.2 Measures

Research diagnoses of ADHD, ASD and CD were assessed using the Development And Well-being Assessment (DAWBA; Goodman et al., 2001), which was completed during the testing day and conducted by trained psychologists. Research diagnoses of ADHD and ASD were obtained using data from the parent DAWBA interview, while CD diagnosis was determined using an and/or measure with both parent and child DAWBA data. The DAWBA offers a symptom count of disorders and their subtypes as well as enabling the presence of research diagnoses to be established. The DAWBA enables subtype scores for social and communication and repetitive behavior symptoms, as well as inattention, hyperactivity and impulsivity symptoms to be measured for ASD and ADHD, respectively.

IQ was assessed using the two-subset form of the Wechsler Abbreviated Scale of Intelligence (WASI), which measures cognitive ability in individuals from six years to adulthood (Wechsler, 1999). The two subsets consisted of the matrix reasoning test and the vocabulary test. FER was tested using 60 slides from the Ekman and Friesen (1976) facial affect battery, consisting of black and white photographs of male and female faces. The hair and background was blacked out so that only the faces appeared on each slide. The slides contained faces that represented one of four basic emotions (happy, sad, anger or fear) or a neutral face. The emotional faces were morphed with their corresponding neutral faces to demonstrate emotional intensity at 50% and 75%. Neutral faces were only shown at 100% (see Figure 3.1.1 for example stimuli). Facial slides contained equal numbers of all emotions at each intensity (12 slides for each emotion), and equal numbers of male and female faces were shown (30 male, 30 female). The order facial slides were presented was not counterbalanced. The task was presented on a laptop and used in conjunction with eye tracking software. Participants were asked verbally, “What emotion is this person showing?” when each stimulus face was presented. Participants were required to choose the emotions from a list of numbered options (1-5) that were shown alongside the face for the same time the face itself was presented (See Figure 3.1.2 for an example stimuli slide). Responses were recorded on paper by the experimenter. Participants pressed the space bar to move on to the next stimulus face after responding. There were no time constraints.

Figure 3.1.1 Example FER facial stimuli (from Bowen et al., 2014)

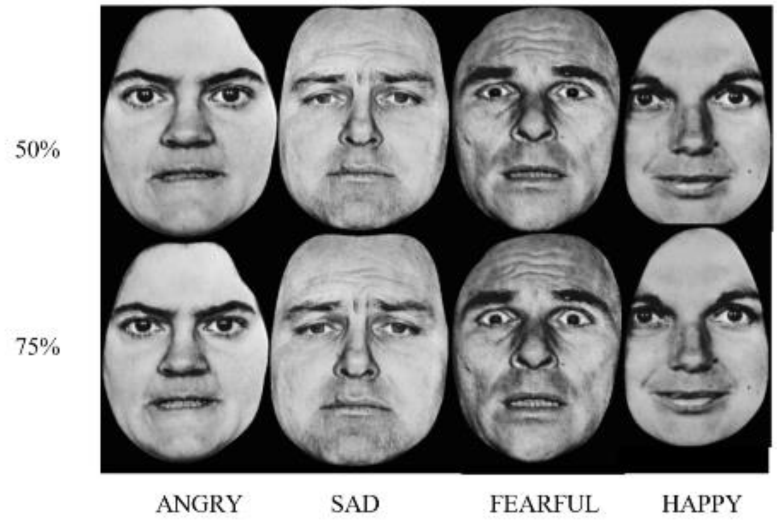
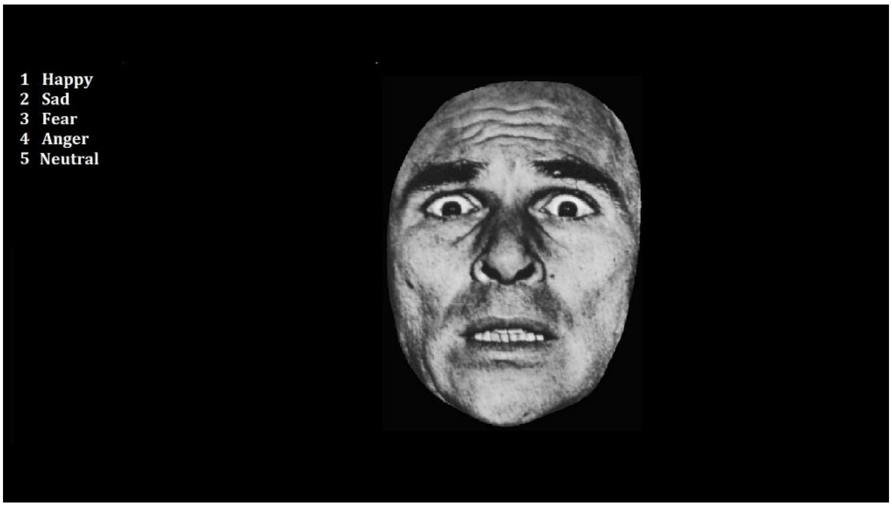


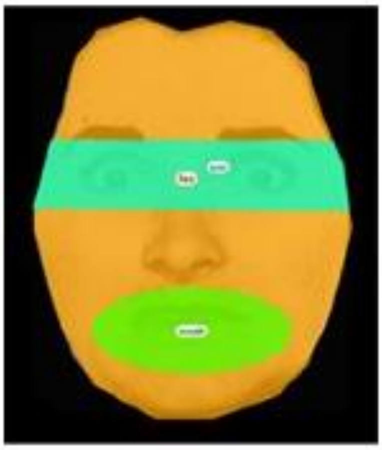
Figure 3.1.2 Example FER facial slide stimuli showing fear



Eye movements were recorded with a portable Tobii X2-60 compact eye-tracker sampling at 60Hz with a screen resolution of 1920 x 1080 mm. Participants were sat approximately 60-65 cm from the eye-tracker laptop and a 9-point calibration was used. The quality of calibration was checked before commencing the task; if there were no data for one or more points, or if calibration quality was poor, calibration at those points was repeated. Tobii eye tracking software was used to create three AOIs (areas of interest) for the eye, mouth and face region as a whole (see Figure 3.1.3).

Eye movements were measured from when the stimulus face was presented to when the participant pressed the space bar. Percentage dwell time (the sum of the duration of all fixations to an AOI divided by the total time spent looking at the face) for eye and mouth AOIs was calculated for each slide. The amount of time spent looking at the face as a whole was calculated by subtracting the time spent looking at the face from the rest of the screen (not including the time spent looking at the response options).

Figure 3.1.3: Example face showing AOIs for FER task; eye, mouth and face region



Eye-gaze validity was checked using a sample rate percentage of 70% that gives a rough estimate of the quality of the eye tracking in a participant’s recording (for the entire FER task duration) by providing a percentage score of data that has been successfully recorded.

Participants that had less than 70% validity for an individual clip were excluded from the analysis. This resulted in the exclusion of the data of 12.3% of participants. The 70% validity threshold was used following the protocol set by (Hubble et al., 2015) in a study of adolescents with ADHD.

3.1.2.3 Data analyses

First, the effect of age, IQ, gender and DAWBA disorder symptom counts (for ADHD, ASD and CD) on FER accuracy was examined using Pearson correlation coefficients. Pearson correlation coefficients were also used to explore the relationship between eye tracking variables across all emotions, and each emotion individually, as well as ASD and ADHD symptoms. The eye tracking variables examined were dwell time to the eye, mouth and face regions.

Secondly, where ASD symptoms were found to be correlated with FER performance and FER eye tracking, these variables were entered into multiple regression analyses to determine if this relationship held when ADHD symptom severity was taken into account. This resulted in regression analyses for eye tracking variables alone. Dwell time to the eyes for sad and neutral faces, and dwell time to the face for anger, fear and sadness were the dependent variables entered into separate regression analyses. As CD symptoms were found to be related to fearful faces in a previous study using the same sample (Airdrie et al., 2018), CD symptoms were also included in the analysis of dwell time to fearful faces. In order to examine whether ASD symptoms or ADHD symptoms affected accuracy scores through reducing time spent looking at the eyes, two mediation analyses were performed. To determine if an indirect effect was significant, confidence intervals were used. Following previous studies, (Field, 2009; Van Goozen et al., 2016) if the confidence intervals for the path coefficients did not cross zero then mediation was observed.

Finally, the FER accuracy data of the whole sample was compared to control data from the school chapter (Chapter 4) to determine whether the ADHD sample were impaired in comparison to controls.

3.1.3 Results

Table 3.1.1 shows the IQ, ADHD, ASD, age and CD scores of the sample. Table 3.1.2 shows the mean percentage scores for FER accuracy and eye tracking variables across all emotions individually and combined. Happiness was revealed to be the most often correctly identified emotion, with t-tests confirming that accuracy scores for happy faces were significantly higher than scores for the other emotions (all *p*s= < 0.01). Whereas t-tests demonstrated that accuracy scores for sad faces were significantly the lowest (all *p*s= < 0.01).

Table 3.1.1 Sample characteristics for participants that completed the FER task (N=65)

		Mean	SD	Range
WASI	Full scale IQ	83.8	15.8	53.0 – 120.0
Age	Years	14.2	2.1	11.0 – 18.0
ADHD	Hyperactive/impulsive	6.0	2.6	0.0 – 9.0
	Inattention	6.9	2.3	0.0 – 9.0
	Total symptoms	12.6	4.6	1.0 – 18.0
ASD	Social	11.1	7.7	0.0 – 27.0
	Repetitive behaviour	7.9	7.2	0.0 – 25.0
	Total symptoms	19.7	14.3	0.0 – 50.0
CD	Total symptoms	3.4	3.2	0.0 – 12.0

Note: ADHD= Attention-deficit/hyperactivity disorder, ASD= Autism Spectrum Disorder, CD= Conduct Disorder

Table 3.1.2 Mean percentage scores for facial emotion recognition accuracy and eye tracking. Data presented are averaged across 50% and 75% intensity trials (emotional faces) or presented at 100% intensity (neutral face).

Mean % (SD) Range	**Happy**	**Sad**	**Anger**	**Fear**	**Neutral**	**All emotions**
FER accuracy	94.0 (9.9) 50.0 – 100.0	44.4 (15.7) 8.3 – 83.3	71.0 (17.4) 25.0 – 100.0	68.3 (20.0) 16.7 – 100.0	74.3 (30.9) 0.0 – 100.0	70.4 (12.1) 33.3 – 88.3
% dwell time face	78.4 (16.1)	76.5 (17.8)	72.6 (15.9)	72.3 (18.0)	72.6 (19.8)	74.5 (16.1)
% dwell time eyes	44.0 (17.2)	53.2 (21.7)	48.7 (19.4)	50.3 (20.1)	49.6 (19.9)	49.1 (18.3)
% dwell time mouth	26.1 (16.5)	16.7 (13.1)	22.2 (14.2)	19.1 (14.9)	20.1 (14.8)	20.8 (13.4)

Note: FER = Facial emotion recognition task, N= 57 (all eye tracking variables), N=63 (FER accuracy)

Table 3.1.3 shows that correlations between ASD total symptoms and FER accuracy were not significant for any of the four emotions or for neutral faces. ADHD symptom severity was also not significantly correlated with FER accuracy. These accuracy scores refer to the total scores for each emotion (presented at 50% and 75% intensity combined) but examining the emotions at 50% and 75% intensity separately also demonstrated that ASD and ADHD symptom severity had no effect on accuracy.

Table 3.1.3 Pearson correlation coefficients for facial emotion recognition accuracy, FSIQ, age, ADHD total symptoms and ASD total symptoms

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Gender	0.09	0.02	-0.18	0.13	0.03	0.20	-0.05	0.06	0.11
2. FSIQ		-0.03	0.22	0.07	0.29*	0.29*	0.41**	-0.16	-0.18
3. Age			-0.07	0.15	0.16	0.04	0.16	0.01	-0.15
4. FER Happy accuracy				0.24	0.33**	0.60**	0.09	-0.15	-0.13
5. FER Sad accuracy					0.38**	0.24	-0.14	0.03	-0.03
6. FER Fear accuracy						0.38**	0.35**	-0.17	-0.19
7. FER Anger accuracy							0.22	-0.19	-0.03
8. FER Neutral accuracy								-0.18	-0.17
9. ASD total									0.45**
10. ADHD total									

Note: ASD= Autism Spectrum Disorder, ADHD= Attention-deficit/hyperactivity disorder, FSIQ= full scale IQ,*p <.05; ** p < .01, FER= Facial emotion recognition

When eye tracking variables were investigated, both ASD and ADHD symptom scores were found to be negatively correlated with the combined score for dwell time to the eyes and face (Table 3.1.4). ASD symptoms were also found to be negatively correlated with dwell time to the eyes for sad and neutral faces, and the face for sad, angry and fearful faces. ADHD symptoms were shown to correlate significantly with the eyes and face of each emotion individually. Neither ASD or ADHD symptoms were significantly correlated with dwell time to the mouth region of the faces.

Multiple regression analysis found that ASD symptoms were no longer associated with dwell time to the eyes for sad and neutral faces and all emotions combined, and the face for sad and angry faces as well as all emotions combined when ADHD was controlled for (see Table 3.1.5). ASD symptoms also no longer predicted dwell time to fearful faces when ADHD and CD were taken into account. Neither ADHD or CD symptoms continued to predict fearful faces (see Table 3.1.6).

Table 3.1.4 Pearson correlation coefficients for the eye tracking variables for each emotion and all emotions combined with ASD and ADHD total

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. ASD total	0.45**	-0.23	-0.06	-0.23	-0.30*	0.11	-0.31*	-0.23	-0.12	-0.26*	-0.21	-0.02	-0.31*	-0.41**	0.14	-0.22	-0.31*	0.01	-0.29*
2. ADHD total		-0.30*	-0.01	-0.27*	-0.35**	0.11	-0.34**	-0.36**	0.04	-0.38**	-0.32*	0.17	-0.33**	-0.40**	0.06	-0.31*	-0.37**	0.08	0.35**
3. Happy eyes (%)			-0.02	0.32***	0.85**	-0.35**	0.29*	0.85**	-0.24	0.27*	0.84**	-0.30*	0.29*	0.71**	-0.21	0.38**	0.91**	-0.28*	0.34**
4. Happy mouth (%)				0.07	0.02	0.81**	0.17	0.01	0.80**	0.20	-0.06	0.83**	0.21	-0.07	0.72**	0.08	-0.06	0.91**	0.16
5. Happy face (%)					0.33**	0.06	0.74**	0.32**	0.17	0.73**	0.32*	0.05	0.71**	0.29*	0.14	0.72**	0.34**	0.11	0.84**
6. Sad eyes (%)						-0.26*	0.39**	0.90**	-0.07	0.35**	0.89**	-0.17	0.38**	0.80**	-0.13	0.41**	0.95**	-0.13	0.41**
7. Sad mouth (%)							0.10	-0.22	0.82**	0.08	-0.30*	0.85**	0.10	-0.28	0.83**	-0.2	-0.30*	0.94**	0.07
8. Sad face (%)								0.41**	0.19	0.88**	0.43**	0.04	0.92**	0.40**	0.19	0.88**	0.41**	0.15	0.96**
9. Anger eyes									0.21	0.38**	0.89**	-0.19	0.41**	0.83**	-0.14	0.41**	0.96**	-0.15	0.42**
10. Anger mouth										0.19	-0.19	0.87**	0.22	-0.18	0.77**	0.10	-0.17	0.93**	0.19
11. Anger face											0.39**	0.06	0.83**	0.40**	0.18	0.79**	0.39*	0.16	0.91**
12. Fear eyes (%)												-0.33**	0.43**	0.80**	-0.12	0.52**	0.95**	-0.21	0.46**
13. Fear mouth (%)													0.07	-0.27*	0.70**	-0.09	-0.27*	0.93**	0.02
14. Fear face (%)														-0.40**	0.18	0.85**	0.41**	0.17	0.94**
15. Neutral eyes (%)															-0.31**	0.37**	0.89**	-0.24	0.40**
16. Neutral mouth(%)																0.15	0.18	0.87**	-0.20
17. Neutral face (%)																	0.45**	0.93**	0.05
18. Eyes all (%)																		-0.21	0.44**
19. Mouth all (%)																			0.14
20. Face all (%)																			

Note: ADHD= Attention-deficit/hyperactivity disorder, ASD= Autism Spectrum Disorder, *p <.05; ** p < .01

Table 3.1.5 Multiple regression analyses showing the association between ADHD total symptoms, ASD total symptoms, and neutral eyes, and eyes and faces across all emotions combined

Variables	B (S.E)	β	p	Variables	B (S.E)	β	p	Variables	B (S.E)	β	p
ADHD total	-1.28 (0.60)	-0.27	0.04	ADHD total	-1.30 (0.58)	-0.30	0.03	ADHD total	-1.09 (0.51)	-0.29	0.04
ASD total	-0.38 (0.04)	-0.17	0.22	ASD total	-0.20 (0.17)	-0.15	0.24	ASD total	-0.17 (0.15)	-0.15	0.28

DV= Neutral eyes DV= Eyes across all emotions DV= Faces across all emotions

Table 3.1.6 Multiple regression analyses showing the association between ADHD total symptoms, ASD total symptoms, and angry, sad and fearful faces

Variables	B (S.E)	β	p	Variables	B (S.E)	β	p	Variables	B (S.E)	β	p
ADHD total	-1.08 (0.56)	-0.26	0.06	ADHD total	-1.29 (0.50)	-0.34	0.01	ADHD total	-0.87 (0.57)	-0.20	0.13
ASD total	-0.23 (0.17)	0.18	0.18	ASD total	-0.10 (0.15)	0.09	0.51	ASD total	-0.19 (0.17)	-0.15	0.26
								CD total	-1.24 (0.70)	-0.22	0.08

DV= Angry faces DV= Sad faces DV= Fearful faces

Mediation analysis demonstrated that the indirect effect of dwell time to the eyes on the relationship between ASD symptoms and FER accuracy with ADHD symptoms as a covariate was not significant (see Figure 3.1.4) as the confidence intervals passed zero, *b*=-0.06 [CI -0.19, 0.03]. A second mediation analysis found that there was a significant indirect effect of dwell time to the eyes on the association between ADHD symptoms and FER accuracy (see Figure 3.1.5), even when ASD symptoms was included in the model as a covariate, *b*=-0.37 [CI -0.81, -0.11].

Figure 3.1.4 showing the results of a mediation analysis examining the indirect effect of dwell time to the eyes on the relationship between ASD symptoms and FER accuracy with ADHD symptoms as a covariate

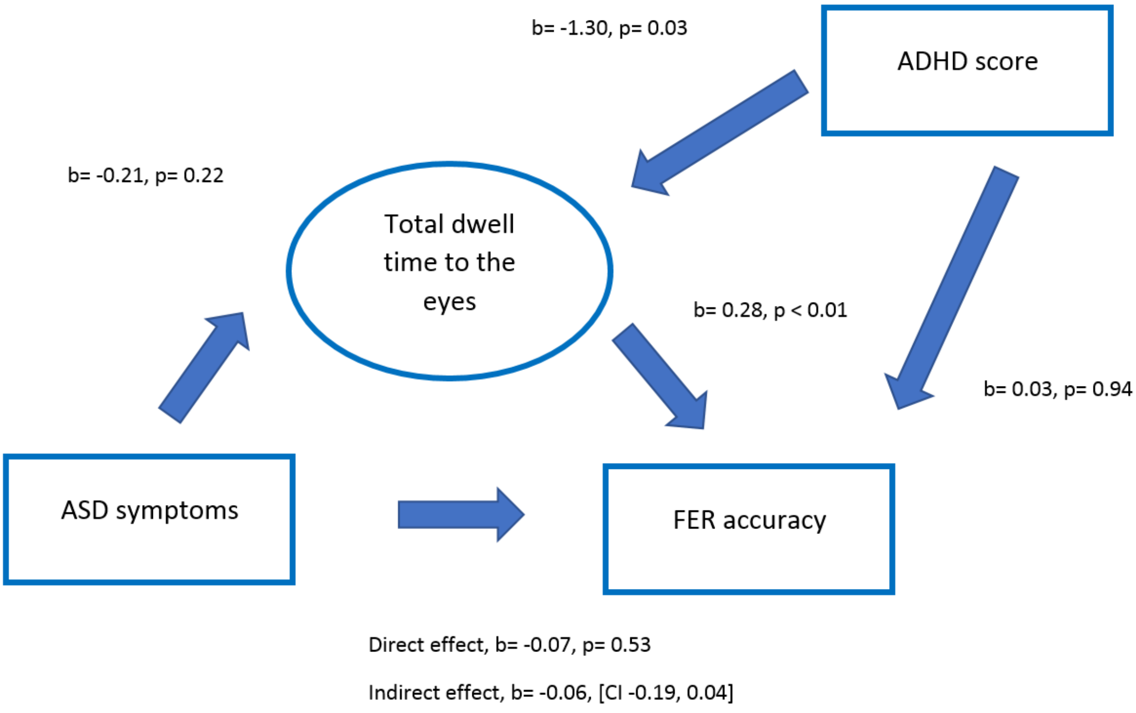


Figure 3.1.5 showing the results of a mediation analysis examining the indirect effect of dwell time to the eyes on the relationship between ADHD symptoms and FER accuracy with ASD symptoms as a covariate

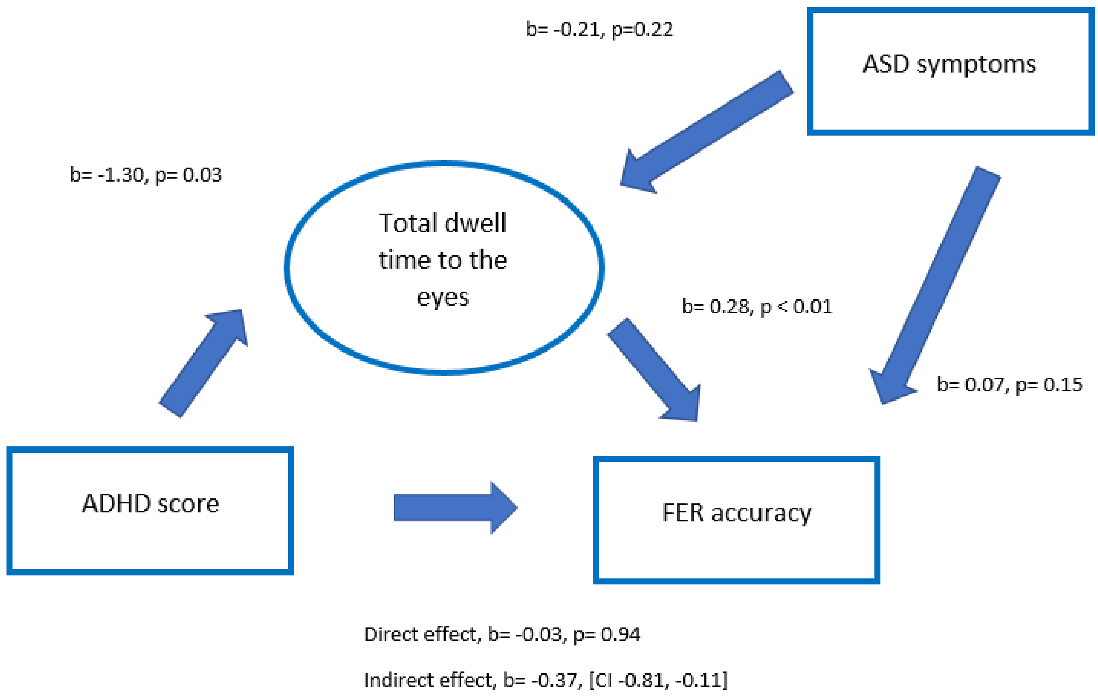


Table 3.1.7 compares the FSIQ, age and FER accuracy scores of this sample with the scores of controls from chapter 4. The table shows that FSIQ is lower for the ADHD sample than controls, and a Welch's t-test showed this difference was found to be significant, t(38.0)= 3.98, $p < 0.001$. The table also reveals that controls have higher mean scores for each individual emotion, although Welch's t-tests demonstrated that this difference was only significant for recognising fear, t(59.9)= 2.66, $p < 0.01$, and neutral faces t(64.4)= $p < 0.01$, no

difference was found for happy, anger or sad (all *p*s > 0.05). A further Welch's t-test showed that across all emotions combined the sample in this study had significantly lower scores in FER accuracy compared to controls from the school study ($t(35.7)= 2.68$, $p < 0.05$).

Table 3.1.7 FER accuracy scores (%) for the whole ADHD sample compared to controls from Chapter 4

		ADHD (N=65)	Control (N=21)
FSIQ	N	65	21
	Mean (SD)	83.8 (15.8)	98.5 (14.2)
	Range	53.0 - 12.0	76.0 - 126.0
Age (years)	N	65	21
	Mean (SD)	14.2 (2.1)	13.2 (2.0)
	Range	11.0 - 18.0	11.0 - 17.0
Happy FER accuracy	N	63	17
	Mean (SD)	94.0 (9.9)	95.1 (7.8)
	Range	50.0 - 100.0	75.0 – 100.0
Sad FER accuracy	N	63	17
	Mean (SD)	44.4 (15.7)	47.5 (27.3)
	Range	8.3 - 83.3	0.0 – 91.7
Anger FER accuracy	N	63	17
	Mean (SD)	71.0 (17.4)	78.4 (14.1)
	Range	25.0 - 100.0	50.0 – 100.0
Fear FER accuracy	N	63	17
	Mean (SD)	68.3 (20.0)	77.1 (9.0)
	Range	16.7 - 100.0	61.1 – 88.9
Neutral FER accuracy	N	63	17
	Mean (SD)	74.3 (31.0)	88.2 (12.9)
	Range	0.0 - 100.0	66.7 – 100.0
Combined FER accuracy	N	63	17
	Mean (SD)	70.4 (1.1)	77.3 (8.5)
	Range	33.3 - 88.3	63.9 – 91.1

Note: ASD= Autism Spectrum Disorder, ADHD= Attention-deficit/hyperactivity disorder FER= facial emotion recognition

3.1.4 Discussion

This study sought to investigate the additional effect of ASD symptoms in children with ADHD on FER accuracy and eye gaze. This was examined using a traditional FER task involving Ekman faces (Ekman & Friesen, 1976) demonstrating four basic emotions (happy, sad, anger and fear) as well as neutral faces, alongside eye tracking technology. Firstly, we expected that elevated ASD symptoms would be related to lower FER accuracy across all emotions. Instead we found that ASD symptoms had no additional effect on the FER accuracy of children with ADHD. Secondly, we expected that ASD symptoms would be associated with reduced looking to the eye region of the faces across each emotion. Although the results revealed that ASD symptoms were related to reduced dwell time to the eye and face region for sad faces, and to the face region for angry and fearful faces, these associations were no longer significant when ADHD symptom severity was controlled for. Finally, contrary to expectations, ASD symptoms were not found to mediate the relationship between dwell time to the eyes and FER accuracy scores across all emotions.

This study did not find any evidence that additional ASD symptoms in children with a diagnosis of ADHD directly or indirectly affect FER accuracy. Although this study has no control sample, the FER accuracy score was compared with the scores from the control group utilised in Chapter 4 as the FER accuracy task is identical (see Appendix 3 and Chapter 4). Firstly, it is important to note that the control group had significantly higher FSIQ scores than the ADHD sample ($p < 0.001$) and that FSIQ was found to correlate with FER accuracy in this chapter (Table 3.1.1) and Chapter 4 (Table 4.1). When comparing the FER accuracy scores, the sample in this study was found to have significantly lower scores across all emotions combined, and for fear and neutral, compared to controls from the school study (all *ps* < 0.05). This suggests that this sample of children with ADHD are impaired in FER accuracy, and that additional ASD symptoms do not exacerbate this deficit. Consequently, perhaps the children are already so impaired in FER that ASD symptoms have no additional effect.

Alternatively this could be because elevated symptoms of ASD are not sufficient to lead to additional impairment, perhaps the symptoms need to reach diagnostic level to have a measurable effect on FER accuracy. Indeed, one overlap study by Colombi & Ghaziuddin (2017) which found that those with ADHD+ASD were significantly impaired in their FER accuracy scores (compared to those with ASD alone) used diagnostic criteria to separate the groups. In our study only 15% of children in the study (N=10) reached criteria for an additional diagnosis of ASD. This is fewer than expected based on previous estimates of between 20 to 50% of children with ADHD reaching criteria for ASD (Rommelse et al., 2010) but likely to be a result of original recruitment criteria excluding children with a known diagnosis of ASD. This small number of individuals with an ASD diagnosis meant that the differences between the groups could not be investigated in any depth.

Although the study did not find that ASD symptoms were related to FER accuracy, an association was found with eye tracking variables. Dwell time to the eyes for sad, neutral and all emotions combined, and dwell time to the face for anger, fear, sad, and all emotions combined were associated with autistic symptom severity. However, this association no longer held when ADHD symptoms were controlled for. ADHD symptom severity was significantly associated with dwell time to sad and neutral eyes and angry and sad faces as well as dwell to time to both eyes and faces for all emotions combined. This suggests that ADHD symptom severity is in fact driving the differences in eye looking of this sample. These findings are supported by other studies finding that children with ADHD have abnormal eye looking patterns (Da Fonseca et al., 2009; Jusyte et al., 2017). Mediation analysis also confirmed that the relationship between ADHD symptom severity and accuracy scores was mediated by dwell time to the eyes when ASD symptom severity was taken into account. Consequently, it seems that this lack of visual attenuation to the eyes and faces in children with more severe ADHD symptoms may indirectly affect FER accuracy, but that ASD symptom severity does not.

There are a number of limitations to our study. Firstly, as no previous studies have explored the contribution of ASD symptoms to FER accuracy and FER eye looking patterns, multiple comparisons were necessary here to explore the FER accuracy scores and eye looking patterns of participants for all the emotions tested. However, it is important to note that if these were corrected the associations found would no longer have been significant. Consequently, these results must be interpreted as exploratory.

Secondly, the absence of a control group meant that it was not possible to establish how our sample directly compared to typical eye looking patterns. Due to task differences, although accuracy scores could be compared, FER eye tracking data could not be compared between this sample and the control sample used in Chapter 4 (see Chapter 4.2 for an explanation of design differences). If our sample was significantly different in looking patterns from controls it would be possible to make more concrete conclusions regarding the role of ASD and ADHD symptom severity in the dwell time to the eyes and face regions of emotional faces. This would then indicate whether interventions to improve emotion recognition should involve increasing attenuation to the eye region of faces, or training in how to recognise the emotions themselves.

Finally, the design of the study stimuli may have influenced the eye tracking data. Each stimulus slide used in the study contained an emotional or neutral face, presented simultaneously with response options (see Figure 3.1.2). Therefore, dwell time may have been influenced by time taken to consider different response options. When total dwell time to the face was measured we examined the amount of time spent looking at the face during each slide while removing the time spent looking at the response options. Nevertheless it is still the case that dwell time to the face may have been affected by the on-screen response options attracting attention away from the faces.

In conclusion, this study did not find that ASD symptoms directly or indirectly affected FER accuracy or time spent looking at the eyes and face regions of emotional faces. Exploratory analysis of the FER accuracy scores of the ADHD sample compared to a control sample indicated that all individuals were impaired. ASD symptoms appeared to have no additional influence. Instead, ADHD symptom severity was found to be associated with eye looking patterns and eye looking mediated the relationship between ADHD and FER accuracy. This study demonstrates the potential of using a response FER task alongside eye tracking when investigating the overlap between ADHD and ASD. Future studies that include a control group and more suitable task design are needed. This section has focused on FER, it is also necessary to examine the other two social cognition abilities, empathy and theory of mind, in order to gain a full understanding of the effect of ASD symptom severity on the social cognition abilities of children with ASD.

COGNITIVE AND AFFECTIVE EMPATHY

3.2 Introduction

In the previous chapter, I examined associations between FER and ASD symptoms in those with ADHD. As noted in the introduction (Chapter 1, section 1.3.2) social cognition is made up of three main skills. It is therefore now important to look at the second of these social cognition skills – empathy. Empathy is a key area of social cognition that has been found to be essential in helping to form friendships and navigate the social environment. For example, Gleason et al., (2009) found that adolescents that had low scores on an empathy task were those who were at the greatest risk of social and internalising problems and had less stable friendships as well as fewer friends. Research has identified two separate components of empathy; cognitive and affective (Barkley, 1997; Cohen & Strayer, 1996; Strayer & Eisenberg, 1987). The distinct nature of these two processes has been corroborated by some research finding that they occur in different areas of the brain (Eres, Decety, Louis, & Molenberghs, 2015; Fan, Duncan, de Greck, & Northoff, 2011; Hooker, Verosky, Germine, Knight, & D'Esposito, 2010; Shamay-Tsoory et al., 2009). Consequently, although cognitive and affective empathy are interlinked in everyday life, when exploring empathy as a skill it is valid to examine both facets in turn.

Children with ASD have been shown to have difficulties with cognitive empathy (e.g. Demurie et al., 2011), while affective empathy remains intact (e.g. Jones et al., 2010), this is often referred to as the empathy imbalance theory (Smith, 2009, see Introduction, section 1.4.2 for an in-depth exploration of empathy in ASD). This means that children with ASD tend to be able to share in the emotional experiences of those around them, but are often unable to independently identify and understand the emotions. The theory additionally highlights the disparity between individuals with ASD and those with CD; while ASD is related to cognitive empathy deficits, CD is associated with affective empathy deficits. For example, Schwenck et al., (2012) used a video sequences task to test empathy that involved watching nine video clips of emotional situations and then identifying and explaining the emotions the main characters felt. This tested cognitive empathy. Affective empathy was tested by asking the children to evaluate their own feelings after watching the clips. Results showed that children with ASD were impaired in cognitive empathy compared to controls and children with CD, whereas those with CD were impaired in affective empathy alone. These findings are supported by further studies investigating empathy in ASD (Dziobek et al., 2008; Hudry & Slaughter, 2009; Jones et al., 2010) and CD (Pasalich, Dadds, & Hawes, 2014; Van Goozen et al., 2016).

Studies investigating empathy in children with ADHD are rare, although findings suggest that children are not impaired in cognitive empathy (Demurie et al., 2011; Dyck et al., 2001), but affective empathy difficulties have been seen in children with ADHD in studies using parental reports (Marton et al., 2009) and a story based empathy task (Braaten & Rosén, 2000). However, these affective empathy deficits have been attributed to co-occurring CD traits and diagnosis. As noted previously, ADHD and CD are highly comorbid, with between 30 and 40% of children diagnosed with ADHD reaching diagnostic criteria for CD (Gresham, Lane, & Beebe-Frankenberger, 2005) and in studies taking CD into consideration, the associations between ADHD and affective empathy do not remain. The study by Marton et al., (2009) found that ADHD symptoms were no longer associated with affective empathy impairment once CD symptoms were taken into account. Similarly, a study by Hubble and colleagues (2015) found that children that met diagnostic criteria for both ADHD and CD were significantly impaired in affective empathy compared to children with ADHD alone (although this study did not include a control sample and so overall deficits in affective empathy cannot be ruled out). Most studies that found children with ADHD had empathy impairments did not take CD symptoms or diagnosis into account (Braaten & Rosén, 2000; Dyck et al., 2001; Serrano et al., 2015). Consequently, it seems then that both cognitive and affective empathy are intact in children with ADHD alone and it appears to be CD that is driving affective empathy deficits that have previously been reported in children with ADHD.

However, while the additional effect of CD on empathic ability in those with ADHD has been investigated, research has not explored the role of ASD symptoms in individuals with ADHD. In view of the empathy research in ASD populations, it could be the case that children with ADHD and elevated ASD symptoms or diagnosis are more at risk of cognitive empathy difficulties. Therefore, children with ADHD and high ASD symptoms could represent a subgroup of children with ADHD that are at greater risk of cognitive empathy difficulties, while those with ADHD and elevated CD symptoms are at greater risk of affective empathy deficits. As discussed in Section 3.1, there is some support for this proposal within facial emotion recognition studies. However, in chapter 3.1 of this thesis, ASD symptoms were not found to reduce the FER ability of children with ADHD. Nevertheless, as previously discussed, social cognition involves three main distinct skills, and it is important to explore the effect of elevated ASD symptoms on each of these skills.

Another way of examining the potential effect of ASD traits in ADHD could be through tracking participants' eye movements when engaged in empathy tasks. As reviewed in section 3.1, eye gaze is essential to emotion recognition and has been shown to be reliably monitored using eye tracking technology (Karatekin, 2007). Indeed, the combination of both eye tracking and behavioural tasks is increasingly valued by researchers to facilitate a better understanding of social cognition impairment in ASD (Freeth, Ropar, Mitchell, Chapman, & Loher, 2011). Although not commonly used in empathy research, eye tracking has often been used in studies involving ASD participants to monitor the way they view static and dynamic images of faces in emotion recognition studies (Harms et al., 2010; Papagiannopoulou et al., 2014). As discussed previously (Introduction, section 1.4.1), many studies have found that children with ASD look less at the eyes, and sometimes more at the mouth region of faces, (See Papagiannopoulou et al., 2014, for a meta-analysis) which has been used to explain difficulties in recognising emotions.

However, there has been much variation within individual studies, with some studies finding that children with ASD have the same looking patterns as typically developing children (e.g. Hernandez et al., 2009). Researchers have suggested that these differences may be primarily down to differences between studies of static versus dynamic stimuli (for a review of this, see Harms, Martin & Wallace, 2010). In addition, in the previous section of this chapter (3.1), the results of the eye tracking data from a static FER task found that ASD symptoms did not affect the eye looking patterns of children with ADHD when ADHD symptoms were statistically controlled. In contrast, eye tracking studies that have used dynamic emotion recognition tasks have all reported that children with ASD look less at the eye region whilst the evidence is more equivocal for studies looking at static images (Harms et al., 2010). Some researchers (Demurie et al., 2011; Harms et al., 2010; Speer, Cook, McMahon, & Clark, 2007) believe that this is because the use of dynamic tasks such as video tapes of acted or natural scenes are more ecologically valid, and better represent the difficulties with emotion recognition (both at the initial viewing level and higher order decision making level) that children with ASD experience in everyday life. Thus, deficits that affect children with ASD are only observed in these more complex tasks. These initial difficulties with avoiding eye gaze suggest problems with emotions in ASD may be founded at this initial perceptual viewing stage rather than difficulties with identifying the emotions themselves. Consequently, the use of eye tracking technology alongside dynamic stimuli, would appear to be particularly valuable in determining the role of ASD symptoms in the empathic ability of children with ADHD.

3.2.1 Aims and rationale

This study had two main aims. The first was to examine associations between ASD symptoms and cognitive and affective empathy task performance in children with a diagnosis of ADHD. Secondly, we aimed to explore whether children with elevated ASD symptoms demonstrated different eye viewing patterns to dynamic emotional images. To my knowledge, no study to date has looked at the role of ASD symptoms on the empathic ability of children with ADHD. Based on previous research, I hypothesised that children with elevated ASD traits would have lower cognitive empathy scores while their affective empathy scores would not differ from the rest of the sample. I hypothesised that ASD symptoms would be associated with eye tracking data, with children that had high ASD symptoms looking less at the eyes, and perhaps more at the mouth. I additionally expected to find a relationship between ASD symptom severity, impaired cognitive empathy scores and reduced viewing of the eye region.

3.2.2 Method

3.2.2.1 Participants

The participants in this study were the same as those in section 3.1. All 70 participants completed the empathy task, and were included in this section. See section 3.1.2, and p.xiii for more details on the sample.

3.2.2.2 Measures

As detailed in section 3.1.2, research diagnoses of ADHD, ASD and CD were assessed using the DAWBA, and IQ was assessed using the two-subset form of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999).

The empathy films clip task was used to test cognitive and affective empathy (Hubble, 2015). First, video clips were presented to participants which involved humans experiencing particular emotions, and then participants' cognitive and affective empathy were measured. Participants watched six video clips of approximately 90 seconds each. Four clips were taken from cinematic films, and two were real-life clips from documentaries. Two clips portrayed each of the three emotions: sadness, happiness and fear. The two sadness clips used were: clip sad 1, the Champ (fictional)- a young boy cries over the body of a boxer who he refuses to believe is dead, and clip sad 2, 9/11 documentary (real-life) – a man is interviewed about his experiences working as a firefighter during 9/11 and losing his colleague in the second attack. The two happiness clips were: clip happy 1, Racing stripes (fictional) - A young girl is seen competing in a horse race while riding a zebra and then celebrates with her father, and clip happy 2, Olympic games 2012 interview (real-life) - Athlete Greg Rutherford is seen receiving the gold medal for the long jump and then describes his happiness and how he succeeded to an interviewer. The two fear clips were: clip fear 1, Jaws 2 (fictional)– A young girl watches her friend being chased and killed by a shark, after which she is left alone in her boat far out at sea, and clip fear 2, Cliffhanger (fictional) – a terrified woman hangs from a rope suspended between two cliffs and the safety clasp on her harness is seen to snap. Video clips were shown to participants on a 15" laptop screen and the order of the clips was counterbalanced. Participants were asked to watch the clips, and no other information was given until the clip finished.

After viewing each clip, participants completed the Cardiff Empathy Scoring questionnaire (Hubble, 2015) which measures cognitive and affective empathy. The cognitive empathy questions presented participants with a list of emotions (anger, sad, fearful, upset, happy, scared, cheerful and suprised) and a likert scale from 0 (not at all) to 10 (very much) to rate the intensity of each emotion. Participants were then asked to indicate, by drawing a circle around the number, how strongly they thought the main character felt each emotion. Participants were then asked to give the reason they identified the two highest rated emotions (if applicable). If more than two emotions were rated highly, participants were asked to choose the highest two. The experimenter then asked, "What happened in the clip to make the main character (insert name/description) feel (insert emotion)?". The affective empathy questions took the same format but asked participants to rate and then explain their own emotions after viewing the clips (see Appendix 4 for the questionnaire).

Participants' responses were then scored for cognitive and affective empathy using the Cardiff Empathy Scoring System (Hubble, 2015, see Appendix for the scoring system). Cognitive empathy scores ranged from 0-9, while affective empathy scores were from 0-6. In both cases a higher score demonstrated a greater empathic response. For example, for cognitive empathy, between 1-2 points were allocated if the target emotion was identified and a further 1-2 points were allocated if a second relevant emotion was identified (0= not identified, 1= identified at low intensity, 2= identified at high intensity). The remaining 5 points were awarded according to the quality of the explanation the participant provided. Higher explanation points were allocated if the participant gave several pieces of factual information and also took into account the consequences of the event for the main character.

As the films used ranged in age appropriate viewing certificates from PG to 15 and the documentary clips had no certificate, parents were given descriptions of each video clip, and gave their consent for their child to watch them during their participation in the study. Consequently, while 60 children saw all six clips, the remaining 10 viewed between two and five clips. As a result of this we used mean scores for both cognitive and affective empathy performance. A second coder rated 20% of the cognitive and affective empathy questionnaires, resulting in an excellent level of reliability, with intraclass correlations of 0.95 for cognitive empathy and 0.95 for affective empathy.

Eye movements were recorded with a portable Tobii X2-60 compact eye- tracker. Eye tracking calibration was identical to that used in section 3.1.2.2. Eye movements were analysed using Tobii analysis software. For each clip, four second segments were created that were judged by six adults to contain the highest emotional content for the specific emotion (sadness, fear or happiness) being portrayed, while also focusing on the main characters' face. The segment in the clip Racing Stripes was not continuous, as was the case for all other clips, but was split into two segments of two seconds each. This was because this clip did not include a continuous four second high emotion window. Within the segments of each clip, separate AOIs were created for the eye region, the mouth, the face and the rest of the screen. AOI sizes differed in conjunction with changing sizes of main characters' faces. Percentage dwell time (the sum of the duration of all fixations to an AOI divided by the total duration of the segment) for eye and mouth AOIs was calculated for each clip. The amount of time spent looking at the face as a whole was calculated by subtracting the time spent looking at the rest of the screen.

Eye-gaze validity was checked using a sample rate percentage of 70% that gives a rough estimate of the quality of the eye tracking throughout the entirety of the video clip. Participants that had less than 70% validity for an individual clip were excluded from the analysis of that clip. This was used following the protocol set by (Hubble et al., 2015) in a study of adolescents with ADHD. For each video clip, the number of participants meeting 70% or more validity varied from 61.4% to 82.9%.

3.2.2.3 Data analyses

First, the effect of familiarity was assessed by using Pearson correlation coefficients to explore whether previously having watched the video clips affected participants' cognitive and affective empathy scores. Then Pearson correlation coefficients were used to explore the effect of ASD symptoms on cognitive and affective empathy scores across each video clip. The decision was made not to merge the data of the two clips for each emotion because of differences in the types of clips (i.e. fictional/non-fictional) and the potential differences in emotional intensity between the clips. The effect of ASD symptoms on eye viewing was then analysed using Pearson correlation coefficients. The eye tracking variables examined were the percentage of time spent looking at the eyes and the percentage of time spent looking at the mouth out of the time spent viewing the face. The amount of time spent looking at the face out of the time spent looking at the screen was also used. Where ASD symptom severity was significantly associated with empathy scores or eye tracking variables, multiple regressions were performed controlling for ADHD and/or CD symptoms.

Following on from the above analyses, to explore whether dwell time to the eyes mediates the relationship between ASD symptoms and cognitive empathy, mediation analyses were used. To determine if an indirect effect was significant, confidence intervals were used, following previous studies (Field, 2016; van Goozen et al., 2015).

3.2.3 Results

In the current study, 17 children had a full scale IQ score of less than 70, but were not excluded from the analysis as empathy was not found to be associated with IQ in a previous study of children with ADHD using the Cardiff Empathy Scoring System (Hubble et al., 2015). In addition results showed that whether or not participants had previously seen the video clips made no difference to the cognitive empathy and affective empathy scores of the clip (see Appendices 6 and 7).

Table 3.2.1 shows the characteristics for the 70 participants that completed the empathy task. There is little difference between the scores here and those in Table 3.1.1. Table 3.2.2 the mean scores for cognitive and affective empathy across each video clip. For cognitive empathy, mean scores for clips sad 1 and sad 2 were the lowest. Mean scores for clips fear 1 and fear 2 were the highest. However t-tests confirmed that scores for the sad clips were not significantly lower, and scores for the fear clips were not significantly higher, than the rest of the clips (all *p*s > 0.05).

Table 3.2.1 Sample characteristics for participants that completed the empathy task (N=70)

		Mean	**SD**	**Range**
WASI	Full scale IQ	83.6	15.8	53.0 – 120.0
Age	Years	14.2	2.1	10.0 – 18.0
ADHD	Hyperactive/impulsive	5.9	2.6	0.0 – 9.0
	Inattention	6.8	2.4	0.0 – 9.0
	Total symptoms	12.6	4.6	1.0 – 18.0
ASD	Social	11.2	7.7	0.0 – 27.0
	Repetitive behaviour	8.0	7.2	0.0 – 25.0
	Total symptoms	19.9	14.3	0.0 – 50.0
CD	Total symptoms	3.4	3.2	0.0 – 12.0

Note: ADHD= Attention-deficit/hyperactivity disorder, ASD= Autism Spectrum Disorder, CD= Conduct Disorder

Table 3.2.2 Cognitive and affective empathy scores for sad, happy and fear film clips in the empathy film clips task

N Mean % (SD) Range	**Sad 1**	**Sad 2**	**Happy 1**	**Happy 2**	**Fear 1**	**Fear 2**	**Combined**
Cognitive empathy (0-9)	69 5.5 (0.9) 3.0 - 8.0	63 5.3 (1.1) 3.0 – 8.0	69 5.4 (1.0) 3.0 – 7.0	64 5.4 (1.0) 3.0 -7.0	67 5.8 (1.1) 2.0 – 9.0	63 5.9 (1.0) 3.0 -9.0	69 33.5 (3.2) 10 - 41
Affective empathy (0-6)	69 3.0 (2.0) 0.0 – 6.0	63 3.3 (2.0) 0.0 – 6.0	69 3.7 (1.6) 0.0 – 6.0	64 3.1 (1.8) 0.0 – 6.0	67 2.7 (2.2) 0.0 – 0.6	63 3.0 (1.9) 0.0 – 0.6	69 17.9 (8.2) 0.0 - 32
% dwell to eyes	52 30.3 (24.4) 0.0 – 92.9	40 52.8 (37.2) 0.0 - 100	54 4.9 (4.5) 0.0 - 100	44 49.3 (32.6) 0.0 – 100	59 45.8 (22.0) 0.0 – 88.2	51 50.9 (17.2) 0.0 – 81.1	--------
% dwell to mouth	52 15.5 (16.8) 0.0 – 61.7	40 14.3 (25.8) 0.0 - 100	54 4.2 (4.7) 0.0 – 76.9	44 4.9 (10.6) 0.0 – 65.4	59 13.3 (18.1) 0.0 – 79.4	51 3.3 (6.9) 0.0 – 28.2	--------
% dwell to face	52 74.4 (20.3) 0.0 – 95.6	40 89.5 (22.9) 0.0 - 100	54 17.4 (11.0) 0.0 – 42.9	44 55.3 (27.6) 0.0 – 88.5	59 69.0 (19.8) 14.1 - 100	51 72.9 (19.7) 1.8 – 96.7	--------

Note: Sad 1 (The Champ), Sad 2 (911), Happy 1 (Racing Stripes), Happy 2 (Greg Rutherford), Fear 1 (Jaws 2), Fear 2 (Cliffhanger)

Pearson correlations examining the effect of ASD symptoms on the empathy scores of each video clip (Table 3.2.3) revealed that for clip fear 2, greater ASD symptoms were associated with lower cognitive empathy scores.

Tables 3.2.4 and 3.2.5 show the Pearson correlation coefficients for eye movements in each video clip. For fear 2, ASD symptoms were significantly associated with less looking at the eye region and an increase in looking at the mouth region. In clip fear 1, ASD symptoms were associated with less looking at the mouth region. The results of tables 3.2.3, 3.2.4 and 3.2.5 showed that follow up multiple regression analyses were not necessary because only ASD symptoms, not ADHD or CD symptoms, were associated with lower cognitive empathy scores and eye tracking data for clip fear 2.

Table 3.2.3 Relationship between empathy scores and ASD and ADHD symptoms

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. ASD total	0.45**	-0.11	-0.07	-0.09	-0.16	-0.20	0.12	-0.23	-0.06	0.18	-0.05	-0.26*	0.08	-0.20	0.09
2. ADHD total		-0.15	-0.10	0.01	-0.15	0.07	0.26*	-0.10	-0.06	0.71	-0.20	-0.13	0.00	-0.03	0.05
3. Sad 1 Cog			-0.02	0.03	0.03	0.15	0.05	-0.07	-0.04	0.06	-0.20	0.17	-0.03	0.39**	-0.08
4. Sad 1 Aff				0.04	0.60**	0.20	0.50**	-0.04	0.40**	0.11	0.54**	0.01	0.60**	0.10	0.35**
5. Sad 2 Cog					0.07	0.30*	-0.01	0.18	0.10	0.24	0.16	0.34**	0.19	0.65**	0.13
6. Sad 2 Aff						-0.03	0.18	0.08	0.37	0.10	0.46**	-0.03	0.39**	0.05	0.71
7. Happy 1 Cog							0.32**	0.24	0.07	0.16	0.17	0.15	0.28*	0.60**	-0.01
8. Happy 1 Aff								-0.08	0.31*	0.15	0.46**	0.11	0.42**	0.18	0.24
9. Happy 2 Cog									0.12	0.08	-0.09	0.28*	0.01	0.50**	-0.03
10. Happy 2 Aff										0.25	0.46**	0.06	0.32*	0.17	0.66**
11. Fear 1 Cog											0.10	0.17	0.05	0.54**	0.13
12. Fear 1 Aff												-0.05	0.44**	0.03	0.78**
13. Fear 2 Cog													0.17	0.64**	0.05
14. Fear 2 Aff														0.18	0.72**
15. All Cog															-0.09
16. All Aff															

Note: ASD= Autism spectrum disorder, ADHD= Attention-deficit/hyperactivity disorder, Sad 1 (The Champ), Sad 2 (911), Happy 1 (Racing stripes), Happy 2 (Greg Rutherford), Fear 1 (Jaws 2), Fear 2 (Cliffhanger), Cog= cognitive empathy, Aff= affective empathy,*p <.05; ** p < .01

Table 3.2.4 Relationship between eye tracking variables for sad and happy faces across both sad and happy empathy film clips, and ASD and ADHD symptoms

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. ASD total	0.45**	-0.02	0.03	0.14	0.03	0.17	-0.41	-0.15	0.06	0.10	-0.02	-0.03	-0.27
2. ADHD total		-0.44**	0.25	-0.06	-0.02	0.13	-0.29	-0.10	0.04	0.14	-0.07	0.10	-0.23
3. Sad 1 Eyes			-0.46**	0.37**	0.14	-0.29*	0.14	0.26	-0.22	0.05	0.19	-0.09	-0.13
4. Sad 1 Mouth				-0.02	0.05	0.00	-0.12	-0.29*	0.17	0.28*	-0.13	0.23	0.10
5. Sad 1 Face					0.30*	-0.29*	0.17	0.19	-0.14	0.11	0.14	0.06	0.19
6. Sad 2 Eyes						-0.43**	0.23	0.14	-0.15	0.08	0.27	0.01	0.17
7. Sad 2 Mouth							-0.28*	-0.15	0.26	-0.50**	-0.36*	0.28	-0.14
8. Sad 2 Face								0.09	0.01	0.15	0.05	0.03	0.22
9. Happy 1 Eyes									-0.67**	-0.31*	0.11	0.03	-0.08
10. Happy 1 Mouth										0.17	-0.01	-0.07	-0.08
11. Happy 1 Face											0.09	-0.01	-0.03
12. Happy 2 Eyes												-0.47**	0.12
13. Happy 2 Mouth													0.15
14. Happy 2 Face													

Note: ASD= Autism spectrum disorder, ADHD= Attention-deficit/hyperactivity disorder, Sad 1 (The Champ), Sad 2 (911), Happy 1 (Racing stripes), Happy 2 (Greg Rutherford) *p <.05; ** p < .01

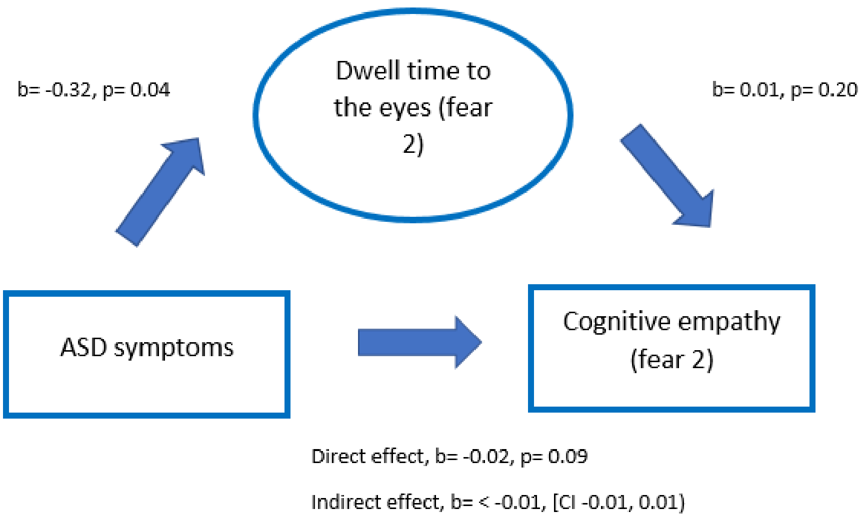
Table 3.2.5 Relationship between eye tracking variables for fearful faces across each fearful empathy film clip and ASD and ADHD symptoms

	2	**3**	**4**	**5**	**6**	**7**	**8**
1. ASD total	0.45**	0.23	-0.32*	-0.00	-0.34*	0.30*	-0.16
2. ADHD total		0.18	-0.04	-0.01	0.10	0.03	-0.23
3. Fear 1 eyes			-0.74**	-0.08	0.29*	0.38**	-0.09
4. Fear 1 mouth				0.14	-0.12	0.17	0.08
5. Fear 1 face					-0.06	0.17	0.47**
6. Fear 2 eyes						-0.67**	0.21
7. Fear 2 mouth							0.10
8. Fear 2 face							

Note: ASD= Autism spectrum disorder, ADHD= Attention-deficit/hyperactivity disorder, Fear 1 (Jaws 2), Fear 2 (Cliffhanger) *p <.05; ** p < .01

Following the results of tables 3.2.3 and 3.2.5 showing ASD symptoms significantly correlated with cognitive empathy and less time looking to the eyes for clip fear 2, a mediation analysis was performed (Figure 3.2.1). The analysis demonstrated that the indirect effect of dwell time to the eyes for fear 2 on the relationship between ASD symptoms and cognitive empathy (score for fear 2) was not significant as the confidence intervals did cross zero, *b* < -0.01 [CI -0.01, 0.01].

Figure 3.2.1 showing the results of a mediation analysis examining the indirect effect of dwell time to the eyes (for fear 2) on the relationship between ASD symptoms and cognitive empathy (for fear 2)



3.2.4 Discussion

This study aimed to investigate associations between ASD symptoms and empathic ability in children with ADHD. This question was addressed by using a behavioural empathy task that assessed both cognitive and affective empathy using dynamic stimuli, alongside the application of eye tracking technology to monitor eye movements. Firstly, I expected that children with ADHD and additional elevated ASD symptoms would have significantly lower cognitive empathy scores, while their affective empathy scores would not differ from the rest of the sample. Whilst there were no significant associations between ASD symptoms and affective empathy, as predicted, an association with cognitive empathy was found for only one specific fear clip. Secondly, I expected that children with high ASD symptoms would look less at the eyes of the main characters in the clip, and more at the mouth. I again found the same one specific fear clip was the only one that supported our hypothesis. In addition, I believed that the relationship between ASD symptoms and cognitive empathy scores would be mediated by participants' eye movements. This was explored for the relevant fear clip where no mediation was observed.

Our results do provide some limited evidence that the cognitive empathic ability of children with ADHD is reduced by the presence of elevated ASD symptoms, albeit restricted to a single emotion – fear – and not both of the fear clips used. However, it should be noted that multiple tests have been conducted in order to investigate the accuracy and eye tracking data of the three emotions, and that significant results would not survive Bonferroni corrections. The fact that our hypotheses were only upheld for fear is in line with previous facial emotion recognition research. Lozier et al., (2014) in their meta-analysis, found that children with ASD show deficits compared to controls across all emotions, but that these deficits are most pronounced for the negative emotions; disgust, fear and sadness (see Introduction section 1.4.1 and Chapter 3.1 for a more detail). However, we did not find that ASD symptoms were related to empathy across fear as a whole or for the other fear clip. It appears that clip fear 2 could be more sensitive to empathic differences between those with and without elevated ASD symptoms, but the reason for this is unclear. Both fear clips are fictitious, and although 50.7% of participants had seen clip fear 1 before compared to 11.9% for fear 2 (see Appendix 6), this was not found to be related to task performance. One possible reason could be that fear 2 had the largest face and eye regions of all the video clips in the segments. Some studies have suggested that individuals with ASD find faces aversive (Hutt & Ounsted, 1966; Joseph, Ehrman, McNally, & Keehn, 2008), therefore viewing such a large emotional face may be more sensitive to empathic differences in those with high ASD traits, and prompt the pattern we found of less looking at the eyes, more looking at the mouth and lower cognitive empathy scores.

On the other hand, perhaps the fact that we did not find that empathy scores and eye movements were associated with ASD symptoms in five of our six clips demonstrates that ASD symptoms do not have an additional effect on the cognitive empathy ability of children with ADHD.

In addition, contrary to expectations, the study found that eye looking did not mediate the relationship between ASD symptom severity and cognitive empathy for clip fear 2. This suggests that although participants with elevated ASD symptoms have lower cognitive empathy scores, this cannot be explained by less time spent looking at the eye region. It is unclear why this was not the case as this relationship has not been examined in previous research. Perhaps, for those with elevated ASD symptoms, difficulties with misinterpreting fear itself are responsible for reducing cognitive empathy fear scores, rather than time spent looking at the eye region of the face.

Furthermore, the findings of this study draw attention to the difficulties of using behavioural paradigms and eye tracking technology together, particularly when dynamic stimuli are involved. In our study the empathy clips were analysed separately, this was primarily because the clips are a mixture of real-life and fictitious clips. Emotions that are scripted and acted out are likely to differ from emotions that occur naturally, making it difficult to group them together. As well as this, it is difficult to group clips as although the segments of highest emotional intensity within each clip (as rated by judges) were analysed, the level of emotional intensity is likely to be different between clips. Another eye tracking difficulty for these dynamic clips is that eye, mouth and face AOIs vary in size from frame to frame, which means that with some clips with smaller AOIs it is easier to avoid looking at the main characters' faces. Future empathy studies could try to reduce this variance by using video clips that are all either real-life or fictitious and involve the same main character/s to attempt to control for differences in facial emotion intensity. An additional problem was that the clips were from films that differed in their age certificates. Both Cliffhanger and Jaws 2 were rated 15, which meant that 10 parents withdrew their consent for their children to watch one or both of these clips. Consequently, future studies should aim to use clips from age appropriate films to avoid losing data.

A further limitation to our study was the lack of a control group. Research suggests that ADHD diagnosis itself is not related to empathy impairment, instead the presence of comorbid disorders such as CD seem to be driving empathic deficits (Marton et al., 2009) or perhaps comorbid ASD, as our hypothesis suggests. However, without a control group we were unable to ascertain if our ADHD sample as a whole was impaired. It could be that the only participants that were impaired were those with elevated ASD symptoms, and their impairment is specific to interpreting fear. Alternatively, additional ASD symptoms could be exacerbating the pre-existing empathic impairment of those with ADHD. The absence of a control sample clearly limits my conclusions. Consequently, the need for a control group in future studies is manifest.

In summary, my results provide limited evidence that ASD symptom severity is related to empathic ability in adolescents with a diagnosis of ADHD. Only one of our video clips, fear 2, demonstrated this distinction between adolescents with and without elevated ASD symptoms. This could be because ASD symptoms have no substantive effect on empathic performance, or alternatively perhaps the fear 2 clip is simply the most sensitive to these differences. Nevertheless, the findings here are interesting as this study is the first to investigate the effect that the overlap between ADHD and ASD has on cognitive and affective empathy performance. In addition, the study demonstrates the difficulties involved in testing empathy using more ecologically valid dynamic stimuli and reveals the necessity for further research to determine the additional role of ASD in empathic ability for children diagnosed with ADHD.

3.3 THEORY OF MIND

3.3.1 Introduction

Section 3.2 of this chapter explored the effect of ASD symptoms on the cognitive and affective empathy ability of adolescents with ADHD, and found that ASD symptoms were only associated with reduced cognitive empathy for fear. The third social cognition skill to be explored in this thesis, theory of mind, refers to the ability to recognise and understand other people's thoughts and feelings, which enables the prediction and interpretation of future behaviour. The ability has been shown to develop from 18 months old and be present at 4 years of age in typically developing children (Frith & Frith, 2003; Perner & Lang, 1999). Theory of mind has been characterised as a social cognition difficulty that is most frequently associated with ASD (see Introduction section 1.4.3 for an exploration of theory of mind in ASD), but the relationship between theory of mind and ADHD is not so clearly stated.

A meta-analysis by Bora and Pantelis (2015) looked at 14 studies that used theory of mind tasks with children with ADHD and found mixed results. While several studies found that children with ADHD performed significantly more poorly than typically developing children in theory of mind tasks (Buitelaar, Van der Wees, Swaab–Barneveld, & Van der Gaag, 1999; Caillies, Bertot, Motte, Raynaud, & Abely, 2014; Kuijper, Hartman, & Hendriks, 2015; Mary et al., 2016; Shuai, Chan, & Wang, 2010), other researchers found no evidence of impairment (Charman et al., 2001; Dyck et al., 2001; Greenbaum, Stevens, Nash, Koren, & Rovet, 2009; Sodian & Hülsken, 2005; Yang, Zhou, Yao, Su, & McWhinnie, 2009). However, overall the authors found a significant association with a medium effect size across these studies (d=0.58), indicating that children with ADHD score lower than typically developing children in theory of mind tasks. What remains unclear is the effect of common co-occurring disorders on this finding; only one of the studies (Shuai et al., 2010) in the meta-analysis looked at the effect of comorbidities on the performance of children with ADHD.

Two of the most common ADHD comorbidities are ASD and CD. As discussed previously, a recent review estimated that between 20 to 50% of children diagnosed with ADHD meet criteria for ASD (Rommelse et al., 2010), whilst estimates for the overlap with ADHD and CD are 30 to 40% (Gresham et al., 2005). Although CD has not been traditionally associated with theory of mind difficulties, as has been the case with ASD (Wellman & Peterson, 2013), the disorder has been increasingly associated with social difficulties in interpreting emotions and empathy (Bowen & Dixon, 2010; Decety et al., 2009; Fairchild et al., 2009) as well as behaviours linked to theory of mind capabilities (Happé & Frith, 1996; Green et al., 2000; Oliver et al., 2011). Consequently, more investigation into the possible associations between theory of mind and CD are warranted. Considering this and the relatively mixed findings regarding ADHD, having additional elevated symptoms of either ASD or CD could have a marked effect on the theory of mind abilities of children with a diagnosis of ADHD.

It has been long established that children with ASD tend to have theory of mind difficulties, (Baron-Cohen et al., 1985) however there have been few studies that have directly compared theory of mind performance between children with ADHD and ASD. Studies that have tend to find that children with either disorder are impaired in comparison to controls. There is mixed evidence, however as to whether those with ADHD are more impaired than those with ASD, or vice versa, or if they seem to be impaired to the same extent (Hutchins et al., 2016). One study found that children with ASD were significantly more impaired than those with ADHD (Yang et al., 2009), and two found no difference in the levels of impairment between the groups (Buhler et al., 2011; Buitelaar et al., 1999). Whereas, Hutchins et al. (2016) tested children using a battery of theory of mind story based tasks ranging from basic to advanced, and found that children with ADHD performed at the same level as controls. Although there are a few, conflicting, studies that have compared those with diagnoses of ADHD and ASD, as far as I am aware, no studies have investigated the effect of autistic symptoms, or a comorbid ASD diagnosis on the theory of mind performance of children with ADHD. Based on these four studies and the results of ASD studies, it seems reasonable to think that children with ADHD and elevated ASD symptoms may have more difficulties with theory of mind task performance than those with ADHD alone.

Even fewer studies have looked at the effect of CD symptoms or diagnosis on theory of mind in children with ADHD. The majority of theory of mind studies have not excluded individuals with CD or taken comorbidity into account (Bora & Pantelis, 2015). As previously discussed, research has tended to find that children with CD have difficulties with affective social skills, such as empathy, whereas their cognitive social abilities, like theory of mind, are intact (Arango Tobón et al., 2018; Blair, 2005; Buitelaar et al., 1999; O'Nions et al., 2014; Schwenck et al., 2012) However, a few studies have tested whether this is the case and investigated the association between CD and theory of mind. For example, Happé and Frith (1996) used first order theory of mind tasks and a questionnaire measure of everyday theory of mind in children with CD. While all 18 children passed the tasks, they found, nevertheless, that the parents of these children reported that they demonstrated fewer behaviours that required theory of mind in everyday life (such as make-believe play and knowing when to apologise) compared to typically developing children.

Two further studies examining theory of mind behaviour (Green et al., 2000; Oliver et al., 2011) have also found that adolescents with CD were reported by their parents as having theory of mind deficits using a questionnaire measure, and thus the theory of mind ability of children with CD may be impaired. It consequently follows that children with elevated CD symptoms or a CD diagnosis may be those that demonstrate a more pronounced theory of mind impairment in ADHD studies. This could in part account for the differences found between studies which may have varying proportions of children with comorbid ADHD and CD. This explanation can be supported by the fact that one study of ADHD and theory of mind that excluded participants that had an additional diagnosis of CD found no impairment (Charman et al., 2001). A further study that also found no evidence for impairment (Dyck et al., 2001) assessed comorbid CD and identified only one child with a diagnosis of CD as well as ADHD. The other studies cited by Bora and Pantelis (2015) that investigated theory of mind ability in ADHD compared to controls did not take CD symptoms into account or exclude for CD in their ADHD group (Caillies et al., 2014; Greenbaum et al., 2009; Kuijper et al., 2015; Sodian & Hülsken, 2005; Yang et al., 2009).

Only one study (Shuai et al., 2010) has directly examined the impact of co-occurring CD on false belief ability in children with ADHD. They found that the theory of mind performance of an ADHD only group and an ADHD group with either co-occurring CD or ODD, was significantly impaired compared to controls. No difference in scores between the ADHD alone and ADHD +CD/ODD group was found. However, this study did not specify the number of participants who specifically had CD or ODD, consequently it is not possible to tell whether the participants with ADHD and CD had a greater deficit that those with ADHD alone or ADHD plus ODD. Accordingly, the effect of elevated comorbid CD symptoms or diagnosis on theory of mind task performance in children with ADHD has not been fully examined.

It is increasingly recognised that theory of mind tasks need to be carefully chosen when used in the ADHD population (for a review, see Uekermann et al., 2010). This is because performance in popular tasks using vignettes, such as strange stories, usually involve reading, which can affect scores. This can be a problem as children with ADHD often have reading disability (Sexton et al., 2012; Williams et al., 2017, submitted). Indeed, Chapter 2 of this thesis found that 30.3% of children with ADHD showed a dip in their literacy abilities, with 50.6% of those with a literacy dip having difficulties across more than one of the three literacy skills examined. In addition, some studies have found that performance in theory of mind tasks such as false-belief are related to attention and EFs (specifically working memory and inhibition) in children with ADHD (Fahie & Symons, 2003; Sodian & Hülsken, 2005). This suggests that theory of mind tasks that reduce attentional demands and require less EFs to be successful may be more suitable for children with ADHD. Consequently, it could be that children with ADHD sometimes perform poorly in theory of mind tasks as the tests are confounded by their co-occurring reading attention, and EF difficulties.

Therefore, it is important to choose a theory of mind task that does not involve reading skills to be successful. The Frith-Happé triangles animations task (Abell, Happé, & Frith, 2000) fits this description as it involves watching short cartoon clips (40 seconds) and verbally describing the events. The clips provide participants with many opportunities to talk about the triangles' feelings and behaviour. As the individual clips are short, visually presented and answers are given verbally during the clips, this task does not have the same issues with reading skills and attention as some other theory of mind tasks do and so it is more suitable for use in a sample of individuals with ADHD. This task has often been used in studies with autistic participants (Abell et al., 2000; Castelli, Happé, Frith, & Frith, 2000; Jones et al., 2018; Jones et al., 2017; Ricketts et al., 2013; Salter, Seigal, Claxton, Lawrence, & Skuse, 2008; Schwenck et al., 2012) and across studies participants with ASD have been impaired compared to controls. The task primarily measures the accuracy of participants' verbal descriptions of the actions presented in the clips (appropriateness score) and their use of mental state language to describe the interactions between the triangle characters (intentionality score). The majority of studies have found that children with ASD were impaired in the appropriateness scores of the theory of mind clips, with some also finding significantly lower intentionality scores (e.g. Bal et al., 2013). Only one study has been conducted in an ADHD population using this task (Mohammadzadeh, Tehrani-Doost, Khorrami, & Noorian, 2015) and they found boys aged 7 to 9 years with ADHD had significantly lower intentionality scores compared to typically developing controls, while there were no differences reported in the appropriateness scores. However, the study did not investigate the role of CD or ASD symptoms on theory of mind performance.

Interestingly, one study (Schwenck et al., 2012) used the triangles task with participants aged 6 to 17 years with CD and found no impairment compared to IQ matched controls. This finding could be because the control participants scored poorly; the mean appropriateness score of control participants was lower than previous studies have found, only 5 out of a possible score of 8. For example, (Jones et al., 2011) found that their control participants had a mean of 6.9. Schwenck et al. (2012) also only scored for appropriateness, and did not investigate the use of mental state language through the intentionality score.

3.3.1.2 Aims and rationale

As has been discussed, previous research investigating theory of mind in children with ADHD has demonstrated that deficits are often found. However, this research has not explored the additional effect of the commonly occurring comorbidities ASD and CD, whilst the tasks used to measure theory of mind may also have been not particularly suitable for children with ADHD that have reading and attentional difficulties. It is therefore important to look more closely at the relationship between ADHD and co-occurring ASD and CD symptoms using the triangles task in a more comprehensive manner.

The current study aims to examine the effect of ASD and CD symptoms and diagnosis on the triangles task performance of adolescents with ADHD. As all participants in this sample have ADHD, we expected that they would have significantly lower scores in the triangles task compared to a sample of control adolescents. Within our sample of adolescents with ADHD, it was predicted that adolescents with elevated ASD symptoms would perform worse on the triangles task. Based on the lack of consensus in the sparse previous literature, we were unsure how children with comorbid high CD symptoms/CD research diagnosis would perform.

3.3.2 Method

3.3.2.1 Participants

The sample in this study consisted of 61 participants that had completed the theory of mind task, from the same ADHD sample as described in Section 3.1.2.1. As previously described, all participants had a clinical diagnosis of ADHD in childhood.

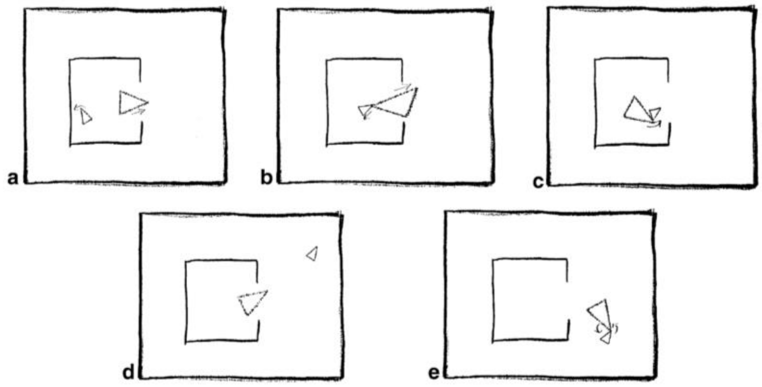
The sample used in this study utilised 21 control participants. Controls were recruited and tested at secondary schools, colleges and community centres across South Wales, or at Cardiff University. Participants were aged between 11 to 17 years, and the mean age was 13.2 years (SD= 2), and 38.1% were female. None of the children were diagnosed with developmental disorders. See chapter 4 (section 4.2.1) for more detailed information about these participants.

3.3.2.2 Measures

Research diagnoses of ADHD, ASD and CD were assessed using the DAWBA, and IQ was assessed using the two-subset form of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1993; see section 3.1.2.2 for more details).

The task used to measure theory of mind was the Frith-Happé triangles animations (Abell, Happé & Frith, 2000, see Figure 3.3.1). These are cartoon clips of two animated triangles shown on a computer screen. Participants were required to describe what they thought was happening in the clips, while the clips were playing. Two goal-directed clips and four theory of mind cartoon clips were used. Goal-directed clips were not intended to elicit theory of mind descriptions, and showed the triangle characters fighting and chasing. The theory of mind clips demonstrated stories that involved seducing, mocking, surprising and coaxing as their main themes. These clips provided participants with many opportunities to comment on the behaviour of the triangles. Participant's responses to clips were recorded using a dictaphone and were later transcribed. Responses were scored for accuracy of description (appropriateness) from 0 to 2 and for use of mental state language (intentionality) out of 5 (see Appendix 8 for scoring criteria). Higher scores indicated better performance. Mental state words are those that describe the triangles' emotions (e.g. happy, sad, crying) desires (e.g. want, need, try) or beliefs (e.g. know, wonder, think). A score of 0 for intentionality demonstrates no mental state language has been used, whereas a score of 5 denotes advanced use of mental state language to describe the triangles' interactions. Length of response was also measured in accordance with the number of clauses used (0 to 4), with lower numbers indicating the participant spoke less. This scoring criteria was based on original scoring by Abell, Happé and Frith (2000) and subsequent studies (Castelli, Happé & Frith, 2000; Ricketts et al.,2013). A second rater scored 40 out of 60 responses, and reliability was good to excellent with intraclass correlations of 0.84 for appropriateness and 0.95 for intentionality.

Figure 3.3.1 Stills taken from the Frith-Happé triangles animations task for a theory of mind clip (coaxing), from (Abell, Happé & Frith, 2000)



(a) Mother tries to interest child in going outside. (b) Child is reluctant to go out. (c) Mother gently nudges child towards door. (d) Child explores outside. (e) Mother and child play happily together.

Note: In the task, the triangles are in colour.

3.3.2.3 Data analyses

First, the effect of IQ, age and DAWBA disorder symptom counts on the triangles task appropriateness and intentionality scores was examined using Pearson correlation coefficients. Then those variables that were significantly correlated with triangles scores were entered into a multivariate regression analysis. The dependent variable in both analyses was the total score in the triangles theory of mind clips; one regression focused on the appropriateness triangles score, the other explored the intentionality score.

Data from all participants was then compared to the data of control participants (see Chapter 4, section 4.2.1 and p.xiii). This comparison enabled further exploration into scores for the triangles task to find out whether this ADHD sample were impaired in their performance compared to controls. Two Welch's ANOVAs were performed due to unequal group sizes. The ANOVAs compared intentionality and appropriateness scores between all individuals with ADHD and the control sample, with the appropriateness score and the intentionality score of the theory of mind clips as dependent variables.

ADHD participants were then split into four groups for further analysis; ADHD alone (N=31), ADHD with CD (N=22), ADHD with ASD (N=4) and ADHD with ASD and CD (N=4). Groups were created using the DAWBA diagnostic thresholds to identify participants with a likely comorbid disorder. As the ADHD+ASD and ADHD+ASD+CD groups numbered only four participants each, data from these groups was not included in any further analysis. Triangles data from control participants were included here to compare performance between groups. T-tests were used to explore differences between the groups for IQ and disorder symptoms. The effect of diagnosis of ADHD alone compared to ADHD+CD and controls on the triangles task was examined using two one way ANOVAs where the appropriateness score and the intentionality score of the theory of mind clips were the dependent variables.

3.3.3 Results

3.3.3.1 Descriptive statistics

Table 3.3.1 shows the characteristics of the sample. FSIQ was below average, 84.6 with a standard deviation of 15.7. Overall, 15 children had a performance IQ of less than 70, but were not excluded from the analysis as the triangles task has not been found to be associated with IQ in previous studies (Mohammadzadeh et al., 2015). The mean appropriateness score for the goal-directed clips was 1.8 out of 2 compared to 1.2 out of 2 for the theory of mind clips. A t-test revealed that the mean goal-directed appropriateness score was significantly higher than the corresponding score for the theory of mind clips, $t(60)= 8.92$. $p< 0.001$. Overall, 36% of the sample met criteria for a research diagnosis of CD, and 13% met criteria for ASD.

Table 3.3.1 Sample characteristics (N= 61)

		Mean	**SD**	**Range**
WASI	Full scale IQ	84.6	15.7	53.0 – 120.0
ADHD	Hyperactive/impulsive	5.9	2.6	0.0 – 9.0
	Inattention	6.7	2.5	0.0 – 9.0
	Total symptoms	12.6	4.6	0.0 – 18.0
ASD	Social	11.2	7.6	0.0 – 27.0
	Repetitive behaviour	7.4	6.8	0.0 – 23.0
	Total symptoms	19.3	13.7	0.0 – 50.0
CD	Total symptoms	3.2	3.1	0.0 – 10.0
Intentionality (0-5)	ToM clips	3.0	0.9	0.5 – 4.8
Appropriateness (0-2)	ToM clips	1.2	0.5	0.3 – 2.0
Appropriateness (0-2)	Goal directed clips	1.8	0.3	1.0 – 2.0
Length (0-4)	ToM clips	2.8	1.3	0.3 – 4.0

Note: ASD= Autism spectrum disorder, ADHD= Attention-deficit/hyperactivity disorder, CD= Conduct Disorder, ToM= Theory of Mind

3.3.3.2 Correlations

Correlations between the ASD total symptom score and the appropriateness and intentionality scores were not significant (Table 3.3.2). ADHD total score was found to be negatively correlated with appropriateness, intentionality and length. Conduct disorder total score was significantly negatively correlated with both appropriateness and intentionality scores. The results showed that correlations between IQ, appropriateness and intentionality were not significant. However IQ was significantly associated with the appropriateness score for the goal-directed clips. Age was positively associated with the appropriateness score alone, whereas gender was not related to any of the variables investigated.

Table 3.3.2 Pearson correlation coefficients for the association between theory of mind triangles scores with length, ADHD, CD and age

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Gender	-0.06	-0.02	-0.09	0.10	0.13	0.06	0.11	0.02	-0.10
2. IQ		-0.11	0.26*	0.18	0.25	0.06	-0.08	-0.03	-0.26*
3. Age			0.08	0.31*	0.10	0.04	-0.06	-0.22	-0.05
4. Goal-directed				0.16	0.25	0.11	0.04	-0.10	-0.03
5. Appropriateness					0.70**	0.47**	-0.13	-0.31*	-0.39**
6. Intentionality						0.75**	0.03	-0.32*	-0.43**
7. Length							0.05	-0.32*	-0.22
8. ASD total								0.44**	0.10
9. ADHD total									0.22
10. CD total									

Note: ASD= Autism Spectrum Disorder, ADHD= Attention-deficit/hyperactivity disorder, CD= Conduct Disorder, *p <.05; ** p < .01

Those variables that were significantly associated with appropriateness and intentionality, were entered into two multiple regression models.

Using the appropriateness score as the dependent variable (Table 3.3.3), ADHD and age were no longer significantly associated with performance. Results showed that CD and response length were significant predictors of the appropriateness score.

For intentionality, ADHD severity was no longer found to be significantly associated with intentionality when response length and CD score were taken into account. Both response length and CD severity were found to be significant predictors of the intentionality score. Overall it seems that having higher CD symptoms leads to poorer performance in the triangles task, even when ADHD symptoms, length and age were taken into account.

Table 3.3.3 Association between triangles scores and length, ADHD symptoms, CD symptoms and age

Variables	**B (S.E)**	**β**	***p***	**B (S.E)**	**β**	***p***
Length ToM clips	0.56 (0.06)	0.71	< 0.001	0.15 (0.04)	0.38	<0.001
ADHD score	-0.03 (0.07)	-0.04	0.66	-0.03 (0.05)	-0.06	0.62
CD score	-0.34	-0.26	0.002	-0.18 (0.09)	-0.28	0.02
Age (years)	_____	_____	_____	0.22	0.24	0.03
	-DV intentionality			- DV appropriateness		

Note: ADHD= Attention-deficit/hyperactivity disorder, CD= Conduct Disorder, ToM= Theory of Mind

3.3.3.3 Relationship between theory of mind Frith-Happé triangles animations scores and research diagnostic groups

The triangles task scores of all participants and a separate sample of controls, are compared in Table 3.3.4. Controls had higher FSIQ scores than the ADHD sample, and a Welch's t-test revealed that this difference was significant, $t(37.9) = 3.8$, $p < 0.01$. Appendix 9 shows that within the control group, Pearson correlation coefficients revealed that FSIQ was significantly correlated with the intentionality score ($r=0.49$, $p= 0.03$) but not the appropriateness score of the theory of mind clips ($r=0.24$, $p=0.29$).

A Welch's t-test found that there was a significant difference between the intentionality score of the triangles task and group membership, with the ADHD group having significantly lower scores than controls, $t(80) = 2.7$, $p < 0.01$.

A further Welch's t-test revealed that the relationship between the appropriateness score of the theory of mind clips and ADHD/control group membership was not significant, $t(80)= 1.1$, $p= 0.35$.

Table 3.3.4 Sample characteristic for ADHD sample compared to controls

		ADHD*	Control
		N=61	N=21
		Mean (SD)	**Mean (SD)**
WASI	Full scale IQ	84.6 (15.7)	98.5 (14.20)
ADHD	Hyperactive/impulsive	5.9 (2.6)	0.07 (0.3)
	Inattention	6.7 (2.5)	0.3 (1.3)
	Total symptoms	12.6 (4.6)	0.4 (1.2)
ASD	Social	11.2 (7.6)	5.0 (3.5)
	Repetitive behaviour	7.4 (6.8)	2.5 (2.5)
	Total symptoms	19.3 (13.7)	8.0 (5.1)
CD	Total symptoms	3.2 (3.1)	0.1 (0.3)
Intentionality (0-5)	ToM clips	3.0 (0.9)	3.7 (0.9)
Appropriateness (0-2)	ToM clips	1.2 (0.5)	1.3 (0.6)
Appropriateness (0-2)	Goal directed clips	1.8 (0.3)	1.7 (0.5)
Length (0-4)	ToM clips	2.8 (1.3)	3.1 (1.3)

Note: ADHD= Attention-deficit/hyperactivity disorder, CD= Conduct Disorder, ToM= Theory of Mind
*The whole sample of children with ADHD examined in this chapter with triangles data

Table 3.3.5 shows the characteristics of the four diagnostic groups compared to the data of control participants from the school study. IQ scores are highest for the ADHD+ASD group, closely followed by controls, and scores are lowest for the ADHD+CD and ADHD+CD+ASD groups. As previously mentioned, analysis was not conducted on the ADHD+ASD and ADHD+ASD+CD groups due to small group sizes. A t-test revealed the difference between IQ scores for the control group and the ADHD+CD was significant ($t(41)= -4.4$, $p < 0.001$). The ADHD+CD group had a lower mean IQ score than the ADHD alone group; a t-test revealed this difference was not significant, $t(51) = 1.5$, $p= 0.15$.

Triangles scores were lowest for the ADHD+CD+ASD followed by the ADHD+CD group, and highest for the control group. A one-way ANOVA found that the association between the appropriateness score of the theory of mind triangles clips and diagnostic group membership for three groups (ADHD, control, ADHD+CD) was not significant, $F(1,71)= 1.76$, $p= 0.18$.

A second ANOVA found that there was a significant relationship between the intentionality score of the theory of mind clips and diagnostic group membership, $F\ (2,71)= 8.29$, $p < 0.01$. A tukey post hoc test revealed that there was a significant difference between the ADHD alone group and the ADHD+CD group ($p= 0.02$) as well as ADHD+CD and controls ($p < 0.001$), with ADHD+CD group having significantly lower scores. There was no statistically significant difference between the ADHD alone group and controls ($p= 0.98$).

Table 3.3.5 Sample characteristics for ADHD alone, ADHD plus CD, and controls from the school sample

		ADHD	ADHD+ CD	ADHD +ASD	ADHD+ ASD+CD	Control
		N= 31	N= 22	N=4	N=4	N=21
		Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
IQ	Full scale IQ	86.1 (16.3)	80.0 (13.2)	103.0 (16.3)	79.8 (10.1)	98.5 (14.20)
ADHD	Hyperimpulsive	5.0 (2.8)	6.6 (2.4)	7.5 (1.7)	7.3 (1.7)	0.07 (0.3)
	Inattention	6.4 (2.7)	6.7 (2.5)	7.8 (1.5)	8.0 (1.2)	0.3 (1.3)
	Total symptoms	11.4 (4.8)	13.1 (4.6)	15.2 (2.7)	15.3 (2.7)	0.4 (1.2)
ASD	Social	9.2 (8.1)	11.1 (6.2)	18.3 (1.5)	19.8 (5.1)	5.0 (3.5)
	Repetitive behaviour	5.3 (5.8)	6.2 (4.1)	19.8 (2.2)	18.5 (4.8)	2.5 (2.5)
	Total symptoms	15.4 (13.6)	17.8 (9.7)	38.3 (3.3)	39.0 (8.4)	8.0 (5.1)
CD	Total symptoms	1.1(1.1)	6.0 (2.7)	0.8 (1.0)	5.3 (2.1)	0.1 (0.3)
Intentionality (0-5)	ToM clips	3.1 (1.1)	2.4 (1.0)	3.8 (0.9)	2.0 (1.2)	3.7 (0.9)
Appropriateness (0-4)	ToM clips	1.4 (0.5)	1.1 (0.4)	1.4 (0.4)	0.4 (0.3)	1.3 (0.6)
Appropriateness (0-4)	Goal directed clips	1.8 (0.3)	1.8 (0.3)	2.0 (<0.001)	1.5 (0.6)	1.7 (0.5)
Length (0-4)	ToM clips	3.1 (1.1)	2.4 (1.4)	2.9 (1.2)	2.2 (1.6)	3.1 (1.3)

Note: ASD= Autism Spectrum Disorder, ADHD= Attention-deficit/hyperactivity disorder, CD= Conduct Disorder, ToM= Theory of Mind

3.3.4 Discussion

The main aim of this study was to investigate the effect of comorbid ASD and CD symptoms on the theory of mind performance of adolescents with ADHD. Firstly, we expected that adolescents with elevated ASD symptoms would have lower appropriateness scores for the theory of mind triangles animations, suggesting a more profound theory of mind deficit. We instead found that ASD symptoms were not associated with the appropriateness or intentionality scores on the triangles task. Secondly, we were unsure of the effect of comorbid elevated CD symptoms on the theory of mind scores of adolescents with ADHD. However, we found that CD symptoms were associated with both appropriateness and intentionality scores for the theory of mind triangles clips, when response length, ADHD symptom severity and age were controlled for. Finally, we sought to determine whether our ADHD sample as a whole were impaired compared to controls from the school study. We did find that our ADHD sample had significantly lower intentionality scores for the triangles task, but there was no difference in appropriateness scores between the groups. Further analyses found that these differences were observed between the ADHD+CD group in comparison to those with ADHD alone and controls. The latter two groups did not differ significantly.

Previous studies using the triangles task in ASD populations have consistently found that children with ASD are impaired in the appropriateness scores of the theory of mind clips, while performance in the goal directed clips is intact (e.g. Abell et al., 2000; Salter et al., 2008). The results of this study showed that ASD symptoms in children with ADHD were not related to the appropriateness or intentionality scores for the triangles animations. There was also no relationship between ASD symptoms and length of response. When separating the sample into diagnostic groups, we found that the four children that reached criteria for a research diagnosis of ASD in addition to ADHD, had higher scores in the triangles task compared to the ADHD alone group and the ADHD plus CD group (Table 3.3.5). However, with such a small group size for ADHD plus ASD we were unable to carry out further analysis. This does, nevertheless, demonstrate that ASD symptoms below the level of diagnosis did not have an additional effect on the triangles scores of children with ADHD.

One reason for these findings could be that only a small number of children in our sample had an additional clinical diagnosis of ASD. Children were recruited to take part in this study following participation in the SAGE study. The SAGE study excluded children if they had a clinical diagnosis of autism. However, it is possible that some children might have had unrecognised autism, or were diagnosed after taking part in SAGE. This can be validated by eight children in our sample reaching research diagnostic criteria for ASD (four of whom also met thresholds for CD diagnosis). Nevertheless, the exclusion criteria of SAGE does mean that the number of children meeting diagnostic criteria for ASD in our sample is lower than usually found in an ADHD sample. For instance, we found that 13% of our sample met DAWBA diagnostic criteria for ASD, when prevalence estimates across a number of ADHD studies were found to be between 20 to 50% (Rommelse et al., 2010). Perhaps a comorbid diagnosis of ASD is necessary to affect theory of mind performance in ADHD.

An alternative view could be that because the sample as a whole had low appropriateness and intentionality scores, ASD symptoms did not have an additional effect on task performance. When comparing the results of our study with ASD studies, it is clear to see that the children in our sample are impaired in their performance of the triangles task. For example, we found that our mean average intentionality score for our whole sample was 3.0

(out of 5) compared to a score of 2.9 for children with ASD in Ricketts and colleagues' (2013) study. Notably, Ricketts et al., (2013) had comparable IQ scores to this study, with a mean of 90.4 and a range of 53-126, while this study had a mean of 84.6 and a range of 57-120, suggesting that this comparison is viable. In addition, when comparing the ADHD sample to controls we found that controls had significantly higher scores for intentionality, but that there was no difference in appropriateness scores for the theory of mind clips. This supports the findings of the one previous study that has investigated triangles task scores in children with ADHD (Mohammadzadeh et al., 2015), which similarly found impairment in intentionality for participants with ADHD.

Based on previous literature, it was unclear as to whether CD symptoms would be related to performance in the triangles task. Research exploring theory of mind in those with CD has been sparse but has not generally demonstrated deficits (see Introduction, section 1.6). However, in this study, CD symptoms were found to significantly predict both appropriateness and intentionality scores. This seems to conflict with the findings of Schwenck and colleagues (2012) who found no difference between the appropriateness scores of children with CD and typically developing children. However, this study involves children with ADHD, 36% of whom reached DAWBA diagnostic thresholds for comorbid CD. Consequently, it could be the case that I have identified a subtype of children that have impaired theory of mind; those with ADHD and high CD symptoms. When separating this sample into children who did and did not reach CD diagnostic criteria (see table 3.3.5) we found that the ADHD plus CD group had significantly lower intentionality scores than the ADHD alone group. Additionally, in the ADHD plus CD group the average mean intentionality score was 2.4 out of 5. Ricketts et al. (2013) found a higher average intentionality mean of 2.9 for their ASD sample; this could indicate that children with ADHD and CD may have a similar theory of mind deficit to children with autism. This finding warrants further investigation.

Additionally, we found that scores for the goal-directed clips were significantly higher than the appropriateness scores for the theory of mind clips. The goal directed clips are simply action clips containing no mentalising behaviour. In fact, 69% of children with ADHD received full marks for both clips. This score does not differ from that of controls, where 68% of participants had full marks. For the theory of mind clips, between 30 and 47% of ADHD participants scored full marks for appropriateness for each individual clip, compared to between 38 and 81% of control participants. This corroborates with several previous ASD studies (Abell et al., 2000; Salter et al., 2008; Zwickel, White, Coniston, Senju, & Frith, 2011) which have ascertained that children with ASD are able to interpret the action of the triangle characters, it is their mentalising ability that is impaired. The high scores on the goal-directed clips also indicate that adolescents in this study understood the task and undertook it to the best of their ability. This provides support for the decision to utilise the Frith-Happé triangles animations in this group as a theory of mind task that is not influenced by problems with reading and limits the attentional demands required from participants.

Although the appropriateness and intentionality scores of the triangles were the primary focus of this study, we were also interested in the length of participants' responses. Previous studies have tended to score for response length, but have not taken this into account when comparing the performance of those with diagnoses to those without (Abell et al., 2000; Schwenck et al., 2012). It is important to consider response length, as participants may appear to have theory of mind deficits due to low appropriateness and intentionality scores, when in fact these scores are lower because they are speaking less than other participants. Mohammadzadeh et al. (2015) found that children with ADHD in their study spoke significantly more than control children, but nevertheless had significantly lower scores for appropriateness and intentionality. Within the ADHD group we found the opposite, length was negatively associated with ADHD symptom severity; children with more ADHD symptoms spoke less when describing the triangles clips. Although ADHD severity correlated with both the intentionality and appropriateness triangles scores, this association was no longer significant when response length was taken into account. Interestingly, CD symptoms were not associated with response length, suggesting that how much the children spoke made no difference to their appropriateness and intentionality scores. These results demonstrate the importance of exploring the role that response length has on performance in this task.

There are limitations to this study. Firstly, as previously mentioned, we were unable to examine the effect of a diagnosis of both ADHD and ASD on triangles performance as only eight participants met diagnostic criteria for both disorders, half of whom also met criteria for CD. Secondly, it is important to note that when comparing the results of the ADHD sample as a whole, and split into diagnostic groups, there is a significant difference in IQ scores. Interestingly, within the control group, IQ was significantly correlated with intentionality score for the theory of mind clips but not with the appropriateness score. Whereas within the ADHD sample, IQ is not related to any triangles scores, with the exception of the goal directed clip score, which do not require mentalising. Consequently it seems that in children with ADHD, IQ is not related to theory of mind ability.

In summary, our results seem to suggest that adolescents with ADHD are impaired in theory of mind using a task where performance is not constrained by reading difficulties or a high level of attentional demands. While elevated ASD symptoms appear to have no additional effect, it seems that children with ADHD with high CD symptoms or who also reach diagnostic criteria for CD have a more pronounced theory of mind deficit than those with ADHD alone. Studies have found that theory of mind deficits not only impact children's day to day social communication and interaction but also effect the ability to trust others and make moral judgements (Korkmaz, 2011; Wellman & Miller, 2008), and can continue to adulthood (Nijmeijer et al., 2008). Consequently, it is important to have a better understanding of children that have an increased likelihood of theory of mind deficits in order to target interventions appropriately. As far as I am aware, no previous study has investigated the effect of ASD and CD symptoms on the theory of mind performance of children with ADHD, whilst only a single study has used this task to look at children with ADHD. Perhaps this study has identified a subtype of adolescents with ADHD and elevated CD symptoms that are at risk of having greater theory of mind difficulties, which may also partially account for the differing results in ADHD literature.

CHAPTER 4

The effect of social cognition ability on the reading comprehension skills of children with ASD

4.0 Summary

This chapter aims to consolidate the findings of Chapters 2 and 3 by exploring whether social cognition skills affect the reading comprehension ability of children with a diagnosis of ASD. To do this, a sample of adolescents with ASD and a control group of children without developmental disorders undertook the literacy and social cognition tasks utilised in the previous chapters. A control group was included in this study to determine whether the expected relationship between reading comprehension and social cognition is unique to those with ASD, or is also true of typically developing children. As the overlap between ASD and ADHD is the primary aim of this thesis, the role of ADHD symptoms in associations between reading comprehension and social cognition will also be taken into account.

The chapter will first seek to replicate established findings that individuals with ASD demonstrate deficits in reading comprehension and all three social cognitive skills (FER, empathy and theory of mind). Next it will investigate the proposed relationship between reading comprehension and social cognition. Finally, the question of whether social cognitive skills affect the reading comprehension ability of children with ASD will be explored using mediation analyses.

4.1 Introduction

As discussed in Chapter 1 (1.2.2) and Chapter 2 (2.1), children with ASD are often found to have reading comprehension deficits while their basic reading and spelling skills are intact (e.g. Jones et al., 2010; Nation et al., 2006; Newman et al., 2007; Åsberg et al., 2008). Consequently, there appears to be a disassociation between reading comprehension and other literacy skills in adolescents with ASD. Evidently basic reading proficiency is not sufficient to ensure strong reading comprehension skills. Although, in chapter 2 of this thesis we found that ASD traits in a sample of children with ADHD, did not predict greater reading comprehension deficits.

Difficulties with social cognition have long been perceived as characterising the social and communication difficulties that are commensurate with ASD diagnosis (see Introduction, section 1.4 for exploration of social cognition in ASD). As discussed previously, social cognition includes three key abilities: facial emotion recognition, empathy and theory of mind. Children with ASD have been found to typically have deficits in FER (e.g. Bal et al., 2010; Wingenbach, Ashwin, & Brosnan, 2016) . A meta-analysis found that children with ASD are impaired in their recognition of all six basic emotions (happy, sad, anger, fear, surprise and disgust; Bons et al., 2013; Lozier et al., 2014) but that the greatest level of impairment lay in the recognition of fear, sadness and disgust. Indeed, the results of Chapter 3 showed that in adolescents with ADHD, ASD symptom severity was associated with significantly lower cognitive empathy scores for the clip fear 2. Previous research has found that children with ASD are impaired in cognitive empathy compared to controls (e.g. Demurie et al., 2011; Schwenck et al., 2012), while affective empathy tends to be unimpaired (e.g. Jones et al., 2010; Schwenck et al., 2012). Again this was supported by the results of Chapter 3 (see 3.1.3) which found that in children with ADHD, elevated ASD symptoms were associated with significantly lower cognitive empathy scores for fear, while affective empathy scores for fear were not associated. Theory of mind deficits have additionality been consistently found in children with ASD (Abell et al., 2000; White et al., 2009), whilst the results presented in Chapter 3 suggested that these deficits are also experienced by children with ADHD, and are exacerbated by elevated CD symptoms.

Eye tracking studies have also demonstrated social cognition impairments in children with ASD, revealing that they tend to look less at the eye region of faces and often more at the mouth region, than typically developing peers, which negatively impacts their ability to recognise emotions (Papagiannopoulou et al., 2014). Chapter 3 of this thesis explored eye tracking in both FER and empathy in a sample of adolescents with ADHD. While FER results showed little evidence that comorbid ASD symptoms had an effect on eye looking patterns in the ADHD sample as a whole, it seemed that ADHD symptom severity was instead associated with eye looking patterns, specifically reduced time spent looking at the eyes and faces across all emotions. When investigating empathy (chapter 3, section 3.2), results did provide some evidence that eye looking patterns were aggravated by the presence of additional ASD symptoms in children with ADHD. When viewing fearful faces, children with elevated ASD symptoms looked less at the eye region and more at the mouth region of the faces, which corroborates with previous research on children diagnosed with ASD (Papagiannopoulou et al., 2014).

Researchers have identified the benefits of using eye tracking in conjunction with FER and empathy behavioural tasks (e.g. Freeth et al., 2011) as this means it is possible to determine whether a social cognitive deficit lies in the initial viewing of the relevant areas of the emotional stimuli, or at interpreting the emotions themselves, which in turn will be beneficial to developing efficacious interventions that target relevant deficits. In Chapter 3, findings from the empathy film clips task showed that time spent looking at the eyes of fearful characters did not mediate the relationship between cognitive empathy for fear and ASD symptom severity. This suggested that the significantly lower cognitive empathy scores observed could be due to higher order processing difficulties with interpreting the emotion as fear, rather than less time spent looking at the eye region. Therefore previous research and the preceding chapters of this thesis, demonstrate the relevance of both reading comprehension difficulties and social cognition deficits in those with ASD or elevated ASD symptoms.

Theoretically, a relationship between reading comprehension and social cognition seems likely. In order to understand a story, a child needs to be able to access prior knowledge of human behaviour, including emotions, thoughts and beliefs, in order to make inferences about the characters and draw conclusions about the events in the story (Mar & Oatley, 2008). When children are able to make these inferences successfully, reading comprehension skills are greatly improved. Reading comprehension and social cognition would therefore appear to be intimately connected. In support of this, a brain imaging study found that when typically developing individuals read mental state stories the regions of the brain involved in social cognition were activated, (Fletcher et al., 1995) whereas this was not the case when participants read physical stories. This suggests that poor social cognition could hamper reading comprehension ability.

One could predict that the relationship between reading comprehension and social cognition is stronger in those with ASD than in typically developing children. Although the dissoociation between basic reading and reading comprehension skills found in children with ASD is present in the typical population (Oakhill, Cain, & Bryant, 2003, see Introduction, section 1.2), a study by Nation and Snowling (1997) demonstrates that the correlations between word reading and reading comprehension are significantly stronger in typically developing children than in children diagnosed with ASD. This suggests that other factors, such as social cognition impairments, could be reducing reading comprehension ability in children with ASD. Perhaps the role social cognition plays in reading comprehension ability is diminshed in typically developing children when compared to those with ASD. The discrepancy so often found between basic reading and reading comprehension abilities in children with ASD, alongside the difficulties with social cognition that are the hallmark of the disorder, suggests that a connection between the two seems likely. The theoretical connection between reading comprehension and social cognition mentioned previously, lends further support to this view. However, there has been little research investigating the inter-relationship between these skills in an ASD population. If impaired social cognition abilities negatively affect reading comprehension skills, this finding would be extremely beneficial in aiding the direction of future interventions for those with ASD. For example, interventions could be tailored to simultaneously support both reading comprehension and social cognition.

Despite the theoretical implications of the relationship between reading comprehension and social cognition in children with ASD, to our knowledge, only one study has examined this. Ricketts et al., (2013) found, within a sample of 100 adolescents with ASD, that a theory of mind measure (the Frith-Happé triangles task; see Chapter 3.3) significantly predicted reading comprehension scores when basic reading was controlled. This demonstrated that poor social cognition reduces reading comprehension capacity in individuals with ASD. However, the authors assessed the association between reading comprehension and social cognition using two tasks (triangles and strange stories; see Chapter 3, section 3.3), both of which test theory of mind. As discussed, there are three main social cognitive skills that although related, represent distinct abilities and consequently investigating all three is essential to a complete understanding of any potential relationship between social cognition and reading comprehension. Ricketts et al., (2013) also did not have a control group, so it was not possible to examine whether this relationship was specific to individuals with ASD or whether it also exists in typically developing children. Understanding whether this relationship is unique to ASD is important as it would suggest that interventions needed to be targeted to those with a diagnosis of ASD. Additionally, the researchers did not examine the effect that ASD symptom severity, or co-occurring ADHD symptoms, could have on this inter-relationship.

As previously discussed, it is the case that ASD and ADHD are highly comorbid at symptom as well as diagnostic level, with between 30 and 80% of children with ASD meeting criteria for ADHD (Rommelse et al., 2010). Although the literature is mixed, children with ADHD have been found to have social cognition difficulties (see Introduction, section 1.5 for an exploration of this). Deficits have been found in FER (Aspan et al., 2014; Da Fonseca et al., 2009), affective empathy (Braaten & Rosén, 2000) and theory of mind (Bora & Pantelis, 2015). Indeed, Chapter 3 corroborated this by demonstrating that children with ADHD are impaired in FER and theory of mind compared to typically developing children (see sections 3.1 and 3.3). In addition, Factor and colleagues (2017) found that children with ASD and higher ADHD traits were reported by their parents as having worse social communication and social awareness ability using a questionnaire measure. This suggests than ADHD symptoms should be taken into account as they do not need to reach diagnostic level to have an affect on the social abilities of children with ASD. Children with ADHD also often have basic reading and spelling difficulties (see Introduction, section 1.2.1 for more detail; Asberg et al., 2010; Asberg Johnels et al., 2014). Chapter 2 of this thesis identified a significant proportion of children with reading comprehension impairments relative to their IQ (see section 2.3). Consequently, including or controlling for ADHD behaviour is vital to ensure that the potential effect of additional ADHD symptoms is taken into account.

4.1.2 Aims and rationale

This study aimed to extend the work of Ricketts and colleagues (2013) by investigating the relationship between reading comprehension and all three social cognitive skills in adolescents with and without an ASD diagnosis. In line with previous literature, it was predicted that ASD diagnosis and ASD symptom severity within the ASD sample would be associated with lower reading comprehension and social cognition scores. Whereas, following evidence presented in previous literature and chapters 2 and 3, ADHD symptoms within the ASD sample were expected to be associated with social cognition difficulties alone.

Finally, the relationship between ASD diagnosis/symptoms and reading comprehension was predicted to be mediated by social cognition ability. This was not expected to be the case for ADHD symptom severity. In order to address these hypotheses, first the relationship between ASD diagnosis/ASD symptoms/ADHD symptoms, literacy skills and all three social cognition skills was investigated. Then the relationship between literacy skills and social cognitions tasks was explored. Finally, mediation analyses were conducted. Accordingly, the results and discussion sections were organised around five questions:

1. Are ASD diagnoses and symptom severity associated with reading comprehension?
2. Are ASD diagnoses and symptom severity associated with social cognition?
3. Is reading comprehension associated with social cognition task performance?
4. Does social cognition mediate the associations between ASD diagnoses/symptom severity and reading comprehension?
5. What is the role of ADHD symptoms in these associations?

4.2 Method

4.2.1 Participants

This sample consisted of participants who were tested in secondary schools, colleges and community centres across the South Wales area or at Cardiff University from May 2016 to December 2017. Participants were recuited if they were aged between 11 and 17 years, had verbal ability, and a reading age of at least five years to enable them to access the research tasks.

This was a case-control study. The case group initially included children with ASD, ADHD or both disorders. The majority of the group were educated in special communication support units within mainstream secondary schools. The data of one participant with ASD was excluded due to low verbal ability, and as only two participants had ADHD alone, there were too few individuals to look at those with ADHD only and this group (and these individuals) were excluded from the final study. This resulted in a case group of 35 participants, 28 of whom had ASD alone and seven with diagnoses of ASD and ADHD. They had a mean age of 13.5 years (SD= 2.0) and 71.4 % were male.

The control group consisted of children from mainstream secondary schools that had no diagnosed developmental disorders. There were 21 participants in the control group, with a mean age of 13.2 (SD=2.0) years and 61.9 % were male.

Testing was conducted on a one-to-one basis with a trained researcher in quiet rooms, and participants took approximately 1 hour and 40 minutes to complete all tasks in one sitting. Children were given breaks if needed. Parents were given questionnaires to complete that asked for diagnosis and behavioral information about their children. Ethical approval was provided by Cardiff University Psychology Ethics, and parents gave written informed consent while children gave written assent.

4.2.2 Measures

4.2.2.1 Research Diagnoses

Confirmation of ASD or ADHD diagnosis was received from participants' parents and also school SENCOs (Special Educational Needs Coordinators) where applicable. Participants with ASD or ADHD were assessed using the Autistic Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012). The ADOS-2 is a semi-structured assessment of social communication, interaction and repetitive behaviour in individuals from the age of 12 months to adulthood. The assessment is standardised and considered to be the 'gold standard' in assessing autism (Ozonoff, Goodlin-Jones, & Solomon, 2005). In this study, the ADOS was used to provide ASD research diagnosis confirmation and a continuous measure of autism severity. ADOS results confirmed ASD diagnosis for 30 out of 35 participants already diagnosed with ASD. As these five partcipants that did not meet criteria had recorded clinical diagnoses of ASD they were not excluded and there is evidence that individuals with ASD are not always idenified as having ASD using the ADOS (Falkmer, Anderson, Falkmer, & Horlin, 2013). Instead, sensitivity analyses determined that results did not differ if their data was removed.

As in chapter 3, research diagnoses of ADHD and CD were assessed using the paper version of the DAWBA, which was included in the parent questionnaire for all participants. All children with clinical diagnoses of ADHD met criteria for ADHD according to the parent DAWBA.

The parents of control participants also completed the ASD section of the DAWBA. The ADOS was not used for these participants as it is only designed to be used in suspected cases of ASD and can take up to an hour to administer (Lord et al., 2012). No control participants met criteria for ASD or ADHD using the DAWBA.

4.2.2.2 IQ

As in chapter 3, IQ was assessed using the two subset form of the Wechsler Abbreviated Scale of Intelligence which measures cognitive ability in individuals from six years to adulthood (WASI; Wechsler, 2003). The two subsets consisted of the matrix reasoning task and the vocabularly test.

4.2.2.3 Reading

Two subsets of the Wechsler Observation Reading Dimensions (WORD; Wechsler, 1993) were used to measure literacy skills, the same assessment as used in chapter 2. The basic reading test requires participants to read parts of words then read aloud whole words that increase in difficulty. Children start on different items according to age, and reverse to earlier items if any of the first five words adminstered are incorrect. Children continue with the test until they finish all items or read six consecutive words incorrectly.

The reading comprehension test involves reading sentences and then answering a question that requires literal or inferential responses. Sentences increase in complexity and vary in length. In the same way as the basic reading test, children start on an item according to age, and must get the first five correct or go back to earlier items. The discontinue rule applies if children fail on four consecutive items. In this study, WORD standard scores were used, which are the age-equivalent scores based on the raw data (Wechsler, 1993).

4.2.2.4 Facial emotion recognition

This facial emotion recognition task used the same facial stimuli slides as Chapter 3. Scoring was also identical. The task involved participants viewing 60 facial stimuli slides that portrayed happy, sad, angry, or fearful expressions presented at 50% or 70% intensity. Neutral facial expressions were also portrayed at 100% intensity. All facial stimuli slides were black and white photographs of male and female faces taken from the Ekman battery (Ekman & Friesen, 1976). Participants were required to state which emotion, from a list of possible choices, was shown on each face. Eye tracking data was also utilised for this task. As a result of issues identified in Chapter 3, an alteration was made to the presentation of the stimuli for this study; each face was shown on a black background for four seconds before the response options were shown.

Eye tracking data was only taken from these four seconds for each face, and AOI sizes and dwell time calculations were the same as Chapter 3. However, as 72% of the sample did not reach the 70% validity level for the task that has previously been applied (Hubble, 2015), the majority of the data was not considered to be sufficiently accurate to analyse, therefore the decision was made to exclude eye tracking data from this sample, and use participants' FER accuracy scores alone.

4.2.2.5 Empathy

This empathy film clip task involved three film clips (of approximately 90 seconds each) from Harry Potter films that portrayed each of the three emotions: happiness, sadness and fear. The task was the same as that used in Chapter 3, but the film clips were different due to the limitations found with the clips used in Chapter 3 (see section 3.2.4). It was concluded that using clips that were either all fictional or non-fictional and that used the same protagonists would be more appropriate as it would reduce variability. Harry Potter clips were chosen as most children would be expected to have either watched the films or be familiar with them, and it was thought that this prior knowledge would mean that the children were more engaged with the characters and the story. The film clips used were: Happiness- Harry Potter and the Philosopher's Stone- Harry wins a game of quidditch for his school house Gryffindor; Sadness- Harry Potter and the Deathly Hallows Part One -Harry is helpless as his friend Dobby the elf dies; Fear- Harry Potter and the Chamber of Secrets- Harry and Ron are confronted by a giant spider and his offspring who threaten to eat them. All these films were rated either PG or 12A, and were therefore suitable for the age range of children we tested. In chapter 3, several parents had withheld consent for their children to watch clips from films rated 15 (i.e. Jaws 2 and Cliffhanger).

Cognitive and affective empathy were measured in the same way as Chapter 3. Briefly, cognitive and affective empathy were scored using paper questionnaires. For cognitive empathy, participants were required to rate the emotional intensity of the main character using a Likert scale (0 to 10) and then explain why they rated the specific emotion/s as high. Similarly, affective empathy used the same Likert scale for participants to rate and then explain their own emotions after watching each clip. A second coder rated 30% of the cognitive and affective empathy questionnaire responses, resulting in excellent reliability, as demonstrated by intraclass correlations of 0.98 for both cognitive and affective empathy. Whether participants had previously watched the films was also recorded.

Eye looking patterns were also measured following the same procedure as Chapter 3, dwell time to the eyes, mouth and face region of the main character were examined. Eye gaze was analysed during a four second segment that was independently judged by 5 adults to contain the highest emotional intensity while also showing the face. For the sad and happy clips, the four second segments containing the most emotional sections of the clip were continuous. For the fear clip, the segment was split into a one second and a three second section. In accordance with Chapters 3.1 and 3.2, eye gaze validity was checked using a sample rate percentage of 70%. For each video clip, the number of participants meeting 70% or more validity ranged from 70% to 76%.

4.2.2.6 Theory of mind (Frith-Happé triangles animations task)

Theory of mind was assessed using the Frith-Happé triangles animations task (Abell et al., (2000) triangles task. The task protocol and scoring did not differ from that used in Chapter 3 (see section 3.3.2.2 and Appendix 8). Briefly, participants watched six animated cartoon clips of triangle shapes moving around. Four of these clips were theory of mind clips, and gave participants many opportunities to discuss the different interactions between the shapes. Two clips were goal directed, and involved no clear social interactions between the triangles, but instead demonstrated fighting and chasing. Participants responses were recorded and scored for intentionality (mental state language), appropriateness (accuracy of description) and length (number of clauses).

4.2.3 Statistical analyses

Firstly, the effect of ASD diagnosis on the three social cognition tasks and literacy skills was explored using one-way ANOVAs. Then the effect of ASD symptoms (ASD sample only) on the three social cognition tasks and literacy skills was examined using Pearson correlation coefficients. Afterwards, further correlations examined the effect of empathy eye tracking variables on ASD diagnosis and symptoms, as well as ADHD symptoms. Further correlations were used to investigate the relationship between literacy skills and all three social cognition tasks.

Once the relationship between reading comprehension, social cognition tasks and ASD was established, mediation analyses were then performed to determine whether the relationship between ASD diagnosis/symptoms and reading comprehension was driven by social cognition. Social cognition tasks that were associated with both reading comprehension and ASD diagnosis/symptoms were used as mediators. This resulted in two mediation analyses, with ASD diagnosis then symptoms as the independent variables and reading comprehension score as the outcome variable.

For the mediation analyses, the confidence intervals were used to determine if mediation had occurred, where confidence intervals do not cross zero, mediation is considered to be present. The Sobel test was not used as it has been reported to be too conservative in small sample sizes such as this, and using confidence intervals is considered to be the most appropriate method (Field, 2016; van Goozen et al., 2015). Finally, the role that dwell time to the eyes had on the relationship between ASD diagnosis and cognitive empathy was examined with a further mediation analysis. The following results section is organised into three sections to examine ASD diagnosis, ASD symptoms and ADHD symptoms in turn, and the relationship with social cognition and reading for each.

4.3 Results

4.3.1 Sample characteristics

The social cognitive scores and demographic data for participants with ASD and control participants are shown in Tables 4.1 and 4.2. Welch's t-tests showed that control participants had significantly higher IQ scores than those with ASD, $t(54) = 1.94$, $p = 0.03$, while the age of participants was not different $t(54) = 0.45$ $p = 0.66$.

Appendices 10 and 11 show that whether participants had seen the Harry Potter films before made no difference to their cognitive and affective empathy scores.

Table 4.1 Sample characteristics for ASD and control participants, with reading, FER and theory of mind scores

	N **Mean (SD)** **Range**	**ASD (N=35)**	**Control (N=21)**
Demographics	ADOS ASD symptoms	35 11.2 (5.3) 3.0 – 22.0	_
	DAWBA ASD symptoms	_	17 2.9 (4.9) 0.0 - 9
	DAWBA ADHD symptoms	35 7.8 (5.8) 0.0 – 17.0	17 0.4 (1.2) 0.0 – 5.0
	IQ	35 87.1 (24.4) 46.0 – 130.0	21 98.5 (14.2) 76.0 – 126.0
	Age (years)	35 13.5 (2.0) 11.0 – 17.0	21 13.2 (2.0) 11.0 – 17.0
Reading	Basic reading	35 96.1 (17.2) 64.0 – 123.0	21 103.4 (12.1) 75.0 – 123.0
	Reading comprehension	35 86.9 (15.1) 54.0 – 118.0	21 95.0 (11.9) 78.0 – 122.0
Facial emotion recognition	% FER accuracy	30 67.7 (14.7) 29.2 – 84.7	17 72.8 (9.6) 57.6 – 89.6
Theory of mind	Triangles- goal directed (0-2)	34 1.7 (0.4) 1.0 – 2.0	21 1.7 (0.5) 0.5 – 2.0
	Triangles- intenionality (0-5)	34 3.3 (0.8) 1.5 – 4.5	21 3.7 (0.9) 1.8 – 4.8
	Triangles- appropriateness (0-2)	34 1.1 (0.4) 0.25– 1.8	21 1.2 (0.6) 0.3 – 2.0
	Triangles- Length ToM clips	34 3.1 (1.1) 0.5 – 4.0	21 3.1 (1.3) 0.8 – 4.0

Note: ASD= Autism Spectrum Disorder, ADHD= Attention-deficit/hyperactivity disorder

Table 4.2 Empathy and empathy eye tracking scores for ASD and control participants

	N Mean (SD) Range	ASD (N=35)	Control (N=21)
Empathy	Cognitive empathy (0-9)	30 5.6 (1.2) 10.0 – 26.0	20 6.3 (1.0) 4.7 – 8.3
	Affective empathy (0-5)	30 3.1 (1.4) 0.0 – 16.0	20 4.0 (1.0) 2.3 – 5.0
Empathy eye tracking	Fear- % dwell time to eyes	16 27.2 (31.6) 0.0 – 87.1	17 52.8 (33.2) 0.0 = 100.0
	Fear- % dwell time to mouth	16 17.2 (30.1) 0.0 – 89.1	17 4.4 (12.6) 0.0 – 51.0
	Fear- % dwell time to face	16 87.3 (13.0) 56.8 – 100.0	17 88.7 (19.8) 27.1 – 100.0
	Sad- % dwell time to eyes	13 39.4 (28.8) 0.0 – 86.0	16 56.9 (23.0) 5.7 – 100.0
	Sad- % dwell time to mouth	13 22.9 (22.9) 0.0 – 69.1	16 7.6 (14.5) 0.0 = 52.1
	Sad- % dwell time to face	13 93.0 (10.4) 68.6 - 100	16 89.6 (10.3) 74.7 – 100.0
	Happy- % dwell time to eyes	15 55.8 (34.0) 0.0 - 100	20 57.4 (30.0) 0.0 – 93.5
	Happy- % dwell time to mouth	15 8.6 (23.3) 0.0 – 90.3	20 7.6 (11.9) 0.0 – 44.2
	Happy- % dwell time to face	15 63.5 (30.7) 0.0 – 100.0	20 83.1 (24.1) 23.8 – 100.0

Note: ASD= Autism Spectrum Disorder, Fear (Giant spiders), Happy (Finding the golden snitch), Sad (Dobby dies)

4.3.2 Associations between ASD diagnosis/symptoms and literacy skills tasks

ANOVAs showed that children diagnosed with ASD were found to have significantly lower reading comprehension scores than controls ($F(1,53)= 4.39$, $p= 0.04$, $\eta p_2 =0.08$), but not basic reading scores ($F(1,53)= 2.90$, $p= 0.10$, $\eta p_2 =0.05$).

For ASD symptoms, Pearson correlation coefficients (Table 4.3) revealed that reading comprehension was shown to be significantly correlated with ASD symptoms, while this association was not found for basic reading.

Table 4.3 Pearson correlation coefficients for the relationship between ASD symptoms, ADHD symptoms, reading and social cognition tasks for whole sample

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1. ASD total score (ADOS)	-0.32	-0.43**	-0.32	-0.45**	-0.02	-0.28	-0.17	0.12	-0.17	-0.31	-0.31	-0.19	-0.40*	-0.19	-0.24
2. ADHD score			-0.08	-0.10	-0.02	-0.23	-0.19	-0.11	0.04	-0.29	-0.11	-0.07	-0.18	-0.41**	-0.38*
3. FSIQ				0.73**	0.32*	0.19	0.34**	0.01	0.16	0.48**	0.65**	-0.30	0.64**	0.59**	0.02
4. Basic reading				0.69**	0.18	-0.01	0.04	-0.09	0.05	0.22	0.50**	0.24	0.40**	0.45**	-0.30
5. Reading comprehension					0.16	0.01	0.17	0.05	0.20	0.22	0.49**	0.22	0.46**	0.47**	-0.02
6. Triangles Goal- directed						0.51**	0.76**	-0.10	0.29	0.01	0.41	0.01	0.14	0.50*	0.02
7. Triangles Appropriateness							0.73**	-0.16	0.03	0.13	0.09	0.07	0.13	0.20	0.16
8. Triangles Intentionality								-0.06	0.08	0.15	0.18	0.17	0.24	0.41**	0.18
9. FER happy accuracy									0.21	0.10	0.25	-0.12	0.18	0.23	0.03
10. FER sad accuracy										0.04	0.31*	-0.37**	0.41**	0.24	0.35*
11. FER fear accuracy											0.53**	0.48**	0.82**	0.53**	0.59**
12. FER anger accuracy												0.11	0.76**	0.63**	0.37*
13. FER neutral accuracy													0.49**	0.24	-0.02
14. FER accuracy all														0.63**	0.51**
15. Cognitive empathy															0.50**
16. Affective empathy															

Note: ASD= Autism Spectrum Disorder, ADHD= Attention-deficit/hyperactivity disorder, FER= facial emotion recognition,*p< 0.05; **p< 0.01, ASD total score (ADOS) only refers to ASD participants

4.3.3 Associations between ASD diagnosis/symptoms and social cognition tasks

ANOVAs showed that there was no difference in the FER accuracy scores of participants with ASD and controls for each emotion separately (all *p*s > 0.05) and combined ($F(1,45)= 1.70$, $p= 0.20$, $\eta p^2 =0.04$).

ANOVAs showed that cognitive empathy scores ($F(1,41)= 4.26$, $p= 0.045$, $\eta p_2 = 0.09$) and affective empathy scores ($F(1,41)= 5.54$, $p= 0.02$, $\eta p^2 = 0.12$) were both significantly higher for controls than for children with ASD. Empathy eye tracking t-tests showed significant differences for percentage dwell time to fear eyes ($F(1,32)= 4.56$, $p= 0.04$, $\eta p^2 = 0.13$), happy faces ($F(1,34)= 4.61$, $p= 0.04$, $\eta p_2 =0.12$) and sad eyes ($F(1,31)= 5.44$, $p= 0.03$, $\eta p^2 =0.15$), with controls looking more at these. Controls also looked significantly less at sad mouths ($F(1,31)= 5.45$, $p= 0.03$, $\eta p^2 =0.15$) than those with ASD.

However, no difference between those with ASD and controls was found for the goal directed ($F(1.53)= <0.001$, $p=0.99$, $\eta p^2 = <0.001$), intentionality ($F(1,53)= 2.53$, $p= 0.12$, $\eta p^2 = 0.05$) and appropriateness ($F(1,53)= 2.85$, $p= 0.10$, $\eta p^2 =0.05$) scores of the triangles task.

Table 4.3 shows that ASD symptoms significantly correlated with FER total accuracy score, but not the individual emotions. For the Frith-Happé triangles animations, neither goal directed, intentionality or appropriateness scores were related to ASD symptoms. Table 4.4 reveals that ASD total symptom score was not associated with cognitive or affective empathy, or any empathy eye tracking measures. However, reading comprehension was shown to be related to ASD symptoms while basic reading was not.

4.3.4 Associations between reading comprehension and social cognition tasks

Table 4.3 also shows the association between reading comprehension and all social cognition tasks. For the FER task, accuracy for angry faces and total accuracy were significantly associated with reading comprehension. Triangles scores were not found to correlate with reading comprehension. Cognitive empathy, but not affective empathy, correlated with reading comprehension, and dwell time to the face for happy stimuli was the only eye tracking variable to be associated with reading comprehension (Table 4.4).

4.3.5 Mediation analyses exploring whether social cognition mediates the relationship between ASD diagnosis/symptoms and reading comprehension

Following on from the significant associations between ASD diagnosis, cognitive empathy and reading comprehension, mediation analyses were undertaken to see if cognitive empathy mediated the relationship between ASD diagnosis and reading comprehension. The results indicated that the indirect effect of cognitive empathy on the association between ASD diagnosis and reading comprehension was significant b=-3.61 [CI -8.99, -0.40]. Finally, analysis to identify whether or not dwell time to the eyes mediated the relationship between ASD diagnosis and cognitive empathy, found no evidence of this as confidence intervals crossed zero, b=0.34 [CI -0.61, 1.93].

For ASD symptom severity, mediation analysis demonstrated that the association between ASD symptoms and reading comprehension was not mediated by FER accuracy scores, with confidence intervals crossing zero b= -0.28 [CI -1.10, 0.03]. See Figures 4.1, 4.2 and 4.3 for illustrations of these analyses.

Figure 4.1 showing the results of a mediation analysis examining the indirect effect of cognitive empathy on the relationship between ASD diagnosis and reading comprehension

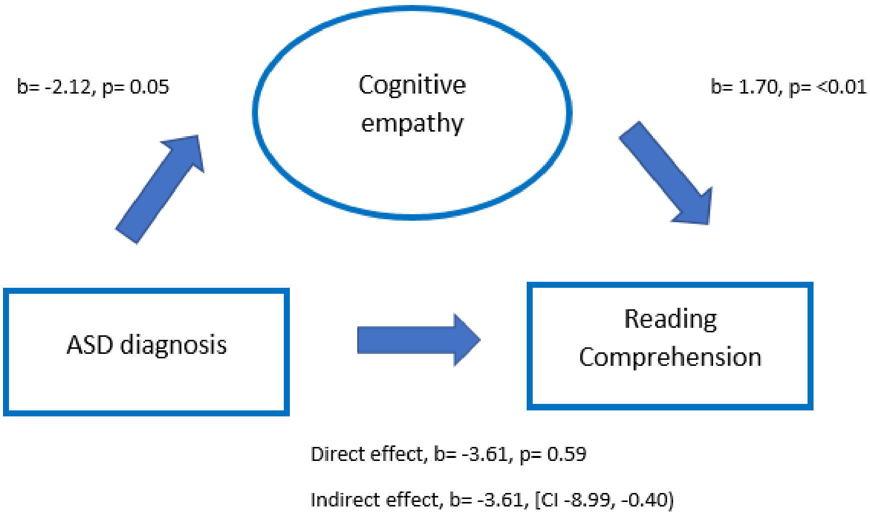


Figure 4.2 showing the results of a mediation analysis examining the indirect effect of dwell time to the eyes on the relationship between ASD diagnosis and cognitive empathy

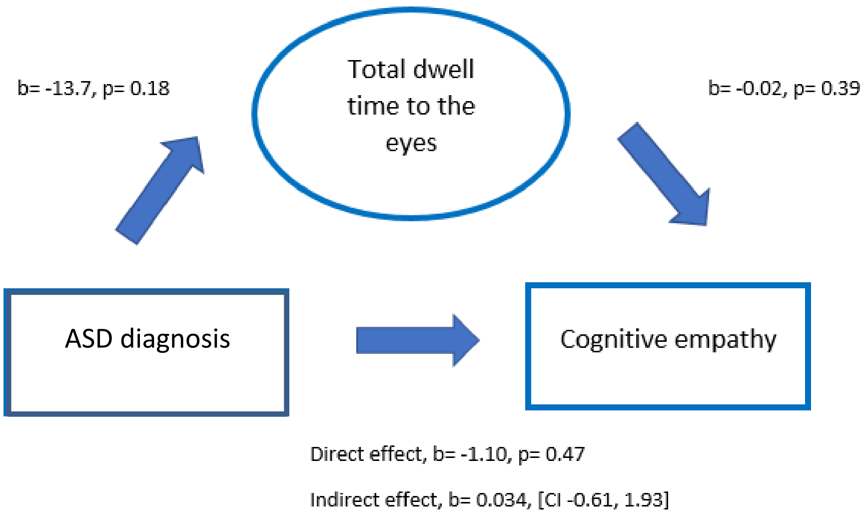
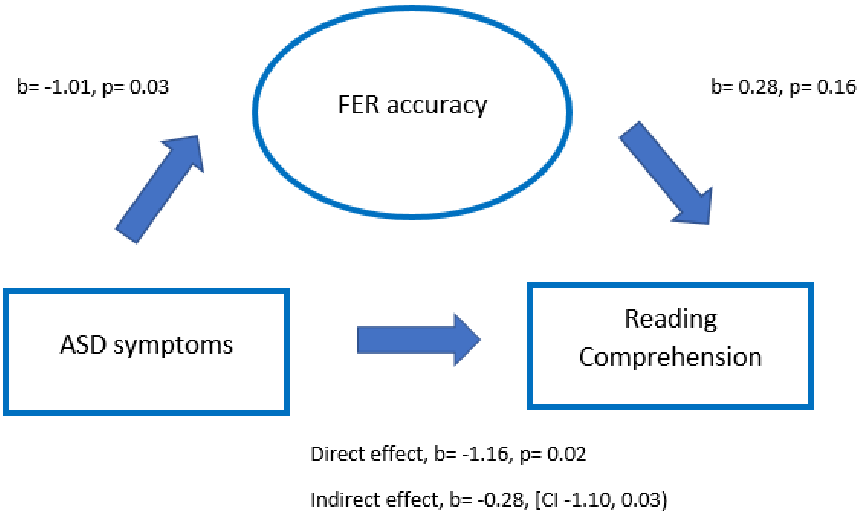


Figure 4.3 showing the results of a mediation analysis examining the indirect effect of FER accuracy on the relationship between ASD symptoms and reading comprehension



4.3.6 Associations between ADHD symptoms, reading comprehension and social cognition tasks

Table 4.3 demonstrates that ADHD symptom severity was significantly associated with both cognitive and affective empathy, while scores on the FER and triangles tasks were not. Basic reading and reading comprehension scores were not associated with ADHD symptoms. Table 4.4 shows that ADHD symptom severity was associated with increased time spent looking at the mouth of sad faces and less time spent looking at happy faces.

Table 4.4 Pearson correlation coefficients for the relationship between ASD symptoms, ADHD symptoms, empathy and eye tracking empathy scores

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. ASD total score (ADOS)	-0.32	-0.19	-0.24	0.15	-0.12	0.18	0.22	0.05	0.16	0.15	-0.16	0.27
2. ADHD score		-0.41**	-0.38*	-0.35	0.37*	-0.22	-0.06	0.04	-0.37*	-0.30	0.33	-0.04
3. Cognitive empathy			0.50**	0.08	-0.08	0.20	-0.32	0.07	0.28	-0.11	0.02	-0.02
4. Affective empathy				0.15	-0.08	0.32	-0.02	-0.24	0.22	0.20	-0.08	0.12
5. Sad % dwell to eyes					-0.61**	0.31	0.42*	-0.37*	0.23	0.65**	-0.56**	-0.04
6. Sad % dwell to mouth						0.16	-0.29	0.44*	0.13	-0.57**	0.76**	0.31
7. Sad % dwell to face							-0.06	-0.10	0.30	0.16	0.06	0.25
8. Happy % dwell to eyes								-0.55**	0.17	0.56**	-0.39*	0.29
9. Happy % dwell to mouth									0.02	-0.39*	0.49**	-0.13
10. Happy % dwell to face										0.16	-0.12	0.56**
11. Fear % dwell to eyes											-0.50**	0.18
12. Fear % dwell to mouth												0.19
13. Fear % dwell to face												

Note: ASD= Autism Spectrum Disorder, ADHD= Attention-deficit/hyperactivity disorder,*p <.05; ** p < .01, ASD total score (ADOS) only refers to ASD participants

4.4 Discussion

The study in this chapter aimed to examine whether social cognition mediates the relationship between ASD and reading comprehension ability. First the study addressed expected associations between ASD and reading comprehension skills, and then ASD and social cognition tasks. These associations were then examined secondly in relation to ASD symptoms, and thirdly in relation to ADHD symptoms, as previous research has shown that the role of ADHD should not be overlooked. Then the relationship between reading comprehension ability and performance in the three social cognition tasks was explored. Finally, the role of social cognition tasks as mediators in the relationship between ASD diagnosis/ASD symptoms/ADHD symptoms and reading comprehension was investigated. The findings are discussed below in relation to the disorders: first ASD diagnosis, then ASD symptoms and finally ADHD symptoms.

4.4.1 Associations between ASD diagnosis, social cognition and reading tasks

As expected, cognitive empathy was related to ASD diagnosis. Children diagnosed with ASD had significantly lower scores for cognitive empathy than typically developing children. This is in line with previous research that individuals with ASD have difficulties with interpreting and explaining the emotions of others (Demurie et al., 2011; Dziobek et al., 2008; Kirchner et al., 2011) However, against expectations, affective empathy was related to ASD diagnosis, with children diagnosed with ASD having lower scores. This contrasts with research which has shown that affective empathy abilty in ASD tends to be the same as controls (Hudry & Slaughter, 2009; Jones et al., 2010; Sigman, Dissanayake, Corona, &

Espinosa, 2003). Also unexpectedly, no association was found between FER and theory of mind triangles task scores and ASD diagnosis.

A follow up mediation analysis was conducted to attempt to discover more about the identified cogntive empathy difficulties experienced by adolescents with ASD. Initial eye tracking data showed significantly lower dwell time to the eyes for both sad and fear, and happy faces for participants with ASD, as well as increased dwell time to sad mouths. However, mediation analyses demonstrated that dwell time to the eyes was not related to the cognitive empathy deficit identified in the ASD group. This suggests that the ASD group had an underlying emotion processing deficit that impaired their emotion identification regardless of eye looking patterns.

Regarding reading ability, children diagnosed with ASD were found to have significantly lower reading comprehension scores than controls, whilst no difference was found in basic reading ability. This corroborates previous research findings that basic reading tends to be intact, while reading comprehension is impaired in children with ASD (e.g. Nation et al., 2006). Reading comprehension scores were also found to be positively associated with cognitive empathy, but not affective empathy or triangles task scores.

Finally, the study sought to determine whether the observed association between ASD and reading comprehension was mediated by social cognition. As cognitive empathy was the only social cognition measure with significant associations with ASD diagnosis and reading comprehension, cognitive empathy was the only social cognition skill used in the mediation analysis for ASD diagnosis. In accordance with the hypothesis, the mediation analyses revealed that cognitive empathy did mediate the relationship between ASD diagnosis and reading comprehension. This demonstrated that this observed association was stronger for those with ASD than for controls.

Overall, the results of the study showed that there is evidence that the association between ASD diagnosis and poor reading comprehension was driven by low cognitive empathy ability. Results also showed that whether participants had seen the Harry Potter films before made no difference to their cognitive and affective empathy scores (see Appendices 10 and 11). To be able to score highly in cognitive empathy in the film clips task it was necessary for participants to interpret the emotions of the main character (Harry Potter) and explain the reasons for this emotion within the context of the clip. It seems that this skill of interpreting emotions does affect the reading comprehension ability of children with ASD. This finding supports the results of Ricketts et al., (2013) who found that scores from two theory of mind tasks (strange stories and triangles) were associated with reading comprehension performance in a sample of participants with ASD. However, our study differed from that of Ricketts et al. (2013) as the addition of a control group meant that we were able to look at ASD diagnosis in our mediation analysis, in order to demonstrate that the relationship between social cognition and reading comprehension was stronger in those with ASD compared to typically developing children.

Contrary to previous literature (e.g. Abell et al., 2000), no significant relationship was found between triangles scores (both appropriateness and intentionality scores for theory of mind clips) and ASD diagnosis. It seems that participants with ASD performed better than those in previous studies, with an average mean score of 3.3 out of 5 for intentionality, compared to Ricketts et al., (2013) finding an average mean score of 2.9 for intentionality for ASD participants that had comparable IQ scores to this study. [1] This could reflect the fact that all the children with a diagnosis of ASD in this study were educated in supportive units in mainstream schools that specialised in ASD support, where anecdotal reports suggested that storytelling activities were particularly utilised as part of the teaching. Such support and teaching methods could have specifically improved the theory of mind abilities assessed in the triangles taks which could help to explain why in this study ASD participants were not impaired compared to controls.

The Frith-Happé triangles animations task is an abstract storytelling task that involves triangle shapes rather than human faces, whereas, the empathy task involves interpreting and explaining emotions from faces within a wider contextual background. Previous studies have suggested that children with ASD are hyper sensitive to faces and find them aversive (Bons et al., 2013). Indeed, in the empathy task, I found that those with ASD looked less at the eyes of sad and fearful faces (Table 4.4), which could indicate that they found it difficult to view the eye area when these strong negative emotions were portrayed. Consequently, it could be that in this sample, the empathy task was better able to tap into the social cognition difficulties of the participants with ASD than the triangles task.

4.4.2 Associations between ASD symptoms, social cognition and reading tasks

Contrary to expectations, ASD symptoms within the ASD group were not significantly associated with either cognitive empathy or theory of mind trinagles task scores. Whereas

[1] Mean FSIQ in this study was 87.1, range 46-130. Ricketts et al., (2013) reported a mean FSIQ score of 90.4 and a range of 53-126 in their sample of children with ASD.

ASD symptoms were found to be associated with FER task scores. As already discussed, there was no association between ASD diagnosis and FER task scores. This finding suggests that it is ASD symptom severity rather than ASD diagnosis that is driving FER deficits in this sample. This result was unexpected as a meta-analysis found that overall children with ASD were found to have deficits across the six basic emotions (Lozier et al., 2014). However, Lozier and colleagues (2014) commented on the heterogenity of studies, which was particularly true for studies involving static facial stimuli. Indeed, it has been argued that static FER studies are lacking in ecological validity and are therefore not as challenging for children with ASD (Harms et al., 2010). Consequently, the finding in this study that FER is associated with more severe ASD symptoms, rather than ASD diagnosis, could be perceived as corroborating with previous research. It could be that simply having a diagnosis of ASD is not sufficient to lead to a marked deficit in FER accuracy when static images are used. This demonstates the importance of taking symptoms into account rather than focusing solely on diagnostic levels.

ASD symptoms, as with ASD diagnosis, were found to be related to reading comprehension scores while no relationship was found with basic reading ability. This was expected based on previous studies finding that while reading comprehension is often impaired in children with ASD, basic reading tends to be in line with IQ scores or even exceeds them (Jones et al., 2009; Mayes & Calhoun, 2003; Minshew, Goldstein, Taylor, & Siegel, 1994). As previously noted, FER task accuracy was found to be related to reading comprehension ability. Consequently, the study sought to discover whether the relationship between ASD symptoms and reading comprehension was mediated by FER task scores. Results showed that the indirect effect of the FER total accuracy score on the relationship between ASD symptoms and reading comprehension was not significant.

4.4.3 Associations between ADHD symptoms, social cognition and reading tasks

Additionally, in a further extension of previous studies, ADHD symptoms were explored in this study. Cognitive and affective empathy were significantly associated with ADHD symptoms in our sample, and this corroborates with previous studies which have found that children with both ASD and ADHD have a greater level of impairment in social cognition tasks than those with ASD alone (Colombi & Ghaziuddin, 2017; Sinzig et al., 2008). Only seven participants with ASD also had a diagnosis of ADHD, which meant that further analysis was not possible. Consequently, having a larger sample size, and comparing those with a diagnosis of ASD alone to those with both ASD and ADHD would be necessary to examine the additional effect of ADHD symptoms/diagnosis on the social cognition ability of children with ASD.

4.4.4 Limitations

As with any research, there were some limitations to this study. The IQ scores of the ASD group were significantly lower than the control group (see Table 4.1). IQ was also found to be associated with performance in cognitive and affective empathy, as well as FER accuracy and the intentionality score of the triangles task (table 4.3). It could be that IQ was influencing the differences found between the groups. In fact, previous studies have sought to control for the effect of IQ on social cognition in neurodevelopmental disorders and have tended to find that IQ is significantly related to social cognition ability, but that impairments remain after IQ is controlled for (e.g. Marshall, Evans, Eiraldi, Becker, & Power, 2014; Rucklidge & Tannock, 2001). However, this study chose not to take IQ into account when examining the relationship between social cognition and reading comprehension in this sample, following Dennis et al., (2009) who argued that IQ should not be used as a covariate in studies involving participants with neurodevelopmental disorders because IQ can never be separated from the disorder itself, consequently, using IQ as a covariate in social cognition studies could be viewed as obscuring potential findings.

This study also did not seek to match IQ between groups or remove the data of participants whose IQ scores were lower than 70 or 80, as has been undertaken for some studies involving children with neurodevelopmental disorders (e.g. Groom et al., 2017; Sinzig et al., 2008). This was because the study aimed to accurately represent the ASD population instead of only focusing on those with higher IQ scores. Again, work by Dennis et al., (2009) supports this resolution by demonstrating that matching IQ in controls and case groups leads to either a case group with unusually high IQ scores or with a control group that are performing below normative expectations. Therefore, matching on IQ or removing those individuals with lower IQs would have resulted in a non-representative sample.

The small sample size of the study was also a concern. When comparing the ASD sample to controls, post hoc calculations using G*power (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that the power to detect a large effect size was 0.83. Conseqently, we were powered to find large effect sizes, but the power was not sufficient for the medium and small effect sizes that were found when comparing the social cognition scores of the two groups. When focusing on ASD and ADHD symptom severity within the ASD sample (N= 35), post hoc power calculations using G*power found that the power to detect a large effect size was 0.92. Correlations identifed several large effect sizes, but again there was not sufficient power to detect medium and small effect sizes. This lack of power could also be responsible for the absence of agreement between the FER and empathy tasks. Cognitive empathy was only found to be related to ASD diagnosis, and not ASD symptoms. Whereas FER total accuracy was found to be significantly related to ASD symptoms, but not ASD diagnosis. These differing results for ASD diagnosis and ASD symptoms were not expected, and could be because the study was undepowered to identify medium and small effect sizes. For example, Table 4.3 shows that the effect size for the non- significant relationship between cognitive empathy and ASD symptoms is small (r=-0.19). In addition, it is important to note that the large number of tests that needed to be run to examine the effect of ASD and ADHD symptoms on social cognition and literacy skills resulted in multiple comparisons, which if corrected would have meant that the group differences found would no longer have been significant. However, due to the exploratory nature of this analysis, these results were left uncorrected.

4.4.5 Conclusion

To my knowledge, this is the first study to explore the relationship between ASD diagnosis/symptoms and all three social cognitive skills, whilst also considering the role of ADHD symptoms using a case-control design. The results met several of our initial hypotheses based on previous literature. The expected associations between ASD diagnosis and cognitive empathy, as well as ASD symptoms and FER task accuracy were found. However, this was not the case for triangles task scores.   As a result of small sample sizes, it was not possible to explore the differences in performance of those with ADHD alone, ASD alone and ASD plus ADHD. Consequently it seems that further investigation is needed with a larger sample size to determine the effect of social cognition on the inter relationship between ASD and ADHD withreading comprehension.

The finding that cognitive empathy, but not FER total accuracy, acted as mediator in the relationship between ASD diagnosis and reading comprehension, shows that there is some evidence to support our hypotheses. There does appear to be a relationship between social cognition and reading comprehension in adolescents diagnosed with ASD. This finding could be extremely valuable in assisting the development of future school based ASD interventions by demonstrating that social cognition based support could also improve reading comprehension ability. Interventions that are able to support both skills simultaneously would reduce the time and resources needed from schools. A dual intervention would also prove more viable for mainstream secondary schools which tend to have fewer opportunties to integrate interventions into the school day.

CHAPTER 5

Discussion

5.1 Overview

This thesis explored the overlap between ADHD and ASD in childhood and adolescence and how this affected literacy skills and social cognition ability, to ultimately determine whether the two skills were related in adolescents with ASD. More specifically, this thesis focused on addressing three main questions: (1) What is the literacy profile of children with ADHD and are autistic traits associated with the reading comprehension performance of children with ADHD? ; (2) Are autistic symptoms associated with social cognitive ability of adolescents with ADHD? ; and (3) Are social cognitive skills associated with the reading comprehension ability of adolescents with ASD? This chapter will focus on each question in turn, to summarise the main findings of this research, before looking across the whole thesis, identifying strengths, limitations and directions for future study.

5.1.1 What is the literacy profile of children with ADHD and are autistic traits associated with the reading comprehension performance of children with ADHD?

Chapter 2 first sought to identify the full profile of literacy skills in children with ADHD, as this was not explored in previous research. Reading research in children with ADHD has tended to highlight reading disability (e.g. de Jong et al., 2009; Del'Homme et al., 2007; Wadsworth et al., 2015) rather than exploring the full profile of literacy skills through the three main areas of basic reading, spelling and reading comprehension. Consequently, I believe that Chapter 2 demonstrates the first study to explore the full literacy profile of children with ADHD.

Chapter 2 found that 30.3% of participants had at least one reading dip, which supported previous research that has found reading disability is common in children with ADHD (e.g. de Jong et al., 2009). However, unexpectedly, 20.8% of participants were found to have at least one reading peak. Peaks in basic reading ability were significantly more common than in spelling or reading comprehension. This finding was particularly interesting, as research has tended to find that basic reading is impaired in children with ADHD (e.g. Åsberg et al., 2008), whereas in this study, with a large sample size (N=340), basic reading peaks were found to be more frequent than basic reading dips. This indicates that children with ADHD can also present with reading strengths, which have not been identified in previous studies because of a tendency to focus on mean scores and deficits alone. In addition, previous studies investigating reading in ADHD have found that reading comprehension deficits are less frequently identified, with some studies finding impairment in relation to controls (Asberg et al., 2010; Martinussen & Mackenzie, 2015) , and others finding no difference in scores (Ghelani et al., 2004; Miller et al., 2013). However, the results of chapter 2 demonstrated that reading comprehension dips were found to be the most frequent deficits, with 23.2% of participants impaired in reading comprehension, compared to 15% and 14.8% for spelling and basic reading respectively. This suggests that children with ADHD are at risk of reading comprehension deficits relative to their IQ, and that reading comprehension ability should be investigated in ADHD alongside basic reading and spelling.

Evidently, exploring the full profile of all three literacy skills in ADHD is vital to understand needs and strengths.

Secondly, Chapter 2 aimed to investigate whether ASD traits affected the reading comprehension performance of children with ADHD. As previously discussed, reading comprehension deficits are less frequently identified in children with ADHD in comparison to reading and spelling deficits. In contrast, studies have shown that reading comprehension deficits are often found in children with ASD (Jones et al., 2009; McIntyre et al., 2017; Nation et al., 2006). Despite the overlap between ADHD and ASD, studies had not previously investigated the role that additional ASD traits have on the reading comprehension ability of a large sample of children with ADHD. It could also be the case that the mixed results regarding reading comprehension ability in ADHD are partially due to comorbid ASD traits and varying levels of such problems in different samples. The results of chapter 2 showed that reading comprehension dips were the most common reading deficit and it was expected that these participants would have the highest level of ASD symptoms. However, this was not the case; ASD traits were not found to be significantly different across the peak and dip groups for all three literacy skills.

Additionally, ASD traits were not found to be significantly associated with the reading comprehension ability-achievement discrepancy score. This demonstrates that elevated autistic traits do not lead to greater reading comprehension deficits in children with ADHD. However, it is important to note that none of the participants had an additional diagnosis of ASD, as participants were originally excluded from the study if they had dual diagnoses. Consequently, it could be that ASD traits do not exert an additional effect on reading comprehension skills unless they are sufficiently impairing. Alternatively, having a diagnosis of ADHD could be the driving force behind these reading impairments, as the study identified impairments relative to IQ in all three literacy skills, and multiple impairments were common. One could also argue that the level of reading comprehension deficits found could instead be the result of EF deficits (see Introduction section 1.2.1) that have been shown to be associated with reading impairment in previous studies of children with ADHD (e.g. Biederman et al., 2004; Jacobson et al., 2011; Kofler et al., 2019). Indeed, research has found that reading comprehension skills are associated with working memory, an EF, in children with ADHD (e.g. Friedman, Rapport, Raiker, Orban, & Eckrich, 2017). The presence of these EF deficits could then have meant that elevated ASD traits had no additional effect on reading comprehension ability in this sample.

Overall, finding that ASD symptoms (at the non-diagnostic level) do not affect the reading comprehension ability of children with ADHD, suggests that there could be less reason to assess for co-occurring ASD symptoms in those with ADHD when reading interventions are chosen. It remains clear that future studies are needed that examine the role of comorbid ASD diagnosis in the reading comprehension performance of children with ADHD, in order to fully investigate the effect of the overlap between these disorders.

5.1.2 Are autistic symptoms associated with the social cognitive ability of adolescents with ADHD?

Chapter 3 investigated the role of ASD symptoms in relation to social cognitive performance across the three main social cognition skills identified (FER, empathy and theory of mind) in children diagnosed with ADHD. Firstly, FER performance was tested using the Ekman facial affect battery (Ekman & Friesen, 1976) demonstrating four emotions (happiness, sadness, fear and anger as well as neutral) in conjunction with eye tracking technology. Previous studies have examined FER in children with dual diagnoses of ASD and ADHD and found a greater level of impairment in comparison with controls and those with a single diagnosis (Colombi & Ghaziuddin, 2017; Sinzig et al., 2008). However, studies have concentrated on those with a dual diagnosis, rather than looking at the influence of elevated symptoms and no overlap studies have used eye tracking to determine whether eye looking patterns affect performance. This is important, as if reduced time spent looking to the eyes is related to FER accuracy, for example, then this would suggest that interventions that aim to increase attenuation to faces would be successful in improving FER ability (Serrano et al., 2015). The results of chapter 3 revealed, as expected, that this sample were impaired in FER accuracy compared to controls. However, ASD symptoms were found to have no additional effect on the FER accuracy score of children with ADHD.

Eye tracking data demonstrated that ASD symptom severity was associated with dwell time to the eyes for sad, neutral and all emotions combined, as well as dwell time to the face for anger, sad, fear and all emotions combined. However, dwell time to the eyes was not found to mediate the relationship between ASD symptom severity and FER accuracy. Instead, dwell time to the eyes mediated the relationship between ADHD symptom severity and FER accuracy when ASD symptoms were controlled. Consequently, it seems that reduced time looking at the eye region of the faces may impair performance in those with more severe ADHD, but not ASD. This could suggest that interventions which involve improving attenuation to the eye region of faces may be beneficial in improving FER in children with ADHD. However, these results must be interpreted with caution as we had no eye tracking data for the control sample, which meant that it was not possible to ascertain whether eye tracking strategies used by those with ADHD were atypical.

Secondly, chapter 3 explored the role of ASD symptoms in the cognitive and affective empathy abilities of children with ADHD. Our study investigated both cognitive and affective empathy using dynamic video clips whilst utilising eye tracking technology. Previous research has found that cognitive empathy is often impaired in children with ASD, while affective empathy ability was not different to controls (Dziobek et al., 2008; Jones et al., 2010). In ADHD on the other hand, few studies have explicitly investigated empathy, with results of those studies suggesting the opposite pattern of impaired affective empathy and intact cognitive empathy (Braaten & Rosén, 2000; Demurie et al., 2011; Dyck et al., 2001; Marton et al., 2009). Studies have suggested that the affective empathy deficits found in ADHD are the result of comorbid CD symptoms (Hubble, 2015; Marton et al., 2009), however the role of comorbid ASD symptoms was not examined in previous research. Results revealed that ASD symptoms were associated with cognitive empathy accuracy and reduced dwell time to the eyes and increased dwell time to the mouth, but only for one of two fear clips. This finding supports previous studies that have found greater levels of impairment for negative emotions in children with ASD (Lozier et al., 2014), and does provide some evidence that additional elevated ASD symptoms reduce the cognitive empathic ability of children with ADHD. Mediation analysis revealed that dwell time to the eyes did not mediate the relationship between ASD symptoms and cognitive empathy accuracy. This suggests that the impaired performance of participants with elevated ASD symptoms was due to difficulties with interpreting the emotion as fear, rather than reduced viewing of the eye region. Once again it is important to note that without a control group for eye tracking data it was not clear whether eye viewing patterns were atypical across the sample.

Finally, chapter 3 investigated the effect of additional ASD and CD symptoms on the theory of mind ability of children with ADHD. The Frith-Happé triangles animations task (Abell et al., 2000) was chosen as a potentially more suitable test of theory of mind for children with ADHD, as previous research has used tasks such as Strange Stories that require literacy skills that are often impaired in children with ADHD (Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004; Mayes & Calhoun, 2006; Sexton et al., 2012) and this was supported by the results of Chapter 2. The one previous study that examined theory of mind performance in children with ADHD using the triangles task identified impairments in children with ADHD compared to controls (Mohammadzadeh et al., 2015), and many studies have found significantly lower appropriateness (accuracy) scores and sometimes also reduced intentionality (mental state) scores in individuals with ASD (Abell et al., 2000; Castelli et al., 2000; Ricketts et al., 2013; Salter et al., 2008; Schwenck et al., 2012). No previous studies have investigated the effect of overlapping ASD or CD symptoms on the theory of mind performance of children diagnosed with ADHD.

Firstly, I established that our sample were impaired in the Frith-Happé triangles animations task through finding that our whole sample of children with ADHD had significantly lower intentionality, but not appropriateness, triangles scores compared to controls. However, against expectations, I found that elevated ASD symptoms were not associated with the intentionality or appropriateness scores of the triangles task. Instead, CD symptom severity was associated with both the intentionality and appropriateness scores when response length, ADHD symptom severity and age were taken into account. This represents a novel finding that contributes to existing research, which has found that theory of mind is impaired in children with ADHD (for a meta-analysis, see Bora & Pantelis, 2015), by suggesting that CD symptom severity could be driving these theory of mind deficits in children with ADHD. Therefore, it could be argued that children with ADHD and elevated CD symptoms represent a subset of children with ADHD who are at greater risk of theory of mind impairments.

Taken together, the results from chapter 3 demonstrate that investigating the role of elevated ASD symptoms on the social cognition abilities of children with ADHD is vital to understanding the nature of these deficits. Few studies have investigated the overlap between these disorders diagnostically (Colombi & Ghaziuddin, 2017; Oerlemans et al., 2014; Sinzig et al., 2008), and no studies have examined this overlap dimensionally in relation to the three main social cognition skills. It is increasingly recognised that examining overlapping symptoms is important (Thapar et al., 2017), and a previous study found that additional ASD symptoms in those with ADHD result in a more severe clinical presentation of this disorder (Cooper et al., 2014). The results presented in this chapter demonstrate that elevated ASD symptoms have no effect on the FER accuracy or associated eye looking patterns of children with ADHD.

In addition, ASD symptoms were found to be significantly associated with cognitive empathy for fear, and less time spent looking at the eyes and more time spent looking at the mouth of a character's fearful face. Finally, theory of mind scores were not associated with ASD symptom severity. Instead elevated CD symptoms were associated with theory of mind impairment in children with ADHD. These findings suggest that assessing for ASD symptoms in children with ADHD can help to determine whether they are a greater risk of having more severe cognitive empathy deficits for fear, while this would not be expected for FER. Additionally, the results of chapter 3.3 suggest that assessing for co-occurring CD traits could help to determine children with ADHD that are more likely to present with theory of mind deficits. Together these results have implications for clinicians in terms of assessment and tailoring interventions to specific subtypes of children with ADHD. There are however a number of limitations regarding the tasks and sample sizes, which will be discussed in section 5.2 below.

5.1.3 Are social cognitive skills associated with the reading comprehension ability of children with ASD?

Chapter 4 takes the findings of chapters 2 and 3 into account to examine the final question of this thesis; whether deficits in the three social cognitive skills are associated with reduced reading comprehension ability in children with a diagnosis of ASD. This research extends upon the findings of Ricketts and colleagues (2013), who addressed this question using theory of mind tasks, by exploring all three social cognitive skills and comparing performance to a control group. Firstly, the study investigated reading and social cognition skills separately to determine whether the findings of previous research studies were upheld. Results showed that both ASD diagnosis and within group ASD symptom severity were associated with lower reading comprehension scores, while no relationship was found with basic reading. Additionally, cognitive and affective empathy were found to be associated with ASD diagnosis, and FER accuracy was related to ASD symptoms. While the associations between ASD symptoms and FER accuracy, as well as ASD diagnosis and cognitive empathy were expected based on previous literature (Lozier et al., 2014;

Schwenck et al., 2012), this was not the case for the relationship between affective empathy and ASD symptoms. This contrasts with the empathy imbalance hypothesis, which proposes that cognitive empathy is impaired while affective empathy is intact for individuals with ASD (Smith, 2009). However, it must be noted that ADHD symptom severity was found to correlate with both cognitive and affective empathy, suggesting that these additional symptoms effected performance in the empathy task. Due to the small number of participants with a dual diagnosis of ASD and ADHD (N=7), it was not possible to split the sample diagnostically to examine this further.

Additionally, no associations were found between ASD symptoms or diagnosis and the intentionality and appropriateness scores of the theory of mind task, the Frith-Happé triangles animations. This finding contrasts with the theory of mind hypothesis of ASD, which views theory of mind deficits as fundamentally responsible for the social communication and interaction difficulties that form part of the diagnostic criteria for ASD (Baron-Cohen et al., 1985). However, it could be that the Frith-Happé triangles animations did not tap into the theory of mind deficits experienced by this particular sample of children with ASD. The reasons surrounding this are discussed in greater detail in section 5.3.

Secondly, the relationship between social cognition and reading comprehension skills was investigated. Results revealed that FER accuracy and cognitive empathy, but not affective empathy or triangles task scores, were associated with reading comprehension standard scores. Finally, the overarching question was addressed, with mediation analyses finding that the relationship between ASD diagnosis and reading comprehension was mediated by cognitive empathy. But this was not the case for FER accuracy. This result supported those of Ricketts and colleagues (2013) by finding that social cognition was related to reading comprehension in children with ASD, but with a cognitive empathy task. Results also found that the relationship between social cognition and reading comprehension was unique to ASD, suggesting that this association between social cognition and reading comprehension is not found in typically developing children.

5.2 Strengths and implications

This thesis represents a novel investigation of the overlap between ADHD and ASD and how this affects reading comprehension and social cognition abilities. Previous literature has identified separate reading and social cognition impairments in children with ASD or ADHD (Nation et al., 2006; Nijmeijer et al., 2008; Sexton et al., 2012; White et al., 2009). This thesis provides a unique contribution to the literature by focusing on the effect that overlapping ASD and ADHD symptoms have on these important skills. A further key strength is that this thesis explores whether reading comprehension and social cognition are related abilities in children with and without ASD diagnoses, which could have substantial implications for the design of future interventions.

Overall, we have shown, in a large sample of children clinically diagnosed with ADHD, that reading comprehension impairment is common and is not associated with additional ASD symptoms. In contrast to previous literature, we sought to examine reading strengths as well as weakness, and we found that basic reading can be a particular area of strength in children with ADHD. Consequently, chapter 2 provides a novel and comprehensive insight into the literacy profile of children with ADHD.

A strength of chapter 3 is that the study sought to investigate performance across all the three main social cognition skills, instead of focusing on one skill, as is often the case in

ADHD studies (see Bora & Pantelis, 2015). In the investigation of facial emotion recognition and empathy, we utilised a behavioural task in conjunction with eye tracking technology in order to better understand the reasons behind any identified impairments. This meant that after discovering that elevated ASD symptoms reduced the cognitive empathic ability of children with ADHD for clip fear 2, we were able to determine that this deficit was not driven by reduced looking to the eye region of the main character's face. Indeed, throughout this thesis, impaired FER and cognitive empathy performance in those with ADHD and more severe ASD symptoms, as well as ASD diagnosis, were not found to be related to less time spent looking at the eye region of faces. This is important as it suggests that elevated ASD symptoms and diagnosis are associated with impaired cognitive empathy and FER due to difficulties with interpreting the emotions themselves. This indicates that interventions which focus on encouraging children with ASD to look more at the key features of faces may not be as successful as interventions that explore what different emotions look like within the context in which they occur.

Although not the main focus of this thesis, it was necessary that CD symptoms were taken into account in chapter 3 due to the substantial overlap between ADHD and CD in the sample, as well as previous literature demonstrating the FER and affective empathy deficits that have been identified in children with CD and ADHD + CD (Airdrie et al., 2018; Van Goozen et al., 2016). As limited previous literature has examined theory of mind in CD, and no studies have examined the abilities of those with ADHD and elevated CD symptoms or diagnosis, I sought to address this lack of research. A further strength is that the Frith-Happé triangles animations task (Abell et al., 2000) was carefully chosen to measure theory of mind as it involves limited demands on EFs and no reading is needed to be successful (see section 5.1.3 and Chapter 3, section 3.3.1). Results revealed that elevated CD symptoms were associated with reduced performance in the theory of mind triangles task when ADHD, age and the length of the task response were taken into account. This suggests that CD symptoms may be driving theory of mind difficulties in those with ADHD. This finding supports research that has found those with ADHD+CD present with a more severe clinical profile than those with ADHD alone (Spencer, 2006; Thapar & van Goozen, 2018). Indeed, current NICE guidelines do recognise the importance of additional CD diagnosis through recommending parent training for children with ADHD and CD, but not for those with ADHD alone (NICE, 2018). Yet no recommendations for interventions to tackle higher order skill deficits such as social cognition are given for this group. Whereas NICE guidelines for ADHD mention an aspect of social cognition difficulties through suggesting that Cognitive Behavioural Therapy would be appropriate for children with ADHD to help with dealing with and expressing feelings (NICE, 2018). This thesis provides some evidence of difficulties with emotions and feelings in ADHD, though demonstrating that children with ADHD are impaired in FER and theory of mind compared to typically developing children. However, this thesis extends upon this to suggest that in fact children with ADHD and elevated CD symptoms or diagnosis should be considered as having a greater risk of theory of mind difficulties than those with ADHD alone, and should therefore be targeted by clinicians as a group that could require more comprehensive theory of mind interventions.

Finally, in chapter 4, we found evidence that the relationship between ASD diagnosis and reading comprehension was mediated by social cognition ability. This indirect effect was shown to be stronger for participants with a diagnosis of ASD compared to typically developing controls. This finding is particularly valuable to the formation of ASD reading comprehension interventions as it suggests that focusing on basic reading and comprehension skills to improve performance, as is typically the case for reading comprehension interventions, may be insufficient. In addition, ASD interventions could be implemented in schools that would improve both reading comprehension and social cognition simultaneously. A dual intervention would be an advantage, as ASD interventions are often costly and time consuming. For example, Buescher and colleagues (2014) estimated that supporting children with ASD costs the UK £3.1 billion annually, of which special education and non-medical interventions make up the bulk of the spend.

Currently, improving reading comprehension skills is high on the agenda for schools in Wales. Since 2013, all secondary schools in Wales have had to administer a standardised reading test, the National Reading Test, to pupils in key stage 3. The test is part of the National Literacy and Numeracy Framework used by the Welsh government to monitor literacy standards across Wales and make comparisons between different schools and regions (Welsh Government, 2013). These literacy tests are dependent on both basic reading and inferential reading comprehension abilities for children to be successful. Consequently, in my own personal experience from collecting data and supporting teaching in a secondary school, schools are keen to integrate reading interventions into the school curriculum. A further point is that mainstream schools are restricted by the curriculum in terms of the time and money available to run interventions. In my experience, this has meant that mainstream pupils with diagnoses of ASD have fewer opportunities to access social cognition interventions that are commonly available in special schools or specialist resource bases. For example, a study (Lindsay, Ricketts, Peacey, Dockrell, & Charman, 2016) investigated parents' perspectives on the educational provision provided by the schools their autistic children attended. Results showed that parents whose children were educated in a specialist ASD resource base of a mainstream school were significantly more satisfied with the school's provision and were more positive that their child's emotional and social needs were met, compared to parents of children with ASD that were educated solely within mainstream classes. As a result, if an intervention was designed that could improve both reading comprehension and social cognition performance for children with ASD, as my findings suggest could be the case, this would be very beneficial for schools as well as the pupils themselves.

5.3 Limitations and future directions

There are a number of limitations to this thesis, relating to tasks and participants, which will now be discussed. In both chapters 1 and 4, I was interested in finding out about the role of ASD symptoms and diagnosis on reading comprehension performance. Chapter 4 also examined the relationship between reading comprehension and social cognition in those with ASD. In both chapters, the basic reading skills of participants were also tested, but no measure of oral language was included. The simple view of reading posits that both basic reading (word decoding) and oral language are necessary precursors to reading comprehension (Ricketts, 2011). Indeed in Ricketts et al., (2013) oral language was found to be a significant predictor of reading comprehension ability in their sample of adolescents with ASD. Although results showed that social cognition scores continued to predict reading comprehension ability when oral language was controlled for, this does nevertheless indicate that oral language contributes to reading comprehension ability in ASD and should be taken into account. This finding is consistent with other studies that have found oral language is associated with reading comprehension in ASD (Lucas & Norbury, 2014; Nation et al., 2006). Consequently, including a measure of oral language in future studies could provide a greater insight into the relationship between ASD and reading comprehension, as well as social cognition.

In chapter 3, a problem was identifed with the design of the facial emotion recognition task. In the task, participants were presented with slides of black and white faces on a black background (See Figure 3.1.2) in which the emotional response options (i.e. happy, sad, fear, anger and neutral) appeared on the screen at the same time as the facial stimuli. This meant that when eye tracking data was analysed it was difficult to tell whether participants that looked less at the key regions of the faces and more at the black background, did so because they found the faces aversive or because they were distracted by the response options. This had clear implications for the interpretation of the findings. As a result of this, when collecting data from a new sample in chapter 4, the decision was made to first present the facial stimuli slides for four seconds before the response options appeared. As previous FER studies have presented facial stimuli to adults for two seconds (Pelphrey et al., 2002), and young children for ten seconds (de Wit et al., 2008), four seconds seemed a reasonable time for adolescents. Eye tracking data was only analysed for these initial four seconds, which meant that this data was not adversely affected by the distraction of the response list. However, I was unable to use the data from this FER measure for chapter 4 as 72% of participants did not meet the 70% validity threshold (see Chapter 4, section 4.2.2.4). This was unexpected as it was a much higher loss of data than the 12.3% experienced in chapter 3 (3.1.2.2). One reason for this could be the order the task was presented in the testing battery. In the school study protocol this task came last, whereas in the ADHD task battery it was the second task participants completed. In the school study participants may have been anxious to return to their lessons, and this could have meant they were more distracted and moved more when completing the FER task compared to the empathy film clips task. Indeed, static FER tasks have been associated with attentional distractability in children with ASD or ADHD (Berggren et al., 2016).

A further limitation of the FER task is that the ecological validity of the Ekman faces battery itself has been called into question as the images are black and white and appear old-fashioned (Goeleven, De Raedt, Leyman, & Verschuere, 2008). The Ekman faces battery was used in the ADHD study and school study as it is very well established in facial emotion recognition studies and has good reliability statistics across samples (Ekman, 1994), which demonstrates that the emotions are accurately depicted in the photographs. In our study the hair of the faces was removed to reduce distraction, however this is not realistic. Removing the hair also meant that some of the faces appeared to be an unususal shape, and partcipants in both the ADHD and school studies commented that they looked odd and that they did not like them. This could have reduced the amount of time they spent looking at the faces or distracted participants from the task. Consequently, future studies using static images should consider their ecological validity.

In chapter 4, alterations were also made to the cognitve and affective empathy film clips task. In chapter 3, the task included a mix of fictional and non-fictional clips from films, interviews and documentaries. Two clips were used to portray each of the three emotions; happiness, sadness and fear. As a result of this mix of fictional and non-fictional clips, empathy scores could not be averaged across each emotion, but had to be investigated separately. In addition, both the size of eye tracking AOIs and the intensity of each emotion differed between the clips, which could have affected participants' responses as well as the amount of time spent looking at these facial regions. In fact, the findings of chapter 3 that ASD symptoms were associated with impaired cognitive empathy and less time looking at the eyes for clip fear 2 alone, could provide evidence of this. Clip fear 2 included a close-up image of the main character's high intensity fearful face which also represented the largest facial AOI of all the clips. Consequently, clip fear 2 could have been the most aversive image, which could have influenced results.

In addition, as the films Jaws 2 and Cliffhanger had a certificate rating of 15, ten parents chose to remove their consent for their children to watch the clips from these films. To counter these inconsistencies, the task was altered in chapter 4 to include film clips from the same range of fictional films, the Harry Potter film franchise. The Harry Potter films are rated PG to 12A, and were therefore appropriate for the adolescents that took part in the study. The majority of participants (64.4%) had seen all three of the clips previously which meant they were familiar with the characters, yet this familiarity did not effect their responses in the cognitive and affective empathy questionnaires (Appendices 8 and 9). I found that participants seemed to be excited about watching the clips and were very engaged in the task. This may have also accounted for the higher number of participants meeting the 70% validity thresholds compared to the FER task. [2] In addition, using Harry Potter as the main character in each clip in order to reduce the variability which could occur from using different film types and various main characters that differ in their emotional

[2] For the empathy film clips task in the school study, 70 to 76% of participants met the 70% validity threshold, compared to only 28% for the FER task (see Chapter 4).

intensity. The task could have been further improved by the addition of a second clip for each emotion, but this was not possible within the time constraints of testing particpants in a school environment.

Although the use of dynamic film clips to measure empathy ability is considered to be a clear strength of this thesis, (see Chapters 1, 3 & 4), it is nevertheless the case that passively observing emotions portrayed by characters in films (though more ecologically valid than static images) does not mimic real-life situations that involve reciprocal interactions (Boraston & Blakemore, 2007; Pfeiffer, Vogeley, & Schilbach, 2013). Recently, studies are attempting to re-create these emotional situations in a laboratory environment using live video links (De & Saha, 2015), or avatars that are programmed to respond appropriately (Johnson et al., 2018). For example, one study (von dem Hagen & Bright, 2017) used videos of an experimenter as the stimuli. When typically developing participants were actively engaged in a live video interaction with the experimenter, those with high ASD traits looked less at the experimenter compared to those with low ASD traits. This suggests that using more ecologically valid stimuli has an effect on participants' behaviour. Tasks such as these could be particularly useful in helping to understand more about the real-life cognitive and affective empathy abilities of children with ASD and ADHD in a realistic yet controlled environment.

In addition, the Frith-Happé triangles animations task was added to the test battery for the ADHD study (chapter 3) and the school study (chapter 4) to minimise the effect of literacy ability and EFs on social cognition performance compared to other popular tasks used in ASD research such as false-belief and strange stories, both of which require working memory and inhibition skills to be successful (Fahie & Symons, 2003; Sodian & Hülsken, 2005). However, it is possible to reduce reliance on EFs even further through removing verbal responses and utilising implicit social cognition tasks that require even less EFs to be successful. For instance, Schneider et al., (2013) measured theory of mind ability in children with and without ASD through tracking the spontaneous looking patterns of children while they watched film clips of false-belief interactions. Future studies examining the overlap between ADHD and ASD and the association with social cognition could use implicit tasks like these, which would be particularly suited to testing children with ADHD who often have EF deficits (e.g. Crippa et al., 2014).

Another task utilised in this thesis that may have limitations is the WORD reading test (Wechsler, 1993) that was used as a measure of basic reading and reading comprehension in chapters 2 and 4. Chapter 2 also included the spelling subset. A review by Ricketts (2011) cautioned that the choice of reading comprehension test in research studies is vital in determining which participants are identified as having deficits, as the tests vary in the aspects of reading that are being tested. For example, one study found that the average overlap between four different reading compehension tests commonly used to test children in America was only 43% (Keenan & Meenan, 2014). The reading comprehension subset of the WORD requires participants to read paragraphs aloud or silently, and then answer one question that is asked by the examiner. The paragraphs increase in length and complexity, and the questions are either literal or inferential. One potential problem with this measure is that children are given no help if they cannot pronounce or understand the words in the paragraphs. This means that as well as measuring reading comprehension, the task is also measuring basic reading skills as participants are unlikely to correctly answer a question on a paragraph that they are unable to read. In support of this observed limitation, Garcia and

Cain (2014) in their meta-analysis, identified that whether or not word decoding help was provided during reading comprehension assessments was signifcantly associated with the reading comprehension scores of typically developing children and adults.

The WORD was examined in this thesis as it had already been used to measure literacy in the first wave of the ADHD study (utilised in Chapter 2) which took place prior to the start of this thesis. It is also a standardised measure that allows for ability-achievement discrepancies to be determined using the WISC Q test (Wechsler, 2003). The measure is also short in length, taking approximatey 20 minutes to test both basic reading and reading comprehension. As I wanted to provide continuity across the thesis and because of time contstraints, the WORD was therefore chosen as the reading comprehension measure of chapter 4. However, with hindsight, a more appropriate measure would be one in which the examiner was able to assist the child with words they were unable to read, such as the Neale Analysis of Reading Ability (NARA; Neale, 1999), which reduces the overlap between basic reading and reading comprehension scores. Alternatively, the York Assessment of Reading for Comprehension (YARC; Snowling et al., 2009) could be used, as in this measure children are given passages to read on the basis of their basic reading skills, which means that the difficulty of the passages has been matched to the individual child's ability level (Ricketts, 2014). This also helps to reduce the length of the task, as passages that are too easy or too difficult for the child to read are avoided. Consequently, although the WORD identified the reading comprehension deficits that I expected to find in Chapter 4 based on previous literature, it remains the case that the reading comprehension deficits found in both chapters 1 and 4 could have been inflated by participants' basic reading difficulties. It seems that the NARA or YARC may be more optimum measures for future studies exploring reading comprehension in ADHD and ASD.

As well as tasks, difficulties with participant characteristics and recruitment represent further limitations. As noted previously (section 2.2.1) participants with ADHD were excluded from the original SAGE study (Chapter 2), of which the ADHD study was a follow-up (Chapter 3), if they had a diagnosis of ASD. As a result, in chapters 2 and 3 only a small number of children reached criteria for an additional diagnosis of ASD using the DAWBA. This meant that it was only possible to analyse the effect of additional ASD symptoms through using continuous measures of ASD traits and symptomology from the SCQ and the DAWBA. This was not a concern for this thesis, as has been outlined in the introduction, this thesis primarily aimed to explore the overlap between ADHD and ASD at symptom level. It is, however, important to note that analysing symptoms continuously has disadvantages as there could have been qualitative differences between those with and without a diagnosis of ASD that were masked by focusing on a continuous measure of ASD symptoms. As there were so few participants that met criteria for a dual diagnosis in chapters 2 and 3, it was not possible to explore this possibility due to a lack of power. Future studies are needed with participants that have diagnoses of ADHD and ASD alone, as well as dual diagnoses, in order to disentangle the effect of elevated ASD symptoms versus ASD diagnosis on literacy skills and social cognition in children with ADHD.

Another issue of note was participant recruitment for the school study (Chapter 4). Originally, it was planned that the study would compare those with different diagnoses and that there would be 25 participants in each of the four groups: ASD, ADHD, ASD+ADHD and controls. However, I was unable to recruit a sufficient number of participants with ADHD or both ASD+ADHD from the schools, community centres and colleges that agreed to take part in the research. There are a few potential reasons for this. Firstly, through the Wales Autism Research Centre social media platforms and events I was able to engage a number of interested parents of children with ASD that were willing to take part in the study. Secondly, the schools and colleges I approached did not think the research tasks suited children who presented with more severe behavioural difficulties or spent time in pupil referral units. Consequently, I had less opportunities to recruit children with more complex difficulties, and the children I recruited were reported by their parents as having either very low or zero CD symptoms. This meant I could not follow up on the findings of chapter 3 to explore the role of overlapping CD on performance in the Frith-Happé triangles animations task across ADHD and ASD. As a result of these recruitment difficulties, I was able to recruit only two children with ADHD alone and seven children with ASD+ADHD. Accordingly, I was unable to compare performance between children with dual diagnoses and those with ADHD or ADHD alone. Whilst the study was designed to identify participants similar to those utilised in Chapter 3 in terms of age and education, the methodological changes to the FER and empathy tasks (discussed above) included in the protocol for this study meant that the participants from Chapter 3 could not be used as the ADHD participants in the study described in Chapter 4. Consequently, future research is needed to identify whether the relationship between social cognition and reading comprehension is also found in children with a dual diagnosis of ASD + ADHD.

Finally, there are a number of other questions that could be addressed by future research. While this thesis primarily aimed to discover the effect of elevated ASD symptoms on the reading and social cognition abilities of children with a diagnosis of ADHD, the underlying aetiology of these key abilities was not investigated. There could be common or different mechanisms that account for reading and social cognition abilities in each disorder. For example, in ADHD, reading comprehension deficits could be the result of executive dysfunction, while in ASD (as chapter 4 suggests) social cognition difficulties could be the primary factor. It is also the case that the aetiology of social cognition and reading abilities in children with ADHD and elevated ASD symptoms could be qualitatively different. One recent study has hypothesised that social cognition difficulties in those with ADHD and ASD would be greater than those with a single diagnosis due to the combination of 'aloof' social behaviour in ASD and 'intrusive' behaviour in ADHD (Mikami, Miller, & Lerner, 2019), although this has not been investigated. Evidently future research is needed to help to determine not only the social cognition and reading difficulties of those with a dual diagnosis or elevated symptoms of both disorders, but also to address different casual hypotheses.

5.4 Conclusion

This thesis has demonstrated that elevated ASD traits have no effect on the reading comprehension performance of a large sample of children with ADHD. We also showed that basic reading skills can be an area of strength for individuals with ADHD. Chapter 3 demonstrated that comorbid ASD symptomology in adolescents with ADHD should be taken into account when exploring social cognition abilities, even when it falls below diagnostic thresholds. I found that ASD symptoms were related to impaired cognitve empathy and reduced time looking at the eye region of faces for fear. Further studies are needed to demonstrate the impact of dual diagnosis of ADHD and ASD on FER, cognitive empathy and theory of mind.

When investigating theory of mind in ADHD, we additionally discovered that CD symptom severity, but not ASD symptom severity, appears to drive deficits in theory of mind ability. Finally, we found that social cognition ability mediates the relationship between ASD diagnosis and reading comprehension skills, a relationship that is unique to ASD and not found in typically developing adolescents. This finding has potentially wide reaching implications for future ASD interventions by demonstating that a dual intervention, encompassing both reading comprehension and social cognition, is possible and could be a practical solution to current difficulties surrounding the implementation of interventions in Welsh schools.

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Appendices

Appendix 1: Table showing the sample characteristics of participants (N=340) with SCQ data in Chapter 2

		Mean	**SD**
WISC	Full scale IQ	88.3	14.2
WORD Basic Reading	Standard score	88.7	14.2
WORD Spelling	Standard score	85.3	12.7
WORD Reading Comprehension	Standard score	85.3	12.7
ADHD	Hyperactivity	4.5	0.8
	Impulsivity	3.4	0.8
	Inattention	7.3	1.7
	Total symptoms	15.3	2.4
SCQ	Social	6.0	3.5
	Communication	3.7	2.0
	Repetitive behaviour	2.4	2.1
	Total symptoms	12.6	6.2

Note: SCQ= Social Communication Questionnaire, ADHD= Attention-deficit/hyperactivity disorder

Appendix 2: Table showing correlations between demographic data, standard and ability-achievement discrepancy literacy skills scores, SCQ and ADHD scores in chapter 2

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1. Gender	0.03	-0.00	0.01	0.02	-0.03	0.00	0.02	-0.04	-0.01	-0.00	0.03	0.07	0.01	-0.00	0.04	-0.00	0.02
2. Age		0.05	-0.05	0.03	-0.09	0.05	0.07	-0.05	0.09	-0.04	-0.09	-0.13*	-0.08	0.04	-0.23**	-0.10	-0.09
3. SES			-0.09	-0.14*	-0.13*	-0.11*	-0.07	-0.06	-0.05	-0.09	-0.00	0.07	-0.03	-0.05	-0.06	0.02	-0.05
4. Full scale IQ				0.48**	0.46**	0.52**	-0.32**	-0.42**	-0.30**	-0.10	-0.21**	-0.01	-0.13*	-0.02	-0.09	-0.02	-0.05
5. SS Basic reading					0.79**	0.78**	0.68**	0.38**	0.45**	-0.04	-0.13*	0.04	-0.05	-0.07	-0.07	-0.02	-0.08
6. SS Spelling						0.65**	0.47**	0.61**	0.33**	-0.02	-0.12*	0.05	-0.04	-0.10	-0.02	-0.02	-0.08
7. SS Reading Comp							0.41**	0.21**	0.66**	0.03	-0.12*	0.02	-0.02	-0.04	-0.08	-0.06	-0.07
8. Ability Basic reading								0.77**	0.74**	0.03	0.03	0.05	0.05	-0.06	0.00	-0.01	-0.04
9. Ability Spelling									0.06**	0.07	0.07	0.05	0.07	-0.09	0.06	-0.00	-0.04
10. Ability Reading Comp										0.12*	0.05	0.03	0.09	-0.02	-0.01	-0.04	-0.04
11. SCQ Social											0.54**	0.31**	0.86**	0.08	0.12*	0.05	0.11*
12. SCQ Communication												0.42**	0.80**	0.07	0.12*	0.07	0.11*
13. SCQ Repetitive behaviour													0.66**	0.07	0.16**	0.16**	0.15**
14. SCQ Total														0.10	0.18**	0.06	0.17**
15. ADHD Inattention															0.20**	0.17**	0.83**
16. ADHD Hyperactivity																0.40**	0.62**
17. ADHD Impulsivity																	0.60**
18. ADHD Total																	

Note: SES= Social economic status, SS= Standard Scores; Ability= Ability-achievement discrepancy scores ; SCQ= Social Communication Questionnaire

Appendix 3 Table showing FER accuracy scores (%) for the ADHD study (Chapter 3) compared to controls for the school study (Chapter 4)

		Happy	**Sad**	**Anger**	**Fear**	**Neutral**	**Combined**
ADHD	Mean (SD)	94.0 (9.9)	44.4 (15.7)	71.0 (17.4)	68.3 (20.0)	74.3 (31.0)	70.4 (1.1)
Control	Mean (SD)	95.1 (7.8)	47.5 (27.3)	78.4 (14.1)	77.1 (9.0)	88.2 (12.9)	77.3 (8.5)

Note: FER= Facial emotion recognition, ADHD= Attention-deficit/hyperactivity disorder

Appendix 4: Empathy film clips task questionnaire used to assess cognitive and affective empathy in chapters 3 and 4

Video 1 – main character

If any, which emotion do you think the main character felt the most (please chose 1 from the list):

____________________: Why do you think the main character felt (insert emotion).

____
____

You also indicated (insert emotion) as high – why do you think the main character felt (insert emotion)?

____
____

Video 1 – you

If any, which emotion did you feel the most when watching the clip (please chose 1 from the list):

____________________: Why did you feel (insert emotion).

____
____

You also indicated feeling (insert emotion)– Why did you feel (insert emotion)?

____
____

Video 2 – main character

If any, which emotion do you think the main character felt the most (please chose 1 from the list):

____________________: Why do you think the main character felt (insert emotion).

____
____

You also indicated (insert emotion) as high – why do you think the main character felt (insert emotion)?

____
____

<u>Video 2 – you</u>

If any, which emotion did you feel the most when watching the clip (please chose 1 from the list):

____________________: Why did you feel (insert emotion).

____
____

You also indicated feeling (insert emotion)– Why did you feel (insert emotion)?

____
____

Video 3 – main character

If any, which emotion do you think the main character felt the most (please chose 1 from the list):

____________________: Why do you think the main character felt (insert emotion).

____

____

You also indicated (insert emotion) as high – why do you think the main character felt (insert emotion)?

____

____

Video 3 – you

If any, which emotion did you feel the most when watching the clip (please chose 1 from the list):

____________________: Why did you feel (insert emotion).

____

____

You also indicated feeling (insert emotion)– Why did you feel (insert emotion)?

____

____

Video 4 – main character

If any, which emotion do you think the main character felt the most (please chose 1 from the list):

____________________: Why do you think the main character felt (insert emotion).

____
____

You also indicated (insert emotion) as high – why do you think the main character felt (insert emotion)?

____
____

Video 4 – you

If any, which emotion did you feel the most when watching the clip (please chose 1 from the list):

____________________: Why did you feel (insert emotion).

____
____

You also indicated feeling (insert emotion)– Why did you feel (insert emotion)?

____
____

Video 5 – main character

If any, which emotion do you think the main character felt the most (please chose 1 from the list):

____________________: Why do you think the main character felt (insert emotion).

____

____

You also indicated (insert emotion) as high – why do you think the main character felt (insert emotion)?

____

____

<u>Video 5 – you</u>

If any, which emotion did you feel the most when watching the clip (please chose 1 from the list):

_____________________: Why did you feel (insert emotion).

____

____

You also indicated feeling (insert emotion)– Why did you feel (insert emotion)?

____

____

<u>Video 6 – main character</u>

If any, which emotion do you think the main character felt the most (please chose 1 from the list):

_____________________: Why do you think the main character felt (insert emotion).

____

____

You also indicated (insert emotion) as high – why do you think the main character felt (insert emotion)?

____

____

Video 6 – you

If any, which emotion did you feel the most when watching the clip (please chose 1 from the list):

_____________________: Why did you feel (insert emotion).

____
____

You also indicated feeling (insert emotion)– Why did you feel (insert emotion)?

____
____

Appendix 5 Scoring system for empathy film clips, chapters 3 and 4

Table 2.1:
The Cardiff Empathy Scoring System for cognitive and affective empathy

Cognitive Empathy
Target emotion
0 = Target emotion not identified in main character 1= Target emotion identified at a low intensity 2= Target emotion identified at a high intensity
Similar relevant emotion
0 = Similar relevant emotion not identified in main character 1= Similar relevant emotion identified at a low intensity 2= Similar relevant emotion identified at a high intensity
Explanation of emotion
0= Incorrect or irrelevant explanation of emotion *e.g.*, "The girl was fearful because she was scared". 1= Explanation provides one factual reason for emotion *e.g.*, "The girl was fearful because there was a shark". 2 = Explanation provides more than one factual reason for emotion *e.g.*, "there was a shark and the boat got knocked" OR provides one consequence of the event *e.g.*, "she thought she might die". 3= Explanation provided one piece of factual information AND took into consideration the consequence of the event for the main character *e.g.*, "There was a shark in the water and she thought it might kill her". 4 = Explanation provided more than one piece of factual information AND took into consideration the consequence of the event for the main character *e.g.*, "there was a shark, her boyfriend fell in the water and she thought she might die". 5= Explanation provided a thorough account of the main character situation providing multiple factual reasons for their emotions and elaborating on the possible consequences of the situation *e.g.*, "There was a shark in the water and it had already killed her boyfriend. She was on her own and would be worried that it might come back for her and kill her as well".
Affective Empathy
Target emotion
0 = Target emotion not identified in self 1= Target emotion identified at a low intensity

2= Target emotion identified at a high intensity
Similar relevant emotion
0 = Similar relevant emotion not identified in self 1= Similar relevant emotion identified at a low intensity 2= Similar relevant emotion identified at a high intensity
Explanation of emotion
0= Incorrect or irrelevant explanation of emotion e.g., "I felt happy because I like seeing people die". 1= Explanation based on factual information e.g., "I felt sad because the man died". 2= Explanation based on main characters emotions or involved participant transposing themselves into main characters situation e.g., "I felt sad because I thought about that happening to me".

Appendix 6: Table showing the percentage of participants that had previously viewed each video clip in the empathy film clips task in chapter 3

	Previously watched (%)
Sad 1	4.5
Sad 2	4.5
Happy 1	29.9
Happy 2	7.5
Fear 1	50.7
Fear 2	11.9

Note: Sad 1= The champ; Sad 2= 911, Happy 1= Racing stripes, Happy 2= Greg Rutherford; Fear 1= Jaws2; Fear 2= Cliffhanger

Appendix 7: Correlations table showing the associations between cognitive and affective empathy scores for each video clip shown for Chapter 3, and whether participants had seen each clip before

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Cog S1	-0.01	0.15	0.05	0.09	-0.19	0.01	<-0.00	-0.07	-0.06	0.17	-0.03	-0.05	0.04	0.06	0.03	-0.12	0.06
2 Aff S1		.019	0.49^{**}	0.04	0.53^{**}	0.03	-0.60^{**}	-0.04	0.39^{**}	0.01	0.59^{**}	< 0.00	-0.02	-0.08	-0.06	-0.13	-0.07
3 Cog H1			0.31^{*}	0.14	0.17	0.29^{*}	-0.04	0.24	0.06	0.14	0.28^{*}	0.20	0.17	0.20	-0.18	-0.14	0.29^{*}
4 Aff H1				0.11	0.46^{**}	-0.03	0.17	-0.08	0.29^{*}	0.09	0.42^{**}	0.09	-0.10	-0.03	-0.29^{*}	-0.13	-0.21
5 Cog F1					0.05	0.23	0.09	0.08	0.23	0.16	0.05	0.13	0.14	0.03	-0.03	0.11	0.17
6 Aff F1						0.17	0.46^{**}	-0.09	0.48^{**}	-0.04	0.44^{**}	0.17	-0.01	0.06	-0.09	0.02	-0.25
7 Cog S2							0.06	0.17	0.07	0.33^{**}	0.18	0.15	0.13	0.13	-0.21	0.04	0.20
8 Aff S2								0.07	0.36^{**}	-0.04	0.38^{**}	<-0.00	0.19	-0.15	0.04	-0.08	-0.15
9 Cog H2									0.11	0.28^{*}	< 0.00	0.07	0.04	0.13	-0.03	-0.12	0.08
10 Aff H2										0.03	0.31^{*}	0.11	0.06	-0.09	-0.14	0.01	-0.03
11 Cog F2											0.16	-0.05	0.19	-0.01	-0.06	0.02	0.17
12 Aff F2												0.21	-0.01	-0.12	-0.08	-0.04	0.04
13 Seen S1													0.02	.057	-0.05	0.21	0.39^{**}
14.Seen H1														0.04	0.34^{**}	0.06	0.27^{*}
15 Seen F1															0.07	0.25^{*}	0.18
16 Seen S2																0.25	0.14
17 Seen H2																	0.42^{**}
18. Seen F2																	

Note: Cog= cognitive empathy, Aff= affective empathy; S1= clip sad 1, S2= clip sad 2; F1= clip fear 1; F2= clip fear 2; H1= clip happy 1; H2= clip happy 2; *<0.05, ** < 0.01

Appendix 8: <u>Frith-Happé Scoring Criteria (used in Chapters 3 and 4)</u>

<u>A = Score 0-5 for Intentionality</u>

0 = Action, non deliberate.
 (e.g. “Bouncing,” “Moving around,” “Rotating”
1 = Deliberate action with no other.
 (e.g. “Ice skating”)
2 = Deliberate action with another.
 (e.g. “Blue and red are fighting,” “Parent is followed by child”)
3 = Deliberate action in response to other’s action.
 (e.g. “Big is chasing little,” “Red is allowing the Blue to get close to him,” “Big is guarding little who was trying to escape”)
4 = Deliberate action in response to other’s mental state.
 (e.g. “Two people are arguing,” “A parent is encouraging a child to go outside,” “The triangle does not want to go out”)
5 = Deliberate action with goal of affecting other’s mental state
 (e.g. “The blue triangle wanted to surprise the red one,” “Child pretending not to be doing anything”)

<u>B = Score 0-2 for Appropriateness</u>

0 = No answer, “I don’t know” OR inappropriate answer: reference to wrong type of interaction between triangles.
1 = Partially correct answer: reference to correct type of interaction but confused overall description.
2 = Appropriate, clear answer

Appropriateness score based on underlying script for each animation:

Theory of mind animations

3.4 - Surprising:

2 = any mention of tricking, surprising, hiding, hide and seek
1 = description which gives part of the story but misses critical point (see above)

0 = description not related to any of the events in the sequence, or focus solely on a minor part or action (e.g. knocking on the door)

3.1 - Coaxing:

2 = description that conveys the idea of little triangles reluctance to go out and big triangle's attempt to get the little one out (e.g. persuading, coaxing)
1 = partially correct description focusing on one aspect of the story or one character only

0 = actions that do not relate to any of the events or relate to a very minor aspect of the sequence (e.g. the two triangles didn't like each other)

3.2 - Mocking:

2 = description that conveys idea that little triangle is copying big one with the intention of not being noticed (e.g. pretending, hiding, being naughty)
1 = partially correct description (e.g. following, pursuing, copying)

0 = description that does not relate to the events (e.g. big triangle not interested) or relate to a very minor aspect of the sequence only (e.g. little triangle ran away)

3.3 - Seducing:

2 = description that conveys the little triangle is trapped in and escapes by persuading, tricking the big one (e.g. little convinces big in a seductive way to let him out)
1 = partial story with minimal action for each character (e.g. little trying to escape)
0 = description which is too minimal (e.g. she got out) or unrelated to the sequence

Goal directed animations

1.4 - Chasing:
2 = description that conveys the idea of a chase
1 = description that is related to but somewhat remote from chasing (e.g. following)
0 = action that does not relate chasing
1.3 - Fighting: (animation with no enclosure)
2 = action implying physical fight (e.g. bashing each other)
1 = action that conveys the idea of a conflict, but is either too specific or too vague, e.g. biting; pushing)
0 = action that does not relate to conflict (e.g. following each other) or focus solely on minor aspect of the sequence

C = Score 0-4 for Length

0 = no response, 1 = one clause, 2 = two clauses, 3 = three clauses, 4 = more than three clauses

Appendix 9 Pearson Correlation coefficients showing the association between Frith- Happé triangles animations, length, FSIQ and age

	2	3	4	5	6	7
1.Gender	-0.10	0.40	-0.40	-0.67**	-0.41	-0.55**
2. FSIQ		0.46*	0.50*	0.24	0.49*	0.48*
3. Age			<0.01	-0.16	-0.07	0.07
4. Goal-directed				0.74**	0.76**	0.67**
5. Appropriateness					0.77**	0.73**
6. Intentionality						0.86**
7. Length						

Appendix 10: Table showing the percentage of participants that had previously viewed each Harry Potter video clip in the empathy film clips task in chapter 4

	Previously watched (%)
Sad	66.1
Happy	72.9
Fear	72.9
Seen all	64.4
Seen none	5.1

Appendix 11: Correlations table showing the associations between cognitive and affective empathy scores for each Harry Potter video clip shown for Chapter 4, and whether participants had seen each clip before

	2	3	4	5	6	7	8	9
1. Seen Fear	1.00**	-0.62**	-0.04	-0.19	0.03	-0.03	0.29	0.05
2. Seen Happy		0.62**	< -0.01	-0.19	0.03	-0.03	0.29	0.05
3. Seen Sad			-0.07	-0.12	0.04	0.14	0.15	0.06
4. Cog Fear				0.41**	0.51**	0.09	0.57**	0.41**
5. Aff Fear					0.42**	0.28	0.31*	0.34*
6. Cog Happy						0.35*	0.57**	0.27
7. Aff Happy							0.21	0.51**
8. Cog Sad								0.39**
9. Aff Sad								

Note: Aff= Affective empathy, Cog= Cognitive empathy, Fear (Giant spiders), Happy (Finding the golden snitch), Sad (Dobby dies), *p <.05; ** p < .01