The role of inhibitory control in the cooperative play of high-functioning children with autism

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Thesis submitted for the degree of Doctor of Philosophy

University of Sussex

September 2014

Statement

I hereby declare that this thesis has not been and will not be submitted in whole or in part to another university for the award of any other degree.

…………………………………

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30 September 2014

UNIVERSITY OF SUSSEX
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Summary

This thesis contributes to the executive dysfunction account of autism by demonstrating that impairments in inhibitory control, an aspect of executive functioning, are partially responsible for deficits in the cooperative play of high-functioning children with autism (HFA).

As past research on whether inhibitory control is impaired in autism has been inconclusive, a meta-analysis of 42 empirical studies (57 effect sizes, total n = 2,256) was conducted, which provided clear evidence for impaired inhibition in HFA children. It was also found that the degree of impairment shown does not vary across measures of inhibition, which has important methodological implications for future research.

Two experimental studies were carried out to directly test the link between inhibition and three components of cooperation: reciprocity, accepting the play partner's input, and fairness. In study one, HFA children in primary school and age-matched typically-developing (TD) peers were tested on engaging in joint attention, theory of mind (ToM), measures of inhibition, and a cooperative drawing task. The groups did not differ on first-order ToM and joint attention, but HFA participants demonstrated poorer inhibitory control and less cooperative behaviour. Importantly, the degree of impairment in inhibitory control predicted reciprocity and accepting the play partner's input in HFA children.

The second experimental study investigated whether poor inhibitory control can explain the well-established discrepancy between moral reasoning and actual sharing behaviour. A sample of HFA and TD children of primary school age completed a moral reasoning interview, inhibitory control tasks, and a Dictator Game. The results showed that while HFA children demonstrated age-typical levels of moral reasoning and sharing, inhibitory control emerged as the most important

predictor of sharing behaviour, lending support to the hypothesis that the ability to suppress one's own desires is a prerequisite of acting considerately.

The last study comprises a qualitative investigation of TD children's experience of engaging in cooperative play with their sibling who has a diagnosis of HFA. Six children between the ages of 5 and 11 were interviewed, and their reports analysed using interpretative phenomenological analysis (IPA). Five themes emerged: poor emotion regulation, restricted interests, and no acceptance of the playmate's contributions reduced the hedonistic value of joint play for the participants, but these were mitigated by appreciation for the HFA sibling's creativity and adjustment to the HFA sibling's behavioural atypicalities. These results can inform the development of support programmes for TD siblings and social skills training for HFA children.

Overall, the results of the studies included in this thesis provide evidence that deficits in inhibitory control moderate the relationship between relatively intact social knowledge and impaired social competence in HFA children. This refinement of the executive dysfunction account is a useful building block for an improved multiple-deficit model of the autism phenotype.

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Introduction

1. Autism: a brief overview

Autism spectrum disorder (ASD) is a pervasive developmental disorder characterised by deficits in social communication and social interaction, and by restricted, repetitive patterns of behaviour, interests, or activities (American Psychiatric Association, 2013).

According to the definition adopted in the latest edition of the Diagnostic and Statistical Manual (DSM-V), the term encompasses not only classic autism, but also the related disorders previously referred to as Asperger syndrome (AS) and pervasive developmental disorder not otherwise specified (PDD-NOS), respectively.

Autism is typically diagnosed in childhood, often with a comorbid diagnosis of intellectual disability (Chakrabarti & Fombonne, 2001), obsessive-compulsive disorder (OCD, Russell et al., 2013), attention-deficit / hyperactivity disorder (ADHD, Reiersen & Todd, 2008), or other medical and neurological problems.

Over the past 20 years, there has been a marked increase in the number of ASD diagnoses (Baron-Cohen et al., 2009). Current estimates suggest that around 1 in 100 children are affected. ASD is more common among males: a commonly referenced consensus ratio is 4:1 (Werling & Geschwind, 2013).

1.1. Prevalence

A recent epidemiological study conducted on a British sample estimated the prevalence of ASDs at 116 in 10,000 or 1 in 86 (Baird et al., 2006), very close to the US Centers for Disease Control and Prevention figure of 113 in 10,000 or 1 in 88 (Baio, 2012), but estimates of the prevalence of autism vary broadly across studies conducted in various parts of the world, ranging from 60 to 260 in 10,000, or between 1 in 166 to 1 in 38 (Fombonne, 2009; Gillberg, 1984; Kawamura, Takahashi, & Ishii, 2008; Kim et al., 2011). In a meta-analysis of 37 prevalence studies, Williams et al. (2006) found that prevalence estimates were significantly affected by the diagnostic criteria used, the age of the children screened, and geographic location. There is consensus among experts, both researchers and practitioners, however, that the prevalence of ASDs has increased greatly over the past few decades (Kawamura et al., 2008; Kim et al., 2011; Walsh, Elsabbagh, Bolton, & Singh, 2011), apparently as a result of greater public awareness, the broadening of diagnostic criteria for ASDs, lower age at diagnosis, and diagnostic substitution (Fombonne, 2008). For example, a US-based study reported a threefold increase in the number of ASD diagnoses given between 1997 and 2008 (Boyle et al., 2011).

Nonetheless, the actual number of people with autism may be higher still: in a Korean epidemiological study (Kim et al., 2011), two thirds of the children identified as having an ASD were undiagnosed. Similarly, Baron-Cohen et al. (2009) estimated the ratio of known to unknown cases at 3 to 2 (i.e. 60 per cent undiagnosed) amongst British children of primary school age. This means that as many as 700,000 people may be affected by ASD in the UK.

1.2. Aetiology

Although autism was first described over 70 years ago (Kanner, 1943), its aetiology is still unclear. Attempts to link susceptibility to autism to environmental factors, such as detached and unemotional ("refrigerator") parenting (Bettelheim, 1967; Eisenberg & Kanner, 1956) or, more recently, to exposure to the MMR vaccine (Wakefield et al., 1998) or thimerosal (Centers for Disease Control and Prevention, 1999) have been unsuccessful. A meta-analysis that examined over fifty prenatal risk factors concluded that no single factor was implicated in the aetiology of autism, although there was some evidence that complications in pregnancy (resulting, for example, from advanced parental age or prenatal medication use by the mother) were associated with increased risk of the disorder (Gardener, Spiegelman, & Buka, 2009).

The search for biological markers (e.g. abnormalities in brain morphology and function) has proven similarly elusive for a number of reasons. Firstly, autism has a multidimensional and complex phenotype with substantial overlap with other disorders (Walsh et al., 2011), which makes it difficult to map biological markers onto clinically defined categories. Also, because autism is a developmental disorder, its clinical, cognitive, and behavioural manifestations change as the individual ages, suggesting an interplay between various risk factors, and making the identification of the (typically unchanging) implicated biological markers a difficult task (Elsabbagh & Johnson, 2010).

The early onset of the symptoms, the fact that autism tends to run in families (Rutter, 2000), and the results of twin studies (Bailey et al., 1995; Hallmayer et al., 2011) suggest that autism has a moderate to strong genetic component. The identification of an "autism gene", however, seems an ever more unattainable goal, because although a large number of promising susceptibility loci that have been identified, each only accounts for a small amount (between 1 and 2 per cent) of variance (Weiss et al., 2008), leading researchers to believe that the behavioural and cognitive heterogeneity of autism is mirrored at the genetic level (Unwin, Maybery, Wray, & Whitehouse, 2013).

As a result of these difficulties, autism is still defined and diagnosed solely on the basis of behavioural criteria.

1.3. Issues of diagnosis

1.3.1. Gender bias in diagnosing autism

Autism is a male-dominated diagnosis, and has been since its conception: eight of the eleven children described by Kanner (1943), and all four children described by Asperger (1944) were boys. It has even been conceptualised as a manifestation of an "extreme male brain" (Baron-Cohen, 2002). The extent of this gender bias varies across prevalence studies, with estimates ranging between 1.33:1 to 15.7:1 (Fombonne, 2009), and is affected by whether a comorbid diagnosis of intellectual disability is given. In the "low-functioning" cases, the genders are more equally represented, but there is a very strong male bias in "high-functioning" autism. In his review of prevalence studies, Fombonne (1999) reported median sex ratios of 1.7:1 when moderate to severe intellectual disability was present, and 6:1 when it was not. The fact that comorbid intellectual disability increases the likelihood of an autism diagnosis in females may suggest that girls' generally faster social development leads to the diagnostic substitution of autism with another disorder (or no diagnosis) in "high-functioning" cases (Werling & Geschwind, 2013).

1.3.2. The "spectrum" of autism

As noted above, the diagnostic criteria for autism have been revised in the latest edition of the DSM, and AS and PDD-NOS have now been merged into ASD. Formerly, a diagnosis of AS was given when impairments in social interaction and communication, and restricted and repetitive behaviours and interests were not accompanied by a clinically significant delay in cognitive development (including language use). PDD-NOS was used for cases of "atypical autism", i.e. when late age of onset, atypical or subthreshold symptomatology, or a combination of these factors meant that the presentation did not fully meet the criteria for an autism diagnosis.

This revision of the diagnostic categories reflects that the former clinical subgroups have not been successfully mapped to specific aetiologies, or to distinct cognitive and behavioural profiles (Walsh et al., 2011), and represents the latest change in the ever developing perception of autism, both public and professional. Originally conceptualised as a categorical disorder that manifests itself in a well-defined set of impairments and affects only a small number of people, autism later became an umbrella term for a diverse group of conditions that affect individuals differently, and to different extents, with the emergence of the concept of an autistic "spectrum" in the 1980s (Wing, 1996). While a substantial proportion of people affected by autism have a comorbid intellectual disability and no language, those on the "high-functioning" end of the spectrum can sometimes lead independent lives despite sharing the core diagnostic features of impaired social interaction and restricted interests (Farley et al., 2009) although this is, sadly, not the typical outcome (see e.g. Howlin et al., 2014; Seltzer et al., 2004).

Extending the idea of a spectrum even further, there is increasing consensus today that a diagnosis of ASD represents a quantitative, rather than qualitative, difference, i.e. that there is a smooth continuum between autism and the general population (Baron-Cohen, 2002). Mirroring this process, the public perception of a person with autism is shifting away from Raymond Babbitt (the Rain Man character) and towards Sheldon Cooper (a socially awkward but highly intelligent physicist in US sitcom The Big Bang Theory). ASD is portrayed in the media as the "geek syndrome" (Silberman, 2001), i.e. an extreme manifestation of the restricted interests and difficulties in social interaction that characterise certain subgroups of the non-clinical population.

An important implication of this shift in the definition of autism is the growing appreciation of phenotypic heterogeneity, which poses substantial challenges to formulating a comprehensive theory of autism. This has prompted a number of researchers to abandon the search for a single genetic, neurological, or psychological explanation for the diverse symptoms that characterise autism (e.g. Happé, Ronald, & Plomin, 2006). They opt instead to focus on multiple-deficit accounts, hoping that these would be better able to capture the diversity of the phenotype and the overlap between autism and other disorders, as well as with the general population.

2. Theoretical framework

2.1. Psychological accounts of autism – a changing landscape

The theoretical framework of autism is in a state of transition. The psychological accounts that shaped our understanding of the disorder for several decades have proven unable to provide a comprehensive explanation for its diverse behavioural manifestations, and in the wake of a landmark article by Happé, Ronald and Plomin (2006), an increasing number of researchers now argue that further progress requires a paradigm shift: namely a recasting of autism as a 'fractionable' set of impairments, each with its own distinct aetiology (see also Brunsdon & Happé, 2014; Happé & Ronald, 2008).

There is, of course, considerable disagreement among researchers over not just the details of this 'fractionable triad' account, but also about whether its fundamental assumption, i.e. that no single-deficit model can prove satisfactory, is correct (e.g. Hobson, 2014; Rutter, 2014). Chevallier et al. (2012), for example, have recently put forward their social motivation theory, which posits that the origin of autistic symptoms lies not in a combination of cognitive impairments, but rather in an extremely reduced drive for social acceptance. Hobson (1993, 2007), on the other hand, argues that the multiple and diverse deficits that characterise autism are linked by a 'final common pathway' (Hobson, 2014, p. 10) that can be comprehensively described in terms of his intersubjectivity theory.

The restructuring of diagnostic categories in the latest edition of the DSM also reflects a change in how ASD is construed: Asperger syndrome and PDD-NOS are no longer included, in what can be interpreted as an acknowledgement that this way of dividing up autism 'had not worked' (Rutter, 2014, p. 55). On the other hand, the introduction of a new diagnostic category, social (pragmatic) communication disorder, seems to suggest that the social and non-social impairments are increasingly perceived as separable.

2.1.1. Single-deficit accounts of autism

Because of the lack of a biomarker for autism, it is defined as a constellation of impairments, namely difficulties in social interaction (including social communication and language use), and repetitive behaviours and narrow interests. Although the association between these symptoms is not immediately obvious, and it has long been known that their relative severity varies across individuals (Wing & Wing, 1971), early epidemiological data showed that their co-occurrence is well above chance levels, giving the impression of a monolithic disorder. In a study of 35,000 children from London, Wing and Gould (1979) found that all those who experienced substantial social difficulties also displayed repetitive stereotyped behaviour, and nearly all of them had abnormal language development and impairments in symbolic play. As a result, autism has been perceived as a coherent (albeit heterogeneous) syndrome, and it was assumed that all of its behavioural manifestations stem from the same genetic, neural, and cognitive atypicalities (Brunsdon & Happé, 2014).

Substantial research efforts have been expended in attempting to identify the single underlying cognitive or social deficit responsible for the whole of autistic symptomatology, which has been variously posited to lie in fundamental problems in language development (Rutter, 1968), sensory and perceptual abnormalities (Ornitz & Ritvo, 1968), abnormal affective responses to social interactions (Mundy & Sigman, 1989), or an imbalance between systemising and empathising (Baron-Cohen, 2009), among others. The three most influential single-deficit theories have been the theory of mind account (e.g. Baron-Cohen, Leslie, & Frith, 1985), which posits that individuals with autism are 'mind-blind', i.e. have deficits in understanding and attributing mental states to themselves and to others (for a review, see Tager-Flusberg, 2007); the weak central coherence account (e.g. Frith & Happé, 1994), which claims that the behavioural symptoms of autism are manifestations of a difficulty in integrating contextual information, accompanied by an overemphasis on details (for a review, see Happé & Booth, 2008); and the executive dysfunction account (e.g. Hughes & Russell, 1993), which proposes that domain-general deficits in planning, inhibition, and cognitive flexibility underlie the autism phenotype (for a review, see Hill, 2004). Two of these single-deficit theories, namely the theory of mind and the executive dysfunction accounts, are particularly germane to the questions of theory addressed in this thesis, and are therefore discussed in more detail here.

The theory of mind explanation of autism was the first major cognitive account, which posits that all autistic symptomatology stems from an inability to infer one's own and others' mental states, which leads to difficulties in interpreting others' behaviour, a prerequisite of being an effective social agent. In a landmark study, Baron-Cohen et al. (1985) found that 80 per cent of their participants with autism were unable to complete a false-belief task, even though their mental age was over the 4-year-old level, which is when success on this task is achieved in typical development. Since then, countless studies have demonstrated that individuals with autism have difficulties in attributing knowledge to others (e.g. Leslie & Frith, 1988), understand deception (e.g. Baron-Cohen, 1992), intention (e.g. Philips et al., 1998), and complex emotions (Baron-Cohen et al., 1993), all of which are essential for relating to and communicating with others effectively. Although there is overwhelming evidence that theory of mind is impaired in autism, the claim that this is the single reason underlying all behavioural manifestations of the disorder has been challenged robustly by more recent evidence.

Even in Baron-Cohen et al.'s original 1985 study, one in five children passed the false-belief task, demonstrating that impaired mentalising is not universal in autism. In subsequent studies, the success rate varied from 15 per cent (Reed & Peterson, 1990) to 55 per cent (Prior et al., 1990). In her review, Happé (1995) found that children with autism can indeed pass tests of false-belief, provided they have reached a mental age of 12 years, which is considerably higher than in typical development, but certainly not uncommon. On the basis of these results, she argued (Happé et al., 1996) that success on false-belief tasks in autism does not indicate an intact theory of mind mechanism, but rather is the result of recruiting alternative cognitive resources. This claim is supported by brain imaging studies (e.g. Castelli et al., 2002), which found that high-functioning adults with autism, who succeeded on theory of mind tasks, showed less activation in the brain areas typically associated with completing these tasks.

Another challenge to the theory of mind account comes from the fact that impairments in this ability are not unique to autism: similar difficulties have been found in children with moderate learning disability (Yirmiya et al., 1996), oral deafness (Peterson & Siegal, 1999), congenital blindness (Green et al., 2004), and specific language impairment (Miller, 2001), calling into question whether a specific impairment in theory of mind is sufficient to explain all behavioural manifestations of autism.

Finally, evidence for a direct relationship between the severity of autistic symptoms and theory of mind difficulties is mixed. A number of studies (e.g. Pellicano et al., 2006, Travis et al., 2001) found no significant association, although a longitudinal study (Tager-Flusberg, 2003) reported that early theory of mind (at age 4) emerged as a significant predictor of social functioning and severity of socio-communicative symptoms a year later. Despite its intuitive appeal and concordance with anecdotal reports in terms of social difficulties, the theory of mind account ultimately failed to explain the non-social aspects of autistic behaviour, such as repetitive behaviours and restricted interests.

The executive dysfunction account is, in some ways, a counterpart to the theory of mind account, in that it grew out of the observation that non-social aspects of autistic symptomatology, such as the tendency for inflexible, repetitive behaviours, is shared by patients with damage to the frontal lobe, which is responsible for higher-order cognitive functions that support flexible, goal-oriented behaviour (Damasio & Maurer, 1978). Individuals with autism perform poorly on tests of cognitive flexibility and planning (e.g. Prior & Hoffmann, 1990), and Ozonoff et al. (1991) showed that executive function, rather than theory of mind performance, could best distinguish between individuals with and without autism.

Impairments in executive function seem to be common in autism: 13 of the 14 studies included in Pennington and Ozonoff's 1996 review identified some form of executive dysfuction in this population. The prevalence reported in individual studies, however, varies widely, between near-universal at 96 per cent (Ozonoff et al., 1991) to barely more than half at 57 per cent (Liss et al., 2001), depending on the aspect of executive function measured, the experimental task of choice, and the cut-off point for 'impairment' (Pellicano, 2011).

Another major challenge to this theory comes from the 'discriminant validity problem', i.e. the fact that impairments in executive function are, of course, far from being unique to autism. They are well documented in ADHD, Tourette's syndrome, and conduct disorder, among others. More recent studies have focussed on identifying an autism-specific profile of executive impairments, and there is strong evidence for deficits in cognitive flexibility and planning (Geurts et al., 2004; Ozonoff & Jensen, 1999), but the picture is more mixed as regards working memory (Bennetto et al., 1996; Griffith et al., 1999) and inhibitory control (Christ et al., 2007; Russell et al., 1996).

If executive dysfunction is indeed the cause of autistic symptoms, it should be demonstrable at a very early age. Griffith et al. (1999), however, found no evidence for impairments in inhibition, set-shifting, and working memory at age 4 and at one-year follow-up. This and similar findings (Dawson et al., 2002; Stahl & Pry, 2002) suggest that executive difficulties emerge later, and are actually a consequence of atypical development that originates from other social and/or cognitive impairments.

Finally, a theory of autism that posits executive function as the sole (or primary) cause of the symptomatology associated with the disorder must be able to account for social as well as non-social atypicalities of behaviour (Bennetto et al., 1996; Pennington et al., 1997). Evidence for such a link is limited. While some studies found an association between various aspects of executive functioning and social competence (e.g. McEvoy et al., 1993; Ozonoff et al., 2004), others did not (e.g. Bishop & Norbury, 2005; Liss et al., 2001). The complexity of both areas of functioning (i.e. executive and social) and the multitude of measures used to assess performance in them make cross-study comparisons difficult, and so which, if any aspects of executive function affect which aspects of social competence, is still unclear.

Although the vast number of studies inspired by these theories (whether aiming to confirm or refute their central claims) have been invaluable in mapping out the cognitive and behavioural profile of autism, empirical findings have conclusively shown that none can provide a comprehensive account of autism on its own (Pellicano, 2011). For example, the theory of mind hypothesis struggles to explain non-social impairments (i.e. restricted and repetitive interests and behaviours) and sensory abnormalities (Brunsdon & Happé, 2014). While weak central coherence can account for these particular deficits, performance on measures of central coherence seems to be unrelated to the overall severity of autistic symptoms (Pellicano, Maybery, Durkin, & Maley, 2006a). The main weakness of the executive dysfunction account, in turn, is that it is poorly specified: the specific pattern of executive impairments that are proposed to lead to the autism phenotype is unclear (Williams & Bowler, 2014), and the results of experiments attempting to link various executive functions to social competence are highly varied (Pellicano, 2011).

These facts, along with evidence for genetic heterogeneity in the components of the autistic triad (Ronald, Happé, Bolton, et al., 2006), as well for low correlations between the degree of social impairments, communication impairments, and restricted and repetitive interests and behaviours (Ronald, Happé, Price, Baron-Cohen, & Plomin, 2006) have prompted some researchers to “abandon the attempt to find a single cognitive explanation [for autism], in favor of good accounts for each distinct aspect of the triad" (Happé et al., 2006, p. 1219).

2.1.2. The fractionable autism triad

According to the interpretation championed by Happé and collaborators (Happé & Ronald, 2008; Happé et al., 2006), deficits in social interaction and in communication, and restricted and repetitive behaviours and interests, i.e. the traditionally conceived 'triad of impairments' (Wing & Gould, 1979), constitute orthogonal axes of a multivariate space (Pellicano, 2011) that can be used to describe the severity of difficulties in each area faced by individuals with autism (and, indeed, by the typically-developing population). They further claim that cognitive impairments map neatly onto behavioural symptoms, i.e. that poor theory of mind is associated with social difficulties; poor executive function, with non-social symptomatology; while weak central coherence explains the uneven cognitive profile and preponderance of savant skills that are characteristic of autism (Brunsdon & Happé, 2014).

The benefit of such a clearly specified theory is that it leads to easily testable hypotheses. The fractionable triad account makes three important predictions: that the triad of impairments will be separable at the behavioural level; similarly, that performance on various cognitive measures (i.e. theory of mind, executive function, and central coherence) will show separation; and that the degree of impairment in these three component cognitive mechanisms will be uniquely associated with a particular 'axis' of autistic symptomatology. Evidence for these three predictions is reviewed below.

Evidence from the Twins Early Development Study seems to support the proposition that the triad of impairments is behaviourally and genetically separable. Ronald et al. (2006) found that 10 per cent of children in the general population presented with an impairment (i.e. scored in the bottom 5 per cent) in one domain, without concurrent deficits in the other two domains. Also, there were only low to modest correlations between difficulties on the three axes (Ronald, Happé, Price, et al., 2006). Interestingly, similarly weak relationships were found between behavioural difficulties in a subset of this sample (189 children) who had a diagnosis of ASD, and were therefore, by definition, impaired on all three components of the triad (Dworzynski, Happé, Bolton, & Ronald, 2009). Coupled with the results of genetic studies showing relatively independent heritability for the individual autistic traits (e.g. Robinson et al., 2012), this lends credibility to the fractionable triad hypothesis.

Evidence for the second prediction, i.e. that performance on tests of theory of mind, executive function, and central coherence will be largely unrelated to each other, is substantially weaker. Some studies suggest that central coherence is dissociable from theory of mind (Happé, 1994, 1997), and others find that although a relationship exists between performance on these measures, it no longer reaches significance once the effect of age and cognitive ability are taken into account (Burnette et al., 2005; Pellicano et al., 2006a). Jarrold et al. (2000), on the other hand, found a significant positive association between theory of mind and central coherence, both in typical development, and in autism. The separation between central coherence and executive function seems to be clearer. In their study cited above, Pellicano et al. (2006a) found that the association between central coherence and executive function measures was fully mediated by age and cognitive ability, and Booth et al. (2007) found no relationship between relationship between performance on a planning task and weak central coherence in autism or in ADHD. Central coherence therefore appears to be dissociable from both theory of mind and executive functioning, but there is substantial evidence for a strong link between the latter two. Significant correlations between theory of mind (measured using false-belief tasks) and various (but not all) tests of executive function have been reported in numerous studies (Bigham, 2010; Colvert, Custance, & Swettenham, 2002; Joseph & Tager-Flusberg, 2004; Ozonoff, Pennington, & Rogers, 1991; Pellicano, 2013; J. Russell, Mauthner, Sharpe, & Tidswell, 1991a; Zelazo, Jacques, Burack, & Frye, 2002). Taken together, these results lend only partial support to the fractionable triad account (although see below for a discussion of potential methodological confounds).

Empirical support for the existence of unique relationships between primary cognitive deficits and certain aspects of the autism phenotype (i.e. the third prediction made by Happé and her collaborators) is mixed. Theory of mind has been linked to various aspects of social competence, such as keeping secrets and telling lies (Frith, Happé, & Frances, 1994) or acting fairly (Takagishi, Kameshima, Schug, Koizumi, & Yamagishi, 2010). The pattern is far from universal, however: some studies have found no association between the severity of social symptoms and theory of mind (Loth, Happé, & Gómez, 2010). Longitudinal investigations also show a mixed picture: in a large-scale study, theory of mind predicted better social functioning, as assessed by the Vineland Adaptive Behaviour Scales (Tager-Flusberg, 2003), while Bennett et al. (2013) reported that theory of mind in late childhood was associated with communication skills but, unexpectedly, not with social skills, in adolescence. Many studies found associations between executive dysfunction and the non-social symptoms, but not the social symptoms of autism (e.g. Mosconi et al., 2009; Pellicano, 2013; Yerys et al., 2009), but a substantial number reported that executive function was linked to better social functioning (Berger, Aerts, Spaendonck, Cools, & Teunisse, 2003; Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002; McEvoy, Rogers, & Pennington, 1993; Pellicano, 2013), contrary to the prediction of the fractionable triad account. Weak central coherence is put forward as an explanation for restricted interests, insistence on sameness, sensory abnormalities, and islets of ability (Happé & Vital, 2009), but empirical evidence for this is likewise equivocal. For example, Chen et al. (2009) found that a detail-focused processing style was associated with repetitive behaviours, but not with sensory abnormalities in children with autism. While some researchers were able to link central coherence and non-social symptom severity (Loth, Carlos Gómez, & Happé, 2008), others found no evidence for this relationship (Pellicano, 2013).

Overall, the fractionable triad hypothesis is appealing because it addresses the issue of extreme heterogeneity in behavioural manifestations that is a hallmark of autism, and attempts to merge the most influential theories of the disorder so that they become complementary, rather than competing accounts, thus benefiting from the wealth of experimental results accumulated over the past decades. Empirical evidence for the account, however, is as yet far from overwhelming. That behavioural symptoms are potentially separable, if not unconnected, seems clear, and has in fact been recognised for several decades (Wing & Wing, 1971), although perhaps not to the same degree as Happé and her collaborators are now claiming. The parsing of cognitive impairments and linking them to specific groups of autistic symptoms, however, have proven a lot more challenging, which should not be surprising if we consider the profound limitations inherent in measuring cognitive impairments, and the surprisingly little attention that the developmental changes in both cognitive abilities and autistic symptoms have enjoyed from researchers until recently. These issues are briefly summarised below.

2.1.3. Unresolved issues

It should be clear from the above that the fractionable triad account of autism is far from universally accepted. Hobson (2014), for example, argues that the undeniably diverse behavioural manifestations of autism all share a common origin, namely an impairment in intersubjective engagement (Hobson, 1993, 2007). Chevallier et al. (2012), on the other hand, focus their explanation on the role of reduced social motivation in the evolutionary, neurological, and behavioural levels. As this thesis adopts a cognitive theoretical approach, the critical evaluation of these alternative accounts of autism is beyond the scope of this chapter, but two important questions that arose from the critique of cognitive models of autism are discussed above: our surprisingly poor understanding of the relationship between cognitive test performance and real-life behaviour (Rutter, 2014); and the potential convergence or divergence of autistic traits during development.

First of all, some of the ambiguity in the pattern of empirical findings is presumably due to the inherent insensitivity of the measures used to assess cognitive abilities or autistic symptoms. It is, of course, recognised that few, if any, cognitive tests are ‘process-pure’, therefore it can never be self-evident whether a statistically significant relationship between performance on two measures arises because of a meaningful link between the cognitive abilities of interest or shared task requirements. While controlling for the effect of obvious candidate confounds, such as verbal ability and mental age, can go some way towards clarifying the pattern of results, the possibility of as yet unrecognised shared mechanisms is very difficult to rule out.

To illustrate this point, consider the case of individuals with autism who can pass false-belief tests. Because these tests were considered sensitive and reliable measures of theory of mind, the fact that some individuals with autism completed them successfully seemed to suggest that theory of mind deficits are not, in fact, universal in autism. Some researchers, however, argued that in these cases, the task was solved through alternative, compensatory mechanisms (e.g. Happé, 1995), rather than through engaging the theory of mind mechanism. This claim was later confirmed through neuroimaging (Frith & Frith, 2003) and eye-tracking (Senju, Southgate, White, & Frith, 2009) studies, and thus a previously unrecognised confounding variable was identified.

A more extreme example in the same vein is the inferring implicit information (or Triple I) impairment hypothesis recently proposed by White (2013), which suggests that apparent executive impairments in autism are, in fact, due to an underlying difficulty with mentalising, which prevents participants from completing the tests to the best of their abilities because they cannot fully infer the experimenter's expectations (and, therefore, the requirements of the task). If correct, this hypothesis would essentially mean that all past studies that employed executive function measures without ensuring that impaired theory of mind did not interfere with successful task performance are fundamentally and fatally flawed.

It is worth asking the question whether cognitive mechanisms are even theoretically dissociable. For example, in order to successfully complete the Sally-Ann task, a well-established measure of false-belief understanding, the participant must first engage their executive function, and inhibit the prepotent response of pointing to the container in which they know the ball to be. An impairment in mentalising or in inhibition would be behaviourally indistinguishable. Conversely, it is difficult to imagine an experimental task that measures only, say, inhibitory control, and does not require relatively unimpaired working memory (to remember the instructions) or mentalising (to understand the experimenter's expectations), among a multitude of other capacities.

The other, equally important, and equally often overlooked issue is that of interactions between cognitive capacities as they mature throughout development. In a longitudinal study of cognitive impairments in autism, Pellicano (2010a, 2010b) showed that while performance on tests of central coherence, theory of mind, and executive function loaded onto separate factors in a sample of children with autism between the ages of 4 and 7, the latter two were no longer distinct three years later. In terms of primacy, she found that causal links were one-directional: executive function and central coherence were significant and independent predictors of development in theory of mind, but improvements in neither executive function nor central coherence were predicted by performance in the other two cognitive domains. This pattern of results highlights the possibility of developmental convergence (see also Karmiloff-Smith et al., 2012; Pellicano, 2013), i.e. traits that are initially relatively independent may become increasingly interlinked and inseparable over development.

2.2. The theoretical approach of this thesis

For the purposes of this thesis, the importance of the broader theoretical framework lies in the fact that it implicitly shapes not only the interpretation of empirical results but also the formulation of research questions and the design of experiments. The primary focus of the studies presented here, however, is not theoretical. Throughout this investigation of the effect of impaired inhibitory control on social functioning, theory of mind is measured and controlled for as a potential confound, but single-deficit cognitive accounts of autism are not directly contrasted with each other in the explanation of the results. Instead, inhibitory control is construed as a potential bottleneck, i.e. a necessary but not sufficient prerequisite of success in diverse social interactions. In order to avoid some common pitfalls described above, the interaction between theory of mind and executive function is considered, and issues of measurement are directly addressed, wherever possible.

3. The importance of cooperative play for social development

Both cooperation and play are fuzzy terms: easy to understand intuitively, but difficult to definitively delineate. For the purposes of the following, play is understood as an activity that is (i) pleasurable and enjoyable; (ii) pursued for its own sake, i.e. without an externally imposed objective; and which (iii) involves active engagement from the participant(s). This is in line with generally accepted definitions (for a review, see Sherratt & Peter, 2002). Cooperation, on the other hand, is defined according to Bratman’s (1992) criteria of (i) mutual responsiveness to each other’s intentions and actions; (ii) commitment to the joint activity; and (iii) mutual support of each other’s efforts as needed. Cooperative play is thus defined to mean playing together, and to be synonymous with social or joint play.

It is one of the few undisputed psychological findings that cooperative play is essential for social development in childhood. It provides an opportunity to acquire and practise vital social skills (Sherratt, 1999), experiment with various roles (Restall & Magill-Evans, 1994) and, through interacting with others, to establish shared meanings and obtain an understanding of prevalent cultural norms (Wolfberg, 2009). The skills and experiences obtained in cooperative play help children develop a capacity for building friendships (Parker & Gottman, 1989) and attain cognitive, social, and cultural competence (Arthur, Bochner, & Butterfield, 1999). There is evidence that the infant’s understanding of the world has its origins in personal interactions (e.g. Hobson, 2004), and Dunn (1991) suggested that children learn to engage with their environment through early playful interactions. Vygotsky (1978) saw play as “a major source of development ”, which contained “all developmental tendencies in a condensed form” (p. 102).

Children with autism, however, regardless of level of functioning, have well-documented and profound deficits in cooperative play (Jordan, 2003) as well as in other forms of play, such as pretend and shared pretend play, which are linked to social engagement (Hobson et al., 2013), and therefore potentially miss out on a range of developmental benefits. They may also suffer significant social disadvantages because, as Boucher (1999) points out, cooperative play is the currency of childhood, and failure to engage in mutually satisfying cooperative play is the main cause of social isolation in childhood.

Symbolic (pretend) play has downstream developmental benefits (Kasari, Chang, & Patterson, 2013), but it develops late, and often not at all, in children with autism (Jarrold, Boucher, and Smith 1996). When prompted, children with autism are capable of engaging in the same level of pretend play as their typically-developing peers (e.g. Charman and Baron-Cohen 1997), but their behaviour is not as ‘playful’, i.e. spontaneous and creative. Hobson et al. (2012) rated the symbolic play behaviours of children with autism qualitatively, and found that while the ‘mechanics’ of play were present, the children appeared less emotionally invested in the activity. As a result, teaching pretend play through verbal or physical prompts and adult modelling has been only moderately effective (e.g. Barton & Wolery, 2008).

Unlike symbolic play, which can be a solitary activity, shared (cooperative) play requires mutual engagement and the ability to share goals, attention, and intentions (Kimhi & Bauminger-Zviely, 2012). As such, it is also profoundly impaired in autism (Hill 2004; Pellicano, 2007). Although the aetiology of this impairment has not yet been fully established, there is evidence for links with abnormalities in joint attention (Kasari, Sigman, Mundy, & Yirmiya, 1990), imitation (Brown & Whiten, 2000), executive function (Atlas, 1990), and sensory processing (Miller-Kuhaneck & Britner, 2013). In this thesis, cooperation is defined as synonymous with ‘shared play’, following Bratman’s (1992) definition of a shared cooperative activity as a behaviour characterised by mutual responsiveness in the pursuit of a common goal with mutual support as required throughout. In the case of play, mutual responsiveness manifests as readiness to incorporate the play partner's contributions into the activity; the common goal is primarily mutual enjoyment of the interaction, but may also involve the attainment of external objectives, e.g. completing a puzzle or other challenge. Mutual support is provided by the play partners when needed, and this aspect of shared (cooperative) play is closely linked to mutual responsiveness. Clearly, cooperative play encompasses a set of different behaviours, such as reciprocity and accepting the play partner's input, which are multifaceted and complex in themselves, and rest on diverse socio-cognitive capacities.

The implications of this fact are twofold. On the one hand, it is unlikely that a single social or cognitive ability responsible for the whole range of deficits in cooperative play in autism will ever be identified. Nor can the teaching of discrete "play skills" be wholly successful, as cooperative play is essentially context-dependent (Strain & Schwartz, 2001). On the other hand, however, because of the complex set of interdependencies in the skills and abilities that are prerequisites of successful cooperative play, it is possible that enhancing even a single social or cognitive ability, either through specific training or 'online' support during the interaction, would measurably improve the children's capacity for cooperative play.

The severity of particular socio-cognitive impairments varies considerably across children with HFA, and so there are, presumably, individual differences in the mechanisms that lead to the breakdown of cooperative play. It is possible, for example, that while one child with HFA struggles to sustain cooperative play interactions because of atypical sensory processes, another finds them difficult because of deficits in joint attention. Importantly, the behavioural manifestations of these impairments may be indistinguishable to an observer of the interaction. These considerations highlight the importance of approaching HFA children's difficulties in cooperative play from a multiple-deficit perspective.

4. Thesis overview

4.1. Background and motivation

Cooperative play with a peer has numerous and long-lasting benefits for children's socio-cognitive development (Jordan, 2003), including the opportunity to acquire and practise social skills, and forge early friendships. Children with autism may miss out on these benefits because of their well-documented impairments in social communication and interaction (American Psychiatric Association, 2013). Previous research has linked deficits in the cooperative play of children with autism to poor imitation and joint attention (Colombi et al., 2009), and social and communication impairments in general have long been explained in terms of difficulties in mentalising (Frith, 2001).

This research project was motivated by the puzzling anecdotal evidence from caregiver and teacher reports that ‘high-functioning’ children with autism (HFA, i.e. those without a concurrent learning disability) often seem to have a good grasp of the ‘rules’ of social interaction, but nevertheless struggle to put their relatively intact social knowledge to use during real-life interactions, including cooperative play. Clearly, mentalising is necessary, but not sufficient for effective cooperative play, and the role of other cognitive mechanisms should also be investigated.

4.2. Aims and hypotheses

The primary goal of this thesis was to evaluate a novel account of impaired cooperative play (see Figure 1), in which behavioural rigidity, arising from deficits in executive functions, prevents children with HFA from fully utilising their relatively intact social knowledge.

‘Executive functions’ is as umbrella term for a group of cognitive processes linked to the prefrontal cortex (Kane & Engle, 2002) that are essential for the planning and execution of complex behaviour. Although executive deficits are well-documented in autism (Hill, 2004), they have been investigated primarily in connection with non-social impairments, such as restricted interests and repetitive behaviours. This thesis explores the contribution of inhibitory control, a domain of executive functioning, to competence in an important aspect of social behaviour, namely cooperative play.

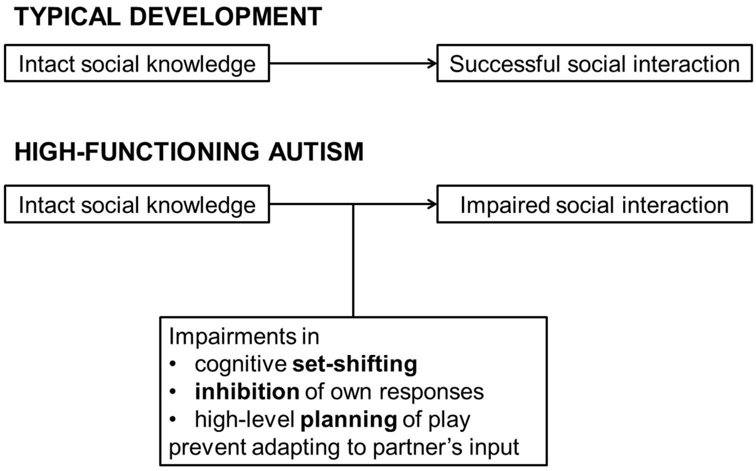

Figure 1. Hypothesised model of executive function as a moderator between social knowledge and behaviour

4.3. Outline of studies

This thesis consists of four research articles: a meta-analysis, two experimental studies, and a qualitative investigation. Article 1 describes a systematic review and meta-analysis of 42 studies that compared inhibitory control between children with HFA and a TD control group. The results provide strong evidence for an inhibitory impairment across all commonly used experimental measures.

The link between inhibitory control and three prerequisites of mutually satisfying cooperative play: reciprocity, accepting the play partner's input, and fairness, was investigated in two experimental studies (Articles 2 and 3). These studies involved children with HFA between the ages of 5 and 11 and age-matched TD comparison groups.

In the first experimental study, the participants were tested on theory of mind, joint attention, inhibition, and a measure of cooperative play: the Interactive Drawing Test. While children with HFA performed at age-typical levels on theory of mind and joint attention, they showed impaired inhibition, and were less likely than TD children to engage in reciprocal drawing and to accept the play partner's input. The severity of the deficit in cooperative play was significantly linked to inhibitory control.

In the second experimental study, theory of mind, moral reasoning, inhibition, and sharing behaviour in the Dictator Game were assessed. There was no significant group difference on theory of mind, moral reasoning, and sharing, but children with HFA showed a deficit in inhibitory control. Multiple regression was carried out to identify the predictors of less self-centred ('fairer') decisions in the Dictator Game. Inhibitory control was the only variable significantly associated with fairness.

The last study constitutes a qualitative investigation of TD children's experience of cooperative play with their HFA sibling. Six TD children between the ages of 5 and 11 were interviewed, and their reports analysed using interpretative phenomenological analysis (IPA). Five superordinate themes emerged from the participants' accounts about factors that affect the quality of playing with the HFA sibling: poor emotion regulation, a narrow range of interests, reluctance to accept the play partner's input, admiration for the creativity of the child with HFA, and adjustment to the HFA sibling's atypical behaviour.

The four papers are not presented in chronological order; the thesis is structured thematically, and the articles build on the findings of the previous paper. First, the aim of the systematic review and meta-analysis was to ascertain whether inhibitory control is impaired in high-functioning children with autism. This is a fundamental assumption of the model of social difficulties that is explored in the thesis. If no such impairment exists, it obviously cannot moderate the relationship between social knowledge and social behaviour. As a significant impairment was identified in this paper, the second and third articles investigate whether this impairment makes a unique contribution to social impairments. These two studies also contribute to the broader research literature through investigating cooperative play and the understanding and practice of fairness in sharing situations, respectively, which have received relatively little attention in children with autism. The results of these two studies provided strong evidence for inhibitory control being an enabler of effective cooperative play and fairness in experimental tasks. Although every effort had been made to ensure that the tasks used are ecologically valid and, therefore, the findings can be generalised to real-life cooperative interactions with peers, the limitations of the measures was recognised, and the fourth study therefore adopted a qualitative approach in order to explore the actual lived experiences of the most frequent playmates of children with autism: their typically developing siblings. This paper constitutes the first qualitative exploration of typically developing children's experience of playing with their autistic sibling, but it also contributes to the overarching theme of the thesis directly: two of the themes that emerged in the participant reports in connection with factors that limit the hedonistic value of joint play were related to executive functions. This corroborates the findings of the two experimental studies, and lends further support to the model being evaluated.Overall, these four studies lend credence to our hypothesis that inhibitory control is a prerequisite of cooperative play and, more broadly, that deficits in executive functions can lead to a breakdown in social interaction, even when the ability to mentalise is unimpaired.

The implications of this work are discussed, along with two important questions for future research: regarding the link between inhibition and emotion regulation, and the extent to which inhibition and theory of mind are separable, both theoretically and experimentally.

Article 1: Inhibitory control in high-functioning children with autism: A meta-analysis and problems of measurement

Abstract

Inhibitory control is an aspect of executive function that has been linked to impulsivity and social functioning. While anecdotal evidence suggests that children with autism are impaired in this domain, experimental results are equivocal. Tentative explanations for the contradictory findings have focused on purported differences between the experimental measures commonly used to assess inhibition, suggesting that children with autism may be impaired in some aspects of inhibition (e.g. prepotent responses) but not in others (e.g. interference). In a meta-analysis of 42 studies, with a total of 57 effect sizes and 2,256 participants, we found clear evidence for impaired inhibition in high-functioning children with autism (HFA), and no evidence for differential performance across measures. These results are discussed in terms of their implications for improving the methodology of measuring inhibition experimentally.

Introduction

Inhibitory control (IC) is considered part of a set of cognitive mechanisms, along with working memory, set shifting, and planning (Stuss & Knight, 2013), collectively referred to as executive function, whose purpose is to support planned action by filtering out irrelevant information, suppressing task-inappropriate actions, and adapting to changing task requirements in order to ensure success. Well-developed inhibitory control has been linked to a broad range of areas including emotion regulation (Carlson & Wang, 2007; Goldin, McRae, Ramel, & Gross, 2008), academic success (Liew, McTigue, Barrois, & Hughes, 2008; Valiente, Lemery-Chalfant, Swanson, & Reiser, 2008), moral cognition (Kochanska, Murray, & Coy, 1997), and the ability to engage in cooperative play (Borbely & Yuill, 2014), among others.

Deficits in executive function, and in inhibitory control in particular, are common in several developmental disorders, e.g. attention-deficit / hyperactivity disorder (Schachar, Mota, Logan, Tannock, & Klim, 2000) and Tourette's syndrome (Channon, Pratt, & Robertson, 2003), but evidence for impairments in this domain in autism is equivocal, despite the fact that the executive function account has become one of the most influential single-deficit models of autism, purporting to account for non-social impairments, such as repetitive actions and narrow interests, in its weak form (Lopez, Lincoln, Ozonoff, & Lai, 2005; Turner, 1997), and also for deficits in social interaction in its strong form (Griffith, Pennington, Wehner, & Rogers, 1999; Hill & Bird, 2006; McEvoy et al., 1993). As early as in 1972, Frith showed behavioural inflexibility in individuals with autism. Later, Damasio and Maurer (1978) demonstrated behavioural similarities in tests of executive function between individuals with autism and those with acquired damage to the prefrontal cortex, which is the primary brain area associated with executive function (Stuss & Knight, 2013). Since then, a large number of studies have been conducted on executive function in autism (for reviews, see Hill, 2004; Kenworthy, Yerys, Anthony, & Wallace, 2008; O'Hearn, Asato, Ordaz, & Luna, 2010; Pellicano, 2011; Pennington & Ozonoff, 1996; Russo et al., 2007), yet the picture that has emerged over the decades is still unclear. Despite a wealth of promising results, the executive function model of autism has been challenged on multiple accounts: its specificity, universality, and predictive power have all been questioned (Pellicano, 2011). Narrative reviews of the executive function account of autism have generally concluded that some domains were indeed impaired in this disorder, e.g. set-shifting (Ozonoff et al., 1991; Shu, Tien, & Chen, 2001; Szatmari, Tuff, Finlayson, & Bartolucci, 1990) and planning (Ozonoff & Jensen, 1999; Pellicano, 2007), but that evidence in other domains, e.g. inhibitory control, was mixed: individuals with autism were outperformed by a typically-developing control group in some studies (Hughes & Russell, 1993; Russell et al., 1991a) but not in others (Ozonoff & Jensen, 1999; Ozonoff & Strayer, 1997; Russell, Jarrold, & Hood, 1999).

In situations like this, pooling the available quantitative information through a systematic review has a number of important benefits (Cartwright-Hatton, Roberts, Chitsabesan, Fothergill, & Harrington, 2004). The increase in statistical power allows for more precise estimation of effect sizes, which is of particular importance in a field like autism research, where studies typically involve relatively small numbers of participants and are, therefore, underpowered. A better understanding of the pattern of findings, in turn, helps clarify the extent and nature of impairments, and is essential for evaluating current theories and mapping out directions of future research (Mulrow, 1994). Also, systematic reviews have great utility in assessing commonly used experimental paradigms and identifying methodological pitfalls, which is essential in a field like the study of inhibitory control, which is characterised by a huge diversity of measures and tasks (Garon, Bryson, & Smith, 2008).

Issues of measurement

Any successful investigation of the extent to which inhibitory control is impaired in autism has to first overcome a number of methodological obstacles. Firstly, tests of executive function are not 'process-pure', meaning that they involve more than a single cognitive mechanism: for example, it is notoriously difficult to design an experimental task that requires set-shifting, but not working memory.

Secondly, although some standardised tests of executive functions do exist, there is also a plethora of commonly used tasks (for a summary, see Garon et al., 2008) the procedural details of which (e.g. stimulus type, modality, inter-stimulus interval, number of trials, etc.) are routinely modified by researchers, sometimes perhaps without due consideration of the potential implications of these changes. This makes the comparison of results across studies difficult. As Garon, Bryson and Smith (2008, p. 40) poignantly state: "Ironically, one of the challenges in understanding the development of response inhibition is the multitude of response inhibition tasks." This heterogeneity of experimental tasks means that variations of task characteristics are always readily available explanations for any inconsistencies in results.

Indeed, fundamental differences between the measures of inhibitory control have been hypothesised to explain the equivocality of findings. There is no agreement amongst researchers, however, on which underlying characteristics set apart tests of inhibitory control on which individuals with autism show deficits from those on which they do not.

Bíró and Russell (2001), for example, suggested that it is the arbitrary nature of the rules of a task that leads to impaired performance, and they went further to postulate that the same pattern applies to measures used in other subdomains of executive function, as well, such as the Tower of Hanoi (a measure of planning) and the Wisconsin Card Sort Task (a measure of set-shifting). Hill (2004), on the other hand, hypothesised that the tasks on which children with ASD show impaired performance are distinguished by the requirement of suppressing a prepotent response. In the Windows task (Russell et al., 1991a) for example, two open boxes are presented, one of which contains a desirable object (a sweet). In order to obtain the sweet, the child must suppress the salient response of reaching for it and must instead point at the empty box. Children with autism consistently showed impaired performance on this task (e.g. Russell, Hala, & Hill, 2003). Russo et al. (2007) interpreted this pattern of findings in terms of a distinction between direct and indirect measures of inhibition. They posited that impaired performance on the Windows and other tasks is due to the fact that these are indirect measures, i.e. in addition to inhibitory control, they also require mental flexibility and disengagement, that is, they impose a larger cognitive load than pure measures of inhibition, and require the simultaneous use of diverse skills from the participants. O'Hearn et al. (2010) in turn, drew a contrast between tasks where an automatic response needs to be suppressed, such as the anti-saccade task, which consistently shows impairments in autism (e.g. Luna, Doll, Hegedus, Minshew, & Sweeney, 2007), and paradigms like the Stroop task, where interference from irrelevant stimuli needs to be suppressed. They point to the possibility of developing alternative strategies for solving this latter group of tasks. In the Stroop task, for instance, where participants are required to name the colours that words are written in rather than the (incongruous) colour that they represent, it is possible to blur one's vision to minimise the interference of the verbal information, which, O'Hearn and colleagues suggest, might account for the unimpaired performance displayed by autistic but cognitively able participants. Although the use of such strategies could indeed distort test results, it is questionable whether children with autism would be motivated and able to do so. There is no empirical evidence that this population of experimental participants systematically employ such strategies to improve their performance on measures on inhibitory control.

So far, none of these hypotheses have been tested directly in an empirical study, although a recent meta-analysis (Geurts, van den Bergh, & Ruzzano, 2014) which compared studies on prepotent response inhibition and interference suppression tasks in autism found no evidence for differential performance across the two domains. In order to evaluate each of the above theories, a systematic review would be of great use, not only because of the increased potential to survey the landscape of findings from a "tower of statistical power" (Gelber & Goldhirsch, 1991, p. 467) but also because it introduces controls for sampling error, which individual studies more easily fall victim to. This is an important consideration because frequent Type II errors are an inevitable consequence of the low power that characterises many psychological studies, and the resulting uneven pattern of findings can easily lead to “barren controversy” (Oakes, 1986): as the number of studies in the field grows, so does the apparent degree of disagreement between researchers.

This review: inhibitory control in high-functioning children with autism (HFA)

The focus of this meta-analysis is narrow: we only included studies on children (defined as under the age of 18) who were ‘high-functioning’ (defined as having an IQ of no lower than one standard deviation below the age-matched typically-developing population). Our reasons for restricting the population of interest in these two ways are briefly outlined below.

We chose to investigate only studies involving children for two reasons. On the one hand, the scarcity of research on adults with autism precludes the drawing of meaningful conclusions from a meta-analysis. On the other hand, inhibitory control develops dramatically from early childhood into adolescence, but there is little difference between the inhibitory performance of teenagers and adults – at least in typical development (Williams, Ponesse, Schachar, Logan, & Tannock, 1999). Additionally, measuring inhibitory control, fraught with difficulties as it is in childhood, as discussed above, is even more problematic in adulthood because as other cognitive mechanisms mature, they are more easily recruited to compensate for shortcomings in inhibitory control. Brain imaging studies show that the brain areas activated during the completion of inhibitory control tasks are different in adolescence and in adulthood (Casey, Tottenham, Liston, & Durston, 2005). For this reason, we hoped to be better able to isolate inhibitory control in a young population.

As for focusing on children with autism who can be described for convenience as ‘high-functioning’, our decision was informed by the fact that the interaction between learning disabilities and impaired inhibitory control in autism is poorly understood (Passolunghi & Siegel, 2001) and therefore including children with autism who also have a diagnosis of a learning disability would have introduced another layer of complexity into our investigation. For the purposes of this review, we defined ‘high-functioning’ as scoring within one standard deviation of the population mean on a standardised test of general cognitive ability (IQ).

This systematic review and meta-analysis is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Guidelines compiled by Moher et al. (2009).

Method

Literature search

Relevant articles were identified in several stages. First, we consulted the reference sections of seven previously published reviews of executive functioning in autism (Geurts et al., 2014; Hill, 2004; Kenworthy et al., 2008; O'Hearn et al., 2010; Pellicano, 2011; Pennington & Ozonoff, 1996; Russo et al., 2007) This yielded a pool of 72 potentially relevant research reports (excluding duplicates).

A search of Web of Knowledge was conducted with the following keywords: autism ("autism" or "ASC" or "ASD" or "autistic" or "PDD-NOS" or "asperger") and inhibition ("inhibition" or "inhibitory control"). For practical reasons, search results were restricted to articles published in English, and in the past 30 years (i.e. since 1983). The 182 search results were further winnowed down by excluding patents (57), reviews (6), letters to the editor (4), data sets (1), data studies (1), editorials (1), and corrections (1), leaving 111 titles in total. Ancestor searches performed on the ten most recent studies included in the analysis helped locate three studies not identified in earlier stages of the process.

Criteria for inclusion

The abstracts (and, where necessary, the Method sections) of each of the 186 potentially relevant studies that had been identified by this stage were then read and assessed for inclusion. To be selected, an article had to satisfy the following criteria: (a) the study was conducted on children (i.e. participants under the age of 18); (b) one of the groups consisted of children with a diagnosis of high-functioning autism (defined as having a full-scale IQ over 85); (c) a typically-developing comparison group was included; and (d) inhibitory control was measured in both groups of children. At this stage, 139 studies were excluded: 120 of these did not meet the inclusion criteria (inhibitory control not measured: 75; adult participants: 11; no TD comparison group: 19; children with autism not high functioning: 8; non-human animal subjects: 6; only abstract available in English: 1), and 19 were inaccessible (e.g. conference presentations). In five studies, the published information did not allow the calculation or estimation of effect sizes; these were excluded from further analyses, leaving a final pool of 42 (see Figure 1). Altogether, the studies involved 2,256 participants (1,054 children with HFA, and 1,202 TD children).

A randomly selected sample of 21 abstracts (10%) was also assessed for inclusion by a second coder; there was perfect agreement between the coders on whether each study should be included in the meta-analysis.

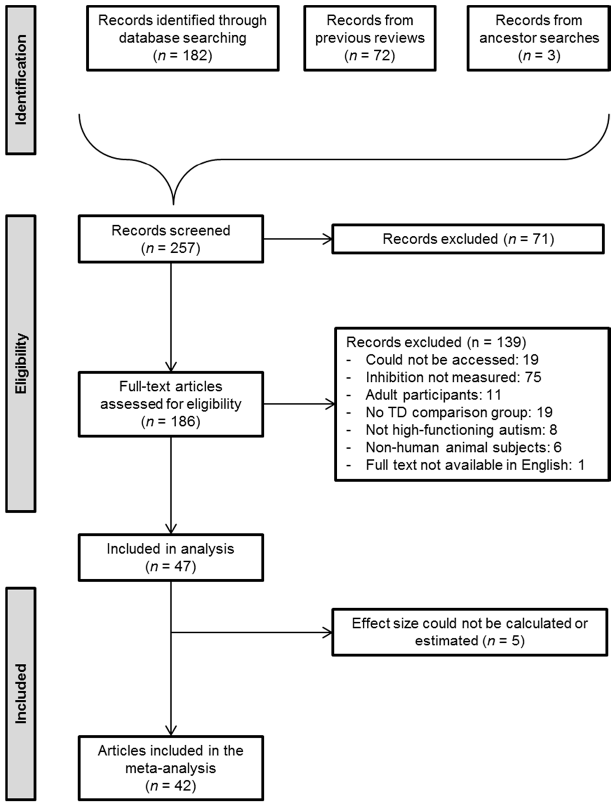

Figure 1. Details of the literature search and study selection process

Data extraction

The following details were recorded for each study included in the meta-analysis (see Table 1):

- year of publication;
- number of participants;
- proportion of genders (where reported);
- age (mean and standard deviation) of the participants;
- IQ of the participants (verbal, performance and/or full-scale, as reported);
- inhibition task(s) used (including modality of stimuli);
- dependent variable(s) reported.

Table 1. Summary of details for studies included in the meta-analysis

Authors and year of publication	Number of participants		Age M (SD)	FSIQ M (SD)	Task (stimulus)	Paradigm	Dependent variable	Effect size Hedges's g
Adamo et al., 2014	*HFA:*	46	10.00 (1.00)	109.00 (17.00)	go/no-go (numbers)	go/no-go	commission *errors*	0.33
	TD:	36	10.00 (1.00)	112.00 (14.00)				
Adams & Jarrold, 2009	*HFA:*	24	13.45 (1.71)		Stroop (colour/word)	Stroop	interference on RT	-0.39
	TD:	24	9.76 (0.18)					
Adams & Jarrold, 2012	*HFA:*	15	14.42 (1.73)		flanker (arrows)	flanker	RT on incongruent trials	-0.28
	TD:	15	9.83 (1.03)					
					Stop-signal (pictures/auditory)	stop-signal	commission errors	0.30
Bishop & Norbury, 2005	*HFA:*	14	8.30 (1.00)	107.20 (15.60)	TEA-Ch (numbers)	opposite worlds	time difference	0.98
	TD:	18	8.60 (1.00)	110.80 (10.40)				
					walk/don't walk (visual/sound)	stop-signal	accuracy	1.15
Brandimonte et al., 2011	*HFA:*	30	8.25 (2.44)		stop-signal (pictures/pictures)	stop-signal	accuracy	0.35
	TD:	30	8.33 (1.91)					
Chan et al., 2009	*HFA:*	16	10.54 (1.73)	96.75 (18.72)	Continuous Performance Test	go/no-go	commission errors	-0.06
	TD:	38	9.31 (2.20)	114.70 (16.60)				
Chan et al., 2011	*HFA:*	20	10.75 (2.07)		go/no-go (coloured balls)	go/no-go	commission errors	0.59
	TD:	20	9.80 (1.88)					
Christ et al., 2007	*HFA:*	15	8.20 (1.60)		flanker (simple shapes)	flanker	RT on incongruent trials	2.05
	TD:	48	10.77 (2.85)					
					go/no-go (simple shapes)	go/no-go	commission errors	0.95
					Stroop (colour/word)	Stroop	RT on incongruent trials	1.46

Authors and year of publication	Number of participants		Age M (SD)	FSIQ M (SD)	Task (stimulus)	Paradigm	Dependent variable	Effect size Hedges's g
Christ et al., 2011	*HFA:*	28	13.10 (2.80)		flanker (arrows)	flanker	accuracy on incongruent trials	0.65
	TD:	49	13.30 (2.70)					
					digit count	other	accuracy	0.16
Corbett & Constantine, 2006	*HFA:*	15	10.01 (2.04)	97.70 (17.47)	Continuous Performance Test	go/no-go	response control quotient	2.31
	TD:	15	9.56 (1.89)	117.40 (15.17)				
Corbett et al., 2009	*HFA:*	18	9.44 (1.96)	94.17 (17.79)	Continuous Performance Test	go/no-go	response control quotient	1.30
	TD:	18	9.56 (1.81)	112.22 (14.84)				
					D-KEFS (word/colour)	Stroop	standardised interference score	1.46
Geurts et al., 2009	*HFA:*	18	10.30 (1.60)	108.00 (19.00)	go/no-go (faces)	go/no-go	commission errors	0.42
	TD:	22	10.30 (1.40)	103.20 (24.10)				
Geurts et al., 2008	*HFA:*	22	10.10 (1.60)	102.70 (15.00)	flanker (pictures)	flanker	RT on incongruent trials	0.15
	TD:	33	9.40 (1.10)	103.30 (14.00)				
Geurts et al., 2004	*HFA:*	41	9.40 (1.80)	98.30 (18.40)	Change Task (picture/auditory)	stop-signal	stop-signal reaction time	0.73
	TD:	41	9.10 (1.70)	111.50 (18.00)				
					circle drawing	other	time difference	0.68
					TEA-Ch (numbers)	opposite worlds	time difference	0.37
Goldberg et al., 2005	*HFA:*	17	10.30 (1.80)	96.50 (15.90)	Stroop (colour/word)	Stroop	interference on RT	-0.11
	TD:	32	10.40 (1.50)	112.60 (12.10)				
Happé et al., 2006	*HFA:*	32	10.90 (2.40)	99.70 (18.70)	go/no-go (pictures)	go/no-go	commission errors	-0.19
	TD:	32	11.20 (2.00)	106.80 (13.40)				

Authors and year of publication		Number of participants	Age M (SD)	FSIQ M (SD)	Task (stimulus)	Paradigm	Dependent variable	Effect size Hedges's g
Jahromi et al., 2013	*HFA:*	20	4.90 (0.90)		day/night (pictures)	opposite worlds	accuracy	0.34
	TD:	20	4.20 (0.90)					
Johnson et al., 2007	*HFA:*	21	12.20 (2.40)	97.30 (12.30)	SART (numbers)	go/no-go	commission errors	1.25
	TD:	18	11.10 (1.90)	107.70 (11.60)				
Joseph et al., 2005	*HFA:*	37	7.01 (1.75)		day/night (pictures)	opposite worlds	accuracy	0.32
	TD:	31	8.25 (2.08)					
					knock/tap (gesture)	other	accuracy	0.57
Larson et al., 2012	*HFA:*	28	13.00 (2.00)	105.00 (16.00)	flanker (arrows)	flanker	RT on incongruent trials	0.07
	TD:	36	14.00 (2.00)	19.00 (11.00)				
Lee et al., 2009	*HFA:*	11	10.20 (1.60)	113.30 (17.30)	go/no-go (letters)	go/no-go	commission errors	0.26
	TD:	10	11.00 (1.80)	114.90 (10.30)				
Lemon et al., 2011	*HFA:*	23	11.04 (0.00)	94.86 (-)	stop-signal (colours)	stop-signal	stop-signal reaction time	0.60
	TD:	22	11.18 (0.00)	107.36 (-)				
Marotta et al., 2013	*HFA:*	14	10.60 (2.70)	107.63 (9.15)	Posner cueing task (face/cross)	other	reaction time	0.41
	TD:	14	10.40 (2.00)	-				
Ozonoff & Jensen, 1999	*HFA:*	40	12.60 (3.40)	95.20 (18.80)	Stroop (colour/word)	Stroop	accuracy	0.40
	TD:	29	12.10 (1.00)	107.80 (10.80)				
Ozonoff & Strayer, 1997	*HFA:*	13	13.90 (2.50)	101.00 (18.80)	negative priming (letters)	other	interference on accuracy	0.56
	TD:	13	13.10 (1.40)	100.10 (11.90)				
					stop-signal (words)	stop-signal	SSRT	0.49
Ozonoff et al., 1994	*HFA:*	14	12.43 (2.47)	101.90 (17.17)	go/no-go (simple shapes)	go/no-go	commission errors	0.04
	TD:	14	12.15 (1.73)	100.40 (13.39)				

Authors and year of publication	Number of participants		Age M (SD)	FSIQ M (SD)	Task (stimulus)	Paradigm	Dependent variable	Effect size Hedges's g
					global-local task (letters)	other	accuracy	0.47
Pellicano, 2007	*HFA:*	30	5.63 (0.97)		Luria hand game (gestures)	other	accuracy	0.26
	TD:	40	5.48 (0.96)					
Pellicano et al., 2006	*HFA:*	40	5.60 (0.91)		Luria hand game (gestures)	other	accuracy	0.67
	TD:	40	5.48 (0.96)					
Pooragha et al., 2013	*HFA:*	15	9.33 (1.79)		Stroop (colour/word)	Stroop	interference on accuracy	1.07
	TD:	15	10.13 (2.44)					
Rinehart et al., 2008	*HFA:*	24	12.00 (3.54)	96.80 (16.38)	Posner cueing task (cross)	other	commission errors	0.67
	TD:	24	11.80 (3.61)	100.15 (10.41)				
Robinson et al., 2009	*HFA:*	54	12.54 (2.80)	103.53 (10.54)	Junior Hayling Test (sentences)	other	accuracy	0.42
	TD:	54	12.08 (2.34)	104.80 (9.07)				
					Stroop (colour/word)	Stroop	interference on RT	0.29
Schuh, 2011	*HFA:*	13	13.00 (2.70)	106.00 (12.00)	homograph task (words)	other	accuracy	0.36
	TD:	22	13.10 (2.70)	105.00 (12.00)				
Semrud-Clikeman et al., 2010	*HFA:*	15	10.60 (2.60)	100.80 (13.00)	D-KEFS (word/colour)	Stroop	standardised interference score	0.47
	TD:	32	9.80 (2.10)	109.40 (10.00)				
Sinzig et al., 2008	*HFA:*	20	14.30 (3.00)	112.00 (17.70)	go/no-go	go/no-go	commission errors	-0.17
	TD:	20	13.10 (3.00)	113.00 (11.90)				
Solomon et al., 2009	*HFA:*	20	15.17 (1.67)	107.00 (14.00)	POP task (arrows)	other	accuracy	0.97
	TD:	23	15.92 (2.08)	113.00 (11.00)				
Solomon et al., 2008	*HFA:*	31	12.30 (2.50)	110.00 (20.00)	POP task (arrows)	other	accuracy	0.52
	TD:	32	12.20 (2.50)	115.00 (12.00)				

Authors and year of publication	Number of participants		Age M (SD)	FSIQ M (SD)	Task (stimulus)	Paradigm	Dependent variable	Effect size Hedges's g
Tsai et al., 2011	*HFA:*	15	7.85 (0.79)		Posner cueing task (cross and arrow)	other	interference on RT	0.85
	TD:	16	7.51 (0.85)					
Vaidya et al., 2011	*HFA:*	15	10.80 (1.30)	113.90 (15.40)	Posner cueing task (arrows)	other	accuracy	0.61
	TD:	18	11.00 (1.30)	119.20 (14.20)				
Verté et al., 2005	*HFA:*	61	9.10 (1.90)	99.20 (17.10)	TEA-Ch (numbers)	opposite worlds	time difference	0.56
	TD:	47	9.40 (1.60)	112.10 (9.70)				
					circle drawing	other	time difference	0.72
					Change Task (picture/auditory)	stop-signal	stop-signal reaction time	0.90
Verté et al., 2006	*HFA:*	66	8.70 (2.00)	101.50 (18.20)	stop-signal (pictures)	stop-signal	stop-signal reaction time	0.54
	TD:	82	9.20 (1.70)	112.20 (16.00)				
Xiao et al., 2012	*HFA:*	19	10.11 (2.08)	99.26 (9.03)	go/no-go (simple shapes)	go/no-go	commission errors	0.87
	TD:	16	9.69 (1.74)	105.63 (13.12)				
					Stroop (colour/word)	Stroop	RT on incongruent trials	0.19
Yoran-Hegesh et al., 2009	*HFA:*	23	15.10 (3.60)		Stroop	Stroop	RT on incongruent trials	1.55
	TD:	43	15.50 (0.60)					

Analysis

Effect sizes

Effect sizes were calculated as the standardised difference between the mean scores of the HFA and TD groups, divided by the pooled standard deviation (i.e. Hedges's *g*), which is a good and accepted measure (Hunter & Schmidt, 2004). A positive effect size indicates impaired performance in the HFA group. Because of the slight upward bias of this value, we applied the small-sample correction factor recommended by Hedges and Olkin (1985). For clarity, the formula used to compute the effect size is given below:

$$Hedges's\ g = \left(1 - \frac{3}{4(n_1 + n_2) - 9}\right)\left(\frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}}}\right)$$

The reported effect sizes were weighted by the inverse variance including a random-effects variance component, which Hedges and Olkin (1985) showed to be ideal for meta-analyses. This ensures that studies with small samples that report extreme effect sizes do not have undue influence on the final estimate.

Outliers and publication bias

Potential outliers were identified through visual inspection of the forest plot (see Figure 3). Although one study (Corbett & Constantine, 2006) appeared to be an outlier (*z*-score = 3.27), no Cook's distance was above the threshold of 1 recommended by Cook and Weisberg (1982) for identifying studies with undue influence on the model. Nonetheless, the meta-analysis was repeated with this potential outlier excluded, and yielded the same results, which are therefore not reported separately below.

In order to locate relevant unpublished results, the corresponding authors of the research studies included in this meta-analysis were contacted, along with other researchers who the literature review suggested might potentially have such results. Of these 73 researchers, 27 responded (37%), but none held relevant unpublished data.

Possible publication bias was explored using a funnel plot (see Figure 2), the regression test recommended by Sterne and Egger (2005), and the trim-and-fill method proposed by Duval and Tweedie (2000). The regression test indicated no asymmetry in the funnel plot ($z = 0.87$, $p = .383$), and the trim-and-fill analysis suggested that no studies were missing from either side of the distribution. These results point to no publication bias resulting from the suppression of extreme results in either direction.

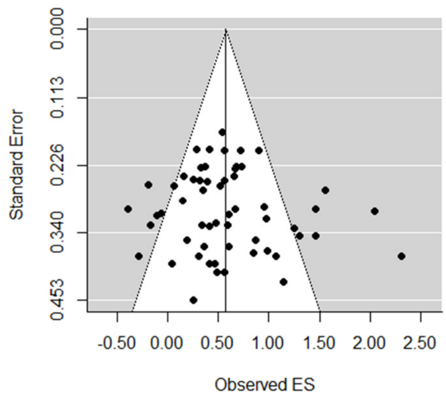

Figure 2. Funnel plot

Results

In the first step, a random-effects model was fitted to the data in order to aggregate effect sizes from all studies while accounting for variation in the observed effect sizes due to sampling error and the impact of potential moderators. This analysis revealed that the mean effect size for IC impairment was significantly above zero, $g = .58$ [0.45, 0.71], $p < .001$ (see Figure 3). The homogeneity statistic (Cochran's Q) indicated significant heterogeneity across the studies, $Q(56) = 156.77$, $p < .001$, suggesting that the effect size is affected not only by sampling error but also other confounding variables.

Moderator analysis

The potential moderating effects of choice of experimental paradigm, participant age, full-scale IQ (FSIQ), and the difference in FSIQ between the HFA and TD groups were explored using weighted meta-regression. Age and cognitive ability were examined because both of these factors are known to affect IC (Huizinga, Dolan, & van der Molen, 2006; Carlton & Moses, 2001), and were found to be significant predictors of ES in Geurts et al.'s aforementioned meta-analysis (2014). The potential impact of the difference in general cognitive ability between the TD and HFA participants was investigated in order to ensure the comparability of the experimental groups.

Experimental paradigm

Choice of experimental paradigm was not a significant moderator of IC impairment effect size, $QM(5) = 0.36$, $p = .996$, and heterogeneity between studies remained significant after accounting for its effect, $QE(51) = 155.22$, $p < .001$. The mean effect size was calculated for each paradigm separately; these ranged between 0.50 and 0.63, and were all significantly above zero (see Table 2). An experimental task was categorised as 'other' if it had been used in fewer than five studies included in the meta-analysis.

Age and full-scale IQ

The effects of age and FSIQ of the HFA participants were analysed using weighted meta-regressions. There was no significant effect of age on the size of IC impairment, $QM(1) = 2.69$, $p = .101$, and the residual heterogeneity was still significant, $QE(55) = 151.29$, $p < .001$. As not all studies reported the FSIQ of the HFA group, the effect of this variable was tested on a subset of effect sizes ($n = 48$). Overall, the FSIQ of the HFA group did not emerge as a significant moderator, $QM(1) = 0.15$, $p = .699$, and a significant amount of heterogeneity remained, $QE(46) = 90.15$, $p < .001$.

Group difference in full-scale IQ

The relative cognitive ability of the TD comparison group was indexed as the standardised effect size (i.e. Hedges's *g*) for the difference between the FSIQ of the two groups. These figures were reported in 39 studies. The effect of IQ difference emerged as a significant moderator, $QM(1) = 8.22$, $p = .004$, and accounted for a substantial amount of variance in effect sizes (31.79%). Nevertheless, the excess heterogeneity remained significant, $QE(37) = 69.27$, $p = .001$.

As the difference in FSIQ between the groups was substantial ($M = -0.44$, $SD = 0.43$), the basic meta-analysis was repeated on a subset of the studies where the HFA and TD groups were closely matched on FSIQ, i.e. where the absolute value of the standardised mean difference between the FSIQ scores of the two groups did not exceed 0.3. The purpose of this analysis was to test whether the overall significant ES was due to the difference in FSIQ between the groups. The mean ES in the subset of studies where the HFA and TD groups were closely matched on FSIQ ($n = 16$) was significantly above zero, $g = 0.39$ [0.24, 0.54], $p < .001$. Cochran's Q-test indicated that residual heterogeneity was not significant, $Q(15) = 11.82$, $p = .692$.

Table 2. Mean effect size of inhibitory impairment by experimental paradigm

Paradigm	Number of ESs	Mean ES (*g*)	95% CI	*p*
Flanker	5	0.54	[0.10, 0.99]	.017
Go/no-go	13	0.59	[0.30, 0.88]	< .001
Opposite worlds	5	0.50	[0.06, 0.94]	.026
Stop-signal	8	0.63	[0.28, 0.99]	< .001
Stroop	10	0.63	[0.31, 0.95]	< .001
Other	16	0.55	[0.30, 0.80]	< .001
Overall	57	0.58	[0.45, 0.71]	< .001

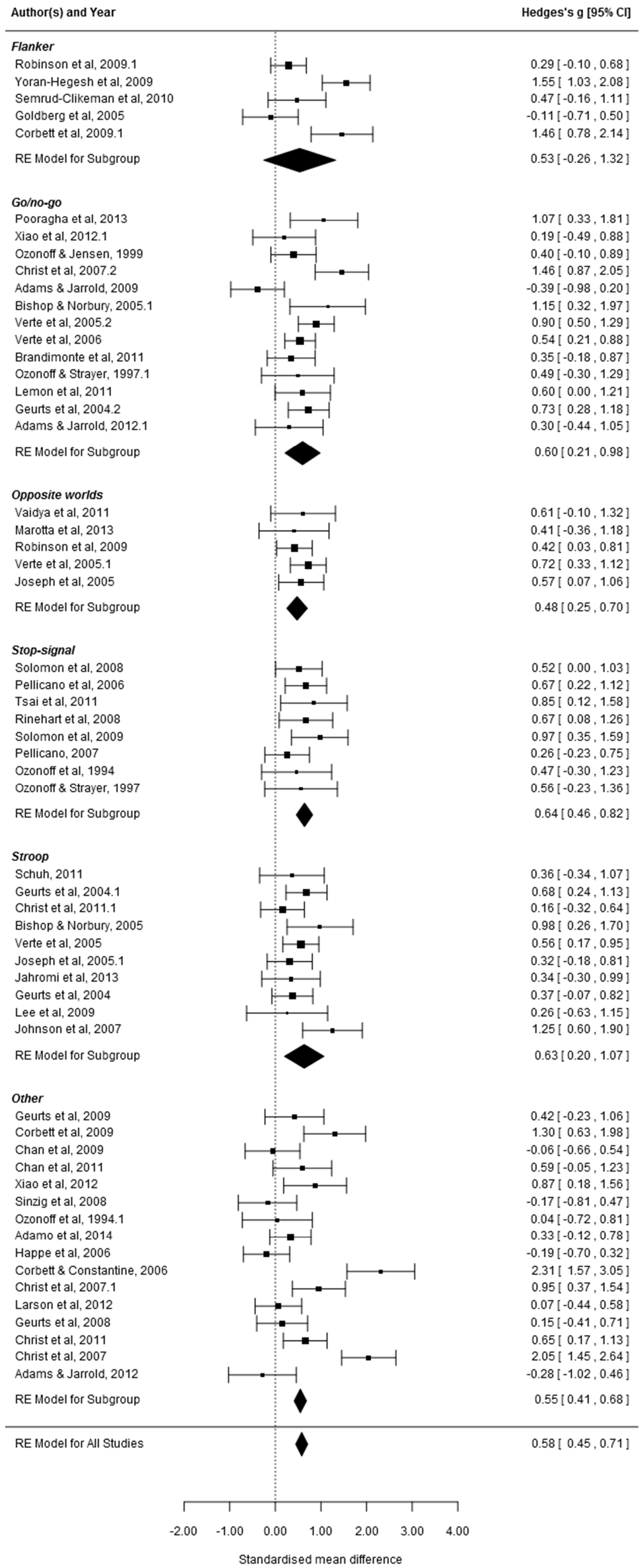

Figure 3. Forest plot of effect sizes by paradigm and overall

Discussion

In this systematic review, we sought to answer two main questions: first, whether inhibitory control is impaired in children with HFA, and second, whether this impairment, if it exists, is evident on some, but not all, measures of inhibitory control. Through a meta-analysis of 57 effect sizes, reported in 42 studies, we found strong evidence for a substantial impairment: the weighted average standardised mean difference between the HFA and TD groups was 0.58, above the threshold for a 'medium-sized' effect according to Cohen's (1992) guidelines. There was, however, no evidence of differential performance across experimental paradigms: effect sizes were calculated separately for each paradigm, and they varied within a relatively narrow range (Hedges's *g*'s between 0.50 and 0.63), and were all significantly above zero, showing a relatively similar degree of impairment in HFA. Moderator analysis confirmed that choice of experimental measure did not have a significant impact on the degree of inhibitory impairment observed.

Exploratory moderator analyses were carried out to test the effect of participant age, FSIQ, and the difference between the HFA and TD comparison groups' general cognitive ability (indexed as the standardised mean difference between the FSIQs of the HFA and comparison groups in each study). We found that whereas participant age and IQ were not associated with the size of the IC impairment shown by the HFA group, the difference in cognitive ability between the HFA and TD comparison groups was. Specifically, a larger IC impairment was reported in the studies where the TD comparison group was relatively more able than the HFA participants (as indexed by the difference in FSIQ between the groups). The meta-analysis was repeated on a subset of the studies, in which the HFA and TD groups were closely matched on FSIQ. This analysis showed a reduced, but still substantial effect size, suggesting that the apparent inhibition is partly, but not wholly, due to the matching of participants with HFA to a TD comparison group with higher general cognitive ability.

The effect of choice of experimental task

Although the executive dysfunction account has been an influential model of autistic symptomatology, there is considerable uncertainty as to the exact nature and pattern of impairments in the various executive functions, including inhibitory control, that define the disorder (for a recent review, see Pellicano, 2011). This uncertainty stems from the equivocality of experimental findings.

Various tentative explanations have been proposed for this diversity of the results, mostly in terms of differences between the diverse experimental tasks used to test inhibitory control. Some of these explanations highlight differences in the type of inhibitory control measured, e.g. the distinction between prepotent response inhibition and interference suppression (Hill, 2004), the former of which is supposed to be impaired in autism, and the latter, intact. Others focus on task characteristics, such as the use of arbitrary rules (Bíró & Russell, 2001) the availability of alternative strategies to solve the task (O'Hearn et al., 2010), or whether the task requires the recruiting of cognitive mechanisms other than inhibition for success, i.e. direct versus indirect measures of inhibition (Russo et al., 2007). None of these hypotheses had been tested empirically, however, and in the studies that used more than one measure of inhibition, the pattern of results has been inconsistent. For example, Adams and Jarrold (2012) found that children with autism were impaired on inhibiting interfering stimuli, but not prepotent responses, while Hill (2004) suggests the opposite trend.

In this meta-analysis, we found no difference in the degree of inhibitory impairment shown by the HFA group across the various experimental paradigms. The choice of task did not emerge as a significant predictor of effect size, thus our results do not support any of the theories that purport to explain the difference in performance across tasks as outlined above, simply because there appears to be no such difference. This result is in accordance with the conclusions of a recent systematic review that contrasted prepotent response inhibition and interference suppression studies (Geurts et al., 2014), which found that the performance of participants with HFA relative to TD comparison groups did not differ significantly between studies that used either a prepotent response inhibition or an interference suppression paradigm.

Instead, sampling error and low power are the most likely explanation for the aforementioned equivocality of experimental results, which had clouded the question of whether inhibitory control is impaired in autism. The power of the studies included in this meta-analysis ranged between .37 and .96; the mean was .67. While this is considerably higher than the figure typical in psychological research (Cohen, 1962; Hunter & Schmidt, 2004; Sedlmeier & Gigerenzer, 1989), it still means that there was, on average, a 1 in 3 chance of a Type II error, i.e. failing to find the inhibitory impairment that characterises HFA children, in each study. Low statistical power is an unfortunate, but often inevitable characteristic of behavioural research: keeping the Type II error rate at the level conventional for Type I errors (i.e. 5 per cent) would have required over 130 participants in each of the studies included in this meta-analysis, which is rarely feasible. Nonetheless, careful consideration of the potential impact of low statistical power when interpreting non-significant results may help avoid unnecessary theorising and the search for non-existent ‘factors’.

While Type II errors arising from low statistical power must be responsible for a considerable amount of variation in past experimental results, the heterogeneity diagnostics calculated in the meta-analysis suggested the existence of moderating factors, which we also explored.

The effect of age

In our meta-analysis, we found no association between participant age and the size of inhibitory impairment in the HFA group. IC improves considerably with age in typical development (Huizinga, Dolan, & van der Molen, 2006; Schachar & Logan, 1990; Williams et al., 1999), but the lack of a statistically significant link between participant age and inhibitory impairment in the HFA group suggests that the performance gap is not widening between the two populations. One possible explanation is that the developmental trajectory of inhibition is the same, albeit delayed, in HFA as in typical development. Alternatively, as children with HFA mature, they may become able to recruit other, intact, cognitive mechanisms to compensate for their impaired inhibition.

This finding of no age effect on inhibitory impairment is partly in contradiction with Geurts et al.’s (2014) systematic review of prepotent response inhibition and interference suppression: while they, too, found no link between participant age and interference control, age did emerge as a significant moderator of the effect size in prepotent response inhibition: generally, studies with older participants found a smaller impairment of this ability. The two reviews differed in their age range: whereas we only analysed studies with under-18s, Geurts et al. included studies on adult participants, as well. Taken together, the reviews seem to suggest that HFA children have consistently poorer inhibition than TD peers, but once adult levels of inhibition are reached in typical development, individuals with HFA have the potential to ‘catch up’ through either (or both) of the mechanisms proposed above, and the apparent IC impairment lessens with age.

The effect of IQ

The relationship between executive functions and intelligence is complex (for an overview, see Friedman et al., 2006), but there is strong evidence that performance on tests of inhibitory control is linked to IQ (e.g. Ardila, Pineda, & Rosselli, 2000; Friedman et al., 2006; Geurts et al., 2014; Ogilvie, Stewart, Chan, & Shum, 2011). The results of our meta-analysis are in line with previous research inasmuch as we found that while the FSIQ of the HFA group was not a predictor of the reported inhibitory impairment in itself, the difference in FSIQ between the HFA and TD participants was, and it explained a substantial amount of variance in effect sizes. This means that when the general cognitive advantage of the TD comparison group was larger, the inhibitory impairment shown by the HFA was also larger.

In the studies included in our meta-analysis, the TD participants typically had substantially higher FSIQs than the HFA children, so in order to test whether the inhibitory impairment effect found was entirely explicable by this difference in general cognitive ability, we reran the meta-analysis on a subset of the studies in which the two groups were closely matched on FSIQ. In these studies, the inhibitory impairment was still significantly above zero, but about a third smaller, suggesting that a substantial portion of the apparent inhibitory impairment is due to the fact that the TD comparison group often has considerably higher general cognitive ability than the participants with HFA. This highlights the fact that poor matching of the clinical and TD groups on mental age can lead to inflation of the observed effect sizes on the cognitive ability of interest.

Methodological considerations

As detailed above, sampling error, inconsistent matching of the comparison group, and low power can account for much of the apparent diversity of results in studies that investigated the inhibitory control of children with HFA. Diagnostics calculated in the meta-analysis showed, however, that a significant amount of residual heterogeneity exists in the results even after taking these factors into account, pointing to the existence of other moderators. Using the Go/no-go Task as an example, we will argue below that the lack of standardisation of experimental tasks, including the dependent variables reported, may be partly responsible for this unexplained variance in study results.

In the Go/no-go Task, the participant is presented with two types of stimulus: 'go' trials, on which a motor response (e.g. button press) must be given, and 'no-go' trials, on which the response must be withheld. 'Go' trials are more salient, creating a tendency in the participant to respond on all trials ('prepotent response'), which then must be inhibited for successful completion of the task. The higher salience of 'go' trials is typically achieved through their higher relative frequency (Cragg & Nation, 2008). Of the 13 studies included in this meta-analysis that used the Go/no-go Task, only seven reported the proportion of 'no-go' trials: these ranged from 11 to 50 per cent. The low number of studies for which 'no-go' trial frequency data were available precluded the performance of moderator analysis on this variable, but there is evidence from both brain imaging (Braver, Barch, Gray, Molfese, & Snyder, 2001) and behavioural studies (Berwid et al., 2005; Durston, Thomas, Worden, Yang, & Casey, 2002) that the frequency and distribution of 'no-go' trials has a large impact on performance on this task. Yet, the effect of this heterogeneity is universally ignored when results are interpreted.

The proportion of 'no-go' trials on which a response was given (i.e. the rate of 'commission errors' or 'false alarms') is the universally reported dependent variable in the Go/no-go Task. All of the Go/no-go studies in our meta-analysis reported this statistic, and only one (Happé, Booth, et al., 2006) also included a measure of sensitivity (A'). The rate of commission errors, as *prima facie* examples of failed inhibition, seems an obvious choice for outcome variable, but it is extremely sensitive to bias: since success on the Go/no-go Task requires inaction, the score of participants who are distracted or fail to understand the task will be inflated, distorting the analysis. A measure of sensitivity that takes into account overall performance on the task should be used instead. One such option is A', a nonparametric measure of sensitivity proposed by Norman and Pollack (1964) and formulated by Grier (1971) as

$$A' = 0.5 + \frac{(H - FA)(1 + H - FA)}{4H(1 - FA)}$$

where H is the probability of a correct response on a ‘go’ trial (i.e. a ‘hit’), and FA is the probability of an incorrect response on a ‘no-go’ trial (i.e. a ‘false alarm’). The benefit of A' over the commission error rate is that no false alarms resulting from responding to no trials at all or from flawless inhibitory performance are easily distinguished in the score. More recently, Zhang and Mueller (2005) proposed a more sophisticated, although computationally more intensive version of this measure, which they called A, and which also allows for the calculation of a bias arising from the difference in the distribution of hit and false alarm scores.

The Go/no-go Task aside, there was a substantial amount of heterogeneity in task characteristics across all the studies that were included in our meta-analysis (e.g. type and modality of stimulus, inter-stimulus interval, number of trials, relative frequency of ‘no-go’, ‘stop’, or incongruent trials, etc.). A detailed evaluation of these manipulations and their potential effect on the pattern of results is beyond the scope of this paper. An experimental study on the effect that systematically varying task characteristics has on performance could cast more light on the issue, but it is clear from the evidence available that they do influence task performance (Adams & Jarrold, 2012; Geurts et al., 2004). Similarly, the choice of dependent variable may affect results, and therefore inconsistency across studies in this regard will make the interpretation of the pattern of findings more difficult. For example, in their review of studies into prepotent response inhibition and interference suppression in autism, Geurts et al. (2014) found that the choice between reaction time and accuracy as the outcome measure of interest was a significant moderator of impairment effect sizes.

Conclusions and implications

In our meta-analysis of experimental studies comparing inhibitory control in children with HFA and typical development, we found strong evidence for a substantial deficit in HFA. We found that while age was not a significant moderator of effect sizes, a large amount of variance was explicable by difference in the FSIQ of the HFA and TD comparison groups, lending further support to the link between intelligence and executive functions, and highlighting the importance of using appropriate matching procedures.

Importantly, the inhibitory deficit was apparent across all commonly used experimental tasks, casting doubt on the relevance of theories that have attempted to explain the diverse pattern of results in terms of a differential inhibitory impairment in autism. We suggest instead that previous equivocal findings were the result of typically underpowered studies, a great degree of heterogeneity in the experimental measures, including the choice of dependent variable, and inconsistent matching of the TD comparison group on general cognitive ability to the participants with HFA. The standardisation of experimental tasks and careful consideration of the impact of low power when interpreting non-significant findings are recommended as improvements to current research practice.

Article 2: Inhibitory control is a prerequisite of cooperation in high-functioning children with autism

Abstract

Cooperation is impaired in autism, but the proximate causes of this difficulty are little understood. Previously identified candidate mechanisms include theory of mind and joint attention. In older high-functioning children with autism (HFA), however, these capacities are relatively unimpaired, while cooperation continues to be poor. In search of an alternative explanation, we tested the link between cooperation and inhibition. Twelve HFA children attending mainstream primary schools and twelve age-matched typically-developing peers completed tests of join attention, false-belief understanding, inhibition and a cooperative drawing task. A parent-report measure of social functioning was obtained using the Strengths and Difficulties Questionnaire. We found that while HFA children performed at normal levels on a false-belief task and in joint attention, they were impaired in inhibitory control, and the degree of this impairment was linked to effective cooperation in an experimental task and to parental reports of everyday social functioning, even after accounting for the effect of verbal ability. The results highlight the potential of inhibition to contribute to an account of social impairments in autism.

Introduction

The ability to cooperate is important for children's social development because it is an essential component of social play. Social play, in turn, allows children to experiment with social roles, learn about understanding their own and others' emotions, and gain expertise in social interaction through developing essential social skills such as coordinating their attention and actions with others or discussing and jointly developing ideas. It also provides an opportunity to forge friendships (Jordan, 2003), which support psychological well-being (Bauminger, Shulman, & Agam, 2004). The skills fostered by social play are also needed to succeed in the classroom: lack of proficiency in skills such as interpersonal communication, turn-taking and proxemics have an adverse effect on a child's ability to engage with the curriculum in group learning settings.

Children with autism spectrum disorder (ASD) suffer significant and wide-ranging impairments in their capacity for social interaction, including cooperation

(Downs & Smith, 2004). Yet, cooperation is one of the relatively less well-studied aspects of social impairments in autism. The paucity of research into this area is exacerbated by the fact that there exists no 'gold standard' test or even a universally accepted definition for cooperative skills and behaviours. Here, cooperation is defined following Bratman's (1992) criteria as an activity performed by mutually responsive partners who support each other in attaining a shared goal. Cooperation requires joint engagement with and a shared understanding of the task at hand, and may also involve a continuous exchange of ideas and flexibly shifting behaviour in response not only to the requirements of the task but also the reactions of the partner or partners.

The causes of poor cooperation in ASD have been tentatively posited to lie in impaired theory of mind (Downs & Smith, 2004; Hill, Sally, & Frith, 2004; Sally & Hill, 2006) and joint attention (Colombi et al., 2009; Liebal, Colombi, Rogers, Warneken, & Tomasello, 2008), but the evidence only partly supports these theories.

Sally and Hill (2006), for example, suggested that mentalising ability is linked to making more 'cooperative' (i.e. trustful or fair) decisions in strategic games (the Prisoner's Dilemma, the Dictator and Ultimatum scenarios, described below). Contrary to their expectations, however, success on a second-order false-belief test did not predict the ability of children between the ages of 6 and 10 to 'cooperate' in the Prisoner's Dilemma and to make fair offers in the Ultimatum Game. Also, children with ASD were no less cooperative than typically-developing (TD) children in these strategic games. In a similar set-up, Downs and Smith (2004) found that children with ASD between the ages of 6 and 10 were no less cooperative in the Prisoner's Dilemma than TD controls matched on IQ. The proposition that considering the play partner's mental states is a prerequisite of cooperative behaviour in the Prisoner's Dilemma is further undermined by self-reports of verbally able adults with ASD. In Hill, Sally and Frith's (2004) study, participants were asked to complete three versions of the Prisoner's Dilemma task, and then took part in a semi-structured interview designed to identify the spontaneous strategies they had used in the game. It was expected that TD controls would use a strategy based on the mental states attributed to the play partner, and would therefore be more cooperative. In fact, individuals with ASD displayed the same level of cooperation as the TD controls, and both groups reported using a purely logical approach to maximising their payoffs.

Using a similar social hunting game, Yoshida et al. (2010) compared the strategies employed by adults with and without autism. Contrary to the results of Hill, Sally and Frith (2004), they found that control participants were more likely to use a strategy based on inferring the opponent's goals, but participants with autism tended to stick to either a cooperative or a competitive strategy throughout the experimental session. Problematically for the explanatory power of these results, however, mentalising ability was not measured directly in this study, and none of the correlations were significant between the severity of autistic symptoms and using what the authors labelled as the 'theory of mind strategy' in the game.

One explanation for the failure to link theory of mind to cooperation lies in the unsuitability of the methodology used to measure the latter construct. In the Dictator Game, one of the players (the Dictator) is assigned a quantity of valuable resources, which she is then free to share with the other player as she deems fit. The Ultimatum Game introduces an element of interaction: the second player has the option to reject the split, in which case neither player receives anything. In the Prisoner's Dilemma (PD) scenario, the two players may choose, independently and blind to the other player's decision, to either 'cooperate' or to 'compete'. The payoff matrix is so defined that although mutual cooperation results in the best outcome for both parties, a player who chooses to cooperate exposes herself to exploitation by an uncooperative partner, and so the rational (self-interested) decision is for both players to compete, which then leads to the worst overall outcome.

The problem with these economic 'games' in measuring cooperation is that they were developed specifically to eliminate social factors: personal interaction of any kind between the partners is explicitly forbidden under the rules, and in order to eliminate the expectation of future reciprocation, the play partner is typically a stranger or even non-existent. Although acting trustfully or prosocially in these scenarios is referred to as 'cooperating' in the research literature, it might be more accurate to discuss it in terms of understanding abstract social norms of reciprocity and fairness. There is little similarity between making such a decision and the behaviours that comprise cooperation as defined above (characterised by mutually supportive partners working towards a shared goal and also, potentially, by co-location, shared attention and verbal and non-verbal communication). These characteristics make the game theory paradigm particularly ill-suited for the study of cooperation in episodes of social play and learning. In order to gain a more ecologically valid measure of cooperation, it is important to observe real-life activities, such as joint drawing or construction.

For our study, we chose the Interactive Drawing Task (van Ommeren, Begeer, Scheeren, & Koot, 2012)[1], a joint drawing activity that involves co-located partners sharing a workspace and allows for, although it does not require, real-time communication and joint attention. Although interacting with an unknown adult (i.e. the experimenter) in an experimental setting obviously has important differences from a spontaneous peer play session, the IDT is a good measure of cooperative play because it comprises an activity that is familiar and inherently enjoyable (i.e. drawing), the pace and level of interaction is dictated by the child, and there are no arbitrary rules to learn and keep in mind. The IDT has been used successfully to assess the cooperative play of children, both typically developing, with autism, and with learning disabilities.

We also used the parent-report Strengths and Difficulties Questionnaire to obtain an independent measure of social competence in everyday peer interactions.

In addition to theory of mind, the ability to share intentions and attention has been put forward as essential prerequisites of successful cooperation, in line with the evolutionary account proposed by Tomasello et al. (2005). Colombi et al. (2009), for example, set out to identify the correlates of cooperative ability in preschool children (mean age: 3.5 years) with ASD or developmental delay (DD), and concluded that a deficit in the ability to respond to joint attention (RJA) is responsible at this age for impaired cooperation. Similarly, Liebal et al. (2008) found that children with autism showed less cooperation than DD controls, and were also less likely to invite the adult partner to re-engage with the task when the experimenter stopped playing. The authors interpreted these results in terms of an impaired ability to form shared intentions and engage in joint attention. Travis, Sigman and Ruskin (2001) measured social understanding and social responsiveness in children with ASD (mean age: 12.7 years), operationalised as initiating joint attention (IJA), false-belief

[1] Although the first author's surname is Backer-van Ommeren, the study is cited as above in academic databases. In the interest of ease of identification, we use this (incorrect) form here and in the References section, with apologies to Dr Backer-van Ommeren.

understanding, affective perspective-taking, empathy and concern to distress. Of these variables, only empathy and IJA showed a significant relationship with prosocial behaviour and spontaneous engagement in peer play on a playground.

While the capacity for shared intentions and attention is, by definition, an essential component of cooperation, it is clearly not sufficient in itself. Several studies (e.g. Leekam & Moore, 2001; Mundy, Sigman, & Kasari, 1994; Sigman & Ruskin, 1999) have shown that the severity of impairments in RJA lessens in autism with increasing chronological or mental age, but this improvement is not paralleled by an increase in the quality of peer interactions. Similarly, Mundy et al. (1994) found no relationship between RJA and the intensity of social symptoms in pre-school children with ASD. This leaves open the question of what residual impairments are responsible for poor cooperation in HFA children beyond the preschool years.

Executive dysfunction has been proposed as one such candidate component of a multiple-deficit model of social impairments in autism (for a recent review, see Pellicano, 2011), but the evidence is equivocal. In a longitudinal investigation of the predictive power of specific cognitive skills on autistic symptoms, Pellicano (2013) found that at three-year follow-up, EF (planning, cognitive flexibility, and inhibitory control) uniquely predicted social communication and repetitive behaviours and interests in children with autism. Early individual differences in EF and central coherence were linked to social functioning, but ToM (false-belief understanding) did not contribute to the explanatory power of the model. Similarly, McEvoy, Rogers and Pennington (1993), for example, found that level of executive functioning (EF) at the age of five was significantly related to the ability to engage in joint attention and social interactions, even after controlling for verbal ability. Griffith et al. (1999) demonstrated a link between the number of perseveration errors committed by children with ASD and measures of initiating and responding to joint attention. These findings lend support to the idea of specific subdomains of EF acting as a prerequisite of fully functioning social skills. Happé et al. (2006), for example, showed that performance on a variety of executive function tasks was related to specific aspects of social communication and adaptive behaviours, and negatively correlated with symptoms of hyperactivity. Similarly, Ozonoff et al. (2004) showed that performance on the CANTAB suite of EF tests was correlated with adaptive behaviour (as measured on the Vineland Adaptive Behavior Scales). In an investigation of the relationship between EF, false-belief understanding and social competence in a longitudinal sample, Razza and Blair (2009) concluded that preschool performance on measures of inhibitory function, working memory and set-shifting predicted social competence both in preschool and a year later. A similar link between EF and social functioning was found in Fahie and Symon's (2003) study: teacher and parent reports of social problems were related to performance on measures of impulsivity, attention and working memory, even after the effect of theory of mind was accounted for. The evidence for an EF account of social impairments is far from conclusive, however: a number of studies failed to find a relationship between EF and social capacities in autism (e.g. Bennetto, Pennington, & Rogers, 1996; Pennington et al., 1997; Rumsey, 1985; Russell, 1997), and in other cases, the explanatory power of EF disappeared when verbal ability was accounted for (e.g. Bishop & Norbury, 2005; Liss et al., 2001; Pellicano, Maybery, Durkin, & Maley, 2006).

In a recent study, Li et al. (2014) investigated the predictive power of ToM and EF on the performance of children with and without HFA on two tests of cooperation: the Prisoner's Dilemma and an 'implemental task'. They found that children with HFA had an uneven cooperation profile: there was no significant difference between the groups in the Prisoner's Dilemma, but the TD children outperformed the participants with HFA on the implemental task. Importantly, EF was predictive of cooperation in both tasks.

There is considerable evidence that the equivocality of findings in the area of executive dysfunction in autism is partly caused by methodological issues, namely the nature of the tasks used and the choice of matching tasks and control groups (see Hill & Bird, 2006; and Russo et al., 2007). Inhibitory control is a domain of EF where the choice of task, age and comparison group plays a particularly substantial role in whether individuals with ASD are found to have impairments (for reviews, see Hill, 2004; O'Hearn, Asato, Ordaz, & Luna, 2010; Russo et al., 2007). As Garon, Bryson and Smith (2008, p. 40) poignantly state: "Ironically, one of the challenges in understanding the development of response inhibition is the multitude of response inhibition tasks." Two recent meta-analyses have investigated the impact of choice of measure on inhibitory performance. Geurts et al. (2014) compared tests of 'prepotent response inhibition' with tests of 'interference suppression', and found that children with HFA showed impaired performance both types of task. Similarly, Borbely (submitted) conducted a meta-analysis of studies that directly compared inhibition in children with HFA with TD controls, and found that while choice of experimental measure was not a significant predictor of inhibitory performance, there was a large amount of heterogeneity across studies that could not be explained by the age or cognitive ability of the participants. This suggests that methodological differences across measures of inhibition as well as between how the same task is administered by different researchers have a profound impact on performance. Until the details of this interaction between methodological details and experimental performance are clearly understood, inhibition should be measured using a battery of diverse tasks to ensure a comprehensive picture.

We hypothesised that HFA children struggle in cooperative situations partly because they are less able to accept the play partner's contributions, as a result of their difficulty in inhibiting the prepotent response, which is to follow their own plans and preferences for the play session. The objective of this study was, therefore, to contribute to the EF account of social impairments in autism by testing the hypothesised link between inhibitory control and cooperation, and between inhibitory control and everyday social functioning in a primary school age sample, expanding on previous investigations into the correlates of cooperation in autism. As our autistic sample consisted of high-functioning children, we expected that they would not show impairments in false-belief understanding and joint attention, but would nonetheless be less able than their TD peers to engage in a cooperative task, and that they would experience more difficulties related to everyday social interaction. In terms of the causes of these social problems, we hypothesised that the HFA sample would show impairments in inhibitory control and that the degree of this impairment would be linked to the severity of difficulties in social interaction.

Method

Participants

Twelve high-functioning children (11 males) with a diagnosis of autism spectrum disorder between the ages of 5;6 and 11;5 (M = 8;5, SD = 1;9) and an equal number of typically-developing peers (8 males) aged between 6;6 and 11;5 (M = 8;2, SD = 1;9), groupwise matched on chronological age, participated in the study.

The HFA participants were recruited from a play scheme run for children with special educational needs and from autism charities. The TD children were recruited from local primary schools. Those in the HFA group did not have a comorbid diagnosis of any other developmental disorder (e.g. ADHD).

Matching children by chronological age (rather than verbal mental age) was chosen because the inhibitory tasks and the cooperative activity were predominantly visual-motor in nature. The HFA children in our sample had lower than average verbal ability, and so using a verbal matching measure would have resulted in choosing a comparison group with lower general ability. Since visuo-spatial and nonverbal skills are relatively intact in autism (Shah & Frith, 1983), however, comparison with such a low-ability control group would have led to an overestimation of the HFA group's performance.

Measures

Baseline measures

Verbal ability: The British Picture Vocabulary Scale (BPVS-III, Dunn & Dunn, 2009) was used, a test of receptive verbal ability that provides a standardised verbal IQ score and an equivalent verbal mental age.

Theory of mind: Mentalising ability was tested using two standard measures of first-order and second-order understanding of false beliefs: the *Sally-Ann* (Baron-Cohen et al., 1985) and the *birthday puppy* (Sullivan, Zaitchik, & Tager-Flusberg, 1994) tasks, respectively. The stories were acted out with Playmobil figures.

Joint attention: An adapted version of the *Early Social Communication Scales* (Seibert, Hogan, & Mundy, 1982) was used to gauge the participants' ability to initiate and respond to joint attention and behavioural requests. The experimenter invited the participant to engage in a 10-minute joint building task using Lego Duplo blocks. The experimenter performed a series of predefined actions intended to elicit each of these behaviours (e.g. withhold a brick needed by the child for the construction task in order to elicit asking or looking and pointing at the construction model while giving the instructions for the task).

These sessions were videotaped and the child's behaviour coded for the frequency of asking questions, making behavioural requests and initiating joint attention (showing or pointing) as well as for the proportion of responses to questions and behavioural requests made by the experimenter, and responding to joint attention.

Inhibitory control

The *Bear/dragon Task* (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Reed, Pien, & Rothbart, 1984) is a version of the 'Simon Says' game. Children receive instructions to perform a series of self-directed actions (e.g. "Clap your hands"), given alternately by a "nice bear" or a "naughty dragon", and must comply with the instructions of the bear while refraining from following the orders of the dragon. In this study, the experimenter used hand puppets of a (nice) fairy and a (naughty) crocodile, and gave the commands in a high-pitched voice (for the fairy) or in a low, gruff voice (when speaking as the crocodile). After confirming that the participant was able to perform each of the actions, there were two practice rounds, followed by ten trials. Regardless of performance, the children were reminded of the rules halfway through. Following the coding scheme used by Kochanska et al. (1996), each of the crocodile trials (i.e. when children had to refrain from complying with the command) was coded on a scale of 0 to 3 (0 = command fully performed; 1 = command partially performed; 2 = wrong movement; 3 = no movement). The fairy trials were coded reversely (i.e. 0 for no movement and 3 for command fully performed).

In a computerised *Go/no-go Task*, images of cats and robots were presented in a random sequence on a 15" laptop screen for 750 ms each, with an inter-stimulus interval of 1250 ms. The participants were instructed to press the space bar for cats, and to refrain from any action on the robot trials. After ten practice trials, the participants completed fifty trials (in which the ratio of cat and robot pictures was 4:1) and were given generic praise, regardless of performance. Anticipatory responses (i.e. responses given within an excessively short time of exposure to the stimulus) were not excluded from the analysis because they represent a prima facie example of failed motor inhibition.

The *Windows Task* (Russell, Mauthner, Sharpe, & Tidswell, 1991) was originally proposed as a measure of the capacity for strategic deception. It involves two opaque boxes that have an opening on one side. They are placed between the experimenter and the participant in a manner that the latter can see their contents, but the former cannot. A desirable object is then placed in one of the boxes, which the participant can acquire by pointing to the empty box. This task was used as a measure of inhibitory control because the salient response of pointing to the desirable object must be suppressed in order to acquire it. In this study, a piece of sweet was placed in a randomly chosen box, and the rule of the game was explicitly explained to the participant. After two practice trials, the rules were reiterated, followed by twenty rounds of the game. The task was terminated early if the participant either failed or passed all of the first six trials. In order to eliminate social considerations on the part of the participant (e.g. failing the test deliberately so as not to appear greedy or to make sure that the sweets are evenly distributed between the participant and the experimenter), the game was not framed as a competition but as a chance to 'win' sweets. Sweets lost by the participant were returned to the original container, rather than going to the experimenter.

Delay inhibition was measured using the *gift delay* task used by Kochanska et al. (1996). The participant was told that they would get a gift but in order that it could be a surprise, they were asked to close their eyes. The experimenter then proceeded to noisily wrap the gift for 60 seconds. The participants' behaviour was videotaped and coded for whether they peeked and, if so, for the onset time of the peeking.

Parental questionnaire on adaptive behaviours

The *Strengths and Difficulties Questionnaire* (Goodman, 1997) is a parent-rated measure of behavioural problems in four domains: emotional; conduct; hyperactivity-inattention; and peer relations. In addition, it gauges the frequency of prosocial behaviours. The SDQ contains five questions in each domain (for a total of 25), the order of which was randomised for administering. The measure has good internal consistency (mean Cronbach's α = .73) and test-retest reliability (mean correlation = .62) (Goodman, 2001). The questionnaire was handed out to parents in hard copy, who returned it to the first author when completed.

Cooperation

Cooperation was measured using the *Interactive Drawing Test* (van Ommeren et al., 2012), which involves taking turns to draw on an A3 sheet of paper with different coloured markers. The participant is simply told: "We are going to draw together". The experimenter followed a predefined routine throughout the task. In the first stage, he drew a simple house, followed by two shapes: a semicircle and a wavy line. In the second stage, he contributed to the participant's drawings, at first constructively ('appropriate input', e.g. adding windows to a house), then in a manner that altered the nature of the child's drawing ('radical input', e.g. turning the house into a robot). This task was terminated after approx. 10 minutes. After each of his turns, the experimenter turned the sheet over (so that it would face the child) and passed it across the table. Using the coding method developed by Backer van Ommeren et al., the drawings were scored for collaborative reciprocity (i.e. number of times the child joined the experimenter in drawing an object), turn–taking (i.e. number of times the paper was passed back to the experimenter, with or without turning it over), and degree of accepting the experimenter's input (separately for appropriate and radical contributions). The experimenter's contribution was considered as accepted if the child continued the drawing or made a positive verbal acknowledgment (e.g. "Yes, that's good."), while abandoning the drawing for another one, crossing out the addition and negative verbal comments (e.g. "Don't do that. Draw your own!") were coded as rejection. A second coder was trained on three video recordings. A sample of another six video recordings (25 per cent) was double-coded and perfect inter-rater agreement was achieved on both degree of reciprocity and acceptance of experimenter input.

Procedure

The experimental tests were administered by the first author, in the order described above, except that the gift delay task was performed last, as a natural conclusion of the session. The experimental sessions lasted approx. 45 minutes. Participants were tested individually in a quiet room at a play scheme for children with special educational needs or in a laboratory. Parental consent and the participants' assent were obtained, and we checked prior to testing whether the participants understood their right to withdraw from the study. The study was approved by the university's ethics committee.

Results

Baseline measures

<u>Age and gender:</u> There were no significant differences between the groups with respect to gender, Barnard's exact test $p > .05$, or age, $t(22) = .28$, $p = .779$.

<u>Verbal ability:</u> HFA participants showed lower verbal ability than controls. A one-tailed between-subjects t-test on standardised scores on the BPVS showed that HFA participants had a significantly lower verbal IQ ($M = 92.91$, $SD = 18.87$) than the

controls (M = 115.58, SD = 13.92), $t(21) = 3.30$, $p = .003$, $d = 1.38$. The effect of verbal ability was therefore included as a covariate in the main group comparisons, and was partialled out in all subsequent correlation analyses.

Theory of mind: There was no difference between the HFA and TD groups' performance on first-order theory of mind, i.e. the Sally-Ann task (Barnard's exact test $p > .05$); HFA participants did perform more poorly, however, on the birthday puppy story (Barnard's exact test $p < .05$, $\phi = .60$). All but one TD participant passed the second-order false-belief task, but only a third of the HFA participants did.

Joint attention: Mann-Whitney U tests revealed no difference between the HFA and TD groups on initiating joint attention ($p = .279$), responding to joint attention ($p = .71$), the frequency of making behavioural requests ($p = .505$), or the proportion of behavioural requests made by the experimenter that the participant complied with ($p = 1$) (see Table 1).

Table 1. Participant characteristics, joint attention and theory of mind performance

	TD *M* (*SD*) Range	**HFA** *M* (*SD*) Range	**Difference between groups**
N	12	12	
CA (years)	8.2 (1.72) 6.5-11.42	8.4 (1.74) 5.5-11.42	ns, $p = .779$
VIQ (BPVS-II)	92.91 (18.87) 73-132	115.58 (13.92) 92-133	TD > HFA, $p = .003$
Joint attention			
Initiating joint attention	4 (4.04) 0-8	2.38 (2.88) 1-13	ns, $p = .369$
Behavioural requests made	4.88 (3.91) 0-11	3.5 (4.34) 0-11	ns, $p = .516$
Responding to joint attention (proportion of bids responded to)	.95 (.12) .25-1	.89 (.2) .38-1	ns, $p = .51$
Complying with behavioural requests (proportion of bids responded to)	All behavioural requests were complied with in both groups.		
Theory of Mind			
First-order false belief (pass / fail)	11 / 1	8 / 4	ns, $p >.05$

Second-order false belief (pass / fail)	11 / 1	4 / 8	TD > HFA, $p < .05$

Inhibitory control

In order to account for the non-normal distribution of scores on inhibition tasks, one-tailed t-tests were calculated with bias-corrected accelerated bootstrapping. These tests revealed that the HFA group performed more poorly on all measures of inhibitory control, i.e. proportion of correct responses in the Windows Task, $t(11.28) = 2.62$, $p = .012$, $d = 1.02$, average score for dragon trials in the Bear/dragon Task, $t(11) = 2.46$, $p = .016$, $d = 0.88$, the proportion of incorrect responses on no-go trials in the Go/no-go Task, $t(11.22) = 1.82$, $p = .048$, $d = 0.74$, and peeking onset on the gift delay task (in seconds), $t(18.48) = 1.8$, $p = .044$, $d = 0.73$ (See Table 2). In order to address the theoretical issues regarding the measurement of inhibitory control that were raised above, an aggregate inhibition score was computed for each participant by taking the average of the proportion of correct responses on each of the above tasks. In the case of the gift delay task, the proportion was calculated as the number of seconds until peeking divided by the total length of the task (i.e. 60 seconds). As such, a child who peeked immediately would score 0/60 = 0, and a child who did not peek at all would score 60/60 = 1. Thus, a single inhibitory control score was obtained, which ranged between 0 (poor inhibition) and 1 (faultless performance on all inhibitory control tasks completed). Of the 96 data points (scores on each of four tasks for each of 24 participants), only a few were missing due to technical problems ($n = 4$) or participant non-compliance ($n = 2$), and each participant completed at least three of the four measures of inhibition. This distribution of aggregate inhibition scores was approximately normal in the HFA group, but had a strong positive skew (skew $z = 4.71$, $p < .001$) in the TD group because five children in this group completed all inhibitory tasks faultlessly.

Table 2. Inhibitory performance across groups

	TD *M* (*SD*)	**HFA** *M* (*SD*)	**Difference between groups**
Proportion of correct responses on Windows Task	.98 (.04)	.66 (.43)	TD > HFA, $p = .012$
Proportion of incorrect responses on no-go trials	.96 (.05)	.85 (.2)	TD > HFA, $p = .048$
Average score on dragon trials (max.: 3)	3 (0)	2.12 (1.24)	TD > HFA, $p = .016$
Average seconds' delay to peek on gift delay task (max.: 60)	55.54 (15.46)	40.4 (24.68)	TD > HFA, $p = .044$

Aggregate inhibition score	.97 (.06)	.71 (.33)	TD > HFA, $p = .007$

Social functioning

Children in the HFA group scored significantly higher on the hyperactivity, $t(19) = 4.10$, $p < .001$, $d = 1.81$, emotional symptoms, $t(19) = 2.28$, $p = .018$, $d = 1$ and peer problems, $t(19) = 4.63$, $p < .001$, $d = 2.04$, subscales of the Strengths and Difficulties Questionnaire, as well as on the difficulties composite, $t(19) = 4.38$, $p < .001$, $d = 1.93$. There was no significant difference between the groups on conduct problems ($p = .062$), and HFA children scored significantly lower on the prosocial behaviours subscale, $t(19) = 4.06$, $p < .001$, $d = 2.04$ (See Table 3.).

Even after accounting for differences in verbal ability, inhibitory control remained a significant predictor of the total difficulties composite score, $r(10) = -.42$, $p = .018$, as well as of scores on three subscales: emotional symptoms, $r(10) = -.51$, $p = .014$; prosocial behaviour, $r(10) = -.40$, $p = .044$, and peer problems, $r(10) = -.43$, $p = .033$. The significant correlation between inhibitory control and hyperactivity was reduced to borderline significance after partialling out the effect of verbal ability, $r(10) = -.39$, $p = .051$. Because of ceiling effects in the TD group, which could have distorted correlational analyses, Pearson's r was calculated for the HFA group only.

Table 3. Parent report of social functioning on the Strengths and Difficulties Questionnaire

	TD	**HFA**	**Difference between groups**
	M (*SD*)	*M* (*SD*)	
Prosocial behaviour	7.5 (2.36)	3.22 (2.44)	TD > HFA, $p < .001$
Difficulties			
Hyperactivity	3.83 (1.03)	6.22 (1.64)	TD < HFA, $p < .001$
Emotion regulation	2.92 (0.79)	3.89 (1.17)	TD < HFA, $p = .017$
Conduct problems	6.5 (0.91)	6 (0.5)	ns, $p = .153$
Peer relations	1.58 (1.93)	5.22 (1.56)	TD < HFA, $p < .001$
Difficulties composite score	14.83 (3.69)	21.33 (2.87)	TD < HFA, $p < .001$

Interactive Drawing Test

Drawing process: One-tailed t-tests revealed no significant difference between the groups on the number of turns taken or the proportion of turns in which the participant shifted ($p = .137$) or shifted and rotated ($p = .98$) the paper.

Reciprocity: Each participant's every contribution to the drawing was rated as showing no reciprocity, basic reciprocity or collaborative reciprocity as defined by Backer-van Ommeren et al. (2012). Drawing elements that were more than 2 cm away from the experimenter's drawing were coded as 'no reciprocity', unless they were thematically related to it. If the participant drew in the vicinity (within 2 cm) of the experimenter's contribution or if their drawing showed awareness of it (e.g. they copied experimenter), the turn was coded as 'basic reciprocity'. The 'collaborative reciprocity' label was used for turns when the participant added a detail to a drawing that the experimenter had contributed to, i.e. the two members of the dyad were 'drawing something together'.

One-tailed t-tests with bias-corrected accelerated bootstrapping revealed that the proportion of 'no reciprocity' contributions was significantly higher in the HFA group, $t(17) = 3.13$, $p = .003$, $d = 1.44$. There was no significant difference between the groups on the proportion of basic reciprocity, $p = .183$. The HFA group engaged in significantly less collaborative reciprocity, $t(17) = 2.62$, $p = .009$, $d = 1.20$. After partialling out the effect of verbal ability, the correlation between inhibition and the proportion of turns with collaborative reciprocity was reduced to non-significance ($p = .188$), but the relationship between inhibition and the proportion of turns with no reciprocity remained significant, $r(10) = -.45$, $p = .037$.

Accepting partner's input: In the turns when the experimenter made an appropriate or radical (i.e. inappropriate) contribution to the participant's drawing, the participant's response was coded as accepting or rejecting. One-tailed t-tests with bias-corrected accelerated bootstrapping showed that children in the HFA group rejected both appropriate and radical contributions significantly more often than the TD controls: $t(10.95) = 3.81$, $p = .002$, $d = 1.67$ for appropriate and $t(17) = 2.03$, $p = .030$, $d = 0.93$ for radical contributions. There was no significant difference between the groups on response to radical contributions, $p = .139$. This was presumably due to the dichotomous distribution of results: participants either accepted all radical contributions (44% in the TD and 20% in the HFA condition) or rejected all, with no participant in either group accepting some and rejecting some.

Correlations between cooperation (i.e. accepting partner input and collaborative reciprocity in the IDT) and verbal intelligence, first and second-order false-belief understanding, and responding to joint attention scores were calculated in the HFA group, but none of these relationships reached significance (lowest p = .064). However, the aggregate measure of inhibition showed high correlations with accepting both appropriate input, $r(10) = .66$, $p = .002$, and radical input, $r(10) = .52$, $p = .017$, even after the effect of verbal intelligence was accounted for.

Two typical examples are provided to illustrate the difference between the performance of TD and HFA children on this task. Figure 1 shows part of a drawing created by a 9-year-old TD girl. When the experimenter added roller-skates to her drawing of a cat, she turned it into a jet-propelled sabre-toothed cat, demonstrating both acceptance of the experimenter's radical input and collaborative reciprocity. In contrast, an 8-year-old HFA boy ignored the experimenter's drawing (an upside down house) and filled the page with robots, completely disregarding the cooperative aspect of the activity (Figure 2).

Figure 1. Drawing of a 9-year-old TD girl

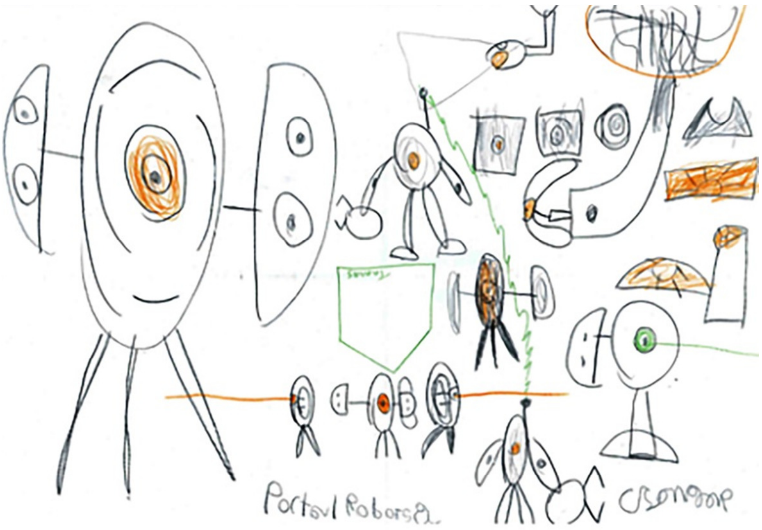

Figure 2. Drawing of an 8-year-old HFA boy

Discussion

The purpose of this study was to investigate the impact of inhibitory control on the ability to engage in a cooperative task, and on general social functioning. In accordance with our hypothesis, we found that children with HFA performed at age-typical levels on first-order false-belief understanding and joint attention, but showed impaired performance on all tests of inhibitory control. The degree of this impairment was a significant predictor of the children's ability to accept the play partner's input in a collaborative drawing task. Additionally, performance on experimental measures of inhibition was found to predict parent reports of certain aspects of social competence (emotion regulation, prosocial behaviour and peer relations) in everyday life, even after the effect of verbal ability has been accounted for.

We set out to investigate the hypothesised effect of impaired inhibition on the ability of HFA children to engage in cooperative interaction, and found that inhibition was negatively correlated with the quality of cooperation, operationalised as reciprocity and accepting the play partner's input on the Interactive Drawing Task. While the relationship between inhibitory control and reciprocity weakened once the effect of verbal intelligence was included in the model, inhibition remained a strong predictor of accepting the play partner's input. One possible explanation of this effect is that inhibitory control enables the individual to suppress their own preferences for the drawing and reach a compromise with the play partner. Accepting the play partner's contributions is strongly linked to the quality of cooperation, because without it, no activity can be truly cooperative. Our results fit a model of social impairments in which inhibition is a prerequisite of cooperative behaviour because one's own intentions and desires need to be suppressed before the play partner's contributions can be taken into account and accepted. If this interpretation is correct, the level of inhibitory control would effectively act as a limit on the extent of cooperation. In previous work with toddlers, Colombi and colleagues (2009) concluded that RJA was the underlying proximate cause of good cooperation. Importantly, however, we found no sign of impaired RJA in an older sample to explain poor cooperation. Colombi et al.'s regression model did not include any measures of executive function, so our findings represent an interesting contribution towards fully mapping out the prerequisite cognitive capacities of cooperation at different stages of social and cognitive development. Our results also highlight the importance of investigating the correlates of the capacity for cooperation across multiple stages of socio-cognitive development, because the processes underlying impaired cooperation in HFA children will likely change as new skills are acquired.

Inhibitory function was also found to be related to day-to-day social adaptation as measured by the peer relations, prosocial behaviours and emotional difficulties subscales, as well as the total difficulties score, on the Strengths and Difficulties Questionnaire. Our finding that inhibitory control is linked to parental reports of effective social functioning is in line with several previous studies that found a relationship between executive function and social adaptation (e.g. Fahie & Symons, 2003; Happé et al., 2006; Ozonoff et al., 2004; Razza & Blair, 2009). Although other researchers reported no significant relationships or relationships that were reduced to non-significance after accounting for the effect of verbal intelligence, it is likely that the equivocality of findings is, at least in part, due to methodological differences and the difficulty of investigating a link between two very broad areas (i.e. executive function and social competence), which are defined and operationalised in diverse ways by different researchers (for discussions of methodological concerns, see Hill & Bird, 2006; Russo et al., 2007).

In this study, individual differences in the level of inhibitory control naturally did not account for all the variability in performance on the IDT. Of course, inhibition is only one domain of executive control, and although the unique contributions of other executive functions to children's cooperative play is beyond the scope of this paper, this is an important area for future research. Cognitive flexibility, i.e. the ability to disengage from one cognitive set and shift to another is a particularly strong candidate as a mechanism that underlies the difficulties in social play that arise from behavioural rigidity in autism, not only because of the intuitive link between cognitive and behavioural inflexibility, but also because impairments in this domain of executive function are well documented in autism (for reviews, see Hill, 2004; Pellicano, 2011).

The typically-developing participants in our study were matched to the HFA group on chronological age, rather than verbal ability. This decision was made for two reasons. First, because our focus was on how the cooperative play of children with HFA compares to that of age-matched peers that they would interact with daily, e.g. at school. Second, because the primary measures of interest (the inhibitory tasks and the IDT) are non-verbal, and so a comparison group matched on verbal age but, presumably, of lower chronological age would have been outperformed by our HFA group, distorting the results. Nonetheless, an extended replication of this study using a TD comparison group matched on verbal mental age would be useful, not only to clarify the picture further, but also in the light of the results of a meta-analysis on inhibitory control in HFA that has been completed since the conclusion of this study (Borbely, under review). This meta-analysis showed that difference between the general cognitive ability of the HFA and TD participants was a significant predictor of effect size. When only studies that used participants closely matched on general cognitive ability were considered, the difference in inhibitory performance was substantially lower, although still significant.

Through investigating the degree of impairment in inhibitory control displayed by primary-aged children with HFA, and linking this impairment to social difficulties, both in everyday life and in an experimental task, our study represents a step towards clarifying the role of executive dysfunction in autistic symptomatology. In the model we proposed, inhibition acts as a moderator between social understanding and social behaviour. Future research regarding the relationship between executive function and social competence would benefit from a better understanding of the landscape of executive impairments in autism.

Article 3: Inhibitory control and fairness in distributive justice in autism and typical development

Abstract

There has been little research on the understanding and practice of fairness in high-functioning children with autism (HFA), but parent and teacher reports suggest a pattern of self-centred behaviour, which hinders integration and social interaction. In this study, we gauged the moral reasoning, sharing behaviour, and inhibitory control of 17 HFA children between the ages of 5 and 11, and 15 TD controls, using the Early Positive Justice Levels Interview, the Dictator Game, and a computerised Go/no-go Task, respectively. Results indicated no group difference between the children on moral reasoning or sharing, but the HFA children performed significantly worse on the inhibition task. Inhibitory control predicted acting fairly in the Dictator Game, after controlling for mental age, moral reasoning level, and theory of mind. The results lend support to a model of the judgement-behaviour gap in which impaired inhibitory control moderates the relationship between intact moral knowledge and impaired moral behaviour. The generally poorer inhibition of HFA children may play a role in their typically self-centred behaviour.

Introduction

Acquiring an understanding of fairness that is in line with prevalent norms, and learning to behave accordingly are important aspects of a child's social development, and are essential for becoming an effective social agent. Because so many personal interactions are based on explicit or implicit social negotiations, an individual without a solid understanding of conventional norms of fairness will find day-to-day social situations more difficult to navigate. Importantly, fairness also facilitates building early friendships, which are essential for social adjustment (Bauminger-Zviely & Agam-Ben-Artzi, 2014; Ladd, Kochenderfer, & Coleman, 1996), because individuals perceived as unfair can expect negative treatment from their peers (Fehr & Fischbacher, 2004; Fehr & Gächter, 2002; Yamagishi, 1986), while children as young as 3 years old show more positive attitudes towards people they witness sharing fairly with others (Ng, Heyman, & Barner, 2011), and are prepared to sacrifice a reward in order to punish those who transgress moral norms of sharing (Robbins & Rochat, 2011).

The foundations of much of the research into moral development over the past decades had been laid by of Piaget's model, first outlined in The Moral Judgment of the Child (Piaget, 1932). Piaget argued for a two-stage model, where 'heteronomy', i.e. a strict observance of externally imposed rules is transformed, through unregulated, symmetrical social interaction with peers into an internally-originating, 'autonomous' mode of moral thinking, based on sympathy, mutuality, and the recognition of reciprocal rights and duties as 'justice'. Kohlberg (e.g. Kohlberg & Candee, 1984) built on and extended Piaget's model by increasing the number of stages to a total of six and, importantly, suggesting that while earlier moral beliefs grow out of internalised societal norms, in later, more sophisticated stages, the individual's morality stems from a recognition of universal ethical principles, which may contradict current norms of behaviour (including laws). In contrast to Kohlberg's idea that all moral reasoning is based on decisions about the value of human life, Damon proposed a system of stages in the development of positive justice, i.e. the allocation of resources. He used the Early Positive Justice Levels Interview (among other measures) to investigate a progression from wishes and desires (4-5 years) through equality and reciprocity of action (5-9 years), to a context-specific morality, where decisions are based on the particular demands of the situation and people involved. Importantly, Damon concludes (1977; Gerson & Damon, 1978) that moral judgement and behaviour were only very loosely related to each other before the age of around 10.

When discussing the development of fairness, a distinction is therefore usually drawn between reasoning about it and acting upon it, because it is a well-established finding in psychology that there is no direct correspondence between a child's moral judgement in hypothetical scenarios and their behaviour in similar but practical situations when personal interest is at stake (Damon, 1977; Gerson & Damon, 1978). This discrepancy between moral reasoning and moral behaviour has been repeatedly demonstrated since the earliest of judgement-behaviour studies, e.g. when Hartshorne and May (1928) found no relationship between children's familiarity with the Ten Commandments and their behaviour in experimental situations that allowed them to cheat and lie. Although later research rarely compared moral knowledge and behaviour directly, and tended instead to focus either on reasoning about fairness (e.g. Olson & Spelke, 2008; Peterson, Peterson, & McDonald, 1975; Rochat et al., 2009) or on sharing behaviour (e.g. Almås, Cappelen, Sørensen, &

Tungodden, 2010; Benenson, Pascoe, & Radmore, 2007; Fehr, Bernhard, & Rockenbach, 2008), a comparison of findings across studies suggests that the developmental trajectories of moral thought and behaviour are indeed different. The few recent studies that tested both children's moral reasoning and their behaviour (Gummerum, Keller, Takezawa, & Mata, 2008; Smith, Blake, & Harris, 2013; Takezawa, Gummerum, & Keller, 2006) have also identified this 'judgement-behaviour gap'. Yet, systematic research into its causes has been scarce.

There is some recent evidence pointing to inhibitory control as one potential explanation for the apparent discrepancy between the level of moral reasoning and sharing behaviour. In this model, even a relatively well-developed understanding of the social norm of fairness may not manifest itself in practice because of underdeveloped inhibitory control which is not sufficiently strong for suppression of the prepotent response of acting selfishly. For example, Blake and McAuliffe (2011) found that when children between the ages of 4 and 7 were presented with unfair resource divisions that favoured them (i.e. advantageous inequity), they took longer to reject these offers than to accept them. This suggests that inhibitory control needs to be engaged to suppress the prepotent response of accepting an advantageous offer. In the same study, eight-year-olds were just as quick to reject advantageous inequity as to reject it, which may reflect the maturation of inhibition.

Inhibitory control has been linked to other aspects of competence in social interactions (e.g. Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996), and Borbely and Yuill (under review) showed that inhibitory control can predict the degree to which high-functioning children with autism (HFA) accept the contributions of a play partner in a joint drawing task. This bears a conceptual similarity to fair resource allocation, because it involves suppressing the prepotent response, which is to stick with one's own ideas. To date, however, there has only been one study that directly tested the role of inhibitory control in the judgement-behaviour gap. Smith et al. (2013) used two measures of inhibition, the Day/night Task (Gerstadt, Hong, & Diamond, 1994) and the bear/dragon task (Kochanska et al., 1996) with children aged between 3 and 8, and found that while performance on the Day/night Task was marginally correlated with fair sharing, this relationship was fully mediated by participant age. They therefore concluded that inhibition was not linked to the ability to act fairly in a resource allocation paradigm. The fact that there was no significant relationship in this study between performance on the two inhibition tasks ($r = .24$, $p = .07$), however, calls into question whether either of them was a reliable measure of the construct of interest in this sample. Thus, the question of whether inhibitory control contributes to the judgement-behaviour gap remains unanswered.

The case of children with HFA represents an interesting opportunity to put the inhibitory model of the judgement-behaviour gap to the test because such children commonly display difficulties in both inhibition (Hill, 2004; Pellicano, 2011; Borbely & Yuill, in preparation) and in various aspects of social interaction (American Psychiatric Association, 2013). Although there has been very little research on the understanding and practice of fairness in autism (for an exception, see Sally & Hill, 2006), anecdotal evidence strongly suggests that children with autism struggle in social situations that involve sharing and their resource allocation decisions tend to be dominated by self-interest. Investigating the moral reasoning and behaviour of children with HFA also makes it possible to evaluate an alternative explanation for the judgement-behaviour gap, namely a mentalising model, which assumes that acting unfairly reflects the individual's failure to take into account other people's interests, needs, and mental states.

This mentalising account rests on the finding that selfish behaviour seems to be due, at least in part, to a consideration of what one can 'get away with'. According to this interpretation, selflessness stems, at least in part, from the recognition that selfish acts will be punished by others. For example, the average offer is consistently higher in Ultimatum Games than in Dictator Games (40 per cent and 25 per cent, respectively) (for reviews, see Camerer, 2003; Oosterbeek, Sloof, & Kuilen, 2004). In the latter, the participant can make a unilateral decision about sharing a pool of resources with a partner. The Ultimatum Game, however, allows the partner to reject the share offered, in which case neither party receives anything. The threat of retaliation evidently encourages fair behaviour (Fehr & Gächter, 2002). In an innovative setup that allowed participants to act unfairly in the UG without fear of punishment because some of the coins were only visible to the proposer, Overgaauw et al. (2012) showed that strategic considerations start playing a part in acting fairly at an early age. All participants offered fewer coins when the recipient could not see all of them, but there was an interaction between age and condition: adult participants and children aged 10 to 12 acted more strategically than 8- to 9-year-olds, whose offers in the typical and hidden conditions tended to be less different.

Mentalising ability, i.e. the capacity to predict the play partner's reactions to one's own actions, has been shown to be linked to fairness in typical development (e.g. Takagishi, Kameshima, Schug, Koizumi, & Yamagishi, 2010). The impaired ability of individuals with autism to simulate their reputation in others' eyes could therefore explain why they are more prone to acting selfishly. Izuma et al. (2011), for example, found that whereas TD adults donated significantly more to charity when they knew they were being observed, there was no such difference in a group of 10 adults with ASD. In the presence of an observer, both groups performed better on a test of executive function, suggesting intact general social facilitation in autism. Cage et al. (2013) replicated these results, but also refined them by showing that when the participants believed the observer was the recipient of their donations, and would later have the opportunity to reciprocate, adults with ASD also donated more, although the difference was not as large as in the TD group. Taken together, these results suggest that adults with ASD do not spontaneously manage their reputations in sharing situations, but are capable of doing so, although to a lesser extent than TD peers, when they have a vested interest in doing so.

There has been only one study so far that put this hypothesised link between theory of mind and fairness to the test in children with autism (Sally & Hill, 2006), and it has not shown a clear link between the two constructs. Sally and Hill found that although children with HFA were impaired on both first-order and second-order theory of mind, their offers in the Ultimatum Game were not significantly different from those of their typically-developing (TD) peers. These results cast some doubt on the explanatory power of the mentalising account for the judgement-behaviour gap. In our study, we set out to evaluate the hypothesis that inhibition moderates the relation between moral knowledge and moral behaviour in resource allocation decisions. We used a sample of primary school children, both typically-developing and with high-functioning autism, because previous research suggests this is a period of transition, from strictly egalitarian to equity-based thinking (Hook & Cook, 1979). We combined the moral reasoning and resource allocation paradigms to directly gauge the gap between children's understanding and practice of fairness. We expected that this difference would be stronger in the children with HFA than in an age-matched TD comparison group, because children with autism typically show underdeveloped inhibitory control for their mental age (Geurts et al., 2014).

In order to be able to also test a mentalising account of the judgement-behaviour gap, we assessed the participants' theory of mind (operationalised as false-belief understanding and the ability to attribute situation-specific emotions to others). A hierarchical regression model was used to identify the best predictors of fair sharing, allowing us to directly compare and evaluate the mentalising and inhibitory control accounts of the judgement-behaviour gap.

In what is the first direct comparison of moral reasoning and sharing behaviour in children with HFA, we set out to test three hypotheses pertaining to an inhibitory control model of the judgement-behaviour gap. As previous research on other aspects of moral reasoning in autism have been inconclusive as to whether this capacity is impaired, we made no predictions regarding how the moral reasoning of children with HFA about fairness would compare to that of age-matched TD peers but, in line with previous research, we expected children with HFA to show impaired performance on tests tapping into the ability to inhibit a prepotent response. Secondly, we hypothesised that the severity of this impairment would predict the degree of unfairness in distributive justice and thirdly, therefore, expected that children with HFA would make more unfair decisions (favouring themselves over the recipient) than children in the TD comparison group in a Dictator Game framed as a reward allocation task. We also evaluated a mentalising account of the judgement-behaviour gap, but made no predictions as to whether fairness in resource allocation would be associated with theory of mind.

Method

Participants and power

Seventeen high-functioning children with autism (13 males), between the ages of 5.25 and 10.83 (M = 8.40, SD = 1.62), and fifteen typically-developing children (8 males), between the ages of 7.42 and 10.75 (M = 9.03, SD = 1.14) participated in this study. For the purposes of eligibility to participate, 'high-functioning' children were defined as those without a comorbid diagnosis of a learning disability or other developmental disorder, and including those with a diagnosis of Asperger syndrome and pervasive developmental disorder not otherwise specified (PDD-NOS). Three additional participants with HFA had been recruited but excluded from the analysis because they did not complete all experimental tasks. Participants in the HFA group were recruited from play schemes for children with special educational needs and through autism charities. All the children in this group had a diagnosis of high-functioning autism, and no other developmental disorders (e.g. ADHD). The TD children were recruited from local primary schools and play schemes. Four participants in the HFA group had also taken part in an earlier, unpublished study on the role of inhibitory control in cooperation.

Six children with HFA were of Hungarian nationality, and tested in Hungarian by a native speaker (the first author). There was no difference between the English and Hungarian participants on any of the variables measured in this study (lowest $p = .111$), and so the two groups were analysed together.

In a previous study that compared the performance of TD children and children with HFA on a battery of inhibition tests (Borbely & Yuill, in preparation), a substantial impairment was found in the autism group on all measures (Cohen's *d*'s ranging between 0.74 and 1.1). Using the average of these effect sizes (0.88) as a guide, an a priori power calculation showed that the power of groupwise comparisons on inhibition in our current study (with 32 participants) would be near 0.80.

Measures

Verbal ability

As the articulation of moral knowledge requires verbal skills, the participants' linguistic ability was gauged with the British Picture Vocabulary Scales-I (Dunn & Dunn, 1982), which provides standardised scores and verbal mental age equivalents. The verbal ability of all Hungarian participants had been recently (i.e. within 12 months) assessed using the Wechsler Intelligence Scale for Children (WISC-IV, Wechsler, 2003), so they were not re-tested.

Emotion attribution and false-belief understanding

In order to ascertain whether the participants could attribute situationally adequate emotions to others and, therefore, understand the potential consequences of their resource allocation decisions (see below) on another child's mental states, a subset of the emotion prediction tasks described by Harris and collaborators (1989) was administered.

The participants were introduced to a toy animal that had a strong preference of snack: "This is Bruno the Bear. His favourite snack is honey. He really doesn't like chocolate, only honey.” Understanding of the preference was checked by asking “If Bruno can choose between having honey and chocolate for lunch, which one will he choose?” All children identified the correct snack at this stage.

In the first part of the emotion attribution task, the participants were asked how Bruno would feel (happy or sad) if he got honey or chocolate for lunch (presented in a counterbalanced order). In the second part of this task, a neutral container was presented, along with the following story and questions:

> “Bruno the Bear wants a snack so we’re going to give him one. It’s here in this box. Bruno doesn’t know what’s inside the box but he’s wondering what’s inside. What if Bruno thinks there’s honey inside? Will he be happy or sad if he thinks we’ve given him honey? Now, Bruno is wondering what’s inside the box, but remember, he doesn’t know yet what’s inside. Oh look, it’s chocolate! So is Bruno happy or sad now?”

The same props were also used for testing false-belief understanding through a task similar to the Sally-Ann (Baron-Cohen et al., 1985) story. Mickey the Monkey was introduced and shown to replace the contents of a box of honey (the preferred snack) in Bruno’s absence. The participants were asked to predict Bruno’s emotional response (happy or sad), first on seeing the container, and then on opening it and finding the dispreferred snack (chocolate) inside.

Moral reasoning

In the first part of this test, the participant’s ability to make fair decisions and reason about morality in resource allocation was tested using the Early Positive Justice Levels Interview. This interview was designed by Damon (1977), and consists of a series of hypothetical situations. In the first scenario, primary-school children sold paintings they had produced, and made various claims to a larger than equal share of the profits based on their effort, gender, age, good behaviour, the quality of their work, and need. In the second scenario, a teacher had to choose between rewarding a gifted but lazy pupil or another, who was hard-working but struggled with the curriculum. The third situation concerned the participant sharing toys with a friend during a play date. In each of these scenarios, the participant was invited to give their opinion on how the resources (money, good marks, or toys) should be allocated, and to evaluate the claims of each child in the story. The participants' responses were recorded and scored using Damon's (1977) coding scheme, which is summarised below in Table . Inter-rater agreement was calculated on 20 per cent of the sample, and Cohen's kappa (with linear weighting to account for the ordinal nature of the dependent variable) indicated a high level of reliability on this measure (κ = .92).

As per Damon's (1977) original procedure, the participants' responses on the Early Positive Justice Levels Interview were scored in chunks, with each chunk consisting of an utterance or group of utterances conveying a coherent idea or meaning. A composite score for each participant was obtained by taking the highest level of moral reasoning demonstrated during the interview. According to Damon, this 'best performance' approach allows the child to fully demonstrate their reasoning ability by, for example, disregarding impulsive first answers if a more reasoned and more sophisticated one follows later.

Table 1. Coding scheme for the Early Positive Justice Levels interview (excerpt, based on Damon, 1977)

Lvl	Focus of reasons given	Conflict	Resolution of conflict	Characteristics of reasoning
0-A	**own desire**	self's desire vs obstacles to fulfilling it	**assimilating** other's and own **desires**	no objective reasons; reassertion of desire
0-B	**self-serving but external** characteristics rudimentary reciprocity (impression management)	self's desire vs other's desires	**preferential treatment** of self and liked others	external, observable facts; fluctuating and post-hoc arguments
1-A	**equal shares** in all circumstances	person vs person; self-interested equals no weighing different claims against each other	**equal treatment**; no mitigating circumstances allowed	reference to parties' self-interest; prevention of fighting; unilateral and inflexible
1-B	**reciprocal actions / deserving**; notions of merit and fair exchange; sense of obligation in exchange of reward	deserving claims vs more deserving claims; merit is sole basis of deserving	**differential treatment based on merit**; reward a direct payback for work (achievement, talent, effort)	notions of reciprocal obligation; inflexible, reciprocity is absolute as was equality in 1A
2-A	plurality of acceptable justice claims; equality of persons rather than acts; **equality of outcomes**; compromise between claims, not direct resolution	plurality of disparate claims	**compromise** (often quantitative); need often given special consideration to ensure equal outcome	moral relativity; each party is right 'in a way'
2-B	**situationally flexible**; reject situationally irrelevant claims; realising decision can serve various ends; decision based on most appropriate goal	plurality of disparate claims	**exclude all but best claim**; respect all claims but arrive at definitive judgement as per situational goal	integrating reciprocity (merit, fair exchange) and equality (needs, equal acts) in a way that allows differential application in different contexts

Inhibitory control

The battery of tests gauging the ability to inhibit a prepotent response was presented as a production task: participants were informed that they would be earning points based on their performance, which they could exchange for toys at the end of the experimental session.

In a computerised *Go/no-go Task*, different images of cats and robots (five cartoon drawings and five photos each) were presented in a random sequence on a 15″ laptop screen for 500 ms each, with an inter-stimulus interval (ISI) of 1000 ms. The participants were instructed to press the space bar for cats, and to refrain from any action on the robot trials. After ten practice trials, in which there was an equal number or cat and robot pictures, the participants completed fifty trials, 80 per cent of which were cat ("go") trials and the remaining 20 per cent, robot ("no-go") trials. At the end of the task, a message was displayed that told participants, regardless of performance, that they had done "very well".

A spatial conflict task was also administered as another test of inhibition, but analysis of preliminary results suggested that this had proven too difficult for the participants, with over half of the trials missed ($M = 58.94\%$; $SD = 17.05\%$). There was no difference between the TD and HFA groups on the proportion of trials missed ($p = .624$). Consequently, no further analyses were conducted for the participants' performance on this test.

Sharing (Dictator Game)

At the conclusion of the tests of inhibition, children were presented with a picture of an unknown child, matched on age and gender, and were told that the second child had also completed the production task (i.e. the computerised tasks), but had not received their reward yet, and now it was up to the participant to divide rewards between themselves and the other child. The experimenter produced ten poker chips, each of which was exchangeable for a small toy of the participant's choice. Two paper bags, labelled with the participant's and the other child's name, were provided to place the poker chips in. The participant was informed about the other child's performance on the production tasks: the results were rigged in a manner that the other child always outperformed the participant by 50 per cent (60 points to 40), but the participant was explicitly told that they could divide the rewards in any way they liked, including keeping all tokens. The experimenter left the table while the resource allocation decision was made.

Procedure

After obtaining informed consent from the parents and assent from the participants, the tests were run individually by the first author. All participants were tested in a quiet room of their choice in their homes (i.e. the Hungarian participants were tested in Hungary and the British participants, in England). Assessment of verbal ability was followed by the Early Positive Justice Levels Interview. The tests of the inhibitory battery were completed in the above order. The experimental session was concluded with the resource allocation task (Dictator Game). Overall, each experimental session lasted between 40 and 50 minutes, with no breaks between the tasks. Comfort breaks were offered to the children, but none of them took one.

Results

Descriptive statistics

There was no significant difference between the groups in the distribution of genders, Fisher's exact test $p = .266$, or on chronological age, $t(30) = 1.26$, $p = .219$, $d = 0.45$. The TD group had significantly higher verbal IQ ($M = 112.07$, $SD = 11.07$) than the HFA group ($M = 99.29$, $SD = 16.17$), $t(27) = 2.50$, $p = .019$, $d = 0.93$.

Mentalising ability

Every child completed the belief-based emotion attribution task successfully, i.e. they were all able to understand that being deceived in one's expectations and receiving a non-preferred outcome would make one disappointed ('sad').

One of the TD children (7%), and five of the HFA participants (29%), however, failed the first-order false-belief task; Fisher's exact test showed that although children with HFA found this task more difficult than their TD peers, the difference was not significant, $p = .178$.

Inhibitory control

Performance on the Go/no-go Task was quantified using Grier's (1971) formulation of a nonparametric measure of sensitivity (A') proposed by Norman and Pollack (1964), calculated using the following formula:

$$A' = 0.5 + \frac{(H - FA)(1 + H - FA)}{4H(1 - FA)}$$

where H is the probability of a correct response on a 'go' trial (i.e. a 'hit'), and FA is the probability of an incorrect response on a 'no-go' trial (i.e. a 'false alarm'). An A'

value of 0.5 reflects chance performance, and 1 corresponds to perfect sensitivity on the task. The TD group performed significantly better on this measure (*M* = .81, *SD* = .12) than the HFA group (*M* = .71, *SD* = .08), *t*(30) = 2.88, *p* = .007, *d* = 1.02.

A point-biserial correlation revealed no significant association between performance on the false-belief task and *A′* scores, *r*(30) = .07, *p* = .723.

Moral reasoning

There was no significant difference between the groups on the highest level of moral reasoning demonstrated in the Early Positive Justice Levels Interview, *t*(30) = 1.35, *p* = .187, *d* = 0.48. The median level attained was 2A in both groups, which was also the mode. (See Figure 4.)

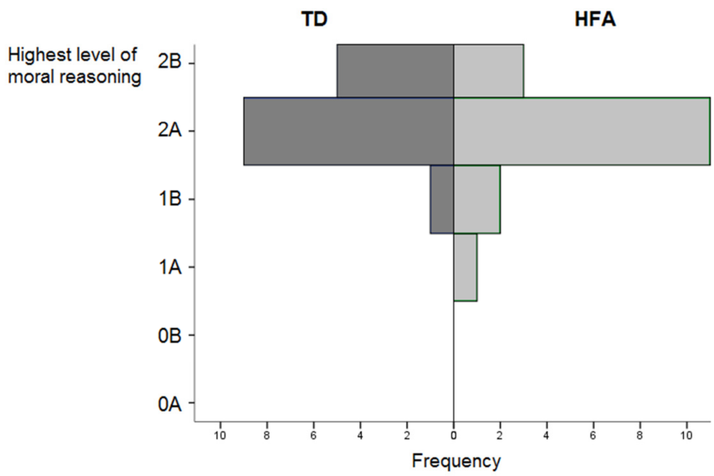

Figure 4. Highest level of moral reasoning demonstrated in the EPJLI

Quotes from the participants demonstrating each level of moral reasoning are given for illustration in Table 2 below.

Table 2. Examples of reasoning in the Early Positive Justice Levels Interview

Level	Focus of reasons given	Typical examples
0-A	**own desire**	"I wouldn't give any of these toys to my brother because I never share with him." "I should have the most cake because it's fun to be able to eat a lot of cake."
0-B	**self-serving but external** characteristics rudimentary reciprocity (impression management)	"Boys should get more [money for their paintings] because they are better at football." "Children should get more than adults."
1-A	**equal shares** in all circumstances	"Everyone should get the same [amount of money] because getting more than others is greedy." "If someone got more than others, there would be a fight in tha class."
1-B	**reciprocal actions / deserving**; notions of merit and fair exchange; sense of obligation in exchange of reward	"The teacher should be able to keep all the money because it was her idea to draw the pictures in the first place." "It's okay not to share with someone if he hasn't shared with you before because you're just doing to them what they did to you."
2-A	plurality of acceptable justice claims; equality of persons rather than acts; **equality of outcomes**; compromise between claims, not direct resolution	"Everyone should get the same, but the poor classmate should get a bit more because he has less toys than the others at home." "They should give all the money to charity, because some people don't have as good opportunities as them."

2-B	**situationally flexible**; reject situationally irrelevant claims; realising decision can serve various ends; decision based on most appropriate goal	“Fairness means everyone gets the same. Kindness means you give more to those who need more.” “[When deciding how much money the children get] the question is if it was a competition. If they did it together, they should split the money equally. But if everyone worked on their own, then they should get what they earned.”

Sharing in Dictator Game

The result of the production task was rigged so that the play partner always outperformed the participant by 50 per cent (i.e. achieving 60 points to the participant’s 40). Therefore, keeping four tokens corresponds to proportional equity, while keeping five represents an egalitarian division. Keeping more than five or fewer than four tokens is not justified under conventional interpretations of fairness (labelled ‘selfish’ and ‘generous’, respectively, on the chart below). The tokens were exchangeable for small toys at the end of the experiment. One HFA child declined to split the tokens because he was not interested in any of the rewards available.

The difference between the average number of tokens retained by children with HFA ($M = 5.63$, $SD = 2.06$) and by TD children ($M = 5.40$, $SD = 0.91$)was not significant, $t(29) = 0.39$, $p = .701$, $d = -0.14$. (See Figure 5.)

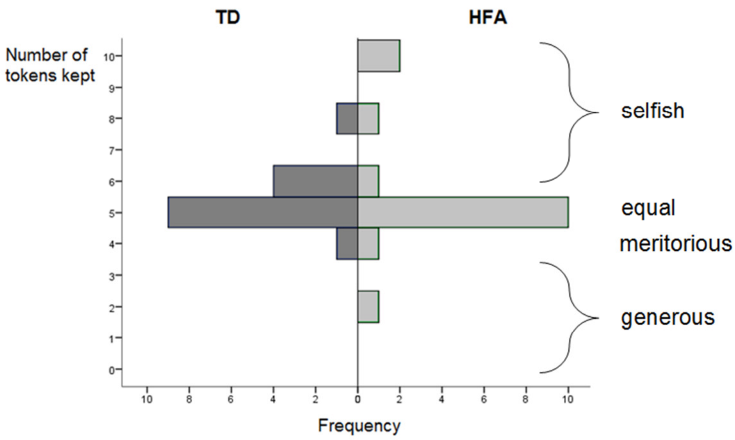

Figure 5. Number of tokens kept in the Dictator Game (out of 10)

Predictors of fair sharing

A hierarchical regression was performed in two steps. The first model included verbal mental age and diagnosis. Theory of mind (operationalised as false-belief understanding and emotion attribution) awas not included in the model because of the lack of variance in performance on both tasks. None of these variables was a significant predictor of the number of tokens kept by the participants in the Dictator Game. In the second step, level of moral reasoning and inhibition (performance on the Go/no-go Task) were entered, and the latter emerged as the sole predictor of fair sharing. (Standardised betas and associated significance levels are shown in Table 3 below).

Table 3. Hierarchical regression on number of tokens kept in Dictator Game

	β	***p***
Step 1		
Verbal mental age	-0.29	.184
Diagnosis	-0.05	.806
Step 2		
Verbal mental age	-0.32	.105
Diagnosis	-0.33	.121
Moral reasoning	0.11	.567
Inhibitory control	-0.632	.004**

Model 1: $F(2,26) = 1.00$, $p = .380$; R^2: .07

Model 2: $F(4,24) = 3.28$, $p = .028$; ΔR^2: .35

Discussion

We set out to evaluate the inhibitory control account of the judgement-behaviour gap, both in typical development and in children with HFA. To this end, we used a hierarchical regression model to identify predictors of self-interested sharing behaviour in a Dictator Game, using age, diagnosis, theory of mind, level of moral reasoning, and inhibitory control as potential predictors. Of these, only inhibition had a significant association with the number of tokens shared.

In this study, children with HFA demonstrated age-typical levels of moral reasoning in the Early Positive Justice Levels Interview and, similarly to the age-matched TD comparison group, mostly elected to share resources equally with an unknown child in a Dictator Game. When compared to TD participants, children with HFA had an uneven performance profile on theory of mind tests: a substantial minority of them were impaired on a first-order false-belief task, but they could all attribute situationally appropriate emotions to others. Performance on a measure of prepotent response inhibition (the Go/no-go Task) was significantly worse in the HFA group.

In order to investigate the understanding of fairness in children with HFA in primary school, a research area that has received little attention so far, we used the

Early Positive Justice Levels Interview (Damon, 1977) to gauge moral reasoning, as well as a Dictator Game to assess moral behaviour (sharing). We also measured inhibitory control and mentalising so as to test an explanatory model of the judgement-behaviour gap, in which poor inhibitory control moderates the relationship between moral reasoning and moral behaviour. We found that neither level of moral reasoning, nor mentalising ability, nor verbal mental age predicted fair sharing; a perhaps counterintuitive finding that is, nonetheless, in line with previous studies in this field (e.g. Gummerum et al., 2008; Sally & Hill, 2006; Smith et al., 2013), providing further evidence that moral reasoning and moral behaviour develop along similar, but distinct trajectories. In line with the prediction of the inhibitory control account of the judgement-behaviour gap, however, performance on the Go/no-go Task emerged as a significant predictor of the number of toys children were prepared to give away to a deserving stranger.

Earlier studies (e.g. Takagishi et al., 2010) found a relationship between fairness and theory of mind in preschool children. The participants in our study were considerably older, and despite the well-documented difficulties in mentalising associated with autism, nearly all completed both theory of mind tasks (i.e. false-belief understanding and emotion attribution) faultlessly. Because of the lack of variance in theory of mind scores, they could not be entered into regression analysis. Future research should investigate whether using more challenging tasks, which require more sophisticated mentalising and are thus able to differentiate between typically-developing children and those with HFA could cast light on the unique contributions of theory of mind and inhibitory control to fairness in action.

Our finding that inhibition moderates the link between social knowledge and social behaviour is in contradiction with Smith and colleagues' (2013) results, who found in a sample of TD children between the ages of 3 and 8 that although performance on a measure of inhibition predicted fair sharing, this relationship was fully mediated by participant age. We offer two tentative explanations for this disagreement between the two studies. Firstly, our sample included a mix of TD children and children with HFA, who were also, on average, older than in the Smith et al. study. The discrepancy therefore might be due to a wider range in the participants' inhibitory control. Secondly, there is increasing evidence that variation in the details of administering an experimental task, such as the modality of stimuli or choice of dependent variable (e.g. reaction time or accuracy) have a substantial and unintended impact on inhibitory performance (Hill & Bird, 2006). Recent meta-analyses on inhibitory control in autism by Borbely (submitted) and Geurts at al. (2014) have identified substantial variation in effect sizes after participant age, cognitive capacity, and experimental paradigm had been controlled for, suggesting that understood task characteristics which are as yet poorly understood can lead to mistaken conclusions about the inhibitory performance of children with autism. In the Smith et al. study, there was no significant correlation between performance on the two tests of inhibition administered, and only one was related to fair sharing. Further research is needed to investigate whether the correlation between inhibition and moral behaviour is specific to certain subdomains of inhibitory control, tapped into by some measures, but not others.

We had made no predictions as to any differences between the level of moral reasoning shown by HFA and TD children because earlier results had been inconclusive: while some researchers reported that the moral judgement of children with HFA was at an age-typical level (e.g. Grant, Boucher, Riggs, & Grayson, 2005; Leslie, Mallon, & Dicorcia, 2006; Li, Zhu, & Gummerum, 2014), others found evidence for an impairment (e.g. Moran et al., 2011; Takeda, Kasai, & Kato, 2007; Zalla, Barlassina, Buon, & Leboyer, 2011). While TD children and children with HFA demonstrated similar levels of reasoning about fairness in our sample, this does not explain the diversity of findings, and we tentatively suggest that it may be due to methodological differences or sampling error, calling for a systematic review of the relevant studies to conclusively answer the question whether moral reasoning is impaired in HFA.

While children with HFA tended to make more ‘selfish’ decisions than their TD peers in the resource sharing task (Dictator Game), this difference also failed to reach significance. This latter result is in line with the only previous study on fair sharing in autism (Sally & Hill, 2006), which found a similar but also non-significant difference between the size of offers made by TD children and children with HFA in a strategic resource allocation game. Further research is needed, however, to ascertain whether failure to find a significant difference is due to Type II error; achieved power in the current study was only .27 for this comparison. Another possible explanation for the lack of a group difference may lie in the TD children’s deliberate ‘underperformance’ on this task, as explained below. There is a substantial body of earlier research (for a review, see Hook & Cook, 1979) suggesting that from around the age of six, children make sharing decisions based on ordinal equity, rather than strict equality, therefore we expected the TD children to prefer an equity-based decision over a less sophisticated, egalitarian split, but this was not the case. In our study, the overwhelming majority of children in both groups split the rewards equally between themselves and another, even though the other child had substantially outperformed them on the production task. It might be a mistake, however, to interpret this action as a failure on their part to apply the principle of merit in reward allocation. In fact, a substantial majority of the TD children argued in the positive justice interview that effort, rather than performance, should be rewarded. Following this line of reasoning, getting fewer points on the production task is no reason to receive a smaller share of the rewards because the poorer performer is no less deserving, as long as they 'did their best'. The TD children's choice to reward themselves for effort with an equal split, and thus, potentially, not to demonstrate the best of their ability on our measure of acting fairly may have masked an existing difference between the groups on sharing behaviour. This is an important consideration for future research because a failure to appreciate the underlying motives of the participants can make a sophisticated resource-allocation decision appear as selfish behaviour, and thereby confound the interpretation of the results. Strategic games are very widely used in the research or moral decision-making for their simplicity and adaptability, but care must be taken when explaining behavioural results in terms of psychological processes that have not been gauged directly.

Our results support the inhibitory control model of acting fairly, but the study suffers from two weaknesses that must be considered: a small sample size and a question over the reliability of the measures of inhibition. The issues arising from the small sample will be considered first. While the power of our study was adequate for detecting the large effect we expected on the basis of previous research (see in Method, above), our non-significant findings (such as no difference in moral reasoning and sharing behaviour between the TD and HFA participants) must be treated with caution, as the achieved power of our study for a medium-sised effect (Cohen's $d = 0.5$) is .46, which is very low, although regrettably typical for psychological research (Schmidt & Hunter, 2003). Additionally, point estimates (i.e. effect sizes) are provided in line with current best practice, but it must be noted that they can only serve as very rough approximations. This is an unfortunate, but inevitable fact, because in order to specify Cohen's *d* for a medium-sised effect even to just the first decimal (i.e. within +/- .05), over six thousand participants would need to have been tested (Hunter & Schmidt, 2004).

The other difficulty in interpreting our results originates from the uncertainty inherent in the measurement of inhibition. There is considerable disagreement among researchers over the comparability of the various tests of inhibition (Hill & Bird, 2006; Hill, 2004; O'Hearn, Asato, Ordaz, & Luna, 2010; Russo et al., 2007). There are few studies that have directly tested whether performance on different measures of inhibition is comparable, and their results are equivocal. For example, Smith and collaborators (2013) found a non-significant correlation between performance on the day/night and the bear/dragon tasks, but in an earlier study (Borbely & Yuill, submitted) we found significant correlations ranging from .51 to .79 between four measures of inhibition (the Bear/dragon, Go/no-go, Gift Delay, and Windows Tasks). Recent meta-analyses (Borbely & Yuill, under review; Geurts et al., 2014) suggest that while children with HFA show impairments on all commonly used measures of inhibition, the degree of this impairment varies across tests. In an effort to eliminate this problem, we used two tests of prepotent response inhibition that have a similar structure: a Go/no-go Task and a spatial conflict task. Unfortunately, although the tasks were successfully piloted on a small number of children, the participants in our study struggled with the latter, leaving performance on the Go/no-go Task as the sole indicator of their inhibition. As a result, further research is required to confirm whether the relationship between inhibition and fair sharing that we found in this study would generalise to other tests of inhibition.

Mentalising ability was measured in this study through two tasks: a (first-order) false-belief task and an emotion attribution task. These were chosen because they tap into the ability to attribute cognitive and emotional states to others that are different from the individual's own, which is a prerequisite of being able to evaluate the impact of one's actions on others, and thus acquire an understanding of fairness. The other consideration when selecting these tasks was their simplicity: understanding and following the instructions does not require a level of cognitive ability that would not be expected from our participants, and therefore failure on the tasks could confidently be attributed to impaired theory of mind, rather than to poor verbal ability, for instance. This strength is also weakness, however, because participants in both groups achieved near ceiling-level performance on both tasks. In future replications, more difficult tasks, tapping into more sophisticated aspects of mentalising ability should be included to more extensively map out the contribution of theory of mind to unfair behaviour.

These caveats notwithstanding, our study contributes to the investigation of moral development of primary school children, both in autism and in typical development, through providing evidence for a novel account of the judgement-behaviour gap, in which inhibitory control moderates children's ability to act on their social knowledge. Although theory of mind had previously been identified as a predictor of fair sharing in typically-developing children aged 5 to 6 (Takagishi et al., 2010), we found no evidence for this link, either in our sample of older typically-developing children, or in the HFA group, which is in line with previous work on fairness in autism (Sally & Hill, 2006). Our results also have methodological implications inasmuch as they highlight the importance of interrogating motivation in research into moral decisions, even if a strictly behavioural paradigm, such as a strategic game, is used, because important developmental differences may otherwise be masked by the limited number of action options.

Article 4: 'I prefer playing together, but sometimes I wish my brother would just disappear' – Typically-developing children's experience of cooperative play with their autistic sibling

Abstract

Cooperative play has a range of developmental benefits, which high-functioning children with autism (HFA) cannot fully enjoy because of well-documented impairments in various aspects of social interaction. This also means that in families with more than one children, the typically-developing (TD) sibling will be exposed to atypical play. In this study, we qualitatively investigated TD children's experience of engaging in cooperative play with their sibling who has a diagnosis of HFA. Six children between the ages of 5 and 11, who had a HFA sibling in the same age range were interviewed, and their reports analysed using interpretative phenomenological analysis (IPA). Five themes emerged: poor emotion regulation, restricted interests, and no acceptance of the playmate's contributions reduced the hedonistic value of joint play for the participants, but these were mitigated by appreciation for the HFA sibling's creativity and adjustment to the HFA sibling's behavioural atypicalities. Results are discussed in terms of their relevance for developing support programmes for TD siblings and social skills training for HFA children.

Introduction

Autism spectrum disorder (ASD, autism) affects not only the approximately 1 in 88 children who have the diagnosis (Baio, 2012), but also those they are in daily contact with, including classmates, parents, and siblings. As around 80 per cent of people in Europe and the United States grow up in a family with more than one children (Dunn, 2002), and the prevalence of autism has been rising dramatically in recent decades (Boyle et al., 2011), partly as a consequence of earlier diagnosis, meaning that a large number of typically-developing children spend their most formative years with a sibling who has a diagnosis of autism.

Sibling relationships have a profound impact on children's development: they are often the most long-lasting relationships in a person's life, and their quality had been linked to various aspects of social and cognitive development, such as socio-emotional understanding (Herrera & Dunn, 1997; Howe, Aquan-Assee, Bukowski, Lehoux, & Rinaldi, 2001) and adjustment problems (Patterson, 1986). A positive sibling relationship can be a valuable source of social support, and has been linked to lower levels of loneliness and conduct problems, as well as a stronger sense of self-worth (Stocker, Burwell, & Briggs, 2002).

Although having a sibling with any kind of disability or developmental disorder poses challenges to the TD child (Ferraioli & Harris, 2009; Seltzer, Greenberg, Orsmond, & Lounds, 2005), the decidedly social nature of the impairments that define autism, and particularly the deficits in developing, maintaining, and understanding interpersonal relationships (American Psychiatric Association, 2013) represents a heightened risk factor for poor sibling relationship quality. For example, in dyads of siblings, one of whom had a diagnosis of autism, Knott et al. (1995) observed less frequent and more impoverished interaction and imitation than in TD pairs. Indeed, some research suggests that having a sibling with autism may have enduring negative effects on development: children with a sibling who has autism are more likely than those with a TD sibling to develop internalising behaviour problems (Ross & Cuskelly, 2006), have poorer social and behavioural adjustment (Orsmond & Seltzer, 2007; Verté, Roeyers, & Buysse, 2003), and fewer friends (Bågenholm & Gillberg, 1991). This effect is magnified by the presence of any demographic risk factors (Macks & Reeve, 2007).

Previous research on the quality of sibling relationships between TD children and children with autism suggests that they are characterised by a unique set of difficulties and strengths. For example, McHale, Sloan, and Simeonsson (1986) interviewed TD siblings of children with autism, of children with Down’s syndrome, or of other TD children, and found no group differences in the reference children’s reports of sibling relationship quality, with all three groups giving generally positive ratings. In Bågenholm and Gillberg’s (1991) study, however, siblings of children with autism reported less positive attitudes towards their sibling and rated their sibling’s role in the family more negatively than siblings in the comparison groups (i.e. siblings of TD children and of children with a learning disability). This discrepancy may be due to a broader spectrum of experiences in families where one of the children has a diagnosis of autism: while McHale et al. (1986) reported no overall group difference in sibling relationship quality, they pointed out the substantially higher variability of children’s ratings in the autism and Down’s syndrome groups. A large number of reference children had either a very positive or a very negative view of their sibling relationships. Kaminsky and Dewey (2001) found that the sibling relationships of children with autism were characterised by less intimacy, prosocial behaviour, and nurturance, compared to where one of the siblings had a learning disability, or both were TD. On the other hand, the TD siblings of children with autism reported higher levels of admiration for their sibling, along with less fighting and rivalry than TD dyads. Other studies (e.g. Konidaris, 1997), however, suggest that although sibling relationships are typically ambivalent, they may be even more so when one of the children has autism, because of the often unpredictable and violent behaviour (aimed at the self or others) displayed by these children.

Although there is a rich literature on the sibling's perspective of living with autism, one area that has received unduly little attention is that of cooperative (social) play between the siblings. This is unfortunate, because cooperative play has numerous developmental benefits (e.g. Gagnon & Nagle, 2004). For example, repeated opportunity to practise social skills in the context of cooperative play has been linked to increased social competence (Newton & Jenvey, 2011). Playing with the TD sibling also provides the child with autism with a safe 'training ground', where social skills can be practised and transgressions are more likely to be tolerated and forgiven. The behavioural profile of autism, however, especially the well-documented impairments in imaginative play, restricted interests, and behavioural inflexibility can mean that both the child with autism and their TD sibling miss out on these developmental opportunities, because social play requires cooperation, adaptation, and sharing (Creasey, Jarvis, & Berk, 1998) that the sibling with autism may be unable to offer.

TD siblings are ideally positioned to offer insight into what makes play interactions successful or break down, because they are typically the most frequent playmates of their sibling with autism and because the everyday experience of living with autism allows them to develop a better understanding of the difficulties associated with the disorder (Powell & Gallagher, 1993). El-Ghoroury and Romanczyk (1999) compared the play of children with autism when the play partner was a parent or a (TD) sibling. They found that although siblings made fewer attempts to engage with the child with autism than did the parents, these overtures were more often successful, making the siblings more effective play partners overall. The study of the TD sibling's experience of cooperative play with their autistic sibling can therefore have important implications for the development of both social skill training interventions and support programmes for the families of children with autism.

The goal of this study was to explore TD children's experience of engaging in cooperative play with a sibling who has a diagnosis of high-functioning autism, with a view to identifying behavioural patterns that hinder smooth and mutually rewarding interaction between the children. Although our theoretical understanding of the social impairments that make cooperative play challenging to children with autism is relatively sophisticated, the objective of this research was to gain an in-depth understanding of the diverse positive and negative aspects of the complex and varied interactions collectively referred to as 'playing together'. For this, a qualitative approach was deemed most appropriate, and interpretative phenomenological analysis (IPA) in particular, because of its focus on the lived experience of the individual. IPA is ideally suited to the study of personal and complex issues (Smith, 2004) with a focus on the participant's interpretation of them. This qualitative approach can not only help acquire a better understanding of the issues at hand, but also help inform further, quantitative research. We expected that first-hand accounts of the primary play partners of high-functioning children with autism would be exceptionally useful in highlighting problem areas as well as the specific strengths that children with autism can bring to cooperative play situations, and thus in informing the development of targeted support and intervention programmes.

Alternative qualitative research methods were also considered, including thematic analysis and grounded theory. The reasons for choosing IPA over these are briefly outlined below.

Generally speaking, thematic analysis requires a larger sample size and is more versatile than IPA. Also, while the focus in IPA is on the individual participants and the patterning of meaning across participants, thematic analysis focuses primarily on the latter, and is therefore better suited for the investigation of research questions that are not about the individual's experience and perspectives (Larkin, Watts, & Clifton, 2006). IPA was deemed better suited to our study because of its idiographic focus and the relatively small sample size (Smith, Flowers, & Larkin, 2009).

Grounded theory is an umbrella term for a variety of approaches to systematically analysing qualitative data (Birks & Mills, 2011). The common characteristic of these approaches is the focus on producing a theory grounded in data. This involves employing particular types of research questions, often with a focus on social processes (Charmaz, 2006). As the purpose of our investigation was not the development of a new theory but, rather, an exploration of typically developing children's lived experience and evaluating the contribution of executive deficits in the poor social play of children with autism, IPA was chosen over grounded theory as methodology.

Method

Participants

Six Hungarian children (two males) took part in this study (for participant and sibling details, see Table). Because IPA requires a homogeneous sample in order to minimise the effect of extraneous variables on life experiences, prospective participants had to satisfy the following criteria:

(a) be between the ages of 5 and 11; and
(b) be TD, i.e. not be diagnosed with or suspected of having ASD or any other developmental disorder (as confirmed by the parents); and
(c) live with two parents; and
(d) live with one sibling, who
    a. has a diagnosis of high-functioning ASD (including Asperger syndrome and PDD-NOS) without a concurrent diagnosis of any other developmental disorder; and who
    b. is also between the ages of 5 and 11.

Families were recruited via autism charities and parental support groups. All participants had received a diagnosis using the ADOS and ADI-R, and parental reports indicated that there were no other cases of autism or other developmental disorders in the immediate family.

Table 1. Participant and sibling details

Participant number	**Participant (TD child)**			**Sibling with ASD**		
	initials	**gender**	**age (y;m)**	**initials**	**gender**	**age (y;m)**
1	AK	male	7;0	LK	male	10;0
2	LS	female	11;0	ES	male	8;0
3	MZ	male	5;6	DZ	female	7;3
4	AN	female	6;0	SN	male	10;8
5	AS	female	7;11	ZS	male	6;7

6	RM	female	10;6	BM	male	8;0

Informed consent

The study had been approved by the appropriate university ethics committee.

On obtaining written parental consent, participants were informed about the content and purpose of the study. After giving verbal assent, the children were asked if they wanted a parent to be present during the interview, but all declined.

Procedure and interview schedule

The interviews were conducted in Hungarian, by the first author, who is a native speaker of the language, and were recorded for subsequent analysis. Each session started with building rapport through general talk about the participant's hobbies, favourite subject at school, the family pet, etc. This phase lasted for as long as was deemed appropriate. The interview was semi-structured and administered in a flexible way, i.e. a set of standard questions was complemented by requests for elaboration as needed, new questions were introduced and subsequent questions adapted in the light of the participant's responses. Participants were encouraged to add anything or ask questions during the interview. Throughout the discussion, the interviewer never used the term 'autism', even if the participant was aware of their sibling's diagnosis.

The interview schedule was designed to probe both positive and negative experiences of cooperative play instances with the autistic sibling, and to identify the characteristics of the sibling's playing style that make these interactions pleasant or unpleasant for the participant. The emphasis was placed on how the participants made sense of their experiences, i.e. on their thoughts, feelings, and perceptions, as expressed during their description of past events. The questions centred on three main themes: (i) positive and negative (i.e. enjoyable and upsetting) aspects of playing with the sibling; (ii) how playing with the sibling compares to the participant's experience of playing with other children; and (iii) the strengths and difficulties of the sibling relative to other children. The interview ended with an open-ended question about the participant's experience of play with their sibling in order to elicit elaboration of previously mentioned themes, or the introduction of new ones.

The discussion was paced by the participants, and therefore the length of the interviews varied, but generally, older children tended to speak longer, presumably due to more developed vocabulary and perhaps a better understanding of their sibling's and their own behaviour.

Analysis

Interviews were transcribed and translated in full by the first author, who is a qualified translator with substantial relevant professional experience. As there are no prescriptive rules for conducting IPA (Smith, 1996), the process followed is described below in detail.

The analysis started with several readings of the interview transcripts in order to familiarise with the text. Initial observations were recorded in the margin. Emergent themes were identified and organised into clusters of superordinate themes in an iterative process, whilst continually referring back to the transcripts. Commonalities and differences across the participants' experiences were noted and considered as part of this process in order to identify convergent and divergent themes. In line with Smith's (1996) guidelines, the importance of a theme was determined not solely on the basis of the frequency with which it was mentioned by the participants, but also with reference to how it helped understand other parts of the interviews.

Results and discussion

Although no group of individuals can ever be perfectly homogeneous, the participants in this study share a number of important characteristics: they all live in a city (Budapest), attend state primary schools, only have one sibling, who has a diagnosis of autism without a concurrent diagnosis of a learning disability or other developmental disorder, and have parents who are educated to degree level. As such, it is not unreasonable to expect that there will be similarities in their lived experience of playing with their siblings. Indeed, there was substantial convergence in the participants' accounts, which clustered around five superordinate themes: poor emotion regulation, not accepting the play partner's input, restricted interests, and appreciation and enjoyment of togetherness. An underlying theme of adjustment, e.g. the development of coping strategies by the respondents or birth-order reversal, was also identified. Each of these themes is discussed below with relevant excerpts from the interview transcripts for illustration.

Emotion regulation

The poor regulation of (negative) emotions on the part of the sibling with autism was a universal theme that each of the respondents highlighted as a source of tension and upset during play. Violent outbursts occur across a variety of contexts, and can be triggered by different events, such as losing in a game, having to wait, or in revenge for a perceived slight.

> RM (f, 10): Well, he plays a bit differently from normal people. For example, when we play a board game, he always wants to go first, and he gets angry if he can't, or even if he rolls something other than what he wanted. So if he wants to roll a 6, but doesn't, he can get very angry. (…) I wish we wouldn't get son angry so often, but react more realistically [proportionately].

The risk of overreactions makes the autistic sibling's behaviour unpredictable, which appeared to be a source of anxiety and emotional tension for the participants. It also affected the siblings' ability to arrive at a compromise by bargaining.

> LS (f, 11): I wish he didn't pester me when I don't want to play with him. I wish he wouldn't throw a tantrum; we could just come to an agreement that he leaves me alone for a bit, and then we will play in the afternoon. But no, he wants to play straight away.

Notably, physical violence was reported in only one of the dyads, which was also the only pair of two brothers. In this case, the participant also felt that his brother does not love him, and his account included examples of emotional and verbal abuse.

> AK (m, 7): He deliberately crashed his police car into me [in a video game], and I lost all my lives. (…) But it's only a game, so I wasn't angry. But when we played again, I pushed him around, and both our cars exploded. So he shook me, and threw me down the stairs.

No acceptance of the play partner's input

Another universally reported experience was related to the autistic siblings' tendency to disregard the cooperative nature of joint play, and treat the play partner as a 'prop', i.e. an aspect of play that they can fully control. One participant commented, 'When I ask him to do something, it's in one ear and out the other'. This can reduce the hedonistic value of playing together for the TD sibling, especially when the play is centred on the autistic child's special interest (see also below), which the TD sibling does not share.

> **AK (m, 7):** [While playing Minecraft] he wanted me to watch him build (…) even though it was dead boring. We had an argument because I always come up with good ideas, like there was this one time I said we should look for a village, but he went 'No, no, no! No, no, no! No, no, no!' and so on.

By the time the play interaction starts, the child with autism often had the the entire story arc planned out. Their reluctance to accommodate the play partner's contributions manifests in behavioural inflexibility. The TD child's insistence on changing an aspect of the game will typically cause anxiety and upset to the sibling with autism.

> **Interviewer**: So when you're playing role-playing games, does he tell you what to do, or can you decide for yourself what you're going to do?
>
> **LS (f, 11):** Mostly I do what I want, but he often says 'And now make him say something or other'. When he comes up with the story, then normally he wants to say what's going to happen.

This, of course, makes play interactions rather one-sided, which respondents felt was unfair on them.

> **AN (f, 6):** For example, not long ago we were playing superheroes, and he said that this one superhero should come, and then he started shouting at me, saying "Come on! Make him come!"
>
> **Interviewer**: Okay. So when he tells you what should happen during play, and you don't want that, what happens?
>
> **AN:** Then he shouts at me. (…) I wish he wouldn't order me around. I should have a say, too.

Narrow interests

Restricted interests are a defining feature of ASD, and these emerged in the participants' accounts as a severe limitation of the range of play experiences they could share with their sibling. Each child with autism in our sample had one or more 'special interests' (e.g. trains, Lego, or Minecraft), which had to feature in every play interaction, regardless of its original theme.

> **AS (f, 7):** Sometimes he plays dolls with me, but even then, a train must be involved.

The participants reported finding this restricted range of play activities monotonous and less appealing.

> **RM (f, 10):** He too often wants to play with Lego, and that gets boring after a while.

The TD children's attempts to involve their sibling in other activities (e.g. playing with stuffed animals, going shopping, etc.) were rarely, if ever, successful.

> **LS (f, 11):** Mostly, we must play Lego, because he is amazingly keen on Lego.
>
> **Interviewer:** So when you play with him, who chooses what you do?
>
> **LS:** It's not really a case of choosing anything, because when he asks me to play with him, I already know he wants to play with Lego. I often ask him to go outside with me, to play on the swings or in the garden. Or to play hide and seek. Very rarely, he will agree, but mostly just wants to play Lego.

Appreciation and enjoyment

Despite the various difficulties in cooperative play reported by the participants, they almost universally reported enjoying playing with their sibling. The only exception to this was the dyad of brothers, whose relationship was reportedly marred by regular verbal and physical abuse by the older (autistic) sibling. In the other sibling pairs, all participants said they preferred playing together with their sibling to playing on their own.

> **AN (f, 6):** He can come up with the funniest things sometimes, and makes me explode with laughter. I actually enjoy playing on my own quite a lot, but it's better with him. Playing on my own is boring, because I can't play a villain like him. And I don't think I could play like that with other girls and boys, either.

Although the participants acknowledged the narrowness of their sibling's interests, they evidently appreciated and admired their sibling's creativity within that particular area, which reportedly made play interactions a lot more enjoyable.

> **Interviewer:** Does it bother you that you have to play what he wants?
>
> **AS (f, 10):** No, because he has good ideas (…) I like playing with him.

> **Interviewer:** So what's the best thing about playing with your brother?
>
> **LS (f, 11):** His imagination, I think. He is really good at combining different games. Like he did with Minecraft, Slenderman, Portal, and Lego yesterday. That was really fun.

Adjustment and coping

All but the youngest respondent were aware of their sibling's diagnosis, but there were differences between them in the extent to which they understood its implications in terms of behavioural and cognitive difficulties. Younger participants struggled not to take behavioural manifestations of the disorder personally, and often interpreted emotional outbursts or anxiety over a change of routine as lack of affection or 'whining'.

> **AK (m, 7):** Well, my brother doesn't love me (...) I did have a wish once, but that didn't come true. I wished for him not to be such a jerk to me, but swish-swoosh, he was a jerk to me again.

Older participants seemed to have a better understanding of which aspects of their sibling's behaviour are affected by autism, and made inferences about their impact on their sibling's effectiveness as a social agent, suggesting, for example, that their sibling's narrow social circle may be due to their atypical behaviour.

> **RM (f, 10):** Making friends is something he's not very good at, because he gets upset at the smallest things.

It was evident that the older participants had also adjusted their behaviour so as to minimise conflict and accommodate the needs of their sibling, sometimes assuming a caregiver role in the process. This often meant that the child with autism makes unreasonable demands on the TD sibling's time, who reluctantly complies out of a sense of obligation.

> **LS (f, 11):** If I could change one thing about him, it would be that he only plays with me, and not with others (...) I wish he didn't pester me when I don't want to play with him (...) If he wanted to play just as frequently as now, but not always the same thing, that would be easier.

Younger siblings, on the other hand, reported perceived birth-order reversal, mostly manifest in 'immature' behaviour that they had grown out of but their sibling had not.

> **AN (f, 6):** When I was younger, around 3 or 4, I kept ordering him around, and he kept shouting at me, and I kept shouting at him. That wasn't very good. But now it is always he who tells me what we should do and what we shouldn't. (...) He always shouts at me, whenever something doesn't go the way he wants. This used to be me, but now it's him...

Yet, the participants appeared to have taken the difficulties associated with growing up with a sibling who has autism in their stride. There was an emphasis on positive experiences, many of which seemed to be of minor importance from an etic perspective. For example, one participant expressed her appreciation of the fact that her brother would 'sometimes' agree to her coming up with her own lines when role-playing. Several participants claimed that they would not change anything about their sibling.

Conclusions and implications

In this study, we qualitatively investigated TD children's experiences of playing with their sibling who has HFA, and found that the sibling's poor emotion regulation, reluctance to accept the playmate's ideas, and restricted interests reduced the hedonistic value of cooperative play for the TD children, and were sources of tension and anxiety for them. These negative effects, however, were mitigated by the participants' admiration for their sibling's creativity (typically expressed within their domain of special interest), and by behavioural adjustment to the sibling's difficulties, such as birth-order reversal or assuming a pseudo-caregiver role. These findings have important implications for the development of support programmes for TD siblings and social play skill trainings for children with HFA; the results are generally in line with previous research on TD children's experiences of having a sibling with HFA, but thanks to the narrower focus of our study on cooperative play, they have more specific implications.

The poor regulation of negative emotions, which is common amongst children with HFA (Mazefsky et al., 2013), and which TD siblings often report as causing anxiety and upset in everyday interactions with their siblings (Konidaris, 1997; Mascha & Boucher, 2006), was also universally reported by our participants as a factor hindering enjoyable cooperative play. Amplified emotional responses and poor emotional control makes behaviour less predictable which, in turn, induces anxiety in the play partner. One participant suggested that unreasonable bouts of anger were the primary reason her brother struggled to make friends. Effective training programmes designed specifically to enhance the self-regulation of emotions do exist (e.g. Schuppert et al., 2012), but they are not routinely administered to children with HFA (for a review, see Berking & Whitley, 2014). Our results highlight the importance of emotion regulation with respect to peer interactions, and the potential of targeted emotion regulation training to enable children with HFA to engage in more mutually enjoyable cooperative play. From the TD child's perspective, these emotional outbursts put a strain on the sibling relationship: Ross and Cuskelly (2006) found that they were the most frequently reported interaction problem, and engendered anger. Support programmes for TD siblings of children with HFA should emphasise strategies for dealing with these effects, as they are at a heightened risk of developing internalising behaviour problems (Ross & Cuskelly, 2006).

Having restricted interests is a core diagnostic feature of autism, but it was somewhat surprising that it emerged in our participants' reports as a major obstacle to enjoyable cooperative play, because previous research on the everyday experience of having a sibling with HFA did not identify this aspect of the phenotype as particularly problematic from the TD child's perspective. In the context of play, however, the restricted interests of the child with HFA severely limit the number of options and, as the TD sibling's interests change through maturation, may lead to a situation where there is very little opportunity for the children to engage in mutually interesting play activities. This was the case with our oldest participant, whose interests were increasingly social in nature (e.g. talking), while her brother was still as 'amazingly keen' on Lego as he had been years before, and unwilling to play anything else.

On the other hand, TD siblings in our sample universally expressed admiration for their sibling's advanced knowledge and creativity within their domain of special interest, which helped make even the otherwise monotonous activity engaging. This result is in line with previous quantitative studies, which reported higher levels of admiration for the sibling with HFA than in TD dyads (Kaminsky & Dewey, 2001). Sibling support programmes that emphasise the HFA child's talents and unique contributions may help increase the appreciation of their role within the family, which is typically lower in the TD siblings of children with HFA than in TD dyads or in families with a child who has a learning disability (Bågenholm & Gillberg, 1991).

All participants in our study reported that their siblings tend to dominate play interactions, and do not usually accept changes to the storyline or rules that are suggested by the TD child. This insistence on one's own ideas emerged as a separate theme from narrow interests and poor emotion regulation, but the three are related: several participants reported that if they wanted to introduce new elements to the play, their sibling would either terminate the interaction or get angry. This finding coincides with some previous quantitative research (van Ommeren et al., 2012), which showed that compared to TD peers, children with HFA were less likely to engage in reciprocal interaction and accept an adult play partner's input in a collaborative drawing task (the Interactive Drawing Test, IDT), even if the input was constructive. Using the same task, Borbely and Yuill (in preparation) found that inhibitory control was linked to the ability to accept the play partner's input, whether it matched the intentions of the child with HFA or introduced new ideas. These results suggest that executive function training might have the potential to enhance cooperative play ability.

Despite the various difficulties that the participants in our study experienced in daily play interactions, it was clear from their accounts that they had adjusted to their siblings' behavioural atypicalities. This adjustment manifested itself in different ways, for example in perceived birth-order reversal, where a younger sibling highlighted problem behaviours that she had grown out of but her brother had not. Older participants had recognised that the balancing of needs which typically characterises sibling relationships (Burton & Parks, 1994) was not always possible, and they gave the impression of feeling an obligation to engage in less enjoyable play in order to please their sibling, whom they perceived as being less able (rather than unwilling) to adapt and take the TD sibling's preferences into account. Overall, the participants mostly reported being satisfied with their sibling relationship, and showed an obvious appreciation for minor but positive events and aspects of cooperative play with their sibling. Perhaps due to their rarity, fun and mutually enjoyable interactions were not taken for granted.

There is an interesting question about the specificity of our findings to the relationship between a typically developing child and their sibling with autism. The participants in our study only had one sibling, and so could not comment on the differences and similarities between the pleasures and difficulties of playing with a sibling with ASD as opposed to a typically developing sibling. Considering the themes that emerged from their reports, some appear to be linked specifically to the sibling's autism (narrow range of interests, adjustment and coping), while others reflect the broader difficulty of coping with poor social competence (no acceptance of the partner's input, lack of emotion regulation). The latter, especially, are also characteristic of playing with a typically developing but younger sibling (e.g. Brody, 1998; Kennedy & Kramer, 2008). The last theme (appreciation and enjoyment) is one that characterises all happy sibling relationships (e.g. Lamb & Lamb, 1982). Interestingly, differential treatment by parents did not emerge as a theme in the participants' account, despite the presumably high level of parental adjustment necessitated by the fact that a child has ASD.

The focus of this study was typically-developing children's experience of playing with their sibling who has a diagnosis of autism. Although the social and non-social deficits in autism are well-documented, as are these children's difficulties in social play, the relationship between these two areas is poorly understood. We set out to investigate the relative importance of these deficits from an emic point of view, interrogating the siblings' lived experience, rather than through imposing a theoretical model of interaction on the personal accounts.

An equally interesting question, of course, is what the autistic children's experience of playing with their typically-developing sibling is like. Although beyond the scope of this paper, further research should explore what the reports of children with autism on playing with their siblings reveals about the unique characteristics of these relationships. Through a comparison of playing with a sibling rather than a classmate or friend, such investigations would also be uniquely positioned to comment on how the unique dynamics of these play sessions may help or hinder children with autism in acquiring and practising transferable social skills.

Birth order is known to play a role in children's play with others (Dunn, 2004), and to affect the experience of having a disabled sibling (Breslau, 1982). At the simplest level, older siblings typically have an experience of living in a family without a disabled child, while younger siblings grow up into a family that includes an atypically developing child. In our study, this variable was not kept constant: there were an equal number of younger and older siblings so that we can examine dyads with both birth orders. Although the gap between the siblings was narrow (no age difference exceeded 3 years), there were differences in how younger and older siblings adapted to autism in the family. While older children tended to adopt an ersatz carer role, younger children reported more conflicted feelings about what they perceived as immature behaviour on their older siblings' part.

Our study is the first qualitative investigation of TD children's lived experience of cooperative play with their HFA sibling. Making use of the unique insight afforded by an emic approach, we identified promising avenues for further research into developing sibling support and social skill training programmes.

General discussion

This thesis constitutes a methodologically diverse investigation into the role of inhibitory control in the cooperative play deficits that are typical of children with HFA. The motivation for this research was the puzzling discrepancy between relatively intact social knowledge and profoundly impaired social (play) behaviour in children with HFA. We hypothesised that deficits in cooperative play may be due to impairments in a cognitive capacity (namely, inhibitory control) which acts as a moderator, and prevents relatively well-developed social knowledge from manifesting in real-life social interactions. In a series of studies, we (i) aggregated previous research to establish whether inhibition was impaired in children with HFA; (ii) used lab-based experiments to test whether children with HFA had relatively intact social knowledge, operationalised as age-typical performance on measures of joint attention, theory of mind, and moral reasoning; (iii) investigated whether inhibitory control impairments could predict deficits in three aspects of cooperative play (reciprocity, accepting the play partner's input, and fairness), independently of theory of mind and cognitive ability; and (iv) employed a qualitative approach to explore TD children's lived experience of cooperative play with their sibling who has a diagnosis of HFA in order to find out whether atypical behaviours associated with poor inhibitory control would be reported by the TD participants as hindering effective cooperative play.

Taken together, these studies lend support to a model of cooperative play deficits in children with HFA in which poor inhibitory control acts as a moderator between social knowledge and social behaviour. The evidence for this model, the strengths and limitations of the studies, and the theoretical, methodological, and clinical implications of the findings are discussed below in detail. The thesis concludes with a highlight of three important areas for further research that have been touched upon in this work: the relationship between executive function and theory of mind; the role of inhibitory control in emotion regulation; and the utility of null hypothesis significance testing in psychological research.

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regulation; and the utility of null hypothesis significance testing in psychological research.

1. Study 1: Systematic review and meta-analysis

1.1. Background and motivation

Narrative reviews of the executive function impairments in autism, published over a period of fifteen years (from Pennington & Ozonoff, 1996 to Pellicano, 2011), were unable to conclusively answer whether inhibitory control is impaired in autism. Empirical findings were equivocal, and based on a wide array of inhibitory tasks, which made results difficult to compare across studies. The heterogeneity of results had been put down to purported differences between the measures used, either in terms of task characteristics (e.g. arbitrary vs. naturalistic rules) or of the type of inhibition measured (e.g. prepotent response vs. interfering stimuli). We expected that the landscape of findings was distorted by the low power that is typical of psychological investigations, and which increases sampling error, and leads to frequent Type II errors.

The purpose of our systematic review and meta-analysis, therefore, was twofold: (i) to test whether inhibition is impaired in autism; and (ii) to compare the degree of impairment shown on different measures in order to evaluate different hypotheses about the cause of differential impairment across tasks.

1.2. Summary of findings

By employing advanced statistical methods, we were able to provide evidence for a deficit in inhibitory control in children with HFA, and show that differential performance across measures of inhibitory control was artefactual, due in fact to sampling error arising from a combination of low statistical power, the lack of standardisation in experimental methodologies, and inappropriate matching of the TD comparison group.

We found that participant age, FSIQ, and choice of paradigm did not significantly influence the size of impairment shown. The difference in FSIQ scores between the participants with and without HFA, however, was positively associated with the size of the impairment, i.e. children with HFA performed relatively worse on measures of inhibition when they were compared against a group of TD children with better cognitive ability. In most studies, the difference in FSIQ was substantial, and this fact explained a significant amount of heterogeneity in the effect sizes across studies, so the analysis was repeated on a subset of studies in which the HFA and TD participants were closely matched on FSIQ. This second analysis revealed a considerably smaller, although still significantly positive impairment in inhibitory performance in the HFA group.

1.3. Strengths and limitations

In a similar review published shortly before the completion of our report, Geurts et al. (2014) aggregated the results of 41 studies that directly compared the inhibitory performance of individuals with autism and TD controls, using either a prepotent response inhibition or an interference suppression paradigm, and concluded that (i) individuals with autism showed a significant impairment on both kinds of inhibition; (ii) the choice of paradigm did not have a significant effect on the degree of impairment shown; (iii) the age of the participants was not related to the size of the inhibitory impairment (after excluding outlier studies); but (iv) the FSIQ of the participants with autism was positively correlated with inhibitory performance, i.e. more cognitively able individuals showed less of an impairment.

Although similar in approach, the focus of our review was different: we only included studies on (i) children; with (ii) ‘high-functioning’ autism. These restrictions of scope allowed us to reduce the variance in effect sizes across the studies, and control for confounding variables arising from the development of alternative strategies for solving inhibitory tasks in adulthood, or from the knock-on effect of impairments in other cognitive domains in participants with a comorbid learning disability.

Another difference between our study and that of Geurts et al. is that they tested one particular taxonomy of inhibitory measures (i.e. prepotent response inhibition vs. interference suppression), whereas we compared all commonly used experimental paradigms. The advantage of our approach is that it makes no a priori assumptions about the type of inhibition measured by each task. This categorisation is not a trivial exercise, as illustrated by the example of the Stroop task. According to Nigg’s (2000) taxonomy, it is a measure of interference control, whereas Friedman and Miyake (2006) consider it a test of prepotent response inhibition. Because dissociation between the two types of inhibition would be most easily shown by differential performance on the tasks, there is an element of circularity to this argument, without an immediately obvious way of resolving disagreements of categorisation. Geurts et al. circumvented this problem by running their analysis twice: once with the Stroop task classed as a test of prepotent response inhibition, then as a test of interference control. It seems to us that a distinction that allows for placing a task in either of two mutually exclusive categories is in need of a better definition, and may not be meaningful at all. Indeed, Geurts et al. found no difference between the results of their two analyses, and in fact no difference between purported measures of prepotent response inhibition and of interference control, on the size of impairment shown by the participants with autism.

Our approach was to estimate population effect sizes separately for each paradigm, then test for a significant difference across them. This allowed us to evaluate all currently available hypotheses about differences between the tasks simultaneously, or to construct a new classification, grounded in data, if need be. We found no evidence for differential performance across tasks: effect sizes varied in a narrow range (+/- 11% from the mean), with no significant difference between any two paradigms. As such, none of the hypotheses concerning the causes of differential performance across tasks seems to be valid, quite simply because there is no differential performance to explain in the first place.

The most important limitation of our review is that we were not able to identify all sources of heterogeneity in effect sizes across the studies. We entered age, participant FSIQ, and paradigm into exploratory moderator analyses, and found that none of these factors explained a significant amount of variance. In studies where the TD group had relatively better general cognitive ability, however, the apparent size of the inhibitory impairment was also larger, suggesting that a significant portion of the impairment is actually due to the poor choice of a comparison group. This fact also highlights the possibility of additional, as yet unidentified, confounding variables that may be responsible for the poorer inhibitory performance shown by children with HFA (see, for example, the Triple I theory, below).

1.4. Implications

The comparison of experimental methodologies showed that the procedural details of inhibitory tasks differed greatly across the studies included in the meta-analysis. In the case of studies that used the Go/no-go Task, for example, the proportion of incongruent ("no-go") trials varied between 11 and 50 per cent (where reported).

Considering that the prepotence of the “go” response relies on its higher frequency, this manipulation will presumably have an effect on the construct validity of the test, but this is not routinely considered by researchers. Similarly, the dependent variable reported (typically reaction time and/or accuracy) varies across studies. Again, the choice is not trivial: Geurts et al. (2014) found that effect sizes calculated on the basis of reaction times and of accuracy rates were significantly different.

Thus, the implications of our study pertain to experimental methodology as well as to the theoretical understanding of inhibitory impairments in autism, and we suggest that concentrated efforts should be made to standardise experimental tasks on the basis of empirically confirmed considerations in order to ensure comparability across studies and, ultimately, accelerate the accumulation of knowledge in the field.

2. Study 2: Inhibition, reciprocity, and accepting play partner input

2.1. Background and motivation

Despite the developmental importance of cooperative play and the well-documented impairments of children with autism in this domain, there has been relatively little research into the proximal causes of these difficulties. One exception to this was Colombi et al.’s (2009) study on pre-schoolers with autism, which identified imitation and responding to joint attention as the primary reasons for deficits in cooperative play. We expected that despite showing deficits at an earlier stage in development, imitation and joint attention will have reached age-typical levels by the time children with HFA are in primary school (which was the age group of interest in this thesis). This development, however, is not reflected in substantially improved cooperative play, which led us to hypothesise that impairments in other cognitive domains may be responsible. We therefore tested the contribution of responding to joint attention, imitation, theory of mind, and inhibitory control to the ability of primary-aged children with HFA to engage in cooperative play.

2.2. Summary of findings

In this lab-based, experimental study, we found that children with HFA performed at age-typical levels on measures on first-order false-belief understanding, imitation, and joint attention. They were impaired, however, on verbal ability, second-order false-belief understanding, and inhibitory control, as well as on reciprocity and accepting the play partner’s input on our measure of cooperative play, the Interactive

Drawing Test (IDT, van Ommeren, Begeer, Scheeren, & Koot, 2012). In the HFA group, we found an association between the degree of inhibitory impairment and the ability to engage in reciprocity and accept the play partner's input, although the former of these correlations failed to reach significance after the effect of cognitive ability (i.e. verbal IQ) was accounted for.

2.3. Strengths and limitations

This study was the first experimental investigation of the proximal causes of poor cooperative play in primary-aged children with HFA, and provided evidence for the role of inhibition in accepting the play partner's input, which is essential for a mutually satisfying interaction. We were also the first to use the IDT outside of the research group who developed it, and verified that it was a useful measure of cooperative play that could be easily adapted for use in a British sample, and also in TD children. We replicated the main findings of the authors regarding the pattern of play shown by children with HFA, corroborating the reliability of the IDT.

The main limitation of our study lies in its small sample size (12 children in either group), which potentially increased the probability of Type II errors. Reassuringly, however, the pattern of findings is generally in line with previous research, suggesting that low power did not lead to spurious null results.

The TD comparison group was matched on chronological, rather than on mental age, to the participants with HFA, which is reflected in their significantly higher verbal ability. The reason for this decision was twofold: on the one hand, the HFA participants in our sample typically attend mainstream primary schools, where their classmates and, therefore, potential play partners and friends, would be of a similar age, although potentially of slightly higher cognitive ability. This comparison was therefore deemed more ecologically relevant. Also, the measure of cooperation was essentially non-verbal, as were the tests of inhibition administered. A TD comparison group matched on verbal mental age would have been younger, and presumably have lower non-verbal intelligence, jeopardising the comparability of their performance on the non-verbal tasks, which were of primary interest in this study.

The downside of the decision to match participants on chronological age is that the TD group showed ceiling effects on several measures, which meant that the relationship between cooperative play performance and proposed predictors could only be tested in the HFA group. This led to loss of power, and prevented us from investigating whether the relationship between inhibition and the ability to play cooperatively is specific to autism or extends to typical development, as well.

2.4. Implications

In addition to providing evidence for our model of inhibitory control moderating the relationship between social knowledge and social behaviour, this study also had methodological implications that informed the design of our next empirical investigation.

The results showed that children with HFA were just as unwilling to accept constructive input from the play partner as they were with contributions that altered the direction of play (e.g. when the experimenter turned the child's drawing of a cloud into a tree). This suggests that the insistence of children with HFA on "having their way" during a play session is not solely the result of a desire to see their plans carried out, but also involves a lack of appreciation of the collaborative nature of the activity. We hypothesised that this may be linked to a failure to realise that a mutually enjoyable experience requires that the play partner should also be able to contribute to an equal degree, and anything less than that will be perceived as unfair.

3. Study 3: Inhibitory control, moral reasoning, and fairness in action

3.1. Background and motivation

The understanding and practice of fairness in autism has received very little attention from researchers and when it was studied (e.g. Sally & Hill, 2006), the authors noted that their results showed considerably smaller differences between the HFA and TD participants than would be expected on the basis of the observation of the real-life interactions of children with HFA. This, to us, suggested a methodological error: strategic games (e.g. the Prisoner's Dilemma), which are commonly used in behavioural economics, seem ill-suited to a nuanced investigation of fairness in autism. We therefore combined an assessment of moral reasoning level with testing behaviour in an actual sharing situation so as to be able to directly test the link between them. We also administered measures of inhibition to test whether the size of the discrepancy between moral judgement and moral behaviour was associated with inhibitory deficits.

3.2. Summary of findings

In line with our model, which purports that social knowledge is relatively intact in HFA, we found no group differences on mentalising (false-belief understanding and emotion attribution), or level of moral reasoning, but the HFA group showed a significant impairment on our inhibitory measure (the Go/no-go Task). Contrary to our hypothesis, we found no difference between the TD and HFA participants on sharing – participants in both groups tended to split resources equally with an unknown other. Multiple regression analysis was carried out to identify predictors of less self-centred sharing, and we found that, in both the TD and the HFA groups, inhibitory control was the only significant variable significantly associated with the number of tokens retained by the participants, while age, mentalising ability, and moral reasoning level were not.

3.3. Strengths and limitations

Recent work on the factors affecting moral choices tended to focus on behavioural measures, mostly strategic games including the Prisoner's Dilemma, and the Ultimatum and Dictator Games (for an exception, see Gummerum, Hanoch, & Keller, 2008). In our study, we combined a behavioural measure of fairness with an interview, which allowed us to take into account important motivational factors when interpreting the pattern of results.

We found, for example, that both TD and HFA participants tended to keep exactly half of the reward offered, even though they had ostensibly been outperformed by the unknown child with whom they were sharing. This behavioural similarity across the groups was surprising, because on the basis of previous work on the development of fairness in childhood (e.g. Hook & Cook, 1979), we had expected that TD children would consider the principle of equity in their decisions, and keep less than half of the reward. Rather than concluding that, contrary to the results of naturalistic observations, HFA children share just as much as their TD peers, however, the combination of a behavioural paradigm with interviews about moral judgement allowed us to identify the confounding motivational factor that potentially masked an existing developmental difference. In the interviews, all TD children claimed that effort, rather than performance, should be rewarded, whereas the HFA children were mostly of the contrary opinion. The apparently self-centred action of the TD participants in the sharing task may actually reflect a "fair" decision, if we accept that reward should be bestowed on the basis of effort, rather than talent: if the participant tried their best, they deserved just as much as the other child, regardless of actual performance.

An important limitation of our study lies in the sensitivity of the measures used. One of the two inhibitory tasks (the Spatial Conflict Task) administered proved too difficult for the participants, despite being completed successfully by the children involved in the pilot phase. As a result, performance on the Go/no-go Task was the only measure of inhibition included in the analysis. Performance on the tests of mentalising was very good in both groups, with no participant making a mistake on the emotion attribution task. There is evidence that the recognition of emotions is not less accurate in HFA than in typical development (Piggot et al., 2004), but this may only apply in the case of "simple" emotions, such as happiness or sadness (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), which were used in our measure. It is not entirely clear, therefore, whether the age-typical performance shown by the HFA group was due to intact ability or the easiness of the task.

3.4. Implications

In this study, we demonstrated that inhibitory control, rather than age, mentalising ability, or level of moral reasoning was the best predictor of making less self-centred decisions in a Dictator Game. The link between inhibition and fairness existed in both the TD and the HFA groups. Our results are contrary to Smith et al.'s (2013), who also found a significant relationship between a measure of inhibition and fairness, but this was fully mediated by participant age. There were a number of methodological differences between the two studies (e.g. participant age, inhibitory measure used), but further research is needed to establish whether inhibitory control plays a role in the judgement-behaviour gap.

Although beyond the scope of this study, the marked difference between TD and HFA children's opinion on whether effort or performance should be rewarded suggests an interesting avenue for further research. Interviews with adolescents or adults with HFA could help establish whether the difference is due to a delay in the moral development of children with HFA or a different understanding of deserving. The latter possibility opens up a whole range of questions about the cognitive or social atypicalities in HFA that may underlie this difference.

4. Study 4: TD children's experience of cooperative play with a HFA sibling

4.1. Background and motivation

Although the adjustment of TD siblings who grow up in a family with a child with HFA has attracted considerable research attention, especially since the early 2000s (e.g. Hastings, 2003; Kaminsky & Dewey, 2001; Macks & Reeve, 2007; Rao & Beidel, 2009), there has been no specific qualitative investigation into TD children's experience of interacting with the HFA sibling in the context of play. In addition to addressing this gap in the literature, the purpose of this study was twofold. First, we aimed to triangulate the source of poor cooperative play ability in children with HFA by exploring the first-hand experiences of the most frequent play partners: siblings. The second goal of this study was to identify avenues for further research. We expected that an emic approach would provide unique insight into the factors that lead to the breakdown of a smooth play interaction.

4.2. Summary of findings

Interviews about the experience of cooperative play were conducted with six TD children between the ages of 5 and 11, who each had a sibling with HFA in the same range. The transcripts were transcribed and analysed using IPA. Five superordinate themes emerged: poor emotion regulation, restricted interests, and resistance to the play partner's ideas were reported as the major hindrances to mutually satisfying play, but these negative effects were tempered by admiration for the HFA sibling's creativity within their domain of special interest, and behavioural adjustment on the part of the TD children to their sibling's difficulties.

4.3. Strengths and limitations

In our sample, we had a mix of younger and older siblings of children with HFA, and nearly all combinations of gender pairings (no girl-girl dyad was included in the study because we could not locate any prospective female participants who had a sister with HFA and also satisfied the other eligibility criteria). Our goal was to collect reports from a more varied source and, thus, to potentially identify more universally applicable themes. This diversity, however, could also be considered a weakness of our design: there is evidence that both birth order and gender affect the impact of having a disabled sibling (Breslau, 1982). While older siblings have an experience of living in a family without an atypically-developing child, younger siblings do not. In our sample, we focused on dyads with a relatively narrow age gap (the largest age difference was 3 years) so that this effect of birth order may be minimised.

Using a qualitative method to analyse the TD siblings' first-hand reports allows us to compare the difficulties in cooperative play that were identified in a lab-based, experimental task (the Interactive Drawing Test) with the emic reports of frequent play partners of children with HFA. There was a reassuring degree of concordance between the results: we had found earlier, for example, that children with HFA were unwilling to accept the play partner's input into a cooperative drawing, and the participants in this study also universally reported that their siblings' ideas tended to dominate all joint play interactions, which substantially reduced the hedonistic value of cooperative play. The siblings' reports also highlighted issues, however, that did not arise in a short interaction with an unknown adult (i.e. the researcher) in an experimental setting, such as the destructive effect of emotional outbursts.

4.4. Implications

There are several interventions that have been used with relative success in the training of social interaction (e.g. Baker, Koegel, & Koegel, 1998; Jahr, Eldevik, & Eikeseth, 2000; Kohler, Anthony, Steighner, & Hoyson, 2001), but the teaching of play, specifically, has proven difficult (Jordan & Libby, 1997). The findings of our study suggest that focus on the HFA child's special interest may be counterproductive, because the TD sibling may soon tire of the topic, and not be motivated to engage. Enhancing the self-regulation of intense negative emotions, however, may make the behaviour of the child with HFA less unpredictable and less anxiety-inducing for the play partner, which may increase the frequency of play interactions.

Encouragingly, we found that the sibling relationships of most of our participants were characterised by warmth, and all participants reported a desire for more joint play and mutually enjoyable shared experiences. Emphasising the talents of the sibling with HFA, such as their creativity in connection with their special interest, may help TD children build a more positive perception of their sibling's role in the family, which is often a problematic aspect of these sibling relationships (Bågenholm & Gillberg, 1991).

5. Thesis summary

5.1. Diversity of research methods

The four studies that comprise this thesis are methodologically diverse because the purpose of this research project was not only to investigate whether a link exists between inhibitory control and successful cooperation, but also to contribute to the evaluation of the research methods currently used to answer this, and similar, questions about the proximal causes of the complex pattern of impairments that characterise autism. This was necessary because although autism has a rich literature, the specific question posed in this thesis, i.e. the role of executive function in cooperative behaviours, is relatively under-researched, especially in the age group of interest and involving playful activities. As a result, the research methods used in this research project evolved and changed as the studies unfolded.

For example, at the start of the research programme, the assumption was made that individuals with autism demonstrate differential impairments across various measures of inhibitory control, which is a result of differences in the exact cognitive demands of those tasks. All reviews of executive functioning in autism that were available at the time (e.g. Hill, 2004; Kenworthy et al., 2008; O'Hearn et al., 2010; Pellicano, 2011; Pennington & Ozonoff, 1996; Russo et al., 2007) agreed that this was the case, although there was disagreement across authors as to the exact pattern of difficulties, and how they are linked to task characteristics. The experimental tasks administered in the first experimental study of this thesis (presented as Articles 2) were selected in a way that would allow an investigation of differential performance, thus contributing to the theoretical debate. The results showed inhibitory impairments across the board, but the low number of participants did not allow drawing definitive conclusions as to why. The findings were then followed up in two ways. For the second experimental study (presented as Article 3), executive tasks selected were selected from a narrower range, focusing on inhibition of a prepotent response, so as to avoid any theoretical confounds. But also, preparation for a systematic review of research into inhibitory control in autism was commenced so as to definitively resolve what had puzzled reviewers for over a decade and a half: on which inhibitory measures do individuals with autism perform at a below typical level, and why.

The meta-analysis provided clear evidence for an impairment in the inhibitory control of HFA children, and also highlighted the detrimental impact of unstandardised experimental tasks on the research literature in general, as theories (about the task characteristics underlying a particular pattern of poor inhibitory performance in autism, for example) had been confidently put forward without proper appreciation of the weaknesses of the empirical evidence. This finding contributed to the decision that the last study included in this thesis should be qualitative in nature, allowing a more exploratory approach and a triangulation of results.

The results of the four studies, although reached through different methodological pathways, are convergent: HFA children have profound impairments in inhibitory control (Article 1), which can be measured using experimental tasks (Articles 2 and 3), are linked to the ability to cooperate successfully, both in laboratory-based tasks (Article 2) and in real-life play situations (Article 4).

5.2. Implications

This thesis contributes to the research into social impairments in autism in two distinct ways: theoretically, through a refinement of the role executive functioning (specifically, inhibitory control) can play in a multiple-deficit account of autism; and methodologically, by highlighting the importance of standardising experimental tasks and accounting for methodological differences across studies when formulating hypotheses on the basis of empirical evidence.

The systematic review and meta-analysis presented here as Article 1 used advanced statistical techniques to investigate the pattern of performance on laboratory-based tests of inhibitory control. Narrative reviews published across three decades, from Pennington and Ozonoff's (1996) to Pellicano's (2011), had been unable to establish which subdomains of inhibition are impaired in autism, mostly because the impact of low power and methodological differences across the studies were not duly appreciated. The meta-analysis confirmed the finding that the empirical results of Articles 1 and 2 had suggested, namely that HFA children show impaired performance compared to age-matched peers across all tasks of inhibition. The experimental studies also showed a clear link between inhibition and important components of social interaction, such as reciprocity, accepting other contributors' input, and acting fairly. Taken together, these results help clarify the role of executive function in social impairments in autism. Although executive deficits have mostly been proposed as an explanation for the non-social aspects of autistic symptomatology (Hill, 2004; Pellicano, 2011), the ‘strong’ version of the executive function account posits that they are also responsible for social deficits. The results of this thesis lend support to this claim, as clear links have been identified between inhibition and effective social interaction, both in experimental tasks and in real-life situations. The impact of executive deficits was statistically separable from difficulties in mentalising, but there is obvious overlap in the manifestations of these cognitive capacities: demonstrating theory of mind, for example, requires using various executive functions, and vice versa – for an elaboration of this idea, see the Triple I theory proposed by by White (2013). As a result, the results of this thesis suggest that the role of executive function in autistic symptomatology may not be as easy to clearly delineate as some current multiple-deficit models, such as that proposed by Happé, Ronald, and Plomin (2006) suggest, but should rather be interpreted as part of a model in which developmental deficits interact longitudinally (e.g. Pellicano, 2013).

An important practical implication of the theoretical finding that inhibitory control underlies difficulties in cooperation is that enhancing inhibition, either through training or adapting the environment to provide ‘on-line’ support, should have a beneficial impact on social interactions. Originally, this thesis was to include an intervention-type study to provide empirical evidence for this claim, but this had to be abandoned, partly because of practical issues, such as time limitation and the difficulty of recruiting suitable participants, and partly because of difficulties associated with training executive function (e.g. Dowsett & Livesey, 2000; Houben & Jansen, 2011) reliably. Nonetheless, a direct empirical investigation of the impact of supporting inhibition on effective social interaction would be the best way to establish the direction of causality and, thus, to test the model proposed in this thesis. As such, such a study is a logical follow-up of the work presented here.

Aside from their theoretical importance, the results of this thesis, and of the systematic review and meta-analysis in particular, have important implications for experimental methodology. Despite the large number of studies inspired by the executive function account of autism, researchers could not reach consensus on whether inhibition was impaired in this population and, if so, whether that impairment was universal or specific to certain types of inhibition. The authors of narrative reviews, from Pennington and Ozonoff (1996) to Pellicano were in no better position, because “some studies have found problems in inhibitory control while others have not" (2011, p. 231). This diversity of findings was, in fact, due to methodological issues, such as comparing HFA participants with a group of TD children of substantially higher general cognitive ability, changes to experimental methodology, which were often poorly reported, and a failure to appreciate the fundamental weaknesses inherent in null-hypothesis significance testing when formulating theories on the basis of poor evidence. The practical implications of this are clear: making comparisons only across groups that are actually comparable, standardising experimental tasks or at least systematically investigating the impact of changing the details of administering them, and giving careful consideration to statistical power would safeguard against the "barren controversy" that Oakes (1986) identified as a hindrance to progress in psychological research.

Obviously, none of the above proposals are original to this thesis, but have been repeatedly formulated by distinguished researchers for several decades. The results of this thesis, however, strongly suggest that they bear reiterating.

6. Future directions

6.1. Inhibitory control and other executive functions

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6.2. Executive function and theory of mind

In this thesis, theory of mind and executive function (or, more specifically, inhibitory control) were not considered as competing explanations, but rather as complementary prerequisites of effective social functioning. Although the emphasis was on the explanatory power of executive function, the intention was not to dismiss theory of mind as an important contributor to social competence, but rather to show that even children with HFA whose theory of mind is (relatively) intact have profound difficulties in cooperative play. Clearing one hurdle is not enough: both executive function and theory of mind are required.

A lot has been written about the relationship between these two cognitive capacities (e.g. Carlson, Moses, & Breton, 2002; Ozonoff, Pennington, & Rogers, 1991; Russell, Saltmarsh, & Hill, 1999; for a recent review, see Brunsdon & Happé, 2014), but there is no consensus on whether impairments in one lead to impairments in the other and, if such a causal link does exist, in which direction. Longitudinal studies (Carlson, Mandell, & Williams, 2004; Hughes & Ensor, 2007; Pellicano, 2010b) suggest that developmentally, executive function is a prerequisite of theory of mind. Other researchers such as White (2013), however, argue that executive function impairments in autism are illusory, and poor performance on experimental tasks is due to the participants' difficulty in understating the experimenter's expectations. Brunsdon and Happé (2014) speculate that theory of mind deficits, such as the difficulty in reflecting on one's own mental states, may have an impact on certain aspects of executive function, e.g. planning.

The situation is further complicated by the fact that executive function and theory of mind are difficult to disentangle experimentally. Nearly all tests of theory of mind require a degree of executive function to complete successfully, and *vice versa*. In the Sally-Ann task, for example, which is a widely-used measure of first-order false-belief understanding, the participant must inhibit the prepotent response of pointing to the container they know the toy to be in. Conversely, to succeed on a test of inhibition such as the Luria hand-game task (inverse imitation), the participant must first infer the experimenter's intentions correctly (Pellicano, 2007).

In the two empirical papers included above, there was no statistically significant association between measures of theory of mind and inhibitory control, but the relevance of this fact to the broader issue is limited. First, because our participants, both in the TD and in the HFA groups, tended to pass the theory of mind tasks, and this lack of variance made correlation analysis difficult or impossible. Second, because our studies were carried out on relatively small samples, which were sufficient to detect the large impairment in inhibition, but would be underpowered to find if a weaker relationship between theory of mind and executive function existed.

In the meta-analysis, we found that a large part of the inhibitory impairment was explained by the participants' general cognitive ability (full-scale IQ). Full-scale IQ, of course, is measured using tests that involve the application of executive control to a considerable degree. A similar difficulty exists in attempting to parse performance on tests of theory of mind and executive function. Overall, the value that an either–or approach can add to future accounts of the autism phenotype is questionable.

6.3. Emotion regulation and inhibitory control

The goal of this thesis was to evaluate a model of social impairments in autism in which inhibitory control acts as a moderator between social knowledge and social behaviour. This hypothesised model, and the design of the studies that were conducted to test it, rest on the underlying assumption that inhibitory control is synonymous with, or at least closely linked to emotional and behavioural self-regulation. This assumption remained implicit, but it is crucial, therefore supporting evidence is briefly presented below.

Until relatively recently, research on inhibitory control and on self-regulation had been conducted in the largely separate domains of cognitive and social psychology, respectively (Baddeley, 2007). Intuitively, the two capacities are related, because the self-regulation of emotions and behaviours requires the ability to inhibit inappropriate prepotent responses (Hofmann, Schmeichel, & Baddeley, 2012). There is now an increasing amount of empirical evidence for a link between cognitive inhibition and behavioural self-regulation, from fields as disparate as overeating (Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010) and sexual infidelity (Pronk, Karremans, & Wigboldus, 2011).

For example, Carlson and Wang (2007) tested preschool children's ability to inhibit a prepotent response and to regulate their emotions, and found a significant association between these capacities, even after controlling for age and verbal ability. The correlations held up for both the understanding and controlling of emotions, of both positive and negative valence. In a study on undergraduate students, Logan et al. (1997) found a significant relationship between performance on a stop-signal test (a measure of cognitive inhibition) and self-reports of impulsivity, suggesting that impulsive behaviour is driven by an inability to inhibit a prepotent response. In yet another experiment (von Hippel & Gonsalkorale, 2005), participants who performed better on a Stroop task were more able to suppress socially inappropriate verbal outbursts in response to a visually unpleasant stimulus.

The pattern of results across our studies also supports this link. Manifestations of poor behaviour regulation, such as the reluctance of HFA participants to accept the play partner's input in the Interactive Drawing Test, were statistically linked to performance on tests of inhibition. In the interviews, TD children universally reported that their siblings' emotional reactions tended to be disproportionate, and that these were linked to perceived challenges to the siblings' preferred routine.

There is direct evidence for the inhibition–emotion regulation link from psychopathologies, including depression (Joormann & Gotlib, 2010) and ADHD (Schachar & Logan, 1990) but not, to our knowledge, from autism. Therefore, although the wealth of corroborating evidence from different populations is indicative, further research is needed to verify that deficits in behavioural regulation and in inhibitory control are interlinked in autism.

6.4. Null hypothesis significance testing

The claim that "null hypothesis significance testing (NHST) has not only failed to support the advance of psychology as a science but also has seriously impeded it" is far from novel. In fact, the quote is from Cohen's (1994, p. 997) article written 20 years ago, which he prefaces by unapologetically disclaiming any degree of originality, and citing researchers describing NHST as worse than useless from nearly 30 years prior. Yet, it bears repeating because NHST continues to be universally used and continues to hinder progress in psychological research.

To illustrate, consider the example of inhibitory control impairments in autism. In a 1996 review of executive deficits in several developmental disorders, the authors concluded that "deficits in inhibition are prominent in ADHD but not in autism" (Pennington & Ozonoff, 1996, p. 80). Fifteen years (and dozens of studies) later, Pellicano (2011) was in no better position to say whether inhibition was impaired in autism because "some studies have found problems in inhibitory control while others have not" (p. 231). This uncertainty has given rise to a number of hypotheses about the complex pattern of inhibitory impairments that exist in autism, such as the prepotent response–interference suppression distinction (for reviews, see Hill, 2004; O'Hearn, Asato, Ordaz, & Luna, 2010; Russo et al., 2007).

Actually, the pattern of findings across studies is clear, and provides very strong support for an inhibitory impairment in autism. If there were really no difference between the TD and HFA populations on inhibitory control, only 1 out of 42 studies included in our meta-analysis should have found a significant impairment in the HFA group (as a result of a Type I error). Also, participants with HFA should outperform the comparison group in roughly half of the studies (although most of these differences would not reach statistical significance), while in fact over 85 per cent of the studies reported that participants with HFA scored lower on inhibition.

The cause of uncertainty despite overwhelming evidence lies in the misinterpretation of non-significant findings.

The question a researcher wishes to answer by running a statistical analysis is this: “Provided a significant effect exists or does not exist in my sample, how confident can I be that there is or there is not an effect in the population?” There are two fundamental problems with NHST: that it does not answer this question; and that, unaware of this, the researcher will proceed as if the question had been answered. Taken together, these two facts have a devastating impact on the validity of research reports. In Johnson’s poignant summary, *p*-values “relate to data that were not observed under a model that is known to be false” (Johnson, 1999, p. 765), and, as such, are irrelevant and misleading.

Failure to appreciate this fact, along with frequent Type II errors arising from low power that is an undesirable but often inevitable trait of psychological research (1 in 4 studies in the meta-analysis had a worse than even chance of finding the correct answer) lead to a “barren controversy” over the cause of heterogeneity in experimental results, and a “continuous search for factors” (Oakes, 1986). The first step forward is to take into account the effect of sampling error when theorising on the basis of a null result but, ultimately, NHST must be abandoned in psychological research for point estimation techniques (Cumming, 2013), Bayesian statistics (Dienes, 2011), or likelihood inference (Dempster, 1997).

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Appendices

Appendix 1. The Early Positive Justice Levels Interview

Adapted from Damon (1977).

Section 1

All of these boys and girls [show pictures] are in the same class together. One day their teacher lets them spend the whole afternoon making paintings and crayon drawings. The teacher thought that these pictures were so good that the class could sell them at the fayre. The children sold the pictures to their parents, and together the class made a whole lot of money. Now, all the children gathered the next day and tried to decide how to split up the money.

1. What do you think they should do with it? Why?
2. Kathy says that the kids in the class who made the most pictures should get most of the money. What do you think?
3. Andy says the kids who made the best ones should get the most. What do you think?
4. There was a lazy kid in the class, Rebecca, who didn't draw as much as the others. What about her? Should she get the same amount of money as the others? Should she get less? Why?
5. Jim says that the best-behaved children should get more than the rest.
6. Lisa says that the poor children should get the money because they don't have much.
7. Billy, here, comes from a very poor family and doesn't get any pocket money. What should the class do about him?
8. Someone said the teacher should get the money because it was her idea to sell the pictures. What do you think?
9. Should the boys or the girls get more?
10. Should the teacher decide? What if she decides to give it all to Melissa because Melissa is her favourite? Does she have the right to decide that?
11. What should the kids do?
12. Should anyone get more than anyone else?

Section 2

Remember there was a lazy kid in class – Rebecca. Now, Rebecca is very smart. She never studies, or does her homework, because she is so lazy. But she always gets all the answers right on tests. Peter, here, is just the opposite. He works really hard, but he's not so smart and usually makes lots of mistakes.

13. Miss Townsend has to decide who she would give the best mark to for schoolwork: Rebecca or Peter. What should she do?
14. Why does a teacher give marks? Is that a good reason?

15. What should Miss Townsend do? What's fairest to Rebecca and Peter? How should she decide?

Section 3

16. Here are some toys [seven poker chips]. Let's pretend your best friend, [name], is sitting right here. Now I'm going to give you all these toys to play with. Would you give [name] any of them? Which ones would you give him? Which ones would you keep yourself? What if s/he wanted all these – what would you say to her/him?
17. Would it make any difference if [name] was poor and never got to play with toys? Should s/he get some more?
18. What if [name] did you a favour or did a good deed? Does that matter? Does it matter if your friend is a boy or a girl?
19. Why do you share with people? How many of your things should you share? Are there some things you share and not others? Are there some people who you share more with than others? What are these people like?
20. What would happen if you said "No, [name], you can't play with my toys"? Is that fair? How come?
21. What would you do if [name] said to you: "You can't play with my toys"? Would that be fair? How come? What if you didn't let her/him play with your toys first? Then would it be fair? What if you did let him play first?

Section 4

22. If you get a cake for dessert in your family, who should get the biggest piece? If there's an extra piece, who should get it?

Appendix 2. Sibling interview about the experience of cooperative play with HFA sibling

Note to interviewer: *This interview is intended to gauge to what extent poor executive function (i.e. inhibitory control, cognitive flexibility, and planning) contributes to difficulties in social play in HFA children. If necessary, adapt / clarify questions to ascertain to what extent the HFA child is capable / willing to adapt and accept the play partner's (i.e. the interviewee's) input during play sessions, After building rapport, the interview should last around 20 minutes.*

- What sort of things do you and [HFA sibling] do together?
- Can you think back to a time when you really enjoyed playing with [HFA child]? Tell me about it. [*solicit details with follow-up questions*]
- Can you think back to a time when playing with [HFA child] wasn't much fun because of something? Tell me about it. [*solicit details with follow-up questions*]
- Is there anything you think that [HFA child] finds more difficult than other children?
- Is there anything you think he is better at than other children?
- What kinds of games do you play with [HFA child]? Are they different from the kind of games you play with your other friends? How?
- Who chooses what you are going to play? Is it you or [HFA child]? When you are playing, who comes up with the ideas? Does [HFA child] like it when you come up with ideas?
- Is there anything you find difficult when you are playing with [HFA child]?
- What is the best thing about playing with [HFA child]?