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**Language alignment in children with an autism  
spectrum disorder**

**A thesis submitted for the degree of Doctor of Philosophy**

Zoë Louise Hopkins

University of Sussex

March 2016

### **Declaration**

I declare that this thesis is of my own composition, and has not been submitted to another University for the award of any other degree.

It should be noted, however, that the thesis incorporates research that has been published in collaboration with others (Article 1), and reports data collected by a postgraduate student, whom I co-supervised (Study 2, Article 2).

The work herein was supported by Engineering and Physical Sciences Research Council Grant EP/K503198/1.

Signature.....

Zoë Louise Hopkins

March 2016

UNIVERSITY OF SUSSEX

ZOË LOUISE HOPKINS

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

LANGUAGE ALIGNMENT IN CHILDREN WITH AN AUTISM SPECTRUM DISORDER

### Summary

This thesis examines language alignment in children with an autism spectrum disorder (ASD), a neurodevelopmental disorder characterised by impaired social understanding and poor communication skills. Alignment, the tendency for speakers to repeat one another's linguistic choices in conversation, promotes better communication and more satisfying interactions (cf. e.g., Fusaroli et al., 2012). By corollary, deficits in alignment may adversely affect both communicative and affective aspects of conversation. Across three studies, I consider whether ASD children's conversational deficits relate to disrupted patterns of alignment, and explore the mechanisms underlying this.

In the first study, I adopt a corpus-based approach to show that syntactic alignment effects are observable in ASD children's 'real-life' conversations, not just in an experimental context. The second study draws on research into the role of inhibitory control in communicative perspective-taking (Nilsen & Graham, 2009) to show that lexical alignment is not socially mediated in ASD. I develop this work in the third study, which highlights how, for ASD children, conversation can be compromised when lexical alignment is driven exclusively by priming mechanisms.

Taken together, these studies advance our understanding of conversational deficits in ASD, and particularly how impaired social understanding affects ASD children's language processing in dialogue. I conclude that, while ASD children have intact alignment, reduced social understanding may prevent them from 'diverging', which can be necessary to move a conversation forward (Healey, Purver, & Howes, 2014). More broadly, the thesis addresses questions of theoretical relevance to the study of alignment, by clarifying the contributions of unmediated (i.e., priming) and socially mediated (i.e., audience design) mechanisms to children's alignment behaviour, both in ASD and typical development.

## Acknowledgements

The medieval philosopher, Bernard of Chartres, described the relation of scholars to their intellectual forebears using this metaphor:

*We are like dwarves perched on the shoulders of giants, and thus we are able to see more and farther than the latter. And this is not at all because of the acuteness of our sight or the stature of our body, but because we are carried aloft and elevated by the magnitude of the giants.*

The giants on whose shoulders I have perched come in a variety of guises, and I want to acknowledge them here.

First, I want to acknowledge my supervisors, Nicola Yuill and Bill Keller: almost four years ago, they put their faith in the possibility that one day, an erstwhile student of medieval religious writings would submit a PhD thesis about conversation in children with autism. Across those four years, Nicola and Bill have given me hours of intellectual stimulation, thoughtful feedback, and pastoral care. Nicola in particular has sustained me with endless cups of tea, and a steady stream of ‘tea-break’ newspaper articles, on the days when I needed them most. Thank you both, for your careful supervision and your friendship.

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**Z.L.H**

**December 2015**

**Dedication**

To Mum and Dad

For 30 years of love, patience, and (re)assurance.



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**List of frequently used abbreviations**

ASD – autism spectrum disorder

BPVS – British Picture Vocabulary Scale

DD – developmentally delayed

DO – double object

ED- executive dysfunction

EF – executive function

IA – interactive alignment

IC – inhibitory control

NLP – natural language processing

PO – prepositional object

SCQ – Social Communication Questionnaire

TD – typically-developing

ToM – Theory of Mind

VM – verbal mental (age)



## 1. Motivation for thesis

This thesis addresses questions concerning the conversational behaviour of children with ASD, a neurodevelopmental disorder for which impaired social functioning is a hallmark. Since communication skills follow a sharp trajectory (Shatz & Gelman, 1973), conversational deficits may be especially conspicuous in childhood, hence the focus of this thesis on ASD children. The articles presented here consider ASD children's conversational deficits from a language processing perspective, by examining their patterns of language alignment.

Alignment is the tendency for speakers to imitate each other's language in dialogue, and is associated with effective communication and satisfying interactions (Fusaroli et al., 2012; Reitter & Moore, 2014). The process of alignment is fundamentally driven by priming (Pickering & Garrod, 2004), but may also be mediated by social factors, such as audience design (Branigan, Pickering, Pearson, McLean, & Brown, 2011) and affective goals (van Baaren, Holland, Steenaert, & van Knippenberg, 2003). ASD children show deficits which are relevant to the different alignment mechanisms: for example, they have impaired social cognition (Baron-Cohen, Leslie, & Frith, 1985), which could compromise alignment mediated by audience design.

Hence the starting point of this thesis was that, if ASD children show atypical patterns of alignment, then this could help to explain why they experience communication difficulties and unrewarding interactions. When this doctoral project began, a very small literature had already suggested that priming mechanisms are intact in ASD, both for children (Allen, Haywood, Rajendran, & Branigan, 2011; Osborne & Allen, 2012) and adults (Slocombe et al., 2012). This thesis builds on such findings, as well as pursuing questions of broader relevance to the theoretical literature on alignment, ASD, and imitation.

Specifically, this thesis draws on *unmediated* (i.e., priming) accounts and mediated (i.e., audience design) accounts of alignment to address three key questions: (1) is ASD children’s alignment a real phenomenon, or an experimental artefact?; (2) is there a mediated component to ASD children’s alignment?; and (3) to what extent does unmediated alignment support successful communication in ASD children? The answers to these questions advance an understanding of conversational deficits in ASD, and in particular how priming and audience design mechanisms affect ASD children’s language processing in dialogue.

## 2. Overview of ASD

### 2.1. *Defining ASD*

ASD is a pervasive neurodevelopmental disorder (American Psychiatric Association, 2013), which is present at birth, and which can be diagnosed in toddlers (Baron-Cohen, Allen, & Gillberg, 1992; Matson et al., 2009). Most ASD cases are diagnosed by three years of age (Landa, 2008), and are made on the basis of impairments of social communication and social interaction (see 2.4., below). An extensive range of interventions exists for addressing these impairments (Francis, 2005).

Previously, standard diagnostic criteria (i.e., the Diagnostic and Statistical Manual of Mental Disorders, or DSM) for ASD recognised separate sub-types within the autism spectrum, such as Asperger’s Syndrome (AS), and pervasive developmental disorder not otherwise specified (PDD-NOS). These subtypes have recently been subsumed under the single label of ASD (American Psychiatric Association, 2013),<sup>1</sup> although they still have

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<sup>1</sup> The terms ‘autism’ and ‘autism spectrum conditions’ are also used by professionals to refer to ASD; members of the ASD community may describe the disorder using different terms to these (Kenny et al., 2015). The term ASD is adopted in this thesis, for continuity with current diagnostic terminology and constructs, and with the wider research literature. Further, all references to ‘ASD children/adults/individuals’ (rather than children/adults/individuals *with* ASD) are adopted solely for the purpose of conciseness.

currency in the research literature. The new typology emphasises that there are behavioural features shared by all who have ASD, but it should be stressed that, within the autism spectrum, there remains wide variability in social, language, and communicative skills, as well as in cognitive measures (e.g., IQ; Wing, 2002).

## *2.2. Prevalence of ASD*

ASD has an estimated global prevalence of between .01 and 1.57% (Zaroff & Uhm, 2012), and is detected more often in males than in females (4:1; Halladay et al., 2015). The number of ASD cases has risen sharply in recent decades (Nassar et al., 2009), and various hypotheses have been proposed for this increase, including changing diagnostic criteria, increased awareness of the disorder, and cultural and environmental factors (Matson & Kozlowski, 2011).

## *2.3. Aetiology of ASD*

The precise aetiology of ASD is poorly defined, but the disorder is thought to be largely genetic in origin (Rutter, 2000), with different sets of genes influencing the social and non-social impairments of ASD (Ronald, Happé, & Plomin, 2005). Such research is supported by twin studies, which report heritability estimates as high as 96% (Freitag, 2007), and which report different concordance rates for monozygotic versus dizygotic twins (Bailey et al., 1995). Further, infants with an older ASD sibling are at higher risk of being diagnosed with an ASD, compared with the general population (Ozonoff et al., 2011). Yet to date, no single gene, or set of genes, has been identified as responsible for ASD. In addition, researchers have not been able to extrapolate putative genetic deficits to the neurological abnormalities underlying ASD symptomatology (Port, Gandal, Roberts, Siegel, & Carlson, 2014).

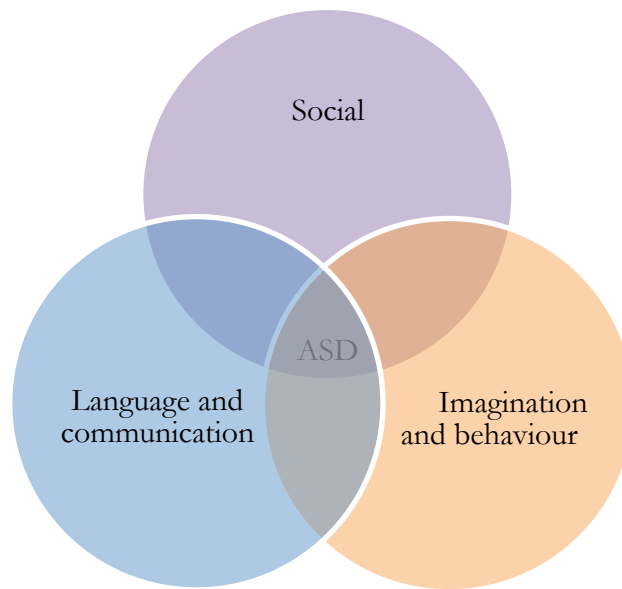
A growing body of evidence suggests that non-genetic (i.e., environmental) factors also have a role in ASD aetiology, supported by monozygotic concordance rates of less than 100%. Environmental factors so far implicated in ASD include prenatal viral infection, maternal diabetes, and teratogenic exposure (Grabrucker, 2012). Different models for the gene-environment interaction in ASD have been proposed (Herbert et al., 2006).

#### *2.4. Diagnostic criteria for ASD*

Since Kanner's (1943) early description of ASD, the diagnostic criteria for the disorder have undergone transformation. The following features were considered diagnostic of 'classic' or 'Kannerian' ASD: profound lack of social responsiveness; obsessive desire for sameness in routines and the environment; good rote memory; a skilful relationship to objects; mutism; oversensitivity to stimuli; and an impression of intelligence. Kanner (1943) also noticed that family members of ASD individuals tend to exhibit these features, in a milder but qualitatively similar form. This observation informs what is now known as the 'broader autism phenotype' (BAP), where an individual might possess ASD traits, but below the clinical threshold for the disorder (Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010).

After Kanner, (1943), both Wing (1976) and Rutter (1978) reformulated the criteria for ASD, with a stronger focus on aspects of an individual's functioning. Broadly, the amended criteria described ASD in terms of (a.) social difficulties; (b.) atypical language and communication; and (c.) repetitive, stereotyped behaviour and/or narrow interests. Wing and Gould (1979) referred to these three main areas of difficulty in ASD as the 'triad of impairments' (see Figure 1), which are core to the criteria for ASD adopted by international systems of classification of psychiatric and behavioural disorders (DSM; International Classification of Diseases). The term 'narrow autism phenotype' (NAP) describes an ASD individual with impairments across the triad.

*Figure 1: Triad of impairments in ASD, as per Wing and Gould (1979)*



### *2.5. How ASD impairments manifest*

As noted, there are three primary areas of impairment in ASD, which are considered in greater detail below. There is an extended discussion of language and communicative difficulties in ASD, which are of particular relevance to this thesis. In this section, it will also become clear that there is overlap in the impairments associated with ASD, as implied by Figure 1.

#### *2.5.1. Social difficulties*

Most ASD individuals have significant social difficulties. For example, ASD children have poorer quality friendships, and experience increased feelings of loneliness, compared with typically-developing (TD) controls (Bauminger & Kasari, 2000). ASD children tend to be socially isolated at school (Kasari, Locke, Gulsrud, & Rotheram-Fuller, 2011), and even within the home environment, the familial relationships of ASD children may also be strained (Kaminsky & Dewey, 2001). Reduced social integration persists into adulthood in

ASD (Howlin, 2000), where the prevalence of friendships and participation in social activities is low (Orsmond, Krauss, & Seltzer, 2004). Such difficulties are widely attributed to ASD individuals' impaired social knowledge or intelligence.

Tager-Flusberg and Sullivan (2000) have argued that the social difficulties of ASD are two-pronged: ASD individuals have impairments of both social cognition (i.e., the ability to make mental state inferences) and social perception (i.e., the ability to make rapid, online attributions of intentional, emotional, or other person-related knowledge). These difficulties fall under the umbrella of the 'theory of mind' (ToM) account of ASD, which proposes that ASD individuals lack the ability to impute mental states, and so struggle to make sense of and predict others' behaviour. The ToM account is examined more thoroughly below (see 2.6.1.).

The *social cognitive* component of social knowledge incorporates a more traditional concept of ToM (cf. e.g., Premack & Woodruff, 1978), which entails understanding the mind as a representational system (sometimes called 'mentalising' or 'mindreading'). In research on ASD (e.g., Baron-Cohen et al., 1985), social cognition is especially closely related to false belief understanding (Tager-Flusberg & Sullivan, 2000), or the ability to understand that a person can possess beliefs or representations which contrast with reality. In TD children, false belief understanding starts to emerge at around three years of age (Gopnik & Astington, 1988), and becomes the foundation for more complex social cognitive skills acquired in later childhood (e.g., understanding speaker intention in non-literal language; Tager-Flusberg & Sullivan, 2000). Further, and as discussed below (2.5.2.), the development of social cognition is closely related to language acquisition (de Villiers, 2007).

Deficits in false belief understanding are a hallmark of ASD. In most studies, ASD individuals significantly underperform controls on tests of first-order false belief understanding (inferring another person's mental state; e.g., Baron-Cohen et al., 1985;

Leekam & Perner, 1991; Swettenham, Baron-Cohen, Gomez, & Walsh, 1996). They also underperform on tests of second-order false belief understanding (reasoning about ‘embedded’ mental states, which are beliefs about another person’s first-order beliefs; Baron-Cohen, 1989; Ozonoff, Pennington, & Rogers, 1991a), which TD children tend to pass at around 6-7 years of age (Perner & Wimmer, 1985). In addition, ASD individuals show deficits of social cognitive abilities which build on false belief understanding, such as deception (Yirmiya, Solomonica-Levi, & Shulman, 1996), or humour (Baron-Cohen, 1997).

Social cognitive impairment in ASD seems to be selective, however (Tager-Flusberg & Sullivan, 2000). Individuals diagnosed with AS, which is associated with greater language and intellectual ability, are able to pass tests of false belief understanding (Bowler, 1992; Ozonoff, Rogers, & Pennington, 1991b). Yet AS individuals still experience social difficulties (e.g., a lack of reciprocity in social interactions), raising the possibility that they solve mental state attribution problems using ‘non-ToM’ strategies (Ozonoff et al., 1991b; cf., also 2.5.2, below), a possibility supported by neuroimaging research (Happé et al., 1996). A more recent hypothesis is that, in ASD, the performance gap between false belief tasks and everyday social interactions could be explained by deficits of executive functioning (EF), a collective term for cognitive processes which help to control action. Nilsen and Fecica (2011) propose that ASD children who pass false belief tasks, but who also have clinically significant social impairments, might lack the cognitive skills (i.e., EF) required to make use of mental state information. The intersection of ToM and EF deficits in ASD is considered more fully in 2.6.3.

The *social perceptual* component of social knowledge is a developmental precursor of social cognition, and is more related to the affective system than to language and other cognitive abilities (Tager-Flusberg & Sullivan, 2000). Social perception involves using immediately available perceptual information to form impressions of people and their behaviour, rather than reasoning about the same (as is the case with social cognition).

There is evidence that social perceptual understanding is impaired in ASD, again selectively (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997). For example, ASD individuals have deficits in face discrimination and recognition, and employ atypical strategies when processing faces (for a review, cf., Dawson, Webb & McPartland, 2005). Relatedly, they experience difficulty gleaned emotional information from faces (Harms, Martin, & Wallace, 2010), and show atypical sensitivity to eye gaze (Nation & Penny, 2008).

While primarily concerned with mentalising deficits, and the wider impact of these, this thesis is alert to the likelihood that perceptual and cognitive impairments jointly produce the social difficulties associated with ASD; this issue is explored further in the General Discussion.

### *2.5.2. Atypical language and communication*

It is important to note that not all ASD individuals develop language, and as many as 30% remain functionally non-verbal (Anderson et al., 2007). ASD children might also be delayed in their development of language: before the reclassification of autism to ASD, language delay was a diagnostic feature used to discriminate AS (involving age-appropriate language acquisition) from higher-functioning autism (HFA). Although ASD is now regarded as a unitary disorder, the level of language ability varies across the spectrum, in some major ways (e.g., language acquisition versus none), but also more subtly. This subsection is intended to give a broad overview of the language difficulties in ASD, as far as this is possible.

Where ASD is concerned, a useful distinction can be made between *structural* and *communicative* language deficits, among individuals who are at least partly verbal (Boucher, 2003). While in practice, there is a close association between structural and communicative language ability in ASD (Saulnier & Klin, 2007), dissociating these elements helps to define the different language profiles of the disorder. Structural language abilities are highly



variable among ASD individuals, who may differ in the extent to which they master the formal aspects of language (e.g., syntax, morphology, and phonology; Grzadzinski, Huerta, & Lord, 2013). Communicative language deficits are more pervasive in ASD, however (Tager-Flusberg, 2006), and constitute a diagnostic criterion for the disorder, whereas structural language deficits do not (American Psychiatric Association, 2013).

The structural deficits observed in ASD vary across the spectrum and by age. For example, in AS, phonological and grammatical abilities are within the normal range (Kjelgaard & Tager-Flusberg, 2001; Saalasti et al., 2008); in contrast, individuals with lower-functioning ASD (associated with lower language and intellectual ability) tend to have difficulties with both these aspects of language (Rapin & Dunn, 2003). Furthermore, ASD pre-schoolers have more pervasively impaired and deviant structural language than older ASD children and adults (Geurts & Embrechts, 2008; Rapin, Dunn, Allen, Stevens, & Fein, 2009). This finding may not be a straightforward consequence of language delay, but a function of comorbid yet transient specific language impairment (SLI) in a proportion of very young ASD children (Boucher, 2012).

Despite the variability just described, group studies suggest an overall ‘ASD-typical’ profile for the structural language abilities of verbal school age ASD children and adults (for a review, see Boucher, 2012). This profile encompasses deficits of semantics and morphology, along with relative sparing of phonology and syntax. Comprehension is also an impairment within the profile, and is more affected than production; this discrepancy may reflect mentalising deficits (Surian, Baron-Cohen, & Van der Lely, 1996), and is perhaps especially relevant to the processing of referential, meaningful aspects of language. It has been proposed that the structural language impairments of ASD are produced by time parsing deficits (Boucher, 2000); according to this hypothesis, ASD individuals have impaired ability to process transient, sequential stimuli, such as speech. An alternative explanation is that processing deficits are related to the reduced orientation of some ASD

individuals to speech; social interest in speech appears to enhance phonetic discrimination skills in young TD children (Kuhl, Coffey-Corina, Padden, & Dawson, 2005).

Difficulties with pragmatic uses of language are regarded as central to the communicative language deficits of ASD (Tager-Flusberg & Anderson, 1991). Pragmatics is the study of the rules and conventions governing the on-line use of language in a social situation, which draws on social mores (e.g., how to address a peer versus an authority figure) and social cognitive understanding (e.g., tailoring speech to accommodate a listener's knowledge; Boucher, 2003). Since pragmatic language use involves the negotiation of meaning between speaker and listener, it is related to semantics, though these areas of linguistic competence are conceptually distinct (for a discussion, see Garnham, 1985). A conceptual distinction between semantics and pragmatics is maintained in this thesis, particularly in Article 3; 'semantic ability' refers to children's understanding of meanings of words or phrases, and the expression of these, whereas 'pragmatic ability' entails the production and comprehension of meaning, not only with respect to linguistic information, but also contextual (e.g., social) factors.

Pragmatic language use is the focus of Grice's (1975) theory of implicatures, which lists nine guidelines (maxims) for the quality, quantity, relevance, and manner of communicative speech. Following these maxims helps to achieve the goal of co-operative conversation:

*The maxim of quantity*

1. Be as informative as possible.
2. Do not give more information than needed.

*Maxim of quality*

3. Be truthful
4. Do not supply information that is false, or which is not supported by evidence.

*Maxim of relation*

5. Be relevant

*Maxim of manner*

6. Avoid ambiguity
7. Avoid obscure expressions
8. Be orderly
9. Be clear

Very young TD children may neglect Gricean maxims when addressing an interlocutor (Warren & Tate, 1992), although 3 year olds are sensitive to others' violations of the relation and quality maxims (Eskritt, Whalen, & Lee, 2008). By contrast, it has been shown that much older ASD children struggle to detect violations of the maxims of relation, quality, and quantity, and that their ability to successfully detect such violations relates to ToM understanding (Surian et al., 1996).

Pragmatic deficits are also evident in ASD children's comprehension of figurative language, examined by Happé (1993) within the framework of Sperber and Wilson's (1986) relevance theory. Relevance theory, like Gricean approaches to pragmatics, highlights the centrality of intention-reading and inference in communication; these skills are required to process the underlying (i.e., non-literal) meaning of figurative expressions. Happé (1993) found that ASD children had difficulties in inferring the pragmatic meaning of metaphors and ironic remarks, which corresponded with ToM impairments of varying degrees. Specifically, ASD children who passed first-order false belief tasks were able to comprehend similes and metaphor, but not irony; those who passed second-order false belief tasks understood all three types of figurative language. More recently, Norbury (2005) has argued that ToM may be necessary but not sufficient for the comprehension of

metaphors; structural language deficits account for poor metaphor comprehension in some ASD children.

A fuller review of communicative language deficits in ASD is deferred to Section 3, which summarises findings about conversation in ASD, and the nature of pragmatic deficits associated with this. At present, further consideration is given to the close relationship between ToM and language, which has been touched on already in this section. Many studies have examined the relationship between ToM and communicative language deficits in ASD (Tager-Flusberg, 2000). It seems intuitive that pragmatic skills, which require understanding of the speaker-listener relationship, depend at some level on ToM abilities (cf., Hobson, 1989, for an alternative view); likewise, it follows that ToM impairment should in some way compromise pragmatic skills, and this is attested by Happé's (1993) and Surian et al.'s (1996) studies, and other studies besides (e.g., Hale & Tager-Flusberg, 2005; Tager-Flusberg, 1993). These demonstrate that ASD children who have impaired mentalising abilities also struggle to use language effectively in a social context, and the influence may be bidirectional (Nilsen & Fecica, 2011). Nevertheless, the relationship between ToM understanding and communicative competence is not straightforward in ASD, a matter taken up more fully in Section 3.

Studies have identified a relationship between ToM and structural language skills, in typical development (cf., de Villiers, 2007) and ASD (cf., Tager-Flusberg, 2000). To some extent, this is an unsurprising finding, since the majority of tasks used to assess ToM have a strong, verbal component, meaning that verbal ability is a precondition for coping with task demands (Malle, 2002). It seems, however, that ASD children require even higher language ability than TD children to be successful on ToM tasks (Happé, 1995), suggesting that the relationship between ToM and structural language skills is especially strong in ASD. Tager-Flusberg (2000) has explained the strength of this relationship in terms of ASD children's bootstrapping of a representational understanding of mind (alternatively

referred to as ‘hacking’; Frith, Morton, & Leslie, 1991), in tests of e.g., false belief understanding. Since ASD children struggle with mental state attribution, they may be more reliant in false belief tasks on their knowledge of complement constructions (e.g., ‘that Mary is at school’, in the sentence ‘John thinks that Mary is at school’), which offer a representational format for conceptualising and articulating propositional attitudes. Tager-Flusberg’s (2000) hypothesis is supported by research showing that knowledge of complement syntax promotes false belief understanding in ASD children (Hale & Tager-Flusberg, 2003; Lind & Bowler, 2009).

There is evidence that structural language, like communicative language, co-develops with ToM in ASD. de Villiers (2007) has argued that, in typical development, there is a bi-directional interface between these faculties: TD infants are sensitive to the communicative intentions of others, providing a foundation for early language acquisition (e.g., Tomasello & Farrar, 1986); TD four year olds then begin to use language to reason about other minds (e.g., Shatz, Wellman, & Silber, 1983). Studies of ASD children also support the notion of a bi-directional influence between ToM and structural language development. While it is known that syntactic knowledge relates to ASD children’s performance on ToM tasks (Hale & Tager-Flusberg, 2003; Happé, 1995; Lind & Bowler, 2009), it has also been shown that ASD children’s early acquisition of language is predicted by individual differences in joint attention, the ability to co-ordinate attention with a partner to an object or event (Mundy, Sigman, & Kasari, 1990). Mundy et al. (1990) found that expressive language was impaired in ASD children who displayed joint attention deficits at initial assessment, suggesting that joint attention is an important developmental precursor of language skills.

Reference to joint attention deficits serves to underline that some of the communication difficulties associated with ASD are in the non-verbal domain. Joint attention deficits are widely reported in ASD (Bruinsma, Koegel, & Koegel, 2004), and recognised by diagnostic criteria as an example of ‘reduced sharing of interests’ (American Psychiatric Association,

2013). ASD individuals are impaired in using other forms of non-verbal communication as well. For example, ASD children and adolescents display fewer gestures (e.g., head nods) than developmentally delayed (DD) controls during conversation (García-Pérez, Lee, & Hobson, 2007), and struggle to integrate gesture with speech (So, Wong, Lui, & Yip, 2014). These findings might reflect deficits of spontaneous imitation in ASD (Vivanti & Hamilton, 2014), a topic which is covered more fully in Sections 2.5.3 and 4. ASD individuals' impaired understanding of non-verbal communication, such as gaze comprehension (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995), are part of the social perceptual impairments described above.

### *2.5.3. Repetitive, stereotyped behaviour and/or narrow interests*

Repetitive, stereotyped behaviours are common in ASD, but have received far less attention than the social and communication difficulties associated with the disorder (Lewis & Bodfish, 1998), although they may compound these difficulties (Hilton, Graver, & LaVesser, 2007). Overall, repetitive behaviours tend to be more common in young ASD children, and tend to be more complex in ASD children who are older and/or who have higher IQ (Militeri, Bravaccio, Falco, Fico, & Palermo, 2002). Further, repetitive behaviours relate to imagination impairments in ASD children, as posited by Wing and Gould's (1979) triad (Honey, Leekam, Turner, & McConachie, 2007). In ASD adults, repetitive behaviour severity predicts the severity of the disorder (Bodfish, Symons, Parker, & Lewis, 2000).

Lewis and Bodfish (1998) propose two distinct presentations for repetitive behaviour in ASD: repetitive sensory-motor behaviour (sometimes called 'stimming'), and insistence on sameness behaviour. Hand flapping, rocking, and head banging are all examples of repetitive sensory-motor behaviour (Wing, 2002), and may emerge as early as infancy (Wolff et al., 2014). These types of behaviour have recently been linked to EF deficits, of

inhibitory control (IC) and cognitive flexibility (Mostert-Kerckhoffs, Staal, Houben, & Jonge, 2015). A similar explanation has been offered for echolalia, a language disorder associated with ASD, and involving automatic, non-intention mimicry of others' speech. Echolalia, which might be considered as a form of verbal stimming, is thought to result from IC deficits (Grossi, Marcone, Cinquegrana, & Gallucci, 2013).

ASD individuals who insist on sameness behaviour pursue elaborate, repetitive routines, or require other people to do so, and such rigidity can persist into adulthood. For example, older ASD children and adults might arrange their personal possessions in a fixed order, which no one is allowed to disturb (Wing, 2002). Insistence on sameness is associated with elevated levels of anxiety, among ASD children who are highly anxious (Rodgers, Glod, Connolly, & McConachie, 2012). Moreover, ASD children who engage in repetitive sequences of play have increased presence and severity of anxiety symptoms (Spiker, Lin, Van Dyke, & Wood, 2012); for these children, repetitive behaviours may serve as a coping strategy for dealing with negative affect. In more able ASD individuals, elaborate, repetitive activities can take the form of narrow interests, or fascination with a specific subject or object (Wing, 2002). There is some evidence to suggest that ASD children are more motivated to engage in social interactions, when they are allowed to focus on their narrow interest (Boyd, Conroy, Mancil, Nakao, & Alter, 2007).

The repetitive behaviours just outlined, which are imitation-like phenomena, hint at imitative abnormalities in ASD; ASD individuals may excessively copy actions and language without regard to a specific goal or meaning (Williams, Whiten, Suddendorf, & Perrett, 2001). Yet as noted, imitative deficits have been widely observed in ASD, in terms of motor acts (Vivanti & Hamilton, 2014). Imitative deficits are especially pronounced when a copyable action is unfamiliar, or when it does not have a clear goal or outcome. For example, after seeing a social partner demonstrating actions on a novel object, ASD children demonstrate a reduced tendency to copy any visibly unnecessary actions,

compared with TD children (Marsh, Pearson, Ropar, & Hamilton, 2013); these deficits may stem from a reduced sensitivity to affective influences, e.g., a desire to affiliate. In contrast to the literature on motoric imitation, studies of linguistic imitation in ASD are few; the limited research available is focused primarily on eliciting speech in non-verbal ASD children (cf., e.g., Field et al., 2013), rather than on imitative linguistic behaviour per se. Studies of language alignment (Allen et al., 2011; Slocombe et al., 2012; see 5.1) have begun to address the disparity of research into linguistic versus non-linguistic imitation in ASD.

## *2.6. Prominent psychological theories of ASD*

Several theories have been proposed to explain the core, defining symptoms of ASD. This subsection outlines two of the most prominent psychological theories of ASD, the ToM account and the Executive Dysfunction (ED) account, which are the most relevant to this thesis. ASD symptomatology is attributed to social cognitive deficits by the ToM account, and to deficits of domain-general processing by the ED account. No account has provided a complete explanation of ASD, however, prompting calls for a more pluralist approach to understanding the disorder (Happé, Ronald, & Plomin, 2006). In fact, the ToM and ED accounts are innately complementary, because there seems to be a developmental relationship between ToM and EF, both in TD children (Carlson, Moses, & Hix, 1998; Carlson & Moses, 2001; Flynn, O'Malley, & Wood, 2004), as well as in ASD children (Joseph & Tager-Flusberg, 2004; Pellicano, 2007; Zelazo, Jacques, Burack, & Frye, 2002). This relationship, which is relevant to Article 2, is explored in greater depth in 2.6.3.

### *2.6.1. The ToM account*

The ToM account (Baron-Cohen et al., 1985) proposes that ASD impairments, especially those in the communication domain, result from metarepresentational deficits. As noted in 2.5.1, deficits of false belief understanding in particular are thought to underlie the



‘mindblindness’ (i.e., mentalising difficulties) observed in ASD individuals, although this may entail broader social cognitive impairment, as well as deficits of social perception (Tager-Flusberg & Sullivan, 2000). According to the ToM account, the effect of mindblindness is that ASD individuals are impaired in their ability to understand and predict behaviours of other people (although cf., Chevallier, Kohls, Troiani, Brodtkin, & Schultz, 2012, for an opposing view of this relation). Neuroimaging studies lend support to this idea: during ToM tasks, both ASD adults (Just, Keller, Malave, Kana, & Varma, 2012) and children (Kana et al., 2015) show altered activation of the frontal posterior network, which is implicated in social cognitive processing in TD individuals.

The strength of the ToM account is that it reliably explains the social and communication difficulties associated with ASD (Baron-Cohen, 2001). Further, because language learning is social and interactional, the ToM account can also explain why some ASD individuals lack structural language skills (de Villiers, 2000). What the account does not explain is the non-social features of ASD (e.g., insistence on sameness behaviour). In addition, the account is less able to explain the social perceptual deficits of ASD (e.g., emotion recognition; Baron-Cohen, 2008), since perceptual judgements do not involve social cognitive reasoning. It has recently been suggested that a more nuanced conceptualisation of ToM is necessary to better understand how different aspects of social intelligence govern different social behaviours (Schaafsma, Pfaff, Spunt, & Adolphs, 2015); this would complement Happé et al.'s, (2006) appeal for a more pluralistic understanding of ASD symptomatology.

### *2.6.2. The ED account*

The ED account (Pennington, Rogers, & Bennetto, 1997; Russell, 1997) ascribes ASD symptomatology to impaired cognitive control processes (i.e., EF), which are not specific to social cognition (Joseph & Tager-Flusberg, 2004). These include cognitive flexibility and

IC, as noted, but also planning, working memory, and the initiation of actions and ideas (also called *generativity*; Hill, 2004). EF supports the planning, organisation, and management of goal-directed behaviour, including motor acts, attention, and thoughts (Baron-Cohen, 2008). Although the component processes of EF likely operate interactively, they are also fractionable (Joseph & Tager-Flusberg, 2004). This is demonstrated by studies which highlight a distinct EF profile for ASD, in which planning and cognitive flexibility are areas of relative weakness (Hill, 2004; Ozonoff & Jensen, 1999), while working memory is relatively spared (Ozonoff & Strayer, 2001). Hill (2004) has pointed out that there is evidence for and against the hypothesis that ASD individuals have IC deficits. More recently, two meta-analyses concluded that two types of IC (delay and conflict IC) are impaired in ASD (Borbély, 2014; Geurts, van den Bergh, & Ruzzano, 2014).

The repetitive, stereotyped behaviours observed in ASD relate most clearly to ED, which would give rise to stimming, through the influence of cognitive inflexibility, and/or impaired IC (Griffith, Pennington, Wehner, & Rogers, 1999; Grossi et al., 2013; Mostert-Kerckhoffs et al., 2015). What is less clear is how social and language difficulties experienced by ASD individuals relate to ED (Griffith et al., 1999). Studies highlighting an association between ToM and EF (Joseph & Tager-Flusberg, 2004; Pellicano, 2007; Zelazo et al., 2002) indicate that EF relates to mentalising abilities in ASD, and may thereby influence social and language skills. Evidence for a link between ED and social difficulties in ASD is mixed, however. Some studies have shown that EF and social competence are related in ASD (e.g., McEvoy, Rogers, & Pennington, 1993), but others have not (e.g., Bishop, 2005).

### *2.6.3. Relationship between the ToM and ED accounts*

There has been much debate over the relationship between the ToM and ED accounts of ASD, and three positions have emerged from this (Hill, 2004). One argument is that the development of EF is necessary for the development of ToM (Ozonoff et al., 1991a), and this draws support from research showing that EF has developmental primacy over ToM in both ASD and TD children (Pellicano, 2007). Such evidence is a challenge to an alternative and opposing argument, which is that metarepresentational ability precedes the development of EF; an individual must first be able to represent their own intentions, if they are to plan ahead (Perner, 1998). A third argument is that ToM and EF are not separate entities at all, and that performance on ToM tasks can be reduced to EF (Frye, Zelazo, & Palfai, 1995).

More recent theorising about ASD has sought to integrate the ToM and ED accounts, reflecting the fact that ASD symptomatology cannot be explained in terms of a single deficit (Happé et al., 2006). Nilsen and Fecica (2011), for example, have proposed that impaired communication in ASD may result from deficits of ToM, or EF, or both. Their model of communicative perspective-taking describes how children process and use mental state information in conversation. Nilsen and Fecica (2011) propose that, for some children, adequate mentalising ability is a necessary but not sufficient condition for successful communicative performance. They point out that, while studies have revealed links between ToM and communication abilities, in TD (e.g., Astington & Jenkins, 1995) and ASD (Eisenmajer & Prior, 1991) children, the picture seems to be more complicated than this. Accordingly, there is evidence that basic ToM ability in TD children does not always translate into communicative competence (e.g., Mitchell, Robinson, & Thompson, 1999). Similarly, gains in ToM understanding do not automatically prompt gains in conversation skills in ASD children (e.g., Hadwin, Baron-Cohen, Howlin, & Hill, 1997).

Hence Nilsen and Fecica (2011) suggest that, for children to make use of their mentalising abilities, they must also possess pre-requisite cognitive skills to support communicative perspective-taking. In particular, they argue that EF underlies children's ability to integrate mental state information during communication exchanges. This claim is partly informed by studies which have specifically implicated IC in communicative perspective-taking, in the typical population. These studies show that TD children and adults who have higher IC are faster and more accurate at using mental state information in conversation; they are better able to accommodate differences between their own and their partners' knowledge during referential processing (Brown-Schmidt, 2009; Nilsen & Graham, 2009; Wardlow, 2013). Since ASD children have IC deficits (Geurts et al., 2014), a link between IC and communicative perspective-taking might explain why some ASD individuals display conversational deficits, despite being able to pass ToM tasks.

The next subsection looks more closely at the communicative difficulties addressed by Nilsen and Fecica's (2011) model, and summarises some alternative theories which have been proposed to account for conversational deficits in ASD.

### **3. Overview of conversation in ASD**

Conversational deficits are widely recognised in ASD (Frith, 1989; Paul, 2005), and are a clinically significant index of the disorder (American Psychiatric Association, 2013). In 2.5.2, it was suggested that pragmatic impairment is central to ASD individuals' communicative difficulties: they struggle with conversation because this requires sensitivity to the social context, and because they must infer a listener's knowledge, both in their production and comprehension of conversational utterances. These are areas of difficulty for ASD individuals, however, owing to their impaired social understanding. ASD

individuals may also struggle with the non-linguistic aspects of conversation, such as gesture (So et al., 2014).

This section provides an overview of the findings about how ASD individuals engage in conversation, although there have been relatively few systematic investigations into this question (as noted by Capps, Kehres, & Sigman, 1998). An aim of this section is to specify more precisely the nature of the conversational deficits associated with ASD. There is particular focus on the linguistic features of conversation in ASD; these are most relevant to the models of language production described in Section 8, and provide the impetus for the articles in this thesis. This section also reviews non social-cognitive accounts of conversational deficits in ASD, such as Hobson's (1989) affective theory.

### *3.1. Past research on conversational deficits in ASD*

Despite evidence that ASD adults lack communicative competence (e.g., Eales, 1993; Trepagnier, Olsen, Boteler, & Bell, 2011), studies have primarily examined the conversational deficits of ASD children. This focus may reflect the developmental trajectory of communicative competence (Shatz and Gelman, 1973): since children are less skilled communicators than adults, the communicative difficulties associated with ASD may seem particularly pronounced in childhood. Communication difficulties may also limit ASD children's social exposure, thereby affording them fewer future opportunities for conversational interaction, and compounding such difficulties further (Nilsen & Fecica, 2011).

The act of conversation involves speaker and listener functions, and as the theories outlined in Section 8 suggest, these appear to be closely linked. ASD individuals encounter difficulties whether they are the speaker or the listener in a conversation. In the role of speaker, ASD children's conversational deficits are multi-faceted. Very young ASD children are less likely than TD children to instigate communication, and when they do

speak to a conversational partner, it is more often to request actions or objects; they less often pass comment, which serves a social function (Stone, Ousley, Yoder, Hogan, & Hepburn, 1997). In later development, ASD children struggle to maintain a topic of discourse: instead of contributing new, relevant information to a conversation, they introduce irrelevant comments (Tager-Flusberg & Anderson, 1991). Further, Tager-Flusberg and Anderson's (1991) study showed that growth in structural language skills is not accompanied by growth in communicative language ability in ASD children, as it is in DD children. This finding underscores how pragmatic deficits can impede the development of conversation skills in ASD.

ASD individuals' conversational deficits extend beyond their difficulties with following Gricean maxims, outlined in 2.5.2. Pragmatic impairment has a more pervasive effect on conversational speech in ASD. For example, higher-functioning ASD individuals commonly have a pedantic speaking style, and adopt unusually sophisticated vocabulary when addressing an interlocutor (Ghaziuddin & Gerstein, 1996; Shriberg et al., 2001). Capps et al. (1998) showed that, compared with DD controls, ASD children do not respond appropriately to questions in conversation, and they are also less successful at enacting effective repair in the event of communicative breakdown (Baltaxe, 1977; Geller, 1998; Volden, 2004). Volden's (2002) taxonomy of ASD children's conversational utterances indicates that, in addition to the difficulties already mentioned, ASD children are more prone than TD children to violating exchange structure, and to exhibiting socially inappropriate content or style. They are also more likely to offer either too much or too little information to an interlocutor (Volden, 2002).

Overwhelmingly, the conversational deficits observed in ASD children have been attributed to impaired ToM, whether presumed (e.g., Volden, 2002) or determined by ToM tasks (Capps et al., 1998). As discussed, the importance of ToM for pragmatic skills seems intuitive, but the relationship between ToM understanding and communicative competence

is not straightforward in ASD. When ASD children are given mental state teaching, this does not promote significant improvements in their conversational ability (Hadwin et al., 1997). Conversely, training ASD children's conversation skills does not lead to improved false belief understanding (Chen & Bernard-Opitz, 2000). While these results may in part reflect the difficulties of training ToM, and in particular concepts such as appearance-reality distinction (Flavell, Green, & Flavell, 1986), they also suggest that a more expansive account may be necessary to understand the conversational deficits of ASD. Nilsen and Fecica's (2011) model goes some way to addressing this need, by identifying ToM, EF, and experiential components in the development of ASD children's communicative competence.

An alternative account of communication in ASD acknowledges the role of pragmatic impairment in ASD individuals' conversational deficits, but attributes pragmatic impairment to affective rather than social cognitive influences (Hobson, 1989). ASD children commonly have affective problems, including reduced social orientation and affiliative behaviour (Klin, 1991). For example, ASD children have deficits in understanding emotion (Hobson, 1986; Ozonoff, Pennington, & Rogers, 1990; Yirmiya, Sigman, Kasari, & Mundy, 1992), and show impaired prosocial behaviour (Liebal, Colombi, Rogers, Warneken, & Tomasello, 2008). Such problems are among the social perceptual deficits described in 2.5.1.

Hence Hobson's (1989) affective theory proposes that the social and communication difficulties seen in ASD, including pragmatic deficits, stem from ASD individuals' lack of ability to interact emotionally with others. While not all the predictions of Hobson's (1989) theory are supported by studies of social deficits in ASD (cf., Baron-Cohen, 1988, for a review), there is evidence to suggest that affective factors influence ASD individuals' communicative behaviour. For example, ASD children who show reduced signs of affiliation (e.g., smiling) in conversation find it more difficult to infer their interlocutor's

intended meaning (Hobson, Hobson, García-Pérez, & Du Bois, 2012). Further, ASD children who show reduced affective engagement (i.e., emotional connectedness) with an interlocutor also have conversations which run less smoothly and appear less well coordinated (García-Pérez et al., 2007).

It is possible that the affective disturbances observed by García-Pérez et al. (2007) and Hobson et al. (2012) relate somehow to the imitative abnormalities outlined in 2.5.3. In the typical population, mimicry is associated with and moderated by affective factors (van Baaren, Janssen, Chartrand, & Dijksterhuis, 2009). For example, typical adults experience increased liking of confederates who mimic their posture and movements (Chartrand & Bargh, 1999), and tend to mimic people they like more than people they don't (Stel et al., 2010). Likewise, TD infants adopt a more pro-social orientation towards others when mimicked by an experimenter (Carpenter, Uebel, & Tomasello, 2013), and TD children who are indirectly exposed to social exclusion show increased affiliative imitation (Over & Carpenter, 2009). Thus it may be that there is a relationship between the reduced emotional engagement and reduced co-ordination observed in ASD children's conversations. If so, this would support the proposal that ASD children's imitative deficits are a function of their reduced sensitivity to affective influences (Marsh et al., 2013). The importance of imitation, specifically linguistic imitation, for promoting mutual understanding in conversation is discussed in Section 4.

### *3.2. Limitations of past research on conversational deficits in ASD*

Since studies of conversation in ASD are relatively few in number (Capps et al., 1998), questions remain over the nature and the causes of ASD individuals' conversational deficits. One topic that has received limited attention in the literature is the extent to which structural language abilities contribute to conversational deficits in ASD. Although the language deficits of ASD are most striking in the communication domain (Tager-Flusberg,



2006), it is clear that ASD individuals' structural language skills relate in some way to their communicative competence (Saulnier & Klin, 2007). Norbury (2005), as noted, found that structural language skills accounted for some ASD children's inability to infer the intended meaning of metaphorical expressions. Further, Volden (2002) reported that ASD children make syntactic errors and unusual semantic selections in conversation (e.g., saying 'beginning' to describe the entrance to a building), which their listeners judge as inappropriate for the conversational context. In Capps et al.'s (1998) study, which demonstrated a relationship between ASD children's ToM understanding and communicative competence, it was found that this relationship was statistically non-significant once language ability was covaried out. Clearly, the importance of structural language skills for ToM task performance (Hale & Tager-Flusberg, 2003; Lind & Bowler, 2009) could explain this finding, but Capps et al. (1998) also found a correlation between ASD children's verbal mental (VM) age and their conversational contributions of relevant, new information; this suggests that ASD children's communicative competence may be limited by structural language deficits, as well as by impaired social knowledge; a dual deficit is especially likely given the close relationship between these entities.

In addition, and as discussed, studies have sought to understand how ASD individuals engage in conversation in terms of a single deficit model of the disorder (e.g., the ToM account). This approach has proved uninformative in the majority of studies, however, and hence a more pluralistic examination of conversational deficits in ASD seems to be in order. Apart from sharpening the focus on structural language deficits, and their contribution to ASD individuals' communicative difficulties, there is scope for considering whether additional mechanisms (i.e., besides ToM) underlie these difficulties. The influence of e.g., ED on ASD individuals' communicative perspective-taking is an obvious avenue for such exploration, as has been proposed (Nilsen & Fecica, 2011).

Theories of alignment (Branigan et al., 2011; Pickering & Garrod, 2004), which are psycholinguistic accounts of dialogue, offer an opportunity for examining the conversational deficits of ASD in terms of their linguistic characteristics, and how these might relate to underlying language processing mechanisms. Alignment involves the convergence of linguistic representations between interlocutors, and as will be elaborated in 4.2.2., it has been implicated in the achievement of successful communication (Pickering & Garrod, 2004), through the promotion of mutual understanding and positive social relations. Further, research suggests that alignment has multiple components (Branigan, Pickering, Pearson, & McLean, 2010), one of which is associated with reasoning about an interlocutor's knowledge states (i.e., *audience design*; Branigan et al., 2011). Thus by studying patterns of alignment, it is possible to confirm and clarify the contribution of audience design mechanisms (e.g., ToM) to communicative language production in ASD.

#### **4. Overview of alignment**

The term alignment describes the process by which, in conversation, interlocutors converge on common ways of speaking. For example, having just heard an interlocutor refer to a religious building as a 'chapel', a speaker might describe the building using the same, uncommon name, rather than a more common one (e.g., church). Alignment is a robust and pervasive tendency in normal adult dialogue, and occurs across different levels of language (e.g., word choice; syntax; description schemes; speech rate). It also helps to promote interactions which are communicatively more effective (Fusaroli et al., 2012; Reitter & Moore, 2014), and which are more satisfying for interlocutors (Putman & Street, 1984).

Alignment is a form of linguistic imitation, a phenomenon which has been referred to as 'entrainment' (e.g., Brennan & Clark, 1996) and 'accommodation' (Giles, Coupland, &

Coupland, 1991) elsewhere in the literature. While these alternative terms are not employed in this thesis, they correspond with concepts explored within the broad alignment framework. The term *entrainment*, for example, is used to describe linguistic imitation which is intentional and driven by social factors (Brennan & Clark, 1996). Speakers entrain linguistically because they form conceptual pacts, implicit agreements about what to call an object, and these are based on common ground (i.e., the knowledge which interlocutors share and know that they share with each other; Clark & Wilkes-Gibbs, 1986). A similar view of linguistic imitation is to be found in audience design accounts of alignment (e.g., Branigan et al., 2011; cf., 4.2.1.1).

The term *accommodation*, like *entrainment*, describes linguistic imitation with a social dimension (Giles et al., 1991; Giles & Powesland, 1975) yet accommodation theory (AT) places a stronger emphasis on how affective factors shape conversational interactions. AT is a sociological account of communicative language use, of which two key concepts are convergence and divergence: convergence occurs when speakers modify their speech to more closely resemble the speech of their interlocutor; divergence is the opposite tendency, occurring when speakers seek to make their speech different from an interlocutor's. Proponents of AT claim that people converge linguistically with an interlocutor in order to signal solidarity and similarity; by contrast, people diverge linguistically to assert their difference from and avoid affiliation with an interlocutor (Giles et al., 1991). Such ideas inform *affective* accounts of alignment (cf., Branigan et al., 2010 and 4.2.1.2).<sup>2</sup>

#### 4.1. *History of alignment theory*

Alignment theory is derived only partly from the accounts of linguistic imitation summarised above. An important advancement of alignment theory, compared with other

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<sup>2</sup> Note that, while the term *convergence* features in this thesis, this is not used in reference to accommodation, but as a way of describing the alignment process.

theories of conversational behaviour, is that it offers an account of the processing mechanisms involved in dialogue. Alignment theory builds on research in the ‘language-as-action’ and the ‘language-as-product’ traditions (Clark, 1996) which represent different approaches to understanding how interlocutors operate in conversation.

The language-as-product tradition is influenced by early ideas about generative grammars (e.g., Chomsky, 1965), and supplies mechanistic explanations for how listeners process different levels of representation in an utterance (Cherry, 1956). The tradition is primarily concerned with decontextualized language, however, where processing is not related to the communicative context (Pickering & Garrod, 2004). Thus accounts within the language-as-product tradition construe conversation as double monologue, where speakers produce and comprehend utterances in parallel; such a view overlooks the interactional nature of conversation.

In contrast, accounts in the language-as-action tradition view conversation as a joint activity (Clark & Marshall, 1981), and highlight how interlocutors interpret utterances with respect to the conversational context. Language-as-action accounts also emphasise the goals and intentions of interlocutors, and the effects of these on discourse (e.g., Brennan & Clark, 1996; Giles et al., 1991). Yet these accounts also tend to have a limited focus on language processing in dialogue, and consider production and comprehension primarily in terms of interlocutors’ goals (Pickering & Garrod, 2004).

The first full presentation of alignment theory (Pickering & Garrod, 2004) regards the language-as-product and language-as-action traditions as complementary rather than competing, and explicitly seeks to integrate these in a processing account of dialogue. Pickering and Garrod’s (2004) interactive alignment (IA) account, which is described more fully in 4.2.2, proposes that to achieve communicative success, interlocutors must align their understanding of a topic under discussion. Priming mechanisms are implicated in this process: alignment occurs because exposure to linguistic stimuli (i.e., in a prior utterance)

primes a speaker's own productions in subsequent conversation. The IA account claims that priming is fundamental to alignment, since priming mechanisms are triggered whenever a speaker encounters a particular linguistic stimulus (Pickering & Garrod, 2004). Yet priming effects may be strengthened by the actions of audience design and/or affective mechanisms, and hence the IA account is a bedrock for other accounts of alignment (e.g., Branigan et al., 2011). It is to these accounts that discussion now turns.

#### *4.2. Different accounts of alignment*

Previous research suggests that speakers' tendency to align is subserved by different mechanisms: priming mechanisms, which are activated on exposure to particular representations, and which operate outside the influence of social psychological factors (Pickering & Garrod, 2004); audience design mechanisms, which are sensitive to the knowledge state of an interlocutor, and which thereby drive communicatively strategic language imitation (Branigan et al., 2011); and affective mechanisms, which are sensitive to an interlocutor's affective state, and which drive language imitation that is associated with the pursuit of affective goals (e.g., affiliation; Giles et al., 1991). Different accounts of alignment consider the separate contributions of these mechanisms to the alignment process. *Mediated* accounts (4.2.1) are concerned with the role of either audience design or affective mechanisms in alignment, while *unmediated* accounts (4.2.2) focus on the influence of priming mechanisms.

##### *4.2.1. Mediated accounts of alignment*

Mediated accounts describe how audience design and affective mechanisms contribute to speakers' alignment in conversation. These different mechanisms may be more or less engaged in the alignment process, depending on the conversational context (Reitter & Moore, 2014) and whether the aspect of language is structural (i.e., syntax; cf., Cowan,

Branigan, & Beale, 2011) or more meaning-based (i.e., lexis; Branigan et al., 2011). The audience design and affective accounts are described below.

#### *4.2.1.1. The audience design account of alignment*

The audience design account is based on research showing that, in conversation, speakers may reason about what their listener is likely to understand, and actively tailor their language to their listener's knowledge and competence level (Bortfeld & Brennan, 1997; Brennan & Clark, 1996; Clark, 1996). The aim of audience design is to achieve mutual understanding, which in turn increases the chances of communicative success. Branigan et al. (2011) provided evidence that alignment can be mediated by audience design mechanisms; they showed that, in the typical population, adult speakers' beliefs about an interlocutor's identity influences their tendency to align on lexical choice. Speakers were more likely to follow a conversational partner in describing a picture with a dispreferred name (e.g., coach), instead of a preferred name (e.g., bus), when they believed that the partner was communicatively less capable. Branigan et al. (2011) suggest that speakers communicate in this way because they reason that an interlocutor's use of a particular word signals that the interlocutor understands it, and prefers it to alternatives; native speakers adopt a similar strategy when communicating with non-native speakers (Bortfeld & Brennan, 1997).

The audience design account of alignment implicates ToM: aligning in a communicatively strategic fashion requires speakers to model an interlocutor's knowledge states, and to keep track of common ground. Audience design mechanisms are thus reliant, not only on a speaker having intact mentalising abilities, but also on a speaker's ability to adopt an interlocutor's perspective in preference to his own; these separate communicative components may be contingent on EF as well as on ToM abilities (Nilsen & Fecica, 2011). Note that alignment is not precluded by mentalising deficits: since priming is fundamental

to alignment (Pickering & Garrod, 2004), only impaired priming mechanisms could completely prevent the alignment process from taking place. Indeed, there is evidence that alignment is intact among individuals with ToM impairment, such as patients with schizophrenia (Stewart, Corcoran, & Drake, 2008) and ASD individuals (e.g., Allen et al., 2011). There is a question, however, over whether the priming-based tendency to align can be strengthened by audience design mechanisms in ToM-impaired speakers; this matter is explored further in Section 9, and is the focus of Article 2.

#### *4.2.1.2. The affective account of alignment*

The affective account of alignment (cf., Branigan et al., 2010) is associated with the literature on behavioural co-ordination, which considers the close relationship between social perception and social behaviour (the so-called ‘perception-behaviour’ link; (Dijksterhuis & Bargh, 2001). There is extensive evidence of a ‘chameleon effect’ (Chartrand & Bargh, 1999) in social interactions, whereby people engage in the same behaviour at the same time: for example, interactants mimic each other in terms of their posture (Tia et al., 2011), motor actions (Lakin & Chartrand, 2003), co-speech gestures (Holler & Wilkin, 2011), and even their manipulation of everyday objects (van Baaren, Fockenberg, Holland, Janssen, & van Knippenberg, 2006).

As noted, behavioural imitation relates to and is moderated by affective factors (Carpenter et al., 2013; Chartrand & Bargh, 1999; Over & Carpenter, 2009; Stel et al., 2010), and there is evidence that linguistic imitation follows the same pattern. For example, it has been shown that adults who converge on speech style with an interlocutor are judged more favourably than those who do not (Bradac, Mulac, & House, 1988). Conversely, it has also been demonstrated that speakers align more strongly if they perceive themselves as similar to their interlocutor, and if they prefer compromise as a conflict management style (Weatherholtz, Campbell-Kibler, Jaeger, Hall, & Ave, 2014). As Branigan et al., (2010)

observe, there may be tangible consequences to linguistic imitation, and any resulting positive affect: waitresses receive larger tips when they repeat a customer's order exactly, instead of paraphrasing this (van Baaren et al., 2003). The affective account of alignment is beyond the theoretical scope of this thesis, which primarily focuses on the audience design account (Article 2) and the unmediated account (Articles 1 and 3) of alignment. In the Discussion section, however, it is suggested that the affective account represents a promising new direction for future research into ASD children's alignment.

#### *4.2.2. Unmediated accounts of alignment*

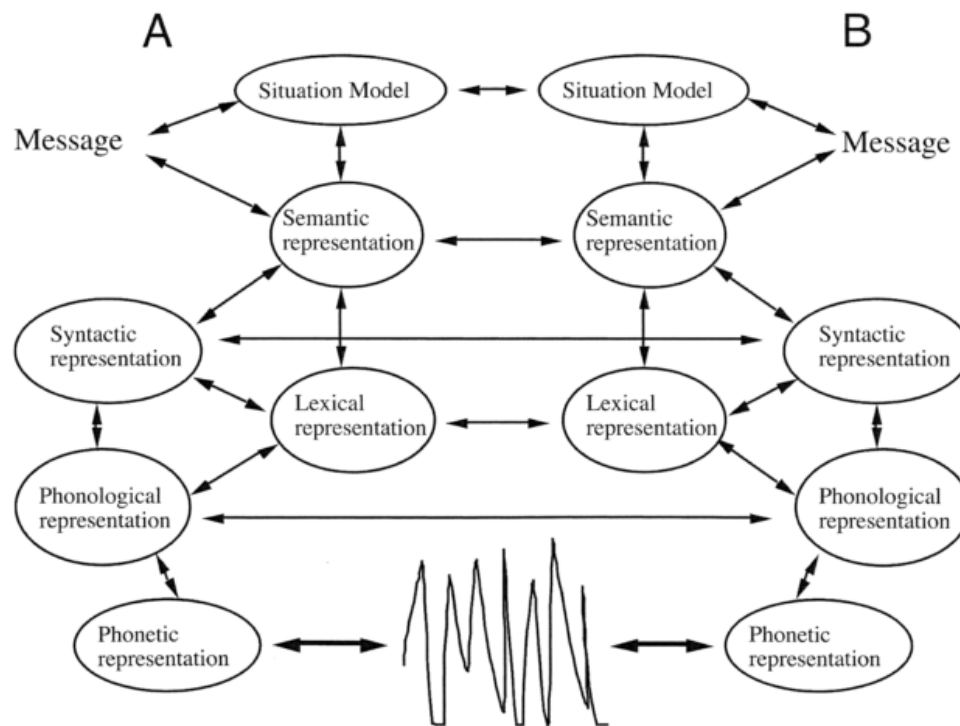
The IA account (Pickering & Garrod, 2004) views alignment as the product of priming mechanisms, and not as a process which is mediated by beliefs about an interlocutor's mental states or social identity (hence the term 'unmediated'). A central tenet of the IA account is that alignment is a largely automatic, unconscious process, occurring as interlocutors converge on linguistic representations. This idea is based on substantial evidence from decontextualized studies of language processing, which show that production is influenced by prior exposure to related linguistic stimuli (Branigan, Pickering, Stewart, & McLean, 2000a); for example, Bock (1986) found that speakers were more likely to repeat the syntactic forms of primes in subsequent utterances. Thus, according to the IA account, alignment comes about for two related reasons: (1) interlocutors prime each other at different levels of representation (e.g., syntax; lexis; semantics); and (2) this is possible because of bidirectional alignment channels, which allow representations to be shared across production and comprehension (see Figure 2). A recent review of neuroimaging research (Menenti, Pickering, & Garrod, 2012) concluded that there is a neural basis for representational parity in production and comprehension processes.

The IA account also proposes that alignment is crucial to conversational success, because it supports interlocutors in developing mutual understanding. For Pickering and



Garrod (2004), mutual understanding is synonymous with aligned situation models; these are multidimensional representations of a discussed subject, and contain information about space, time, causality, intentionality, as well as reference to any contributing individuals (Zwaan & Radvansky, 1998). Alignment of situation models is achieved because there is a percolatory effect to alignment; alignment at one level of linguistic representation (e.g., lexis) promotes alignment at another level (e.g., syntax). An instantiation of this effect is called the ‘lexical boost’ (Pickering & Ferreira, 2008), whereby the sharing of lexical items between utterances increases levels of syntactic alignment.

Figure 2: The IA model, taken from Pickering and Garrod (2004)



NB. Speakers A and B represent two interlocutors in conversation, and arrows represent alignment channels.

Since alignment is automatic, and since the alignment process extends to situation models, a corollary of the IA account is that mutual understanding can be generated simply from the cumulative effects of priming. In this way, the IA account departs from theories

of dialogue in the language-as-action tradition (e.g., Brennan & Clark, 1996), and from audience design accounts of alignment (Branigan et al., 2011), both of which are predicated on the assumption that speakers' communicative behaviour may be governed by beliefs about their interlocutor. The IA account is a cognitively more economical model of dialogue, and concedes a role for social cognitive processes (e.g., mental state inference) only in the event of communicative breakdown, when interlocutors find themselves 'misaligned' semantically. Pickering and Garrod (2004) argue that most instances of communicative breakdown can be repaired via 'clarificatory requests' (Ginzburg, 2001), whereby speakers check a conversation in relation to their own understanding of the conversational topic, and if necessary, revise an utterance to re-establish *implicit common ground* (i.e., information shared by interlocutors during a conversation). If a clarificatory request is unsuccessful, only then might a speaker resort to the more resource-intensive strategy of drawing on *full common ground* (as per Clark & Wilkes-Gibbs, 1986), which involves either overtly or covertly inferring an interlocutor's mental state.

#### 4.3. Theories of priming

There are different explanations for the operation of priming mechanisms, and these are particularly focused on syntactic priming effects (Rowland, Chang, Ambridge, Pine, & Lieven, 2012). One account, the *residual (or transient) activation* model (e.g., Cleland & Pickering, 2003; Pickering & Branigan, 1998) proposes that the comprehension of a particular syntactic structure leads to the activation of lemma nodes associated with that structure in the mental lexicon; residual activation is thought to explain both priming effects and the lexical boost, in dialogue as well as monologue (cf., Branigan et al., 2000b). This model accounts for the finding that priming effects can decay very rapidly (Levelt & Kelter, 1982; Wheeldon & Smith, 2003), since residual activation relies upon memory processes which facilitate short-term recall (Bock & Griffin, 2000).

A second account, the *implicit learning* theory (Bock & Griffin, 2000), understands priming as a form of procedural learning; this view has been developed into a connectionist model of sentence production (e.g., Chang, Dell, & Bock, 2006), wherein syntactic priming is the product of an error-driven learning mechanism. The implicit learning theory fractionates syntactic and lexical priming effects, which may co-occur to produce the lexical boost (cf., Bock & Griffin, 2000; Chang et al., 2006). Further, this theory explains the observed persistence of priming over time (e.g., Hartsuiker & Kolk, 1998), because learning processes would better account for longer term adjustments to sentence production than does memory maintenance (as per the residual activation model).

These different theories of priming also represent different conceptualisations of unmediated alignment, and the functions of this. The residual activation account is concerned with language processing in dialogue, and how alignment relates to successful communication; this account enjoys prominence in this thesis, given that ASD children's communication is the focus of enquiry. Alternatively, implicit learning theory is concerned with language acquisition, since the error-driven mechanism proposed to underlie priming is thought to be the same learning algorithm employed by children in their development of abstract syntax (Chang et al., 2006). The implicit learning theory therefore provides an explicitly developmental model of priming. This model interprets the larger priming effects seen in children (Messenger, Branigan, & McLean, 2011; Rowland et al., 2012) as evidence that they are more easily primed than adults, because children's syntactic knowledge is more weakly represented. The residual activation account predicts that less skilled speakers (e.g., children) are more susceptible to priming because they know fewer structures, and hence primed syntactic structures have fewer competitors when the language processor is recruiting syntax for production (Hartsuiker & Kolk, 1998; Pickering & Branigan, 1999). Recent work has begun to assess how non-linguistic processes (e.g., non-verbal IQ) contribute to TD children's priming (Kidd, 2011).

#### 4.4. *Alignment in TD children*

Although priming effects tend to be stronger in children compared with adults, relatively little is currently known about the nature and mechanisms of alignment in children. Despite efforts to incorporate a developmental perspective into priming-based theories of language imitation (Pickering & Branigan, 1999; Chang et al., 2006; Rowland et al., 2012), most of what is known about alignment is derived from research on normal adult dialogue. Studies have shown that typical adult speakers align on each other's referring expressions (e.g., Brennan & Clark, 1998), their syntactic structures (e.g., Branigan et al., 2000b; Cleland & Pickering, 2003), and even their spatial reference frames (e.g., Garrod & Anderson, 1987) in conversation, and there are cognate findings in the limited literature on alignment in TD children (Messenger et al., 2011; Messenger, McLean, Branigan, & Sorace, 2012; Garrod & Clark, 1993).

Outside of any explicit alignment framework, there is further evidence that TD children converge linguistically in conversation (Branigan, Garrod, & Pickering, 2014). This has been examined by researchers concerned with imitation (e.g., Bloom, Hood, & Lightbown, 1974) as well as in a small number of studies of accommodation. For example, Robertson and Murachver (2003) demonstrated that TD children align their speech style with that of an interlocutor, and that convergence is most prominent on aspects of language where communicative differences between boys and girls might otherwise promote interpersonal conflict. Further, TD 2- and 3- year olds adopt 'baby talk' when speaking to their infant siblings (Dunn & Kendrick, 1982), suggesting that, from a young age, children start to engage in audience design during communication.

The tendency to repeat an interlocutor's language can be associated with more negative outcomes in children than in adults, however. Using a co-operative maze game which prompted dialogue, Garrod and Clark (1993) analysed lexical alignment in pairs of TD children. It was found that, on occasion, alignment precipitated communicative

breakdown, when children assumed from their superficial co-ordination (i.e., shared lexical choices) that they were also co-ordinated on a deeper (i.e., semantic) level. This problem was especially pronounced in the youngest children in Garrod and Clark's (1993) study, whose linguistic and communicative abilities were weakest. The importance of divergence in conversation (i.e., resisting the automatic tendency to align with an interlocutor) is a concern of researchers who challenge aspects of alignment theory (Healey et al., 2014). Their work is considered briefly next.

#### *4.5. The role of divergence in conversation*

Divergence is of central importance to Healey et al.'s (2014) work, which contests the notion of alignment (methodological reasons for this discrepancy are considered in 4.6.); they propose that interlocutors cannot continually align in conversation, and must sometimes systematically diverge from one another, in order to sustain the forward momentum of discussion (cf., also Howes, Healey, & Purver, 2010). The logic of this argument is accepted by theories of alignment (e.g., the IA account), which acknowledge that divergence can sometimes be an essential feature of conversation. For example, if two interlocutors both refer to 'John', but have different underlying interpretations of who John is (i.e., speaker A means 'John Smith' while speaker B means 'John Brown'), then they must at least temporarily reject this shared referent, in order to realign at the semantic level. It may be the case that non-linguistic skills (e.g., non-verbal IQ) support speakers' circumvention of the alignment process, since these contribute to priming (Kidd, 2011). Maturational constraints on the development of such skills would help to explain why children, especially young children, struggle more to resist aligning with an interlocutor, even when doing so is communicatively maladaptive.

#### *4.6. Measuring alignment and divergence*

In the main, studies of alignment have adopted an experimental approach, consistent with earlier, decontextualized studies of linguistic priming (e.g., Bock, 1986). The classic paradigm used in alignment research is a picture description task, wherein language production is elicited under the auspices of a co-operative task. For example, in Branigan et al.'s (2000b) card sorting and description task, a confederate and participant sit either side of a dividing screen, each with a set of pictorial cards. The confederate syntactically primes the participant with a description of a transitive event depicted on her card (e.g., a pirate offering a banana to a robber), which the participant then uses to identify the corresponding card in his own set. The participant then takes his turn to describe another, semantically unrelated card for the confederate to identify. The description-identification roles alternate across the confederate and participant throughout the task, until all cards have been sorted. The participant's tendency (or not) to align with the confederate's syntactic primes is used to calculate an alignment effect; alignment effects represent the difference in the number of aligned descriptions produced by the participant in response to more common ('preferred') versus less common ('dispreferred') primes.

It has been argued, however, that tasks like the one just outlined fail to capture the complexities of 'real-life' conversations (Gries, 2005), raising questions over the ecological validity of the findings obtained through them. Hence an alternative method of examining alignment is to use more naturalistic, corpus data. This approach has been successfully implemented by researchers such as Gries (2005), whose work has informed subsequent, corpus-based investigations of alignment (Healey et al., 2014; Howes et al., 2010). Using natural language processing (NLP) techniques, Gries (2005) found support for the findings of experimental studies of alignment; yet Healey et al. (2010) have partly attributed this to the fact that Gries (2005), like psycholinguistic researchers, includes no control condition in his analyses. Healey et al. (2010) contend that the calculation of alignment effects must

account for chance level repetition of language, in order to establish how much more repetition (i.e., alignment) is produced by the conversational context. Healey et al.'s (2014) different construal of alignment effects is central to their claim that speakers diverge, rather than converge, in conversation.

## **5. Overview of alignment in ASD**

The literature on alignment in ASD is very small, and shows the opposite trend of the wider alignment literature, in so far as there has been greater focus on children than on adults. Studies have considered syntactic (Allen et al., 2011) and lexical (Osborne & Allen, 2012) alignment in ASD children, and Article 1 (Hopkins, Yuill, & Keller, 2015) of this thesis contributes to the same line of enquiry; Slocombe et al. (2012) have examined alignment of syntax, lexis, and spatial frame of reference in AS adults. These studies are considered in more detail below (5.1).

ASD provides an interesting test case for theories of alignment, because several of the impairments associated with the disorder (cf., 2.5) could potentially impact upon the different mechanisms believed to be implicated in the alignment process; this has been the starting point for studies of alignment in ASD, which have hypothesised that ASD individuals show disrupted patterns of alignment in ways that can explain some of their conversational deficits, as outlined in 3.1. For example, given that ASD individuals commonly have imitative deficits, researchers (e.g., Allen et al., 2011) have questioned whether and to what extent the priming mechanisms for alignment are intact in ASD. Other researchers (Osborne & Allen, 2012; Slocombe et al., 2012) have considered whether ASD individuals' social cognitive deficits (e.g., impaired ToM) could affect alignment on levels of language where audience design mechanisms have been shown to influence

language imitation (i.e., lexis) in the typical population. To date, there have been no investigations into whether affective impairments influence ASD individuals' alignment.

### *5.1. Past research on alignment in ASD*

Universally, previous studies of alignment in ASD have been based on psycholinguistic experimentation, rather than corpus data. Further, the ASD participants in these studies are reported as having language skills within the broadly normal range; this is perhaps a reflection of the linguistic abilities required to both understand and engage with the alignment paradigms.

Allen et al., (2011) matched a group of ASD children to two groups of control children, matched for (1) chronological and (2) VM age, and examined the extent to which ASD children aligned syntax with an interlocutor. Syntactic alignment was measured using a variant of the picture description task described in 4.6.; this was a syntactic priming paradigm embedded in the children's card game Snap!, Allen et al., (2011) demonstrated that, first, ASD children had intact alignment, and were more likely to describe a picture card using a passive (dispreferred) structure after hearing their interlocutor use a passive structure to describe another, semantically unrelated picture. Secondly, Allen et al. (2011) reported that ASD children were as likely to align syntax with an interlocutor as were TD children of either the same chronological or same VM age, suggesting that ASD children's conversational difficulties do not stem from a general deficit in linguistic imitation.

Building on the finding that syntactic alignment is intact in ASD, Osborne and Allen (2012) examined whether ASD children also demonstrate lexical alignment. Further, they investigated whether ASD children's lexical alignment reflected audience design considerations, as it does in the typical population (Branigan et al., 2011). Lexical alignment was measured using a version of the Snap! game employed in Allen et al.'s (2011) study, and ASD children's alignment effects were again compared to those of control groups



matched either for chronological or for VM age. Children's performance on the Mind in the Eyes test (Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001), a ToM task which measures emotion processing, provided a proxy measure for their capacity for audience design. Consistent with Allen et al.'s (2011) findings, Osborne and Allen (2012) demonstrated that lexical alignment was intact, but found no relationship between ToM abilities and alignment in any of the groups. They interpreted this as evidence that lexical alignment is unmediated in ASD and TD children.

Slocombe et al.'s (2012) study of AS adults supports and extends the findings of Allen et al. (2011) and Osborne and Allen (2012). The AS group was compared with a group of typical adults on two co-operative tasks: one task was based on Branigan et al.'s (2000b) card sorting task, and was used to measure syntactic alignment; lexical alignment was measured on a novel puzzle solving task, in which participants arranged cards depicting single objects on a grid. The navigational element of this puzzle allowed the researchers to measure alignment on spatial frames of reference as well. Like the ASD children in Allen et al. (2011) and Osborne and Allen's (2012) studies, AS adults aligned syntax and lexis with an interlocutor, and to the same extent as typical controls. Moreover, both AS and typical adults aligned on an interlocutor's egocentric frame of reference, suggesting that they distinguished between their own and their interlocutor's perspective during referential processing; this finding hints at the operation of audience design mechanisms in participants' alignment.

## *5.2. Limitations of past research on alignment in ASD*

Overall, the limited studies that exist suggest that alignment is intact in ASD, and that both ASD children and adults converge linguistically with an interlocutor to the same extent as their typical counterparts (Allen et al., 2011; Osborne & Allen, 2012; Slocombe et

al., 2012). Nevertheless, and mostly owing to a paucity of relevant literature, there are many outstanding questions about alignment in ASD.

An obvious question relates to unmediated accounts of alignment: if unmediated (priming) mechanisms are intact in ASD, why then do ASD individuals not find conversation ‘easy’, as it is assumed to be (Garrod & Pickering, 2004)? It is also a challenge to reconcile aspects of the IA account with the findings of the broader literature about conversation in ASD. As Slocombe et al. (2012) have pointed out, ASD individuals’ failure to tailor communication to the informational needs of their listener implies a failure to align on situational models, suggesting that the percolatory effect of alignment is neither smooth nor automatic in ASD. Allen et al. (2011) have suggested that the unmediated alignment process may be impeded by semantic language deficits in ASD, but the extent to which unmediated alignment promotes successful communication for ASD individuals, and ASD children in particular, is not known.

Another question unanswered by the literature concerns the mediated component of alignment in ASD. While previous research seems to rule out the possibility that audience design mechanisms drive ASD children’s lexical choices in conversation (Osborne & Allen, 2012), this matter deserves further investigation. One reason for this is that, with the exception of Osborne and Allen’s (2012) study, studies of alignment in ASD have not reported measures of ASD individuals’ mentalising abilities (e.g., ToM); this has made it difficult to draw any conclusions about whether and how far audience design considerations might influence alignment in ASD. Secondly, as discussed in 2.6.3, it may be necessary to take more elaborate measures of perspective-taking ability (Nilsen & Fecica, 2011), to gain a better understanding of the nature and role of audience mechanisms in ASD individuals’ alignment. It cannot be assumed that ASD and typical individuals align in the same way, simply because behavioural data suggests this is the case; it is important to determine whether the same mechanisms underpin alignment in ASD and typical

development, and whether these mechanisms contribute to the alignment process in a uniform way (Slocombe et al., 2012).

Lastly, and following the work of Gries (2005), Howes et al. (2010), and Healey et al. (2014), there is a question over whether the experimental findings about alignment in ASD may be generalised to real conversation. It has been observed that there is a discrepancy in ASD individuals' social functioning, between experimental and natural tasks (Klin, Jones, Schultz, & Volkmar, 2003). This discrepancy also applies to ASD individuals' performance in structured versus unstructured conversations (Tager-Flusberg & Anderson, 1991), which could also reconcile the findings that ASD individuals have intact alignment mechanisms, and yet struggle with conversation. Hence a third useful avenue of investigation is whether there is consistency between conversational data generated by psycholinguistic experimentation, and conversational data collected in a more naturalistic setting.

Respectively, these questions are taken up by Article 3 ('Semantic alignment in children with autism spectrum disorder'), Article 2 ('Mechanisms of mediated alignment in children with autism spectrum disorder'), and Article 1 ('Children with autism spectrum disorder align syntax in natural conversation') in this thesis.

## **6. Aims and hypotheses**

The overarching aim of this thesis was to investigate whether ASD children's conversational deficits could in part be explained by atypical patterns of language alignment, which promotes more effective and more rewarding dialogue (Fusaroli et al., 2012; Reitter & Moore, 2014). As mentioned, it is not the case that conversational deficits have been overlooked in the extant literature on ASD (cf., Capps et al., 1998; Hale & Tager-Flusberg, 2005; Hobson et al., 2012; Tager-Flusberg & Anderson, 1991; Volden, 2002); the findings of psychological studies have been sufficient to generate both a social

cognitive and an affective account of ASD individuals' communicative impairments (Baron-Cohen, 1988). Nevertheless, only a small volume of research (Allen et al., 2011; Osborne & Allen, 2012; Slocombe et al., 2012) has considered alignment in ASD, and hence the extent to which basic language processing relates to ASD individuals' conversational deficits. This is surprising, given evidence that linguistic skills may have bearing on communicative competence in ASD (Capps et al., 1998), while social cognitive (i.e., ToM) understanding might not (Hadwin et al., 1997). By extending research on alignment in ASD, this thesis seeks to further clarify the role of processing mechanisms in ASD children's communicative language production; in so doing, it also answers calls for a more pluralistic understanding of ASD and its associated impairments (Happé et al., 2006).

The focus of this thesis is ASD children, whose conversational deficits may be sufficiently pronounced so as to inform diagnosis of the disorder (American Psychiatric Association, 2013). As a result, the Articles presented in this thesis build most directly on the studies of Allen et al. (2011) and Osborne and Allen (2012), which are also focused on ASD children. Respectively, these studies demonstrated intact syntactic and lexical alignment in ASD children, and showed that ASD children align to the same extent as TD controls. Osborne and Allen's (2012) investigation also sought to identify a mediated component to ASD children's alignment, but produced null results. Together, these studies inspired the questions and hypotheses pursued in this thesis.

Article 1 reports an experimental and a corpus-based study of alignment, and the results of both were used to answer the question of whether there is ecological validity to the experimental finding that ASD children's syntactic alignment is intact (Allen et al., 2011). It was hypothesised that, in line with Allen et al.'s (2011) study, ASD children would align syntax to the same extent as TD controls on an embedded priming paradigm (the card game Snap!), but not in real-life conversation, which is inherently less structured (Tager-Flusberg, 1981), and which they might find less motivating (Chevallier et al., 2012).

The studies in Article 2 re-examined the question of whether there is a mediated component to ASD children's lexical alignment (Osborne & Allen, 2012), as suggested in studies of typical adults (Branigan et al., 2011). They extended Osborne and Allen's (2012) study by drawing on experimental evidence (Brown-Schmidt, 2009; Nilsen & Fecica, 2011; Wardlow, 2013) for the role of IC in communicative perspective-taking, and on the theoretical contention that IC is especially relevant to ASD children's use of mental state information in communication (Nilsen & Fecica, 2011). The first hypothesis was that ASD children would align lexis to the same extent as TD controls on an adapted version of the Snap! game described in Article 1. The second hypothesis was more speculative. It was suggested that, by accounting for IC ability, a relationship between alignment and ToM could emerge, suggesting a mediated component to alignment; it was proposed that this relationship might not be observable in all groups, however, suggesting that alignment was driven by different mechanisms in ASD and typical development.

Article 3 considers the limits of unmediated (i.e., priming-based) alignment for ASD children, adopting the methodology of Garrod and Clark's (1993) study of alignment in TD children. ASD and TD children's conversations about a maze game were analysed for evidence of syntactic and lexical alignment, and it was predicted that, consistent with the findings of Article 1, there would be no group differences in the tendency to align. However, a second hypothesis was that superficial (syntactic; lexical) co-ordination would not promote deeper (semantic) co-ordination in pairs of ASD and TD children, versus TD only pairs.

## **7. Outline of studies**

The aim of this section is to give an outline of how this thesis progresses, and in particular how the three Articles herein informed each other. The sequence of the Articles presented

reflects the order in which studies were conducted; hence each study builds intentionally on the one before it.

Article 1 extends Allen et al.'s (2011) investigation of ASD children's syntactic alignment. The aim of the studies reported in Article 1 was to demonstrate that the syntactic alignment effects generated by a controlled experimental paradigm (as per Allen et al., 2011) would not be observed in ASD children's real-life conversations. Contrary to prediction, results highlighted no differences in ASD and TD children's tendency to align syntax with an interlocutor in real-life conversation, implying ecological validity of experimental findings. Article 1 concludes by raising two questions left unanswered by Studies 1 and 2. One question relates to the nature of ASD and TD children's alignment, and whether this is subserved by the same or different mechanisms. Another question concerns the extent to which unmediated alignment supports effective communication in ASD children. These questions are addressed in Article 2 and Article 3 respectively.

Article 2 develops Osborne and Allen's (2012) study, which suggests that ASD children's tendency to lexically align is not mediated by audience design mechanisms. The studies in Article 2 adopt alternative measures of mentalising ability from those used by Osborne and Allen (2012), substituting an emotion recognition task for a false belief task, and adding measures of IC, which is associated with communicative perspective-taking, both in the typical population (Brown-Schmidt, 2009; Nilsen & Fecica, 2011; Wardlow, 2013), and in ASD (Nilsen & Fecica, 2011). The findings of Article 2 support Osborne and Allen's (2012) case for a strong, unmediated component to ASD children's alignment, but provide additional justification for questioning the limits of unmediated alignment in ASD, as addressed by Article 3.

Article 3 builds on Garrod and Clark's (1993) investigation of semantic alignment in TD children, which supports a distinction between 'superficial' and 'deep' co-ordination (i.e., alignment) in children's conversations. The study reported in Article 3 examines whether

and how far this finding extends to ASD children. By corollary, it also tests the assumption that unmediated alignment at one level of language (e.g., syntax) percolates to alignment at a higher level of language (e.g., semantics; Pickering & Garrod, 2004). The results of the study supported a distinction between superficial and deep co-ordination in conversation, while suggesting that the percolatory effect of alignment varies among ASD children, likely as a function of social cognitive ability. Further, Article 3 highlights the importance for children of being able to diverge (i.e., resist the automatic tendency to align) in conversation.

Overall, the Articles in this thesis consistently demonstrate that ASD children have intact syntactic and lexical alignment mechanisms, ruling out a general deficit of linguistic imitation as a factor in their conversational deficits. Nevertheless, the findings of Article 3 suggest that intact syntactic and lexical alignment mechanisms may be a necessary but not sufficient condition of successful communication in ASD.

## Article 1: ASD children align syntax in natural conversation

A version of this paper has been published in *Applied Psycholinguistics*.

Previous experimental work has shown that verbal ASD children converge linguistically, or align, with an interlocutor, and to the same extent as TD children. However, it is not known whether ASD children align in natural conversation. The studies presented in this paper aimed to address this issue. We measured syntactic alignment in ASD children, first using an experimental task, and secondly in natural conversation. We found that ASD and TD children aligned to the same extent in both tasks, suggesting that experimental findings about alignment in ASD are ecologically valid. We argue, however, that the experimental measurement of alignment overstates the prevalence of syntactic alignment in children's conversations.

Hopkins, Z., Yuill, N., & Keller, B. (2015). Children with autism align syntax in natural conversation. *Applied Psycholinguistics*. Advance online publication. doi: 10.1017/S0142716414000599



Alignment occurs in conversation, when interlocutors imitate one another's linguistic behaviour. Unmediated accounts of alignment propose that alignment is unconscious and automatic, occurring as interlocutors prime one another's linguistic representations during language processing. Priming facilitates access to representations, either through residual activation (Pickering & Branigan, 1998), or through an error-driven learning mechanism (Chang et al., 2006). Certain unmediated accounts, such as the IA account (cf. e.g., Pickering & Garrod, 2004), propose that lower level (e.g., syntactic) alignment leads to higher level (e.g., semantic) alignment, and ultimately to alignment of situational models, or mutual understanding of the situation under discussion. Achieving mutual understanding, therefore, need not depend on complex cognitive processes, as previously suggested (Clark & Marshall, 1981). According to Garrod and Pickering (2004), because alignment is automatic and unconscious, it helps to make conversation easy.

Conversation is not easy for many ASD children, however. ASD is a neurodevelopmental disorder characterised by impaired social interaction and communication skills, with a global prevalence of between .01-1.57% (Zaroff & Uhm, 2012). As many as 30% of individuals with ASD never acquire functional language (Anderson et al., 2007), and those who do may struggle to use it appropriately in social, communicative contexts. Such pragmatic deficits are an aspect of language that is seriously impaired in ASD (Tager-Flusberg, 1981; 1996), and the impairment may be conspicuous in conversations. ASD children fail to make new, relevant contributions to discussion (Tager-Flusberg & Anderson, 1991; Capps et al., 1998), and produce unusual content or style (Volden, 2002). Pragmatic deficits in ASD are thought to relate to impaired theory of mind (ToM; Happé, 1993), or mentalising ability. ASD individuals with ToM impairment may struggle to appreciate that others have thoughts and feelings which are unique to them, and may presume that others intuitively know what they are thinking and feeling themselves.

ASD is also associated with imitation deficits, in the domains of body movement, object use, facial expressions, and vocalisation (Ingersoll, 2008), which may relate to atypical connectivity of the imitation network of the brain (Shih et al., 2010). Vocal imitation deficits are complex in ASD. Non-verbal ASD children show reduced vocal imitation (Hartung, 1970), and verbal children may fail to imitate paralinguistic features of speech when vocal imitation is intact (Diehl & Paul, 2012). In contrast, some ASD children show excessive vocal imitation in the form of echolalia, when entire tracts of speech may be copied with exact, or near exact, repetition of words and intonation. Echolalia, another pragmatic deficit, can also compromise conversation skills in ASD (Grossi et al., 2013), suggesting that conversation should involve a certain amount of linguistic imitation, but not too much.

Given ASD can involve under- and over-imitation, unmediated accounts of alignment do not allow a simple prediction to be made about alignment in the conversations of ASD individuals. Since imitation leads to alignment, it might be expected that those who under-imitate would align less with an interlocutor, while those who over-imitate would align more. A further complexity is a growing body of evidence suggesting that the tendency to align is mediated by beliefs about the audience (cf. e.g., Branigan et al., 2011). Mediated accounts conceptualise alignment as a more conscious process, whereby imitation in conversation may be strategically deployed to facilitate communicative success, or for social-affective gains. It is again unclear what the implications of this might be for ASD.

Despite these theoretical uncertainties, recent studies suggest that ASD individuals are not atypical in the extent to which they align. Allen et al. (2011) showed that ASD children converge passive syntax with an interlocutor (e.g., passive phrases such as ‘the queen is being kissed by the sheep’), to the same extent as both chronological- and verbal mental age-matched typical controls. Slocombe et al. (2012) showed that AS adults are as likely as typical controls to align lexis, syntax, and spatial frame of reference with an interlocutor.

The findings of these studies raise questions about the conversation skills of ASD individuals. If alignment abilities are normal in ASD, then this should support participation in dialogue, but many ASD individuals find conversation difficult. A possible explanation for these contradictory findings is that the alignment observed in previous research is an experimental artefact (i.e., task dependent) rather than a real phenomenon, a possibility which has already been suggested (Howes et al., 2010; Healey et al., 2014). Allen et al. (2011) measured alignment using an adapted version of Snap!, a card matching game for children. To play Snap!, a deck of pictorial cards is split evenly between players, who take turns in revealing their cards to each other. If two adjacent cards are matching, players compete to say ‘Snap!’, in order to win those cards. In the adapted version of the game, players are required to verbally describe the picture on each card, for example:

Experimenter: A cow is squashing a doctor

Child: A dog is biting a robber

Experimenter: A crocodile is kicking a knight

Child: A crocodile is kicking a knight. Snap!

Slocombe et al. (2012) used two cooperative tasks to measure alignment, both of which involved guided card sorting. These experimental tasks are highly structured: they enforce turn-taking (Dickson, 1982) and allow tight control over the nature of participants’ verbal responses (Leinonen & Letts, 1997). As a result, they might not be a reliable proxy for natural conversations, a point acknowledged by Slocombe et al. (2012).

Slocombe et al. (2012) suggest that future research should examine alignment in the natural conversations of ASD individuals. They propose two reasons why there might be differences in alignment in natural conversation versus experimental tasks. First, natural conversations are less structured. There is a large discrepancy in the social functioning of

ASD individuals between experimental and naturalistic situations. ASD individuals may perform well in social reasoning experiments, but fail to apply social reasoning to everyday social interactions (Klin et al., 2003). Notably, ASD children tend to be more communicative in more structured conversations (Tager-Flusberg & Anderson, 1991).

Secondly, the focus of natural conversations may be on social affiliation. It is widely accepted, however, that ASD individuals show reduced interest in social stimuli (Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009; Hanley, McPhillips, Mulhern, & Riby, 2013; Klin, Jones, Schultz, Volkmar, & Cohen, 2002), including speech. ASD individuals show weaker brain responses to speech sounds than do typical controls (Boddaert et al., 2003), and may actively ignore speech sounds unless instructed otherwise (Whitehouse & Bishop, 2008). Further, reduced motivation to affiliate with a social partner may result in under-imitation of behaviour by ASD individuals (Hobson & Hobson, 2008; Marsh et al., 2013). This is an important finding, because it suggests that ASD individuals' alignment in conversation might be especially sensitive to social-psychological factors. It also makes a case for considering alignment in ASD from a mediated as well as unmediated perspective.

Since there are grounds for expecting a difference in how ASD individuals would align with an interlocutor in naturalistic versus experimental settings, this paper presents two studies which compare syntactic alignment in ASD and TD children, in an experimental and in a naturalistic setting. The first study was an extended replication of Allen et al.'s (2011) study, measuring dative as well as active-passive alternation using a pictorial card game. In the second study, syntactic alignment was measured across all structures in the conversations of ASD and TD children with a peer. Most children took part in both studies. We predicted that, as per Allen et al. (2011) and Slocombe et al. (2012), ASD children would align syntax to the same extent as TD controls in the card game. However, we also predicted that ASD children would not maintain the level of alignment observed in the card game in natural conversation, which is both less structured and less goal-oriented.

Lastly, given the possibility that alignment is an experimental artefact, the different methods used in our studies are compared in this paper. It was expected that, overall, there would be a discrepancy in syntactic alignment effect sizes between the card game and natural conversation task, with weaker alignment effects in natural conversation, as per data from Howes et al. (2010). Following the lead of Gries (2005), we discuss the merits of studying alignment in an experimental versus naturalistic setting.

## STUDY 1

### Method

#### *Participants*

17 ASD children (12 male) took part in the card game study, with a mean chronological age of 11.4 years, range 8.3-13.7 years. The children had been previously diagnosed with ASD by a paediatrician, psychiatrist, or clinical psychologist, and we corroborated diagnoses using the Social Communication Questionnaire (SCQ; Rutter Rutter, Bailey, & Lord, 2003). The SCQ is a brief parental screening instrument that assesses communication and social skills in children who may have ASD. The recommended cut-off score for the SCQ is 15 (Wiggins, Bakeman, Adamson, & Robins, 2007), and the ASD children in our sample obtained standardised scores at or above the cut-off (mean = 23.1, range 15-33). The children were also administered the Kaufman Brief Intelligence Test (KBIT-2; Kaufman & Kaufman, 2004), a standardised measure of both verbal and nonverbal ability (mean = 77.8,  $SD = 21.6$ ). The SCQ and KBIT-2 are the same measures as those used by Allen et al. (2011).

We also tested language ability using the British Picture Vocabulary Scale (BPVS-3; Dunn, Dunn, & Styles, 2009). Like Allen et al. (2011), we used raw scores to estimate the

verbal mental age of the ASD children (mean BPVS-3 = 9.6 years, range 6.7-12.8 years) by which we matched them with TD controls ( $N = 17$  [10 male], mean BPVS-3 = 9.6 years, range 6.8-12.1 years). Additionally, the Sally Ann false belief task (Baron-Cohen, et al., 1985) was administered to all children. The Sally Ann task assesses first-order ToM, which requires reasoning about the mental state of others. Since alignment may be mediated by beliefs about one's interlocutor, we wished to verify that any between-group differences in alignment could not be better explained by basic ToM impairment, especially in the ASD group. The pass rate (=94.12%) on the Sally Ann task did not differ between groups, however.

All participants were recruited from schools in Dorset, UK. The ASD children were taught within the autism unit of a special needs school. The TD children attended a mainstream primary school. Note that, unlike Allen et al. (2011), we did not compare our ASD group with a group of chronologically aged-matched TD controls. This was owing to their finding that syntactic alignment is unrelated to chronological age, at least in children who are fluent, native speakers.

### *Materials*

Materials were a set of 30 pairs of picture cards, of which there were 24 experimental pairs of a prime and a target card, and six pairs of filler cards, adapted from a game used by Messenger et al. (2012). Our main adaption was to incorporate prepositional (PO) and double object (DO) forms within the game. We also withdrew object-experiencer verbs, since ASD is associated with difficulties in understanding emotional scenes (cf., e.g., Hobson, 1986), and with producing emotional language (e.g., Pearlman-Avnion & Eviatar, 2002).

All cards depicted a transitive event involving either an animal donor and human recipient (e.g., a bear dragging a witch), or an animal donor, human recipient, and an object

of transfer (e.g., a tiger giving a ball to a nurse). There was no repetition of semantic and lexical content in experimental pairs, to ensure that children imitated abstract language structures, instead of copying prime descriptions verbatim. Filler pairs were similar to experimental pairs, but the prime and target cards were identical. There were 2 active, 2 passive, 1 PO and 1 DO filler primes. Two scripts of primed descriptions of the experimenter's cards were prepared, each containing a version of each prime, to control for collostruction strengths (Gries, 2005), or the principle that words may be more or less attracted to certain syntactic patterns or constructions. Of the 24 pairs of experimental items, there were 6 active primes, 6 passive primes, 6 PO primes, and 6 DO primes. Filler items were spaced at even intervals through the scripts, to sustain children's interest in the game. Children were randomly assigned to either one of the scripts (see Appendix).

### *Design*

All children experienced the full range of structural primes. Prime (active form versus passive form versus PO form versus DO form) was a within-participants and within-items factor. Diagnosis (ASD versus TD) was a between-participants and within-items factor. The dependent variable was the children's production or not of the previously-used syntactic form.

### *Procedure*

All children were tested individually, and by the same experimenter, who was aware of the study hypotheses. Both the experimenter and the child had a pre-ordered pile of cards, and took turns revealing and describing their cards to each other. The experimenter always described her card first, using an active, passive, PO, or DO structure (see Table 1), by reading from a hidden script. Hence the experimenter primed the child's description of the subsequent 'target' card. Whoever said 'Snap!' first on filler rounds won the pair of

matching cards, and all cards placed before it. The game took 5-10 minutes to complete, following a practice round where the experimenter and child each described two experimental items and one filler item. The BPVS-3 and KBIT-2 took an additional 20-30 minutes to administer.

*Table 1: Syntactic forms of prime descriptions in card game*

Active	<i>An animal donor is verbing a human recipient</i>
Passive	<i>A human recipient is being verbed by an animal donor</i>
PO	<i>An animal donor is verbing an object to/for a human recipient</i>
DO	<i>An animal donor is verbing a human recipient an object</i>

#### *Coding and analysis*

We adopted a similar coding scheme to Allen et al.'s (2011), extended to cover dative syntactic structures. Target descriptions were coded as containing either a preferred (active; PO) or dispreferred (i.e., passive; DO) syntactic form. This distinction was based on corpus data showing that transitive verbs usually take an active, rather than passive, form (Biber, Johansson, Leech, Conrad, & Finegan, 1999), and that passive constructions are rare in conversation, with a relative frequency of ~2-3% in spoken English corpora (Roland, Dick, & Elman, 2007). Similarly, it has been shown that DO forms are less common than PO forms in speech, especially children's speech (Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989). Roland et al. (2007) have shown that the relative frequency of DO forms in spoken English is ~1-2%. The coding scheme allowed us to measure the extent of children's syntactic repetition, by calculating alignment effects. In this study, alignment effects quantify the difference in the number of dispreferred target descriptions produced in response to dispreferred versus preferred prime descriptions (Table 2).



Table 2: Percentage of target responses by prime condition (card game)

Diagnosis	Prime type	Response type				Alignment effects <sup>1</sup>	
		Active target	Passive target	PO target	DO target	Passive syntax	DO syntax
ASD	Active	81.4%	12.75%	–	–	–	–
	Passive	65.7%	24.51%	–	–	11.76%	–
	PO	–	–	67.1%	12.94%	–	–
	DO	–	–	51.8%	29.41%	–	16.47%
TD	Active	84.2%	8.91%	–	–	–	–
	Passive	67.6%	30.69%	–	–	21.78%	–
	PO	–	–	76.2%	9.52%	–	–
	DO	–	–	56%	35.71%	–	26.19%

<sup>1</sup> Alignment effects are calculated as % of dispreferred targets produced after dispreferred primes, minus the % of dispreferred targets produced after preferred primes. For example, in ASD children, the passive syntax alignment effect is 25.51% - 12.75% = 11.76%.

Some children described target cards with different syntax, or syntax that could not be expressed in an alternative syntactic form (e.g., a fairy is having a cuddle with a bear). Such descriptions were coded as ‘other’, and were excluded from analysis. As in Allen et al.’s (2011) study, ‘other’ responses represented 10.6% of the data set, and were randomly distributed across prime types and group.

All data evidencing active, passive, PO, or DO structures were submitted to a logit mixed effects analysis. This was a departure from the methodology of Allen et al. (2011), who conducted a by-participant and by-item analysis of variance (ANOVA) of their data. This type of analysis, called F1-F2 analysis, is common in psycholinguistic research. However, it has been suggested that ANOVAs are inadequate for dealing with categorical data (Barr, Levy, Scheepers, & Tily, 2013; Jaeger, 2009). Further, ANOVAs of categorical

data may produce spurious results, and are less powerful than mixed effects models (Dixon, 2008).

We therefore fitted logit models to our data. Since ‘other’ data points were excluded from analysis, our dependent variable was binary (i.e., 0 = no production of dispreferred syntax; 1 = production of dispreferred syntax). We treated diagnosis (ASD versus TD) and prime type (active versus passive versus PO versus DO) as fixed effects. Three levels of contrast were defined for the four levels of the prime type variable, with active syntax as a reference category. Participants and items were treated as random effects.

The models reported here were fitted with the statistical package R (version 3.0.2; R Core Team, 2013) and the package lme4 (Bates, Maechler, & Bolker, 2011). We compared three logit models to a baseline model, for which no fixed effects were specified. The first model included only the effect of prime type, to check that our experimental manipulations influenced alignment across all participants. The second model included the effects of prime type and diagnosis, to verify that the experimental manipulations influenced alignment in both groups. The third model included an interaction between prime and diagnosis, allowing us to identify whether the groups aligned to the same extent or not. Chi squared values were calculated in lme4, assessing which (if any) of the models was a significant improvement in describing our data.

The statistical significance of fixed and random effects in the logit models was assessed using Wald’s test (Wald, 1943), for which  $z$  scores and corresponding  $p$  values are reported here (see Tables 3 and 4).

## Results

In line with Allen et al.’s (2011) findings, our analysis showed that our prime-only model significantly improved on the baseline model,  $\chi^2(3) = 22.26$ ,  $p < .001$ . This meant that,

overall, target responses were affected by the prime type the participants heard. Participants were more likely to produce a dispreferred form of syntax in response to the experimenter's use of a dispreferred rather than preferred form. Our prime + diagnosis model was also not a significant improvement on the baseline model,  $\chi^2(1) = .01, p = .93$ , indicating that participants produced more dispreferred syntax in response to the experimenter's use of dispreferred syntax, irrespective of diagnosis. Further, our interaction term model was not a significant improvement on the baseline model,  $\chi^2(3) = 2.31, p = .51$ . This showed that alignment effects did not differ significantly between the ASD and TD groups, again as per Allen et al. (2011).

*Table 3: Summary of fixed and random effects for prime-only model (card game)*

Fixed effects	Estimates	SE	Wald Z	<i>p</i> value
Intercept	2.70	0.46	6.42	<.001
Passive	-1.92	0.53	-3.60	<.001
DO	-2.31	0.51	-4.51	<.001
PO	-.09	0.71	-0.13	<i>n.s</i>

<b>Random effects</b>	<b>SD</b>
<i>Participant</i>	
Intercept	1.66
Passive	1.40
DO	1.73
PO	2.78
<i>Item</i>	
Intercept	0.39
Passive	0.50
DO	0.39
PO	0.38
<i>Item</i>	
Intercept	0.53
Diagnosis	0.59

Table 4: Summary of fixed and random effects for interaction model (card game)

<b>Fixed effects</b>	<b>Estimates</b>	<b>SE</b>	<b>Wald Z</b>	<b><i>p</i> value</b>
Intercept	3.50	.86	4.06	<.001
Passive	-2.47	.94	-2.63	<.01
DO	-2.77	.92	-2.30	<.01
PO	-.18	1.23	-.15	<i>n.s</i>
ASD	-.79	.88	-.90	<i>n.s</i>
Passive:ASD	1.03	.94	1.10	<i>n.s</i>
DO:ASD	1.07	.96	1.11	<i>n.s</i>
PO:ASD	.23	1.32	.17	<i>n.s</i>

<b>Random effects</b>	<b>SD</b>
<i>Participant</i>	
Intercept	1.60
Passive	1.39
DO	1.45
PO	2.62
<i>Item</i>	
Intercept	.47
Passive	.49
DO	.48
PO	.49
<i>Item</i>	
Intercept	.61
Diagnosis	.65

Note that, in the fixed effect summaries (cf. Tables 3 and 4), the ‘intercepts’ are alignment estimates for the reference category (i.e., active primes). Estimates displayed for each subsequent category (passive; DO; PO) represent the difference in alignment between this and the reference category. The non-significant difference between the PO and reference categories reflects the comparable alignment effects produced by active and PO primes, which are both preferred structures. For Table 4 only, ASD provides a reference category for comparing the interaction of participant diagnosis (ASD; TD) with alignment across the different prime types. The random effect summaries in Tables 3 and 4 present variance terms for the random effects of participant and item; both of these show that there was greater variability in alignment by participant than by item in our data set.

Owing to a mean difference in proportions of ‘other’ responses between the groups (ASD  $M = 13.6\%$ ; TD  $M = 7.5\%$ ), we conducted a further logit mixed effects analysis on our data set, including the data points excluded from the previous analysis. This was necessary because, if ‘other’ responses were taken into account, the ASD group produced more non-aligned descriptions than the TD group. Thus we wanted to eliminate the possibility that between-group differences in alignment were being obscured by the exclusion of ‘other’ responses. In this analysis, we coded whether the target was syntactically aligned with the prime description or not. ‘Other’ responses were recoded as being not aligned. These data are presented in Table 5.

*Table 5: Percentage of aligned target responses by prime condition (card game)*

% of aligned target responses (with ‘other’ responses recoded)				
<u>Diagnosis</u>	<u>Active</u>	<u>Passive</u>	<u>PO</u>	<u>DO</u>
ASD	81.37	24.50	67.06	29.41
TD	84.00	30.39	76.19	35.71

As before, we compared three logit models to a baseline model. Model one contained only the effect of prime type, model two the effect of prime type and diagnosis, and model three an interaction between prime type and diagnosis. Items and participants were again treated as random effects. The analysis showed that, even after accounting for the group differences in ‘other’ responses, the effect of prime type remained significant,  $\chi^2(3) = 33.88$ ,  $p < .001$ . The effect of diagnosis was again non-significant,  $\chi^2(1) = 2.82$ ,  $p = .09$ , as was the interaction between prime type and diagnosis,  $\chi^2(3) = .22$ ,  $p = .98$ . Thus the results of both analyses suggest that ASD children are sensitive, not only to the priming of active-passive alternation, but also to the priming of dative alternation in an experimental task. Further, the ASD group was able to align syntax to a comparable extent as TD children.

*Relationships between alignment effects, age, and language ability*

Unlike Allen et al. (2011), we found no significant correlations between alignment effects and raw BPVS-3 scores for either our ASD or TD group, when chronological age was taken into account. This was surprising in the light of evidence that linguistic ability predicts the magnitude of syntactic priming effects in children. Kidd (2011) observed that children with better vocabulary and grammatical knowledge were primed more strongly than were children with weaker skills in these areas. The absence of any significant correlations may reflect the variability of alignment effect scores across raw BPVS-3 scores in our data set (see Table 6).

*Table 6: Correlation matrix of standardised BPVS-3 and alignment effect scores (card game)*

Diagnosis	Measure	1.	2.	3.
ASD	1. Standardised BPVS-3 scores	—		
	2. Passive syntactic alignment effect	-.09	—	
	3. DO syntactic alignment effect	-.08	.44	—
TD	1. Standardised BPVS-3 scores	—		
	2. Passive syntactic alignment effect	.23	—	
	3. DO syntactic alignment effect	-.45	.58	—

More consistently, we found no significant correlations between alignment effects and chronological age. This supports previous studies (e.g, Garrod & Clark, 1993) that have found no significant developmental relationships between age and alignment effects (see Table 7).

*Table 7: Correlation matrix of chronological age and alignment effects (card game)*

Diagnosis	Measure	1.	2.	3.
ASD	1. Chronological age (years)	—		
	2. Passive syntactic alignment effect	-.19	—	
	3. DO syntactic alignment effect	-.48	.44	—
TD	1. Chronological age (years)	—		
	2. Passive syntactic alignment effect	.17	—	
	3. DO syntactic alignment effect	-.32	.58	—

*Interim discussion*

In our first study, ASD children took turns with an experimenter to describe pairs of unrelated picture cards. Ours was an extended replication of Allen et al.'s (2011) study, which showed that ASD children tended to describe using passive syntax when they had just heard an experimenter produce a passive description. We observed a similar pattern in our own data. ASD children produced 11.76% more dispreferred, passive forms to describe a transitive event when they had just heard an experimenter produce a passive description. A novel finding of our study was that this pattern extended to dative alternation. Despite emergent evidence that ASD children may struggle with dative alternation (Stockbridge, Happé, & White, 2013), our ASD group produced 16.47% more dispreferred, DO forms than preferred, PO forms to describe a transitive event, when they had just heard an experimenter produce a DO description. This finding is consistent with Slocombe et al.'s (2012) study, which reported a DO priming effect in AS adults.

Another novel finding was that both ASD and TD children produced more DO targets in response to DO primes than passive targets in response to passive primes. This may be because DO forms are relatively less frequent in spoken language than passive forms (Roland et al., 2007), and Hartsuiker and Kolk (1998) suggest that rarer syntactic structures



are more sensitive to priming effects than more common ones. An alternative explanation for the pattern of our data is that it reflects weaker passive competence in the children. Messenger et al. (2012) observe that the strength of priming effects depends on the extent to which children construct abstract representations for a given structure. It is therefore possible that the children in our sample were better able to abstract DO than passive rules, but this is a matter for further investigation.

Overall, our results lend support to the hypothesis that syntactic alignment is intact in ASD children, relative to TD controls. Both our ASD and TD groups imitated abstract syntactic structures used by the experimenter, without being asked to do so. Since ASD children demonstrate intact syntactic alignment, they should be able to engage in conversation without difficulty, if unmediated accounts of alignment are correct. The alignment process has a percolating effect, whereby syntactic alignment leads to alignment of situational models, which is the basis for a successful conversation. As noted, however, studies suggest that ASD individuals struggle with conversation. They display pragmatic deficits which, as Slocumbe et al. (2012) point out, suggest a failure to accommodate the situational model of an interlocutor. Such evidence suggests that the alignment process might not be robust in ASD individuals, at least in more naturalistic settings. We were interested to know, therefore, whether syntactic alignment occurs in the natural conversations of ASD children, and if so, to what extent. These questions are addressed in our second study.

## STUDY 2

### Method

#### *Participants*

Most children (83%) who took part in the first study also took part in the second, with an interval between the studies. Additional children were recruited from the participating schools used in Study 1. There were no significant changes in participant demographics. 17 ASD children (12 male) completed the natural conversation task, with a mean chronological age of 11.2 years (range 7.9-13.4 years). ASD diagnoses were again corroborated using the SCQ, and all children scored at or above the cut-off (mean = 22.4, range 15-33). The children's mean KBIT-2 score was 77.5 ( $SD = 21.3$ ), and they were well matched for verbal mental age (mean BPVS-3 = 9.5 years, range 6.7-12.8 years) to TD controls ( $N = 17$  [10 male], mean BPVS-3 = 9.9 years, range 6.8-12.1 years). Again, there was no significant group difference in performance on the Sally Ann task.

#### *Coding and analysis*

In this study, a repeated measures analysis of covariance (ANCOVA) was conducted, with syntactic alignment as the dependent variable. Syntactic alignment was calculated as the mean proportion of syntax used by a peer interlocutor (i.e., non-focal child), and reused immediately by a focal child, across pairs of conversation turns (or exchanges). Diagnosis was the only between-participants factor (ASD versus TD). Conversation type was a within-participants factor: we measured syntactic alignment in the real conversations had by the children, and in 'fake', control conversations.

The creation of control conversations is a method, designed by Howes et al. (2010), of establishing how syntactically similar conversation turns would be by chance, and therefore

whether conversations actually evidence alignment. This is a different metric than that used to calculate the alignment effects reported in Study 1, and in the wider alignment literature. Our control conversations were created by separating the conversation turns of each focal child from the turns of the paired non-focal child, and interleaving these with the turns of a non-focal child from a different conversation. As far as possible, all conversations were matched according to length, with any unmatched turns discarded.

We used lexical alignment as a covariate in our ANCOVA model, to correct for a phenomenon called the ‘lexical boost effect’ (Pickering & Ferreira, 2008). This effect describes an increase in syntactic alignment, as a result of a prime and target utterance sharing content words. The correction was applied so that, as far as possible, we could isolate alignment effects on grammatical abstractions, as in Study 1. Note that, as recommended by Delaney and Maxwell (1981), we mean-centred the covariate prior to analysis. This was to prevent the ANCOVA erroneously underestimating the repeated measures effect, as can happen when it is assumed that the covariate partly explains variability between repeated measures variables.

### *Procedure*

Each child was paired with a different peer ( $N = 37$ ) who had no documented impairments of social interaction and communication skills. The children and their peers were known to each other prior to the study. The experimenter explained to each pair that she wished for them to discuss with one another the topic ‘What is the best pet?’. This topic had been tested in a pilot study, and was deemed to be accessible, and of interest to children. Further, the topic promoted collaborative talk during piloting; we aimed to discourage ‘one-sided’ conversations among the children, especially in the ASD group. During the testing session, the experimenter was present but feigned to ignore the children while they talked to one another. All conversations were video recorded and subsequently transcribed.

*Data processing and analysis*

We developed a NLP application to measure alignment in our conversation transcripts (Magonde & Keller, 2014), building on similar work in other, naturalistic studies of syntactic alignment (Howes et al. 2010; Gries, 2005). First, our application uses a word tokeniser to perform parts-of-speech (POS) tagging on the transcripts. Assigned POS tags are fine-grained, containing morpho-syntactic information and semantic information (e.g., noun forms). To measure the accuracy of POS tagging by the application, we manually ratified parsing for 10% of both ASD and TD conversations, and were satisfied with its mean error rate (= 6.59%, range 4.07-10.84%).

After tagging, the application separates the POS tags into bigrams. While previously, syntactic alignment has been calculated from non-terminal syntactic rules (e.g., Howes et al., 2010), bigrams offer the smallest unit in which syntactic alignment can be detected. This level of analysis is an advantage when dealing with shorter conversational utterances, and has already proved fruitful in the study of children's conversations (Dale & Spivey, 2006).

The main body of our application applies a cosine similarity measure to all tokens in each conversation exchange, in order to calculate a syntactic alignment score. The measure determines the likeness of two adjacent utterances, which are treated as vectors, by calculating the cosine value of the angle between them. If the two vectors are perpendicular, then the cosine value will be zero. If the vectors are parallel, then the cosine value will be one. The measure also normalises the alignment score to take into account any differences in the lengths of paired utterances. A mean syntactic alignment score is then generated for all exchanges in a conversation.

Example turn from real conversation:

Child A: My favourite two, three are kittens, bunnies, bearded dragons, and budgies.

Child B: Oh. Dogs, cats, and horses.



Reuse of bigrams (as marked by V) by Child B = .52 (cosine)

Example turn from 'fake' control conversation:

Child A: My favourite two, three are kittens, bunnies, bearded dragons, and budgies.

Child C: pick your letters up for you?

Reuse of bigrams by Child C = 0 (cosine)

If the interactive nature of conversation supports alignment, then the cosine values of utterance vectors which were adjacent in a real conversation should be higher than for utterance vectors which have been randomly paired together (i.e., in fake conversations), as indicated by these examples.

Unlike in certain studies (e.g., Howes et al., 2010), we only considered adjacent utterances in our data set, and did not track decay of syntactic priming across conversation turns. This was owing to mixed evidence regarding the time course of priming effects. Some studies have shown that syntactic priming effects persist over time (e.g., Hartsuiker & Kolk, 1998; Bock & Griffin, 2000). Other studies have shown that syntactic priming effects decay rapidly (e.g., Levelt & Kelter, 1982; Wheeldon & Smith, 2003).

Note that, in this study, we examined alignment on a full range of syntactic structures, and not only on structures that have a semantically equivalent alternative. Ideally, for comparative purposes, we would have preferred to measure alignment on the same, dispreferred structures used in the card game. However, as in other corpora of children's conversational speech (Gerard, Keller, & Palpanas, 2010), such structures were scarce in

our conversation transcripts (one passive with an expressed donor, and five DO forms, in total), and we were compelled to adjust our method accordingly.

A small number of data points were excluded by the application from analysis. These were experimenter interjections, which had been necessary, either to encourage children who were not talking, or to direct those who did not keep to topic. Responses by children to experimenter interjections also do not form part of our analysis.

## Results

The ANCOVA revealed that, when lexical alignment was controlled for, there was a significant main effect of conversation type on syntactic alignment, in the natural conversation task,  $F_{1,31} = 14.95$ ,  $p = .001$ , partial  $\eta^2 = .33$ . This indicates that, overall, children repeated syntax at above-chance level in real conversations (see Table 8), and is evidence of alignment effects. Further, there was no significant main effect of diagnosis on overall syntactic alignment,  $F_{1,31} = .42$ , partial  $\eta^2 = .01$ , *n.s.* There was also no significant interaction between diagnosis and syntactic alignment as a repeated measure,  $F_{1,31} = .02$ ,  $p = .90$ , partial  $\eta^2 = 0$ , demonstrating that alignment effects between the groups were equivalent. Taken together, these findings are consistent with Study 1.

Table 8: Syntactic alignment scores (cosine) by diagnosis and conversation type (natural conversation task)

Syntactic alignment (estimated marginal means)			
<u>Diagnosis</u>	<u>Conversation type</u>	<u>Mean</u>	<u>SD</u>
ASD	Control	.08	.06
	Real	.12	.04
TD	Control	.07	.03
	Real	.12	.05

*Cross-task comparison of alignment effect size*

The third objective of this paper was to find out whether syntactic alignment effect sizes differed between the experimental and naturalistic tasks. To address this question, we compared within-participant alignment effect sizes from the natural conversation task with aggregated effect sizes from the card game (see Table 9). Aggregated effect sizes are calculated as the average of passive and DO syntactic alignment effect sizes.

Table 9: Syntactic alignment effect sizes by task

Syntactic alignment effect size		
<u>Task</u>	<u>Partial <math>\eta^2</math></u>	<u><i>p</i> value</u>
Card game	.52	<.001
NC	.33	<.01

Although effect sizes are large in both tasks, according to Cohen’s (1988) guidelines, there is clearly a stronger syntactic alignment effect in the card game. This finding is in line with our prediction, and most likely reflects the fact that, in the card game, alignment was highly constrained. It is also worth noting that, while children aligned syntax across up to seven bigrams in the card game, our analysis of natural conversation task data offered no

evidence of syntactic alignment beyond the quadrigram level. This means that, in natural conversation, children did not copy grammar sequences of the length of those used in the card game. This lends further support to our suggestion that alignment is superficially heightened in experimental tasks.

## **General discussion**

Across the studies presented here, we sought to discover whether previous findings about alignment in ASD children could be replicated. We also sought to discover how far these findings could be considered as ecologically valid, and thereby how accurately experimental tasks measure alignment in ASD.

In our first study, based on the findings of Allen et al. (2011) and Slocombe et al. (2012), we predicted that ASD children would align syntax to the same extent as verbal mental age-matched TD controls while playing a pictorial card description game. We found evidence in support of this prediction. Like Allen et al. (2011), we found no significant difference in passive syntactic alignment effects between our ASD and TD group. A novel finding was that ASD children also aligned DO syntax to the same extent as TD controls, despite their putative difficulty with dative alternation. Further, these abilities were not related to chronological age or language ability in our sample. The latter finding is different to Allen et al.'s (2011) study, but we suspect this minor difference may simply reflect sampling variability, or the adjustments we made to the task.

In our second study, we predicted that the syntactic alignment observed in the card game would not generalise to natural conversation for the ASD group, owing to the fact that conversation is comparatively less structured and goal-opaque. Against our prediction, but consistent with the findings of Study 1, ASD children did not differ significantly from TD controls in the extent to which they aligned syntax with an interlocutor. To our



knowledge, this study is unique in demonstrating intact alignment abilities in the natural conversations of ASD children. Furthermore, we believe this study is unique in demonstrating above-chance priming effects in natural conversation, which Howes et al. (2010) did not. We speculate that our use of a bigram model to calculate syntactic alignment, rather than the syntactic rule model used by Howes et al. (2010), might explain this inconsistency. Alternatively, the inconsistency may be attributable to the nature of the data analysed in our study versus the other studies. Howes et al. (2010) analysed conversations from a spoken language corpus that is not child-oriented, and it has been shown that syntactic priming effects are stronger in children than in adults (Rowland et al., 2012). Rowland et al. (2012) also demonstrated that lexical boost effects are stronger in adults than children, which may explain why, in Howes et al.'s (2010) study, specifying lexical alignment as a covariate in their analysis eradicated syntactic alignment effects. Our results give us reason to believe that alignment is not merely an experimental artefact.

A third prediction of our studies was that, in line with Howes et al. (2010), there would be weaker syntactic alignment effects in natural conversation than in the card game, again owing to the comparative structuredness and goal-directedness of the game. This prediction was supported, and we also found that, in natural conversation, there was no alignment on syntactic structures of the length of those used in the card game. This finding highlights that, while experimental approaches to measuring syntactic alignment may reliably capture group differences (or lack thereof) in this behaviour, they may also overestimate its prevalence in real life interactions (cf. also Howes et al., 2010). At present, there is therefore a trade-off to be made in the study of alignment, between external and ecological validity. While experimental studies of alignment delimit error variance (Gries, 2005), naturalistic studies assess the prevalence of alignment more realistically.

Overall, the results of both our studies are consistent with unmediated accounts of alignment, which conceptualise lower level alignment as an unconscious, automatic process

facilitated by priming mechanisms. According to such accounts, prior exposure to dispreferred syntactic forms (passive; DO) increased subsequent access to these forms, either through residual activation or through implicit learning. If priming resulted from residual activation, alignment effects can be construed in terms of the short-term activation of lemma nodes representing lexical entries in the mental lexicon. Pickering and Branigan (1998) argue that the comprehension of a sentence with a particular structure activates the syntactic representations associated with that structure, facilitating the subsequent comprehension or production of a sentence containing the same structure. Alternatively, if priming resulted from implicit learning, then alignment effects can be construed in terms of an error-driven implicit learning process. Chang et al. (2006) posit a dual-path model of syntactic priming, which predicts the upcoming structure of a sentence, adjusts its internal representations in response to error, and thereby biases the production of subsequent, similar structures. In either case, our study demonstrates that ASD children align syntax with an interlocutor, without any explicit instruction to do so, and in both an experimental and a naturalistic setting.

We cannot fully discount the possibility that alignment in the ASD group was mediated by mentalising abilities, however. As noted, and despite widely documented ToM impairment in ASD children, our groups performed equally well on the Sally Ann task, suggesting that all the children had at least a basic ability to adopt another person's perspective. Use of other, more advanced ToM measures may be necessary to avoid such ceiling effects in future research, and might elucidate a role for audience design mechanisms in ASD children's alignment. Higher-order ToM impairment does not appear to affect alignment in other clinical populations, however (cf. Stewart et al., 2008).

As well as contributing to the alignment literature, our findings contribute to the literature on imitation in ASD. A review of studies which consider action imitation in ASD concludes that ASD individuals struggle to copy actions which are unfamiliar, and which

do not have a clear goal (Vivanti & Hamilton, 2014). Although motor imitation is a different form of imitation to language alignment, it is nevertheless surprising that the ASD children in our studies showed no deficiencies of imitation in the verbal domain, since conversation can itself be goal-opaque. It is also surprising given that language deficits are a diagnostic feature of ASD. Lower level linguistic alignment may therefore represent a form of imitation that is spared in verbal ASD children.

Two questions remain over the syntactic alignment we observed in our studies. First, while ASD and TD children aligned to the same extent, we were not able to establish whether this behaviour is underpinned by the same or different mechanisms. It is known, for example, that TD children imitate for social affiliative reasons (Over & Carpenter, 2009). However, since ASD children have reduced social motivation (Chevallier et al., 2012), it is possible that their alignment is driven by different mechanisms. Secondly, we do not know whether syntactic alignment actually supports the alignment of situation models in ASD children, as it is theorised to do. We have already argued that the pragmatic deficits associated with ASD imply misalignment of situation models. This suggests that the alignment process in ASD is not wholly unmediated, because alignment at one linguistic level seems not to promote alignment at another.

A plausible explanation for both the alignment and pragmatic findings in ASD is that the syntactic alignment we observed in our sample reflected only superficial but not deep co-ordination processes. The possibility that alignment involves unmediated and mediated components was first considered by Garrod and Clark (1993), and more recently by Branigan et al. (2010). In a study of alignment in the conversations of TD children, Garrod and Clark (1993) sought to explain why, in a group of children aged 7-12 years, the youngest children (7-8 years) showed the least communicative success on a maze task, despite aligning syntax and lexis at a comparable level to the older children. The explanation offered was that the younger children only superficially aligned with an

interlocutor, and were less sensitive than older children to the mutual intelligibility of their conversation exchanges. As an illustrative example, Garrod and Clark offer this exchange between two children aged 7-8 years:

Child B: Tell me where you are.

Child A: I'm at a switch box and mine's flashing.

Child B: Right where your's...where's your switch box...where's your cross.

Child A: Well it's just above a switch box.

Child B: And mine's is kind of diagonal where the switch box is.

Child A: Yeh, right.

(Garrod & Clark, 1993, p. 124)

Although Child A's description of her position in the maze is inadequate, Child B adopts the same description to identify her own position, a choice which subsequently results in communication failure, rather than mutual understanding. The children have difficulties with semantic alignment: while they converge on a lexicon and descriptive scheme, they have no local construal of what their task-relevant language means.

For our purposes, Garrod and Clark's account is appealing in two ways. First, it consolidates alignment and pragmatics findings in ASD, suggesting that lower level alignment may be a necessary but not sufficient condition for establishing common understanding in conversation. Secondly, the account highlights how critical semantic alignment is to the alignment process, and what the costs are of its impairment. This is important because, as Allen et al. (2011) have speculated, the communicative difficulties of ASD children may relate to impaired semantic alignment. Allen et al.'s (2011) proposition is consistent with studies showing that semantic processing can be compromised in ASD (cf. e.g., Tager-Flusberg, 1991). Figurative language can prove particularly challenging for

ASD individuals, who are prone to miscomprehending jokes (Emerich, Creaghead, Grether, Murray, & Grasha, 2003), irony (Happé, 1993), and sarcasm (Persicke, Tarbox, Ranick, & St. Clair, 2013). Therefore, ASD children with no fundamental impairment of alignment may still have poor communicative competence.

Despite the compelling pattern of our data, we acknowledge some limitations to our studies, owing in part to the non-experimental design of Study 2. One limitation was that the interlocutor was not a constant factor across the card game and natural conversation task. This was a practical decision in Study 1, since it was not feasible to engage children as confederates in the card game. Equally, in Study 2, we felt it would have been problematic to have the experimenter hold 34 conversations on the same topic with different children. We do not believe that our results were grossly affected by this methodological inconsistency, especially if alignment is unmediated. Since alignment can be mediated, however, we recognise that children may have aligned less with a peer than they would have done with the experimenter. We assume this on the basis that the children and their classmates already had common ground to draw on. As a result, the need to establish mutually intelligible referents may have been diminished, and syntactic alignment might therefore have been less ubiquitous. The significance of this is that, in our studies, there may have been a smaller difference in alignment across tasks, had the interlocutor remained constant.

Another methodological inconsistency, which we have already highlighted, is that we did not measure alignment in the same way across our studies. The rarity of passive and DO structures in spoken language, which facilitated the calculation of alignment effects in Study 1, was the reason that we had to look more broadly at syntactic alignment in Study 2. While Study 2 has the advantage of not being artificially constrained to two types of syntax, it is the case that the alignment effects that we have presented here are measured differently in Studies 1 and 2. In Study 1, we follow the standard practice of alignment

experiments, calculating how often dispreferred syntactic targets follow dispreferred syntactic primes, and adjusting for dispreferred targets following preferred primes. In Study 2, however, where responses are unconstrained, it was not possible to calculate alignment effects in the same way. As an alternative, and consistent with other, naturalistic studies of alignment, we calculated global alignment effects, which indicate how much syntactic alignment there is above chance (i.e., is there really any alignment at all?), after taking any lexical boost effects into account. Clearly, these are very different measures of alignment effects, but a universal formula for calculating alignment effects in both experimental and naturalistic settings has not yet been devised.

Lastly, and like many studies of ASD, our studies may suffer from small sample size effects, a fact compounded by the notorious heterogeneity of ASD. In particular, we acknowledge that, in Study 1, there were group differences between TD and ASD children, albeit not at the level of statistical significance. It is possible that a larger, more powerful study would have yielded different results, although we observe that Allen et al.'s (2011) study showed equivalent alignment effects between ASD and TD children. A more powerful approach to measure alignment in ASD children's natural conversations would be to analyse large amounts of corpus data, as other studies have done. To date, however, we are not aware of any corpora of conversations in ASD being publicly available. Further data collection is therefore necessary to ascertain whether our pattern of results generalises to a larger sample.

Given that ASD children may have impaired semantic alignment abilities, future research should examine this possibility more closely. There was no scope in our study tasks for examining the communicative success of ASD children, or how alignment might relate to this. A different and more difficult experimental task, such as Garrod and Clark's (1993) maze game, would help to clarify whether semantic alignment is intact in ASD, and if so, how it supports alignment of situation models. A greater challenge would be to develop a

task where these variables could be studied in a real world setting. Further investigation of the mechanisms of alignment in ASD and TD children is also necessary, to probe how similar alignment behaviours actually are between these groups. Research into both these questions is ongoing.

In summary, we found in our studies that ASD children align syntax to the same extent as TD controls, in natural conversation as well as in an experimental task. This finding lends ecological validity to previous experimental work on alignment in ASD, suggesting that ASD individuals are able to align linguistic representations with an interlocutor outside of the laboratory setting. We have also called into question the experimental tasks used to measure alignment, however. While these have not been presented as proxies for real conversations, they do give a false impression of how much people align in natural settings. We therefore recommend that caution be exercised over the generalisability of experimental findings on alignment, pending further naturalistic research. Further studies must also investigate whether ASD children align at higher linguistic levels, such as semantics, and whether alignment is underpinned by the same mechanisms in ASD and TD children.

## **Article 2: Mechanisms of mediated alignment in ASD children**

**Data for the second study reported in this article were collected by Rebecca Donne,  
an MSc student co-supervised by Nicola Yuill and me.**

Lexical alignment occurs when speakers converge on word choices in dialogue, and this process can be mediated by speakers' beliefs about their interlocutor (Branigan et al., 2011). The current study considers whether ASD children engage in mediated lexical alignment. Across two experiments, we measured lexical alignment in ASD children and TD controls, using a priming paradigm embedded within the card game Snap!. We also investigated whether putative mechanisms underlying audience design (theory of mind; inhibitory control) predicted children's tendency to align. In both experiments, ASD children aligned lexis to the same extent as both chronological and verbal age-matched TD children. However, we did not find evidence that lexical alignment is influenced by audience design mechanisms, in either ASD or typical development. We conclude that lexical alignment is instead driven by unmediated (i.e., priming) mechanisms in children, while highlighting the challenges posed by alignment that excludes mental state modelling.



Language alignment is the tendency of speakers to repeat each other's linguistic choices in conversation, and it is readily observed in normal adult dialogue. Two speakers are lexically aligned, for example, when they both refer to a water-going vessel as a 'boat'; if one speaker refers to a 'boat', and the other to a 'ship', then they are not lexically aligned. Alignment also occurs at other levels of linguistic structure, including speech rate (e.g., Giles et al., 1991), syntax (e.g., Branigan, Pickering, & Cleland, 2000b), and semantics (e.g., Garrod & Anderson, 1987). Evidence that alignment promotes better communication and more satisfying interactions (cf. e.g., Fusaroli et al., 2012; Reitter & Moore, 2014) suggests that there are perceptible benefits for speakers who converge linguistically in conversation.

While the occurrence of alignment is mostly uncontentious (although cf. Healey et al., 2014), different mechanisms have been proposed to underlie the alignment process. One account, the interactive-alignment account (Pickering & Garrod, 2004), explains alignment exclusively in terms of priming mechanisms within the language processing system. According to this account, alignment occurs automatically and unconsciously in conversation: prior processing of an interlocutor's utterance primes a speaker's production of a subsequent utterance. Another tenet of the interactive-alignment account is that lower level alignment (e.g., syntactic) leads to higher level (e.g., semantic) alignment, and ultimately to mutual understanding of the situation under discussion. Interlocutors prime each other to think in the same way, therefore, and hence alignment of this kind is termed *unmediated* (Branigan et al., 2010); such linguistic convergence is neither goal-directed, nor influenced by a speaker's beliefs about an interlocutor.

The alignment process is alternatively explained by *mediated* accounts, which link alignment to social-psychological motivations. One such account proposes that linguistic convergence, while prompted by priming, is enhanced by audience design mechanisms (Branigan et al., 2011). Branigan et al. (2011) suggest that, for example, a speaker might use the same word as an interlocutor having reasoned that the interlocutor's use of that word

signals that he understands it, and prefers it to available synonyms. The engagement of audience design mechanisms is therefore contingent on a speaker's having intact mentalising ability, or ToM; to align in a communicatively strategic manner, a speaker must be capable of adopting an interlocutor's perspective (in preference to his own) when formulating utterances. For this reason, speakers with impaired ToM could display reduced linguistic convergence, in interactions where audience design mechanisms might be expected to guide alignment.

In the current study, we focus on lexical alignment in children with ASD, a neurodevelopmental disorder commonly associated with impaired ToM (Baron-Cohen et al., 1985). ASD children struggle with social interaction and communication, and a substantial proportion never acquire functional language (~30%; Anderson et al., 2007). Verbal ASD children may yet display marked pragmatic deficits in conversation (cf. Volden, 2002, for a review): they struggle to adopt an interlocutor's perspective, both when interpreting and formulating utterances (Capps et al., 1998; Loveland & Tunali, 1991; Loveland, Tunali, McEvoy, & Kelley, 1989; Mitchell, Saltmarsh, & Russell, 1997; Surian et al., 1996), and this has been related to ToM impairment. Such evidence suggests that audience design mechanisms might be impaired in ASD children, in ways that could impact lexical alignment that is socially mediated.

To our knowledge, only two previous studies have directly examined whether there is a mediated component to alignment in ASD children. In a lexical priming experiment, Osborne and Allen (2012) showed that ASD children were more likely to produce a dispreferred name to describe a picture, if they had just heard an interlocutor use that dispreferred name to describe the same picture. ASD children's tendency to align, however, did not correlate with their performance on a mental state attribution task (the 'Eyes Test' for children; Baron-Cohen et al., 2001). Osborne and Allen (2012) therefore concluded that children's linguistic convergence did not reflect the workings of audience design

mechanisms, and was instead the effect of priming. However, since the ‘Eyes Test’ primarily measures emotion processing, it is also plausible that these aspects of social cognitive functioning are irrelevant to communicatively strategic alignment.

More recently, Hopkins, Yuill, and Keller (2015) showed that ASD children aligned syntax with an interlocutor, both in a priming experiment and in natural dialogue, but alignment was again unrelated to children’s mental state attribution ability (assessed this time by the Sally-Anne false belief task; Baron-Cohen et al., 1985). This is not an instructive finding, however, since children’s performance on the Sally-Anne task was at ceiling level in the study. Other studies of alignment in ASD (Allen et al., 2011; Slocombe et al., 2012) observe a similar pattern of results to those reported by Osborne and Allen (2012) and Hopkins et al. (2015), but contain no measures of mentalising ability, precluding conclusions therein about whether ASD children’s alignment might be mediated.

We propose to re-examine the possibility that there is a mediated component to ASD children’s alignment, in part because of the methodological shortcomings of previous research on the topic. A second, more theoretical motivation for the current study is emerging evidence that, within a conversational context, mentalising ability may be regulated by executive functioning (EF). EF is an array of domain-general processes which support the planning, organisation, and management of goal-directed behaviour. One aspect of EF in particular, IC, has been linked to communicative perspective-taking, which is analogous to the process of audience design in conversation. IC encompasses the ability to inhibit prepotent responses and control interference, and it has been shown that TD children and adults with greater IC are more able to accommodate differences between their and an interlocutor’s knowledge during referential processing, purportedly through the suppression of their own perspectives (Brown-Schmidt, 2009; Nilsen & Graham, 2009; Wardlow, 2013).

The demonstrated role of IC in communicative perspective-taking may be relevant to ASD children's alignment, owing to the prevalence of executive dysfunction (ED) in ASD. The ED theory (Russell, 1997; Pennington et al., 1997) ascribes autistic symptomatology to EF deficits, and a recent review concluded that ASD children have poorer response inhibition and interference control (respectively termed *delay* and *conflict* IC in the literature) than TD controls (Geurts et al., 2014). Poor IC might, therefore, underpin the pragmatic language deficit associated with ASD; it could explain the observed disjuncture between ASD children's communicative behaviour and their performance on ToM tasks. This is the argument of Nilsen and Fecica (2011), who hypothesise that, for some ASD children, IC limits their communicative perspective-taking, even when ToM is intact. ASD children with poorer IC may recognise mental states in an interlocutor, and yet lack the supporting skills (i.e., IC) to integrate and use this information in their communicative behaviour.

Drawing on Nilsen and Fecica's (2011) work, our primary aim is to examine the contribution of audience design mechanisms to ASD children's lexical alignment, and in particular how these mechanisms might relate to IC. Since EF and ToM are overlapping components (e.g., Joseph & Tager-Flusberg, 2004), our study follows Nilsen and Fecica's (2011) recommendation that they be fractionated, by assessing whether deficits in one component relate to deficits in communicative perspective-taking, while controlling for deficits in the other component. To this end, our study includes measures of ASD children's ToM and IC; we take measures of conflict rather than delay IC, because only conflict IC has been found to predict communicative perspective-taking in TD children (Nilsen & Graham, 2009). We investigate how children's lexical alignment relates to their ToM and IC ability, when these components are considered separately and together.

A secondary aim of our study is a corollary of the first. Through the inclusion of TD controls in our study, we are able to explore the possibility that the mechanisms for lexical

alignment differ between ASD and TD children (and may not be mediated in either case). This is an important matter because, while ASD children (Allen et al., 2011; Hopkins et al., 2015) and adults (Slocombe et al., 2012) align to the same extent as typical controls, these behavioural results do not prove that the same mechanisms underpin alignment for all. Branigan et al. (2010) point out that, in typical adults, mediated and unmediated mechanisms are not mutually exclusive, and may contribute more or less to alignment in different contexts. For example, a speaker's alignment could be influenced by prior processing of an interlocutor's utterance (i.e., priming), but also by his belief that repeating a particular word is communicatively advantageous (i.e., audience design). By taking measures of IC and ToM in our study, we can attempt to separate priming and audience design mechanisms in ASD and TD children's alignment, and to investigate the extent to which the different mechanisms might contribute to alignment in the two groups.

Since priming mechanisms seem to be intact in ASD (Allen et al., 2011; Hopkins et al., 2015), we expect ASD children to show lexical alignment in our study. We also expect that, in line with previous research (Osborne & Allen, 2012), ASD children will align lexically to the same extent as TD controls. What we do not know is whether there will be a relationship in one or both groups between children's tendency to align lexically, and their mentalising ability. If it were the case, for example, that we found a relationship between these variables in TD but not ASD children, this could indicate that ASD children's alignment is a product of priming mechanisms, with TD children's alignment being more socially mediated (i.e., guided by communicative perspective-taking). Such a finding would provide novel evidence that the mediated component of alignment is impaired in ASD, especially if ASD children's IC performance were poorer than that of TD controls.

As noted, the findings of previous research suggest that there is no relationship between alignment and mentalising ability, either in ASD or TD children (Osborne & Allen, 2012), and therefore that the mechanisms of alignment in these groups are the same. However, by

incorporating IC with ToM measures in our study, we hope to elucidate a mediated component in ASD and TD children's alignment that may previously have been hidden. To explore our hypotheses, we employ a previously-used lexical priming paradigm in which a child and an experimenter alternately describe pictures to each other, and decide whether pairs of pictures are matching. We manipulate whether the experimenter uses a preferred or dispreferred form to describe the pictures, and measure the extent to which each child produces the same form in describing each matching picture. This paradigm is employed across two experiments, which also incorporate the same ToM task, but different IC measures.

## STUDY 1

### Method

#### *Participants*

Participants were 12 ASD children (10 male; mean chronological age = 10.8 years, range 8.2-12.5 years) attending a special school in West Sussex, UK, who had been previously diagnosed with ASD by a paediatrician, psychiatrist, or clinical psychologist. We corroborated diagnoses with the Social Communication Questionnaire (SCQ; Rutter et al., 2003), a parental screening instrument that assesses communication and social skills in children who may have ASD. All children obtained an SCQ score above the recommended cut-off of 15 (Wiggins et al., 2007), mean SCQ score = 23.7 and range = 16-29.

We tested the language ability of the children using the BPVS-3 (Dunn et al., 2009), and used the scores as a proxy for verbal mental (VM) age (mean BPVS-3 score = 9.6 years, range 6.7-12.6 years). Raw BPVS-3 scores were used to match the ASD children to a control group of TD children on the basis of VM age. We matched a second control group

of TD children to the ASD children on the basis of chronological age. The groups were matched pairwise, meaning each ASD child was paired with one TD child of a similar chronological age, and one TD child of a similar VM age (see Table 1). All control children were recruited from a mainstream primary school in Dorset, UK.

*Table 1: Participant characteristics (Study 1)*

<b>Group</b>	<b>N =</b>	<b>Chronological age</b>	<b>VM age (determined by BPVS-3)</b>
ASD	12	Mean = 10.8 years Range = 8.2-12.5 years	Mean = 9.6 years Range = 6.7-12.6 years
Chronological age-matched controls	12	Mean = 10.3 years Range = 7.9–11.8 years	Mean = 11.4 years Range = 9.2-12.6 years
VM age-matched controls	12	Mean = 9.3 years Range = 6.6-11.8 years	Mean = 9.9 years Range = 7.9 – 12.8 years

### *Materials*

As well as the BPVS-3, children completed a battery of verbal and non-verbal tasks, including: (i.) a lexical priming paradigm, adapted from Branigan, McLean, and Jones (2005); (ii.) the Junior Hayling Test of inhibitory functioning (Shallice et al., 2002); and (iii.) a false belief task (Tager-Flusberg & Sullivan, 1994)

#### *(i.) Lexical priming paradigm.*

This was embedded within an adapted version of the card matching game Snap!. To play Snap!, a deck of picture cards is divided between two players, who take turns in revealing their cards to each other. If two adjacent cards are matching, players compete to say ‘Snap!’,

in order to win those cards. Branigan et al.'s (2005) paradigm requires players to verbally describe the pictures displayed on their Snap! cards.

There were 20 experimental items in the card game. These comprised a prime and a target card, which displayed the same picture, and which were interposed by two different filler cards (see Figure 1). There were also 8 pairs of snap cards, which displayed the same picture, and which appeared adjacently in the game. These were distributed evenly among the experimental items.

The experimental items were selected on the basis of two pretests. In the first, preschool children ( $N = 18$ ) named 40 pictures that had two possible descriptors. A descriptor was judged as 'preferred' (e.g., bike) if children used it twice as much as a 'dispreferred' alternative (e.g., bicycle). In a subsequent pretest, different preschool children ( $N = 12$ ) had to match a dispreferred descriptor to one picture in an array of four, in which another picture was a semantically related distractor. Only items correctly identified by >70% of children were retained in the game.

There were two lists of experimental items in the card game, with each list containing 10 preferred and 10 dispreferred primes, and with one version of each item in each list. Filler items were in a fixed randomised order, and the order of experimental items was randomised for each child. Children were randomly assigned to one of the two lists.

While playing the card game, the experimenter always described her cards first, reading from a covert script of the experimental items. In this way, she primed the child's target descriptions with either a preferred or dispreferred lexical form. We quantify the difference in the number of dispreferred target descriptions produced in response to dispreferred versus preferred prime descriptions as *alignment effects*. These are priming scores, reflecting the tendency of each child to align lexically with the experimenter.



*Figure 1: Sample trial from card game*

Experimenter: PRIME ('bicycle')



Child: FILLER ('sock')



Experimenter: FILLER ('drum')



Child: TARGET ('bicycle' or 'bike')



*(ii.) Junior Hayling Test of inhibitory functioning.*

The Junior Hayling (Shallice et al., 2002) is a sentence completion task which measures verbal interference control. After a practice round, the task has two parts, A and B, both containing 10 sentences. In part A, children completed each sentence with an expected word (e.g., 'umbrella' after the sentence 'if someone is walking in the rain, they usually carry an...'). The maximum score in part A was 10, with higher scores indicating better performance.

In part B, children completed each sentence with a word that was unrelated both to the words in the sentence, and to the word that would usually complete that sentence. Children were awarded 3 points for finishing a sentence with an expected word, 1 point for finishing

with a semantically related word, and 0 points for an unrelated word (i.e., lower scores indicated better performance in part B).

Children were encouraged to respond as quickly as possible in both parts of the Junior Hayling task, and reaction times (RT) were recorded with a stopwatch. We selected the task because it isolates children's ability to inhibit production of spoken words, and therefore seemed particularly relevant to the study of alignment.

*(iii.) False belief task.*

We also took measures of mental state attribution ability using Tager-Flusberg and Sullivan's (1994) 'birthday puppy' story, which measures second-order false belief understanding. We selected this task to avoid the ceiling effects obtained in our previous work (Hopkins et al., 2015). In a cartoon video version of the birthday puppy story, children heard about a boy who is deceived by his mother over what he is getting for his birthday. Their understanding of the story was assessed by three control questions (a reality and a linguistic control question, testing children's comprehension of the narrative; a first-order ignorance question), and their mental state attribution ability assessed by two test questions (second-order ignorance, second-order false belief). Children were also asked to justify their responses to the second-order false belief question.

*Procedure*

Children were tested individually by the first author, in a single one-hour session. All tasks were presented in a fixed order: BPVS-3 → lexical priming paradigm → false belief task → Junior Hayling. Children were given encouragement, but not feedback, during testing.

*Coding and data processing: card game*

All target descriptions were coded as evidencing either a preferred or dispreferred form of the lexical item. The proportions of preferred versus dispreferred target descriptions produced in response to preferred versus dispreferred primes are reported in Table 2. A small proportion of ‘other’ target responses (5.4% overall) could not be classified as preferred or dispreferred. These responses were randomly distributed across items and groups, and were excluded from analysis.

*Table 2: Percentage of dispreferred targets by prime condition (Study 1)*

Group	% dispreferred targets		
	Preferred	Dispreferred	Alignment
	primes	primes	effect <sup>a</sup>
ASD	7.5%	71.67%	64.17%
Chronological age-matched	.83%	80%	79.17%
VM age-matched	2.5%	75%	72.5%

<sup>a</sup> Alignment effects are calculated as percentage of dispreferred targets produced after dispreferred primes, minus the percentage of dispreferred targets produced after preferred primes.

We analysed remaining card game data using logit mixed-effect (LME) models (Jaeger, 2008), which simultaneously incorporate by-item and by-participant variation, unlike the F1-F2 analyses traditionally used in psycholinguistic research. LME modelling is more powerful than F1-F2 analyses (Dixon, 2008), which may handle categorical data inadequately (Barr et al., 2013).

We started the analysis by specifying a baseline model that included the dependent variable lexical target (preferred versus dispreferred). We also specified random slopes and intercepts (i.e., participant and item-specific) for all fixed effects. As recommended by Barr

et al. (2013), we removed the correlation term between random effects from all models, to allow model convergence.

Incrementally, we added the fixed effects of prime (preferred versus dispreferred), group (ASD versus chronological age-matched versus VM age-matched), and an interaction between prime and group to three models of our card game data. Model 1 contained the fixed effect of prime only, model 2 the fixed effects of prime and group, and model 3 a prime by group interaction term. For each model, the statistical significance of fixed effects was assessed using Wald's test (Wald, 1943), for which  $z$  scores and  $p$  values are reported.

Model fit was assessed using chi-squared tests, which used log-likelihood ratios to calculate whether any of models 1, 2, and 3 were an improvement on the baseline model. The models were fitted with the statistical package R (version 3.0.2; R Core Team, 2013) and the package lme4 (Bates et al., 2011).

## Results

### *(i.) Lexical alignment on card game*

In our LME analysis, model 1 was a significant improvement on the baseline model,  $\chi^2(1) = 47.97, p < .001$ , indicating that, overall, children produced significantly more dispreferred targets after dispreferred primes than after preferred primes. This demonstrates that there was an overall lexical alignment effect in the card game (see Table 3).

Model 2 was not a significant improvement on the baseline model,  $\chi^2(1) = 1.02, p = .60$ , however, meaning that all groups demonstrated lexical alignment effects. Model 3 was also not a significant improvement on the baseline model,  $\chi^2(2) = 4.70, p = .10$ , indicating that the magnitude of lexical alignment effects did not differ significantly between groups.

Table 3: Summary of fixed and random effects for model 1 (prime only; Study 1)

Fixed effects	Estimates	SE	Wald Z	<i>p</i> value
Intercept	-4.26	.47	-9.07	<.001
Dispreferred prime	6.52	.66	9.94	<.001

Random effects	SD
<i>Participant</i>	
Intercept	1.11
Dispreferred prime	2.17
<i>Item</i>	
Intercept	1.24
Chronological age-matched controls	0.91
VM age-matched controls	1.45
<i>Item</i>	
Intercept	.41
Dispreferred prime	1.53

† NB. in the fixed effect summaries, ‘intercepts’ are alignment estimates for the reference category (= preferred prime). Estimates displayed for ‘dispreferred prime’ represent the difference in alignment between this and the reference category. In the random effects summaries, ASD is the reference category for group comparisons (chronological age-matched controls; VM age-matched controls).

Since it could be argued that the ‘other’ responses excluded from our analysis represent acute non-alignment, and because there were group differences in the proportions of other responses given (ASD  $M = 6.7\%$ ; chronological age-matched controls  $M = 5\%$ ; VM age-matched controls  $M = 4.6\%$ ), we ran an otherwise identical second LME analysis

incorporating these data, to check that our results were robust to more absolute coding. In order to incorporate other responses within this analysis, we recoded the dependent variable lexical target. Responses were classified as ‘aligned’ or ‘unaligned’, rather than preferred, dispreferred, or other.

Consistent with the initial analysis, the follow-up analysis showed that model 1 was a significant improvement on the baseline model,  $\chi^2(1) = 5.75, p = .02$ , although the effect of priming was substantially weaker. Again, adding the effect of group (model 2),  $\chi^2(2) = 2.25, p = .32$ , and an interaction between prime and group (model 3),  $\chi^2(2) = 3.51, p = .17$ , did not significantly improve upon the baseline model. While the ASD group produced on average more unaligned responses, their alignment behaviours were not significantly different from both chronological- and VM age-matched controls.

*(ii.) Group performance on the IC task*

Table 4 shows that there were significant group differences in performance on the Junior Hayling task. The ASD group obtained significantly poorer scores on part A compared with chronological age-matched controls,  $t(15.67) = -2.35, p = .03$ . Further, the ASD group obtained significantly higher scores (indicating poorer performance) on part B of the Junior Hayling, compared with both control groups (chronological age-matched:  $t(12.20) = 2.82, p = .03$ ; VM age-matched:  $t(12.34) = -2.36, p = .03$ ).

Table 4: *Junior Hayling task performance*

	ASD	Chronological age-matched	VM age-matched	ANOVA	
	Means ( <i>SD</i> )	Means ( <i>SD</i> )	Means ( <i>SD</i> )	F	<i>p</i>
Part A: total score	7.50 (2.11)	9.10 (.94)	8.83 (.94)	4.12 <sup>†</sup>	.03 <sup>†</sup>
Part A: RT (secs)	1.35 (.70)	.93 (.48)	1.18 (.31)	1.97 <sup>†</sup>	.16 <sup>†</sup>
Part B: total score	9.08 (7.49)	2.83 (1.83)	3.83 (1.85)	6.49 <sup>†</sup>	.01 <sup>†</sup>
Part B: RT (secs)	2.22 (1.22)	1.81 (.79)	1.79 (1.00)	.68	.51

<sup>†</sup>The Brown-Forsythe correction is applied due to violation of the equal variance assumption

*(iii.) Group performance on the false belief task*

Table 5 indicates that there was a marginally significant difference between the groups on the reality control question ( $p = .05$ ), and no significant between-group differences on either the first-order ignorance or linguistic control question (both  $ps > .05$ ). There were significant between-group differences on the test questions, however. In post hoc analyses, we calculated adjusted  $\chi$  scores which indicated that only the ASD children failed both the second-order ignorance and second-order false belief question with a significantly higher frequency than expected (both ASD  $\chi = 2.80$ ,  $p = .005$ ; Bonferroni adjusted  $p = .008$ ).

Table 5: Frequencies for false belief task questions (Study 1)

	ASD		Chronological age-matched		VM age- matched		Chi-square	
	Pass	Fail	Pass	Fail	Pass	Fail	$\chi^2$	<i>P</i>
<i>Control</i>								
Reality	8	4	11	1	12	0	6.04	.05
First-order ignorance	9	3	11	1	7	5	3.56	.17
Linguistic	10	2	11	1	12	0	2.18	.34
<i>Test</i>								
Second-order ignorance	7	5	12	0	11	1	8.40	.02
Second-order false belief	7	5	11	1	12	0	8.40	.02

(iv.) Relationships between lexical alignment effects, IC, and false belief understanding

(a). Lexical alignment and false belief understanding

We conducted two two-way ANOVAs with ToM task question performance (pass versus fail) and diagnosis (ASD versus TD) as between-group factors. We combined the chronological and VM age-matched groups because ceiling effects were observed in the chronological age-matched group on the second-order ignorance question, and for the VMA age-matched group on the second-order false belief question; three-way group comparisons with such invariability would have been uninformative. The dependent variable (DV) was lexical alignment effect scores, which were arcsin transformed to account for missing (i.e., other) responses.



With respect to the second-order ignorance question, there were no significant main effects of diagnosis ( $F(1) = 0, p = .97$ ) and false belief understanding ( $F(1) = 2.25, p = .14$ ) on lexical alignment, and there was no significant interaction between these factors ( $F(1) = 1.15, p = .29$ ). With respect to the second-order false belief question, there were again no significant main effects of group ( $F(1) = 3.87, p = .06$ ) and false belief understanding ( $F(1) = .003, p = .96$ ), and no significant interaction between these factors ( $F(1) = 2.13, p = .15$ ). Consistent with Osborne and Allen (2012), these results indicate that lexical alignment effects do not vary according to ToM ability, in either ASD or TD children.

*(b.) Lexical alignment and IC*

For each group, we correlated alignment effect scores with the four performance indices of the Junior Hayling task. We report Pearson's  $r$  values for these correlations in Table 6. There were no significant correlations between variables for any group, suggesting that IC, like ToM task performance, does not predict children's lexical alignment on its own.

Table 6: Correlations of lexical alignment effect scores with Junior Hayling task indices

Group	N	Measure	Correlations			
			1.	2.	3.	4.
<i>ASD</i>	12	1. Lexical alignment effect				
		2. Part A: total score	.02			
		3. Part A: RT (secs)	.28	-.71		
		4. Part B: total score	0	-.75**	.29	
		5. Part B: RT (secs)	.18	-.03**	.38	-.05
<i>Chronological age-matched</i>	12	1. Lexical alignment effect				
		2. Part A: total score	-.23			
		3. Part A: RT (secs)	.34	.18		
		4. Part B: total score	.33	.37	.27	
		5. Part B: RT (secs)	.35	-.02	.25	.30
<i>VM age-matched</i>	12	1. Lexical alignment effect				
		2. Part A: total score	.21			
		3. Part A: RT (secs)	-.09	-.23		
		4. Part B: total score	.19	.02	.47	
		5. Part B: RT (secs)	-.30	-.49	.56	.23

Notes: \*\*  $p < .10$

It is surprising to note that performance on Parts A and B intercorrelate for the ASD group only; this is an important matter which we address in the interim discussion.

*(c.) Lexical alignment and false belief understanding, accounting for IC*

To address Nilsen and Fecica's (2011) hypothesis that IC impairment acts as a limiting factor on ASD children's use of mental state information in conversation, we submitted our data to Quade (1967) rank analyses of covariance, covarying for IC. We employed the Quade technique because our data violated several assumptions of the classic parametric ANCOVA (namely: linearity of regression; homogeneity of regression slopes; independence of predictor variable and covariate). Because Quade's technique requires that false belief scores have the same distribution across groups, we performed separate tests by diagnosis, since ASD and TD children performed significantly differently on the second-order ignorance and the second-order false belief questions (both  $\chi^2(1) = 8.10, p = .004$ ). Once again, we combined the control groups owing to ceiling level performance on the ToM task.

Question performance (pass versus fail) was therefore the only between-group factor, for each test question on the ToM task. The DV was alignment effect scores, covariate-adjusted for performance on Part B of the Junior Hayling task (score; RT). We did not covary performance indices for Part A because these are not measures of interference control.

With respect to the second-order ignorance question, we found no effects of question performance on lexical alignment for either the ASD children, Quade  $F_{1,11} = .12, p = .74$ , or the TD children, Quade  $F_{1,23} = 2.96, p = .10$ , after accounting for IC. With respect to the second-order false belief question, there were also no effects of question performance on lexical alignment for the ASD (Quade  $F_{1,11} = 1.97, p = .19$ ) or the TD (Quade  $F_{1,23} = 1.44, p = .24$ ) children, after controlling for IC. These results suggest that IC does not modulate a relationship between ToM and lexical alignment, in either ASD or TD children.

*(v.) Relationships between lexical alignment effects, age, and language ability*

There were no significant relationships between alignment effects and age, in the ASD group,  $r = -.33$ ,  $p = .30$ , the chronological age-matched group,  $r = -.36$ ,  $p = .25$ , and the VM age-matched group,  $r = -.25$ ,  $p = .43$ . There were also no significant relationships between alignment effects and BPVS-3 scores, once age was taken into account (ASD  $r = .18$ ,  $p = .60$ ; chronological age-matched  $r = .20$ ,  $p = .55$ ; VM age-matched  $r = .56$ ,  $p = .07$ ). This is consistent with our previous findings (Hopkins et al., 2015).

### **Interim discussion**

Overall, the findings of Study 1 provide further evidence for intact alignment in ASD children. Moreover, and consistent with previous research, ASD children were not significantly different to TD children in the extent to which they align with an interlocutor. We found no evidence, however, of a mediated component to lexical alignment in the ASD and TD groups. Specifically, the results of the analyses presented in (iv.) imply that communicative perspective-taking is not at work in children's lexical alignment. We found that alignment effects were not related to children's ToM or conflict IC, whether these components were considered in isolation or together. This suggests that neither mentalising ability (i.e., ToM) nor the support skills held as necessary for making use of that (i.e., IC) influenced the lexical choices of children playing the card game. The fact that ASD children significantly underperformed TD controls on both the ToM and IC task, and yet did not align significantly less, reinforces this idea. In sum, audience design mechanisms seem not to explain our pattern of results.

Nevertheless, we conducted a second experiment, which shares the objectives of Study 1, but which employed an alternative conflict IC task. The reason for this is that the performance of ASD children on the Junior Hayling task (see (ii.) above), coupled with the

experimenter's impressions while testing, indicated that the task might not have captured ASD children's IC ability very accurately. Conflict IC tasks require children to suppress a salient response and to generate a novel, conflicting response instead (Nilsen & Graham, 2009). For example, in Part B of the Junior Hayling task, children had to avoid completing the sentence 'at the traffic lights, you have to stop when the light is...' with the word 'red' (the expected word), as well as with other, semantically-related words (e.g., orange). *Prima facie*, ASD children's IC was taxed by Part B of the task, reflected by their tendency to complete Part B sentences with an expected word.

However, there were indications that the performance of ASD children on Part B of the Junior Hayling task may also have been influenced by deficits in their verbal fluency (generativity), and that the challenge of Part B was not purely one of inhibition. Hill and Bird (2006) proposed a generativity account of impaired Hayling performance in adults with Asperger's Syndrome, a high-functioning subtype of ASD. In our study, ASD children obtained significantly lower scores than TD controls on Part A as well as Part B of the task; ASD children lost marks on Part A because they struggled to complete some sentences at all, strongly suggesting problems with generativity. This could explain why scores from Parts A and B of the task were so closely correlated in the ASD group only (see (iv.)(b.)).

Another indication that ASD children's IC may not have been reflected by the Junior Hayling task is that their responses on Part A were, overall, less canonical than the responses of TD controls; that is, even when they did complete Part A sentences, ASD children less often supplied the expected final word. This is important because it could suggest that, on Part B of the task, ASD children were less constrained than TD children by knowledge about how the target sentences should be completed, and hence needed to work less hard to suppress what were, for TD children, highly salient responses. If this

were the case then, again, the Junior Hayling task may have failed to provide a reliable measure of ASD children's conflict IC.

For the reasons outlined, we decided to re-run our experiment, with a different sample of children, and using an alternative IC measure. In Study 2, we obtained measures of children's conflict IC on the day/night task (Gerstadt, Hong, & Diamond, 1994), which has lower generativity demands than the Hayling. In addition, the day/night task has lower working memory (WM) demands than the Junior Hayling task; it is known that IC tasks with a heavy WM load are especially challenging for ASD children (cf. e.g., Hughes & Russell, 1993), who have been shown to have worse WM than TD controls (Bennetto, Pennington, & Rogers, 1996; Russell, Jarrold, & Henry, 1996).

## STUDY 2

### Method

#### *Participants*

Participants were 14 ASD children (8 male) attending special schools in West Sussex (7 children) and London, UK. All children had been previously diagnosed with ASD by a paediatrician, psychiatrist, or clinical psychologist, and we corroborated diagnoses with the SCQ (mean score = 21.9; range = 15-31). Matching procedures were the same as in Study 1 (see Table 7). Control children were recruited from members of a community youth group in London, and among personal contacts of Rebecca Donne.

*Table 7: Participant characteristics (Study 2)*

<b>Group</b>	<b>N =</b>	<b>Chronological age</b>	<b>VM age (determined by BPVS-3)</b>
ASD	14	Mean = 12.6 years Range = 10.3-15.8 years	Mean = 7.4 years Range = 2.6-12.4 years
Chronological age- matched controls	14	Mean = 12.6 years Range = 10-15.5 years	Mean = 13.1 years Range = 11.4-13.6 years
VM age-matched controls	14	Mean = 5.7 years Range = 3.1-13.7 years	Mean = 7.5 years Range = 2.9 – 12.3 years

*Materials*

We used the same materials as in Study 1, only substituting the Junior Hayling task for the day/night task, which is a Stroop-like test of inhibition. We followed the procedure of Gerstadt et al. (1994) in administering the day/night task. Children were shown two types of card: dark blue cards depicting a moon and stars, and white cards depicting a sun. They were instructed to say ‘day’ when presented with a moon card, and ‘night’ when presented with a sun card. After a practice round, children were asked to name 16 test items, comprising 8 sun and 8 moon cards, presented to all children in a pseudorandom order. We coded responses for accuracy, and calculated an error score for each child by dividing the number of correct responses by the total number of trials. RT were recorded with a stopwatch.

*Procedure*

Children were tested individually by a research assistant, in a single one-hour session. As before, tasks were presented in a fixed order: day/night task -> BPVS-3 -> lexical priming paradigm -> false belief task.

*Coding and data processing: card game*

Coding of target descriptions on the card game was carried out as in Study 1. There were two rounds of coding, the first excluding and the second including other responses (by-group proportions of other responses: ASD  $M = 9.29\%$ ; chronological age-matched controls  $M = 4.64\%$ ; VM age-matched controls  $M = 3.93\%$ ). The data were submitted to separate LME analyses, reported below. Alignment effects are reported in Table 8.

*Table 8: Percentage of dispreferred targets by prime condition (Study 2)*

Group	% dispreferred targets		
	Preferred	Dispreferred	Alignment
	primes	primes	effect
ASD	2.14%	60.71%	58.57%
Chronological age-matched	5.71%	75%	69.29%
VM age-matched	3.57%	65%	61.43%

## Results

*(vi.) Lexical alignment on card game*

Consistent with Study 1 and previous studies (Allen et al., 2011; Hopkins et al., 2015), the first LME analysis (excluding other responses) showed that only the prime model significantly improved upon the baseline model,  $\chi^2(1) = 50.14$ ,  $p < .001$ , confirming that the experimental manipulation was successful (see Table 9). Again, the alignment effect occurred irrespective of group ( $\chi^2(2) = 4.97$ ,  $p = .08$ ), and did not differ in magnitude across groups ( $\chi^2(2) = 2$ ,  $p = 1$ ).



The second LME analysis (including other responses) reinforced the results of the first. The effect of the experimental manipulation was weaker but still significant when accounting for other responses,  $\chi^2(1) = 31.83, p < .001$ . Again, alignment effects differed neither across groups ( $\chi^2(2) = 2.06, p = .36$ ), nor by group in terms of magnitude ( $\chi^2(2) = 3.63, p = .16$ ).

*Table 9: Summary of fixed and random effects for model 1 (prime only; Study 2)*

Fixed effects	Estimates	SE	Wald Z	<i>p</i> value
Intercept	-4.21	.42	-9.92	<.001
Dispreferred prime	5.19	.46	11.29	<.001
Random effects		SD		
<i>Participant</i>				
Intercept		1.05		
Dispreferred prime		1.83		
<i>Item</i>				
Intercept		.09		
Chronological age-matched controls		1		
VM age-matched controls		.17		
<i>Item</i>				
Intercept		.97		
Dispreferred prime		.52		

*(vii.) Group performance on the IC task*

There were no significant between-group differences in accuracy on the day/night task, on which the chronological age-matched children performed at ceiling level. Concerning RT,

the VM age-matched group were significantly slower at naming cards than both the chronological age-matched group ( $t(26) = -3.20, p = .004$ ) and the ASD group ( $t(26) = -2.96, p = .01$ ).

*Table 10: Day/night task performance*

	ASD	Chronological age-matched	VM age- matched	ANOVA	
	Means (SD)	Means (SD)	Means (SD)	F	<i>p</i>
Accuracy	.89 (.13)	.96 (.10)	.87 (.15)	1.82	.18
RT (milliseconds) <sup>†</sup>	.67 (.31)	.65 (.16)	1.06 (.36)	6.41	.01

<sup>†</sup>Note that RT are supplied for only 9 ASD children, 10 chronological age-matched controls and 10 VM age-matched controls. The missing data are from children whose parents/carers would not give permission for us to film an experimental session; while it was possible to record accuracy in situ, we could not do the same for RT.

*(viii.) Group performance on the false belief task*

As in Study 1, there were no significant group differences on the control questions. We examined significant between-group differences on the test questions with post hoc analyses (Bonferroni adjusted  $p = .008$ ), where adjusted  $z$  scores revealed that the ASD group failed the second-order ignorance ( $z = 2.70, p = .01$ ) and the second-order false belief question ( $z = 3.10, p < .001$ ) at a higher frequency than expected. Conversely, the chronological age-matched group passed the second-order ignorance ( $z = 3.40, p < .001$ ) and the second-order false belief question ( $z = 3.60, p < .001$ ) at a higher frequency than expected.

Table 11: Frequencies for false belief task questions (Study 2)

	ASD		Chronological age-matched		VM age- matched		Chi-square	
	Pass	Fail	Pass	Fail	Pass	Fail	$\chi^2$	<i>P</i>
<i>Control</i>								
Reality	11	3	14	0	11	3	3.50	.17
First-order								
ignorance	12	2	14	0	11	3	3.18	.20
Linguistic	9	5	14	0	10	4	5.94	.05
<i>Test</i>								
Second-order								
ignorance	9	5	14	0	8	6	13.07	.001
Second-order								
false belief	10	4	14	0	8	6	15.34	<.001

*(ix.) Relationships between lexical alignment effects, IC, and false belief understanding**(a.) Lexical alignment and false belief understanding*

Since the chronological age-matched children performed at ceiling level on the false belief task, we again combined control groups to investigate the relationship between lexical alignment and false belief understanding. We conducted two two-way ANOVAs with diagnosis (ASD versus TD) and question performance (pass versus fail) as between-group factors.

Regarding the second-order ignorance question, there were no significant main effects of diagnosis ( $F(1) = .16, p = .79$ ) and false belief understanding ( $F(1) = .49, p = .49$ ) on lexical

alignment, and there was no significant interaction between these factors ( $F(1) = 1.05, p = .31$ ).

For the second-order false belief question, there were no significant main effects of diagnosis ( $F(1) = .81, p = .38$ ) or false belief understanding ( $F(1) = .01, p = .94$ ) on lexical alignment, and there was no significant interaction between these factors ( $F(1) = .60, p = .44$ ). As before, neither index of false belief understanding predicted lexical alignment effects, regardless of diagnosis.

*(b.) Lexical alignment and IC*

For each group, we correlated alignment effect scores with measures of accuracy and RT on the day/night task. Missing cases were excluded pairwise. We found no significant correlations between lexical alignment and IC measures in any group. Table 12 reports Pearson's  $r$  values.

Table 12: Correlations of lexical alignment effect scores with day/night task indices

Group	Measure	Correlations	
		1.	2.
<i>ASD</i>	1. Lexical alignment effect		
	2. Accuracy	.17	
	3. RT (milliseconds)	-.06	-.22
<i>Chronological age-matched</i>	1. Lexical alignment effect		
	2. Accuracy	.03	
	3. RT (milliseconds)	.07	.15
<i>VM age-matched</i>	1. Lexical alignment effect		
	2. Accuracy	.06	
	3. RT (milliseconds)	-.20	-.06

(c.) *Lexical alignment and false belief understanding, controlling for IC*

As in Study 1, we applied the Quade technique to our data, combining control groups to perform separate tests by diagnosis. Comparing the ASD and TD children on the second-order ignorance question ( $\chi^2(1) = 7.47, p = .01$ ) and the second-order false belief question ( $\chi^2(1) = 9.89, p = .002$ ) highlighted significant differences in performance, precluding the inclusion of a grouping variable in the analysis.

Question performance (pass versus fail) was a between-group factor, for each test question on the ToM task. The DV was alignment effect scores, covariate-adjusted for performance on day/night task (accuracy; RT). For the second-order ignorance question, we found no effects of question performance on lexical alignment, for the ASD (Quade  $F_{1,8} = .53, p = .49$ ) or the TD (Quade  $F_{1,19} = .09, p = .77$ ) children, after accounting for IC. Similarly, for the second-order false belief question, we found no effects of question

performance on lexical alignment for the ASD (Quade  $F_{1,8} = .53, p = .49$ ) or the TD (Quade  $F_{1,19} = .79, p = .39$ ) children, accounting for IC. These results, consistent with those from Study 1, suggest that IC does not modulate a relationship between ToM and children's lexical alignment.

*(x.) Relationships between lexical alignment effects, age, and language ability*

As in Study 1, there were no significant relationships between alignment effects and age in the ASD group,  $r = .32, p = .27$ , the chronological age-matched group,  $r = -.34, p = .24$ , and the VM age-matched group,  $r = -.09, p = .76$ . There were also no significant relationships between alignment effects and BPVS-3 scores (ASD  $r = .39, p = .17$ ; chronological age-matched  $r = -.26, p = .36$ ; VM age-matched  $r = .02, p = .94$ ).

## **General discussion**

The current study provides further evidence for intact alignment in ASD children, who aligned lexically with an interlocutor and to the same extent as both chronologically age-matched and VM age-matched TD controls. Moreover, in all children, the tendency to align was unrelated to both chronological age and language ability. Yet in spite of evidence that alignment can be mediated in adults (Branigan et al., 2011), the current study does not suggest that ASD and TD children align lexis for communicatively strategic reasons. We anticipated that, if children's alignment were driven by audience design mechanisms, we would uncover relationships between measures of perspective-taking ability (ToM; IC) and alignment effects. In particular, we speculated that IC supports the operation of mentalising in dialogue, and could serve as a missing link in research which had failed to relate ToM to alignment (Osborne & Allen, 2012), and to conversation skills more

generally (e.g., Hadwin et al., 1997), in ASD. We did not find evidence to support these possibilities.

Across two experiments, we found that alignment was related neither to children's mentalising abilities (i.e., ToM), nor to the skills hypothesised to support mental state attribution in dialogue (i.e., IC; Nilsen & Fecica, 2011). Thus, in line with Osborne and Allen (2012), we propose that our pattern of results is consistent with the idea of a strong, unmediated component to alignment in both ASD and TD children. As per unmediated accounts (e.g., Pickering & Garrod, 2004), the alignment we observed was likely driven by priming mechanisms, whereby a child's prior exposure to a lexical item facilitated retrieval of that item in subsequent production, either through residual activation (Pickering & Branigan, 1998) or through an error-driven learning mechanism (Chang et al., 2006). This kind of alignment is a consequence of the architecture of the language processor, and is not influenced by a speaker's beliefs about an interlocutor.

Furthermore, since the pattern of our results held across the experimental groups, we conclude that the same mechanisms contributed to lexical alignment in ASD and TD children. It was plausible to us that, among TD children (especially older TD children), there might be a relationship between perspective-taking ability and a tendency to align; we considered that such a relationship might not hold for the ASD children, owing to their deficits of social cognition. Against our expectations, however, we found that ToM and IC measures did not predict alignment effects in any group, suggesting that priming mechanisms, and not audience design mechanisms, underpinned alignment for all children in our experiments.

It is intriguing that, in our study, children's alignment appears to have been unmediated on an aspect of language that is known to be vulnerable to audience design effects (i.e., lexis; Branigan et al., 2011). By way of contrast, it has been shown that syntactic alignment effects are less susceptible to a speaker's beliefs about an interlocutor (Branigan et al., 2003;

Cowan, Branigan, & Beale, 2011; Hopkins et al., 2015); this is perhaps because a speaker can signal communicative understanding more explicitly by repeating lexical rather than syntactic choices. In any case, our findings cast some doubt over an assumption of the wider literature on conversation in ASD: that impaired ToM underpins ASD children's pragmatic language deficit, and hence their struggle with conversation (cf. e.g., Capps et al., 1998). Volden (2002), for example, observed that ASD children were more likely than TD controls to produce unusual or socially inappropriate content in a conversational context. If this tendency reflected mentalising deficits, then we might have expected to observe weaker alignment effects among children with impaired ToM and/or IC, and this was manifestly not the case.

A question remains over why lexical alignment seems to be uninfluenced by mentalising in children, when the reverse is true of adults. We propose three explanations for our findings, which need not be mutually exclusive. One explanation is that children simply do not align with reference to an interlocutor's mental state. A study by Garrod and Clark (1993) demonstrated that TD children, especially young ones, could not resist the automatic alignment process while playing a maze game; pairs of children would converge on referential descriptions, even when these descriptions proved futile in helping them to locate one another. Based on this finding, Garrod and Clark (1993) argue that it is possible for a conversation to seem superficially co-ordinated, while it lacks co-ordination on a deeper level. In their study, young children did not, or could not, adjust their utterances in a way that would have been communicatively beneficial. Older children were better able to 'diverge' (i.e., to resist the tendency to linguistically converge) when they could not understand an interlocutor's description, but this is not alignment in the way that mediated accounts construe it. Rather, such deliberate divergence is an example of what Pickering and Garrod (2004) call 'interactive repair': speakers whose alignment has been unmediated must sometimes explicitly check the conversation in relation to their own understanding,



and diverge if required. Divergence may then sustain the momentum of conversation (Healey et al., 2014).

While unmediated alignment is argued to occur independently of interlocutor modelling (Pickering & Garrod, 2004), the latter may be implicated when a more complex assessment of common ground (i.e., interactive repair) is necessary. It is possible, therefore, that children's alignment is initially driven exclusively by priming mechanisms, while audience design mechanisms mature during development. If social cognition has a role in children's alignment, it may only be in repair scenarios, and only then when children are older and communicatively sophisticated enough to manage these. It is also possible that ASD children, who have impaired social cognition, even into adulthood (Kleinman, Marciano, & Ault, 2001), never develop a mediated component to their alignment, although this is unverified by previous research (Slocombe et al., 2012). Further, ASD children might struggle to repair instances of communicative breakdown resulting from automatic alignment, as doing so would involve mental state attribution; this is an important matter for future research.

Other explanations for our unexpected findings are methodologically focused. First, it may be that, even having elaborated our measurement of perspective-taking ability, we still were unable to capture whatever aspect of this relates to audience design mechanisms in alignment. Bloom and German (2000) cite two reasons why false belief tasks may be poor measures of mentalising ability: first, that passing the tasks requires abilities other than ToM (which is Nilsen and Fecica's (2011) argument, with respect to IC); secondly, ToM need not entail false belief understanding. Moreover, Tager-Flusberg (2011) has argued that false belief tasks are especially crude measures of ToM in ASD children, whose ToM might be more deeply impaired. Hence it might be that false belief understanding bears no or only partial relation to the psychological processes involved in communicatively strategic alignment, in both ASD and TD children. It has recently been argued that further research

should specify the psychological processes involved a range of mentalising behaviours (Schaafsma et al., 2015).

Yet IC was also unrelated to lexical alignment in our study, despite its demonstrated role in communicative perspective-taking (Brown-Schmidt, 2009; Nilsen & Graham, 2009; Wardlow, 2013). This finding could reflect the unmediated nature of children's alignment, rather than our failure to capture children's perspective-taking ability in our choice of tasks. It also raises another possibility, however: that the Snap! game, unlike the tasks used in previous research into IC and communicative perspective-taking, exerted insufficient pressure on children to align in a communicatively strategic manner (i.e., involving IC and/or ToM). Note that, in the game, there were no communicative costs for children who did not adopt their interlocutor's perspective on the naming of items, and there were no communicative gains for children who did. Put simply, the alignment we observed could have been unmediated because there was no reason for it to be mediated. Thus we might have obtained a different pattern of results if, following Branigan et al. (2011), we had measured alignment effects after manipulating children's beliefs about their interlocutor. There is evidence that even very young TD children can make appropriate adjustments to their speech, when addressing an infant sibling (Dunn & Kendrick, 1982); whether similar effects could be generated in alignment is a question for future research.

Besides the methodological drawbacks already identified, our study was also limited by its small sample sizes. Our main finding, that lexical alignment effects do not differ between ASD and TD children, is reassuringly consistent with previous studies (Allen et al., 2011; Osborne & Allen, 2012; Hopkins et al., 2015). While we do not believe that the highly non-significant results presented in (iv.) and (ix.) were purely the result of inadequate sampling, larger sample sizes would nevertheless have increased the power of the study; this is especially true of Study 2, which had missing data points. Another limitation was the ceiling or near-ceiling level performance of TD children on the false belief task, and the

consequence of this for our analyses. The imperative to combine the control groups in analyses involving ToM data meant that we were unable to separate the potential contributions of age and language experience to audience design in TD children's alignment.

To summarise, we have demonstrated in this study that ASD children align lexis with an interlocutor, and to the same extent as TD controls. Moreover, we conclude that lexical alignment is unmediated in both ASD and TD children, since it is unrelated to ToM and IC. We acknowledge, however, that there are alternative explanations of our findings, and also speculate over the extent to which unmediated alignment supports effective communication in ASD children: previous research suggests that children with immature mentalising skills may struggle to resist the automatic tendency to align, and thereby encounter communicative problems (Garrod & Clark, 1993). We have recommended, therefore, that an important question for future research concerns the limits for ASD children to an automatic, priming-based account of alignment.

### Article 3: Semantic alignment in ASD children

**A version of this paper is currently under review with *Cognition*.**

Speakers imitate one another's language choices in conversation, a tendency called alignment. The IA account (Pickering & Garrod, 2004) proposes that interlocutors develop mutual understanding of a situation under discussion, not mediated through mental state modelling, but through directly priming each other at different levels of representation. This study considers how far unmediated alignment promotes mutual understanding in the conversations of ASD children, who have significant communication impairments. We found that ASD children show intact alignment at low levels of language (syntax; lexis), and to the same extent as TD children. However, this did not lead automatically to alignment at higher levels (semantics), as the IA account proposes. ASD children experienced more semantic *misalignment* than did TD children, evidenced by their difficulties in repairing communicative breakdown. This is a novel finding, which we attribute to ASD children's poorer social cognitive abilities. We discuss our results in relation to the conversational difficulties experienced by ASD children.

In conversation, interlocutors converge in their use of language. For example, having heard an interlocutor refer to a ‘bicycle’, a speaker might adopt that term, rather than alternatives (e.g., bike), to subsequently refer to the same object. Such linguistic convergence is termed *alignment* in the literature, and this occurs at many different levels of language. Alignment also seems to play a role in increasing the effectiveness of communication, and is associated with more rewarding interactions (e.g., Fusaroli et al., 2012; Reitter & Moore, 2014)

There are differing accounts of why alignment occurs, however. On the one hand, *mediated* accounts view alignment as a product of social-psychological factors. One proposal is that speakers repeat the expressions of an interlocutor in a communicatively strategic manner (cf. e.g., Branigan et al., 2011): they reuse expressions having reasoned that this is language that the interlocutor understands and prefers, and so engage in audience design. Another view is that speakers align with an interlocutor to express affiliation or establish rapport; alignment can therefore be influenced by social-affective goals (van Baaren et al., 2003).

*Unmediated* accounts, on the other hand, explain alignment in terms of simple priming mechanisms, which are not influenced by a speaker’s beliefs about an interlocutor (hence *unmediated*). The present study focuses on one unmediated account in particular: the IA account (Pickering & Garrod, 2004). The IA account claims that alignment arises because prior processing of language (i.e., by listening to an interlocutor) facilitates future retrieval of the same or related items, either owing to residual activation (Pickering & Branigan, 1998) or through an error-driven learning mechanism (Chang et al., 2006). Alignment, according to the IA account, is a product of the architecture of the language processor.

Another important claim of the IA account is that alignment promotes mutual understanding in conversation, without the need for speakers to model and dynamically update aspects of an interlocutor’s mental state. This is possible for two reasons: first, all

linguistic representations are linked to a situation model (Zwaan & Radvansky, 1998), which is a multi-dimensional representation of a discussed subject (containing information about time, space, causality, intentionality, and contributing individuals). Secondly, there is a percolatory effect to alignment: priming at one level (e.g., syntax) promotes priming at another level (e.g., lexis), meaning that alignment at one level leads to alignment at another level of representation (Pickering & Ferreira, 2008). Ultimately, the percolation process promotes alignment of situation models, meaning that interlocutors can develop a shared perspective from the cumulative effects of priming.

While the IA account is robustly supported by studies of typical adult dialogue (cf., Pickering & Garrod, 2004), there is uncertainty over whether and how far it explains the conversational behaviour of children with ASD, a neurodevelopmental disorder affecting between .01 and 1.57% of the population (Zaroff & Uhm, 2012). ASD is characterised by social and communication difficulties, and ASD children display pronounced pragmatic deficits in conversation (Volden, 2002). For example, they struggle to adapt their communicative discourse for a listener's informational needs (Capps et al., 1998; Loveland & Tunali, 1991; Loveland et al., 1989), by extension indicating a failure in alignment on situation models. This suggests that, while unmediated alignment mechanisms seem to be intact in ASD (Allen et al., 2011; Hopkins et al., 2015; Slocombe et al., 2012), the percolation process is in some respect disturbed.

One reason why this might be the case is that, as the IA account recognises, linguistic convergence can lead to misaligned semantic representations. Two interlocutors might both refer to 'John', for instance, and yet each have a different person in mind. What this highlights is that, sometimes, it is necessary to 'diverge' linguistically in conversation (i.e., to resist the tendency to converge on language), in order to realign at the conceptual level (Healey et al., 2014). According to the IA account, linguistic divergence is supported by interlocutors' engaging in *interactive repair*, which can be done in two ways.

One strategy for repair is to reformulate an utterance, if a listener is unable to interpret new input in relation to her own situation model. For example, confused about which 'John' is being referred to, a speaker might subsequently refer to 'John Smith?' (with rising intonation), to ascertain who she believes to be under discussion. Such reformulation, alternatively referred to as a 'clarificatory request' (Ginzburg, 2001), involves the use of implicit common ground (i.e., information shared between interlocutors in the course of conversation): it requires interlocutors to check a conversation in relation to their own knowledge of the situation under discussion, and if necessary, to revise an utterance in a way that leads to the re-establishment of implicit common ground. This can be an iterative process, with both interlocutors engaging in further reformulation until they are conceptually realigned.

A second, more complicated repair strategy may be necessary if the basic interactive repair mechanism fails. Occasionally, interlocutors may have to repair using full common ground (i.e., background knowledge shared between interlocutors; Clark & Wilkes-Gibbs, 1986), either by drawing inferences about the mental state of the other person, or by verbally clarifying the extent of mutual understanding. To use the previous example, the confused speaker might think to herself 'I wonder whether he means John Smith or John Jones? He doesn't know I know John Jones, so he probably means John Smith', or openly ask the question ('When you say John, do you mean John Smith or John Jones?'). Checking full common ground likely relies on social cognition, specifically theory of mind, or mentalising skills (Pickering & Garrod, 2004). In acute cases of communicative breakdown, speakers must form a representation of their interlocutor's situation model, and check its consistency with their own.

Garrod and Clark's (1993) study of alignment in TD children highlights the challenge of both recognising and repairing semantic misalignment, for interlocutors whose language ability and mentalising skills are less mature. In this study, pairs of children aged 7-12 years

played a collaborative maze game where they had to negotiate their way around a series of mazes. Garrod and Clark (1993) found that, although the youngest (7-8 years) children converged on referring expressions and descriptive schemes to the same extent as their older peers, they were less sensitive to the mutual intelligibility of their discussions, and were less able to realign representations in instances of communicative breakdown. In part, younger children experienced communicative difficulties because they could not resist aligning with an interlocutor; they were less able to diverge when it became necessary, in order to re-establish mutual understanding. This finding is consistent with studies of communicative development (e.g., Mitchell et al., 1999), which indicate that, below the age of 6 or 7 years, children are overly satisfied with their first interpretation of an utterance, without considering additional factors (e.g., speaker beliefs). This is despite the fact that, by 4 years, most TD children evidence basic ToM understanding (Gopnik & Astington, 1988).

The findings of the Garrod and Clark (1993) study inspired the current investigation, which takes as its starting point the possibility that conversation can be superficially well coordinated, while lacking deeper level co-ordination between interlocutors. This is an intriguing matter for research into alignment in ASD, which has consistently demonstrated that ASD children (Allen et al., 2011; Osborne & Allen, 2012; Hopkins et al., 2015) and adults (Slocombe et al., 2012) align on several different aspects of language to the same extent as typical controls. As noted, however, the wider literature on conversation in ASD identifies substantial problems with conversation for this population, begging the question: if alignment promotes better communication, and ASD individuals do not display atypical alignment, why do they experience such difficulties in conversing with an interlocutor?

These difficulties could be partly explained by the possibility that ASD children experience semantic misalignment in conversation (Allen et al., 2011), an idea supported by previous research into communicative repair in ASD children. Baltaxe (1977), for example, reported that ASD adolescents fail to revise conversational utterances when faced with



communicative breakdown. Geller (1998) observed that ASD children tend not to resolve communicative breakdowns successfully, even when they recognise the need for repair. An investigation by Volden (2004), which included non-ASD controls matched for language age, produced similar findings to Geller's (1998); ASD children were as likely as TD children to recognise the need to engage in conversational repair, but were significantly more likely to repair using an inappropriate response. Across these studies, ASD children's difficulties with repair reflected deficits in the linguistic and social cognitive domains. As a result, the studies also hint that inadequate repair could disrupt the alignment process for ASD children.

First, while structural linguistic skills (e.g., grammar; phonology) are unimpaired for some (verbal) ASD children, semantic language impairments are pervasive across the autism spectrum (Tager-Flusberg, 2006). Such impairments may be mild for children with Asperger's Syndrome (AS; a high-functioning subtype of ASD), who have difficulties understanding and using non-literal and allusive language (Happé, in Bock, 1996). ASD children with less well developed language skills, however, may have greater difficulties with expressing meaning, and may fail to use language flexibly (e.g., deictic words, forms, and expressions; Bartolucci & Albers, 1974). These findings are relevant to the interactive repair process because, if ASD children are semantically inflexible, then reformulating utterances (i.e., repair strategy 1) may prove a difficult task. More obviously, semantic impairments might also make ASD children likely to generate utterances that are unintelligible to their listener, leading to misalignment in the first place.

Another reason why repair might be difficult for ASD children is that they commonly have poor social cognitive skills. The theory of mind (ToM) hypothesis of ASD (Baron-Cohen et al., 1985) links ASD children's social and communication deficits to their difficulties with mental state attribution. ToM-impaired ASD children may not appreciate that others have beliefs, desires, and intentions which are different from their own, and this

has been viewed as the source of their pragmatic deficits (cf. e.g., Happé, 1993). For example, ASD children struggle to infer a speaker's meaning in a conversational context (Mitchell et al., 1997; Surian et al., 1996). In terms of alignment, ASD children's poorer mentalising skills could frustrate interactive repair, where this depends on full common ground inference (i.e., repair strategy 2).

We take up this matter in the present study, which considers whether and how far unmediated alignment supports effective communication in ASD children. More specifically, to what extent does superficial co-ordination promote deeper level understanding in ASD children, compared with their TD peers? We examine this question by adopting the methodology of Garrod and Clark's (1993) study. ASD and TD children played a maze game with a TD peer, and we measured syntactic and lexical alignment in their conversations about the mazes. We also examined children's descriptive schemes, to better understand how they conceptualised the mazes. Lastly, we coded interactional information about the children's conversations, in order to assess children's inter-speaker co-ordination while playing the game. Our main prediction was that, in line with previous research, ASD-TD pairs of children would align syntax and lexis on the maze game to the same extent as both groups of TD only pairs. We anticipated, however, that the ASD-TD pairs would be less successful at re-aligning semantic representations when necessary, indicating a lack of deeper level co-ordination in conversation.

## **Method**

### *Participants*

15 children (13 male) diagnosed with ASD (mean chronological age: 10 years, range 7 – 13 years) participated, all of who attended a specialist ASD unit within mainstream schools in Sussex and Dorset, UK. The children's inclusion within a mainstream setting meant that

they were higher-functioning (i.e., had higher verbal and nonverbal IQ). The children had been previously diagnosed by a paediatrician, psychiatrist, or clinical psychologist, and we corroborated diagnoses using the Social Communication Questionnaire (SCQ; Rutter et al., 2003). The SCQ is a widely used ASD screening measure, on which parents report any social and communication difficulties experienced by their child. 13 out of 15 SCQs were completed by parents/carers: 11 children obtained an SCQ score at or above the recommended cut-off (15; Wiggins et al., 2007; mean SCQ score = 22,  $SD = 3.92$ ; range 16-32); SCQs returned by 2 children were incomplete.

We measured children's language ability using the BPVS-3 (Dunn et al., 2009), a standardised test of receptive vocabulary. We used children's raw BPVS-3 scores to estimate their verbal mental (VM) age, by which we matched them to a group of TD controls. We also matched ASD children to a second group of TD controls, on the basis of chronological age. Groups were matched pair-wise, such that each ASD child was individually paired with one TD child of the same chronological age and another TD child of the same VM age (see Table 1). Additional TD children (from whom we collected no demographic data) were also recruited as partners for ASD children and TD controls (hereafter, 'focal children') on the maze game. Each of these children ( $N = 45$ ) were selected by their teachers on the basis of their having a good peer relationship with a given focal child.

*Table 1: Participant characteristics*

<b>Group</b>	<b>N =</b>	<b>Chronological age</b>	<b>VM age (determined by BPVS-3)</b>
ASD	15	Mean = 10 years Range = 7-13 years	Mean = 10.1 years Range = 8.5-13.2 years
Chronological age-matched controls	15	Mean = 9.9 years Range = 7.2–13.5 years	Mean = 10.6 years Range = 7.4-13.8 years
VM age-matched controls	15	Mean = 9 years Range = 7.5-11.4 years	Mean = 10 years Range = 7.9 – 12.6 years

*Materials*

Besides the BPVS-3, we administered to focal children a test of their semantic understanding. Both children in the pair were also assessed for left-right awareness, before playing the maze game. Details of these tasks are supplied below.

*(i.) Test of semantic understanding.*

As stated above, ASD children have semantic impairments, and these seem to relate to their production and comprehension in dialogue (Boucher, 2003). Hence we obtained a measure of semantic ability from our sample, using an age-appropriate subtest of the Test of Language Competence (TLC; Wiig & Secord, 1985). The ‘Ambiguous Sentences’ subtest assesses a child’s ability to identify and interpret alternative meanings of syntactic and lexical ambiguities. Both the Level 1 (ages 5-9 years) and Level 2 (ages 10-18 years) versions of the subtest begin with a sentence read aloud to the child (e.g., ‘I saw the girl take his picture’). In the Level 1 version, the child then sees an array of four illustrations which relate to the sentence; in the Level 2 version, the child sees the sentence in written form. The child is asked to provide two possible meanings for the sentence (e.g., ‘take a picture

of him’/’take a picture from him’), and to match these to the appropriate illustrations (Level 1 only).

*(ii.) Left-right awareness.*

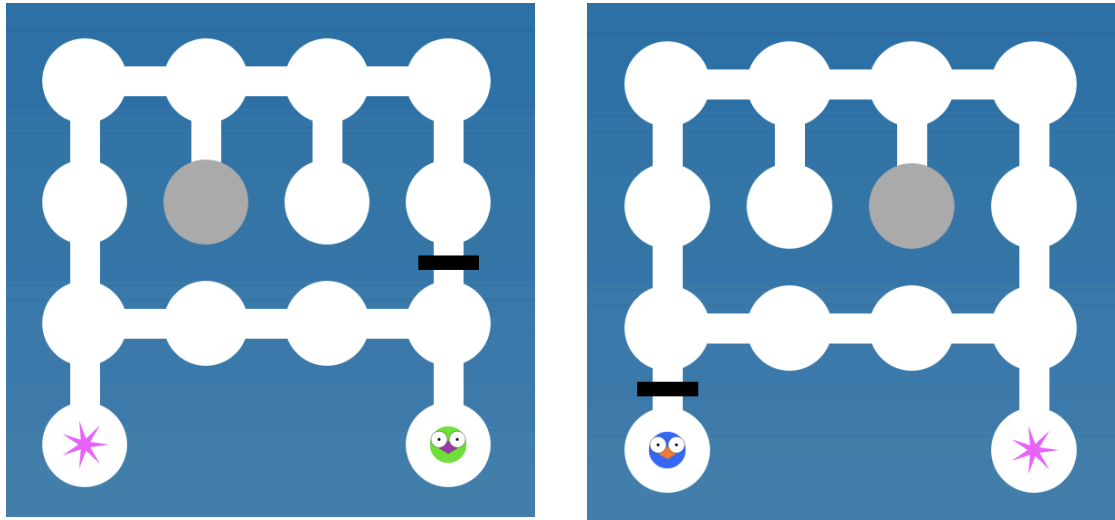
We assessed left-right awareness in all children, to control for the possibility that communication breakdowns in the maze game related to children’s inability to tell left from right. This was particularly important for the ASD group, given the finding that ~75% of verbal ASD children have problems with left-right awareness (Wing, 1971). To check left-right awareness, we presented children with one of two laminated white cards depicting a black cross (in the centre), flanked on both sides by an image of a common animal (card 1: duck × cow; card 2: rabbit × horse). Children were asked to identify which animal was to either the left or the right of the cross. We corrected children who were left-right confused on the first trial (number of left-right confused children: ASD = 2/15; chronological age-matched = 1/15; VM age-matched = 3/15; non-focal children = 4/45), and then re-tested them on a second trial. All children evidenced left-right awareness following correction and re-test.

*(iii.) Maze game.*

The maze game used in the Garrod and Clark (1993) study is a referential communication task, designed by Garrod and Anderson (1987). While Garrod and Anderson’s (1987) maze game is played on computers, we commissioned an adapted version of the game, to be played on WiFi networked iPads (Kreitmayer, 2014); this was because children’s computing experience is increasingly geared towards touch-screen technology, and because iPads are helpfully portable. Children playing the game each have their own iPad, on which a maze is displayed (see Figure 1). The mazes consist of a series of nodes connected by paths, through which each player must move a cartoon avatar (a bird) from a start position to a

pre-determined end position (different for both children). When both players reach their end position, a tweeting sound is heard and the avatars flap their wings.

*Figure 1: Maze screenshots from both iPad screens*



The collaborative nature of the game derives from the fact that the children are only able to see their own iPad screen, as they are separated by a wooden barrier; most children were familiar with the game set-up from playing networked computer programmes like *Minecraft*. The barrier prompts collaboration for two related reasons. First, the mazes contain gates (black lines, Figure 1), which block each child's movement along certain paths. Secondly, any obstructing gates can be removed for a child by their partner, if the partner can be directed to the location(s) of the child's switch node(s) (grey circles, Figure 1) on the partner's own maze. When a child reaches the location of a partner's switch node, a clicking sound effect is produced by the application, and the configuration of mazes on both iPads is instantly inverted (i.e., all gated nodes become ungated, and all ungated nodes become gated).

Conversations between children arose from the necessity of discussing the obstacles in their mazes, in order that they could remove these, and navigate to their end positions. The

dialogues typically contained exchanges in which children detailed where their avatars were within the maze, where their switch nodes were, and where their start and end positions were located.

Children were presented with three experimental mazes, increasing in size and complexity. We imposed a playing time limit of 10 minutes per maze (recorded using a sand-timer that both children could see); this was to ensure that roughly the same amount of dialogue was generated between pairs in the different groups. Prior to playing the experimental mazes, children were given a simple trial maze to practice with, once the experimenter had explained the object of the game and the gate/switch mechanism. We allowed children to complete the trial maze without a barrier between them, to ensure that they fully understood how activity within their own maze affected activity within their partner's maze. A dictaphone, placed between the children, was used to capture their spoken output while playing the maze game.

### *Procedure*

All experimental sessions lasted for approximately 1 hour. For the first 30 minutes, focal children were seen individually by the experimenter, who presented the standardised tests in a fixed order (BPVS-3 -> TLC). The focal child's game partner was invited to join the session for the remaining 30 minutes. Once the children had been separately assessed for left hand/right hand understanding, the maze game was explained to the children, who then played the practice maze. Once the practice maze was completed, and both children stated that they understood the game and how to operate the iPads, they proceeded to play the three experimental mazes.

### *Data processing and coding*

After transcribing the maze game conversations, we processed the data in three ways, enabling us to (i.) measure syntactic and lexical alignment, and to code for (ii.) semantic and (iii.) interactional co-ordination in pairs of conversation exchanges (i.e., pairs of turns).

#### *(i.) Syntactic and lexical alignment.*

We measured alignment in our conversation transcripts using a NLP application (Magonde & Keller, 2014), described fully in Hopkins et al., (2015). In outline, this application performs part-of-speech (POS) tagging on transcripts, before dividing the POS-tagged text into bigrams. The application then applies a cosine similarity metric to the bigrams, to calculate both syntactic and lexical alignment scores for each conversation exchange. Alignment scores represent the mean proportion of either syntax or lexis produced by a playing partner (i.e., the non-focal child) and reproduced immediately by a focal child across conversation exchanges. For each pair of children, the application generates a mean alignment score for all exchanges in a conversation.

A small number of exchanges were excluded from processing by the application. Some of these involved experimenter interjections, which were occasionally necessary to encourage children to persevere with the game, or to keep on task. The application also excluded exchanges where children petitioned the experimenter, rather than their partner, for help while playing the game. Because there was extended three-way dialogue between each maze trial, we treated the trials as discrete entities and generated mean alignment scores for each one; treating data from the three trials as if they were a single discussion would have given a false impression of continuity in the experimental session. An advantage of our approach is that we were able to roughly model how children's alignment evolves over an extended stretch of discourse; recent work suggests that lexical but not



syntactic alignment between typical adult interlocutors increases over time (Foltz et al., 2013).

Using alignment scores, we also sought to demonstrate that alignment occurred above chance level in the maze game conversations. To achieve this, we adopted the methodology of Healey et al. (2014), which is applied to the study of alignment in corpus data, an approach pioneered by Gries (2005). Healey et al. (2014) advocate comparing alignment scores calculated from real dialogue against alignment scores calculated from ‘fake’, control dialogue; this establishes a baseline for how linguistically similar turns are by chance, and therefore whether a conversation actually evidences alignment. We created control dialogues from the transcriptions of real maze game conversations: first, we separated the conversation turns of each focal child from those of the paired, non-focal child; we then interleaved the focal child’s turns with the turns of a non-focal child from another pair, and calculated an alignment score for this fake conversation. Fake alignment scores were calculated for each group and each maze trial, and are incorporated into our analyses (see below).

*(ii.) Semantic information.*

As well as looking at lexical alignment, we were interested in the words children used to describe their mazes and their location within them. The Garrod and Anderson (1987) and Garrod and Clark (1993) studies showed that typical speakers work together to establish description schemes in the course of conversation. These schemes represent speakers’ conceptions of the maze configurations. We adopted the same description coding system used by Garrod and Clark (1993), itself adopted from Garrod and Anderson (1987). The coding system categorises location descriptions according to four schemes: line, path, figural, or matrix. In our transcripts, however, we identified no matrix type descriptions, and so discarded the matrix category from coding. The main characteristic of matrix

descriptions is that locations are identified as intersections between two orthogonal lines, in the manner of co-ordinates. Garrod and Clark (1993) have suggested that, in their study, matrix descriptions were more commonly used by older children familiar with the principles of co-ordinate geometry; we surmise that, in our own study, children's avoidance of matrix descriptions might also reflect the decline in popularity of children's games (e.g., *Battleship*) which employ coordinate systems. Drawing on Garrod and Clark's (1993) study, we define the other description schemes below, and include an illustrative example for each one from our data.

*(a.) Line type descriptions.*

In line descriptions, children identified a line of maze nodes (horizontal or vertical) and then specified the location of a particular node along this line. For example:

Child 2: Now you've trapped me again.

Child 1: Where are you trapped at?

Child 2: Two, three, four. *Fifth row three down.*

Child 1: Ah, I see. Oh. That help you?

Child 2: Er, yeah. (TD only pair)

*(b.) Path type descriptions.*

Children who used path descriptions identified a location on the maze, and then described a path through specific maze nodes which ended up in that location. For example:

Child 1: Um, right, where's your next grey circle?

Child 2: Er, you see the one that's, um, it's, it's really hard because you won't be able to see it.

You see the top left-hand corner?

Child 1: Yep.

Child 2: Er, *go down, it's the one below that and the one on the right to that.* (TD only pair)

Path type descriptions were most frequently observed in the transcripts.

*(c.) Figural type descriptions.*

In figural descriptions, children identified their location relative to a series of nodes in which they could see a particular pattern. For example:

Child 1: And you see those three things going down?

Child 2: What three things going down?

Child 1: You know, it's hard to explain. Erm, you need to get to the, you know, *it's sort of like a 'G'?* (ASD-TD pair)

A proportion of location descriptions did not correspond to any of the four basic schemes, and these were not included in our analyses. Unclassifiable descriptions were more common among ASD-TD pairs (30.26%) and among TD only pairs in the VM age-matched (28.8%) group, compared with TD only pairs in the chronological age-matched (9.61%) group. This may reflect the chronological age-matched children's combined advantage of age and language ability, affording them greater communicative competence.

Unclassifiable location descriptions lacked the linguistic detail needed for classification according to our coding scheme. There were different reasons for this. Some children aborted their descriptions mid-production, as was the case here:

Child 2: My grey circle is where you're starting, where are you starting?

Child 1: I'm starting – oh. I kind of like accidentally clicked on the pink star, and now I'm blocked from anything. And -

Child 2: You, so, how many squares?

Child 1: It's -

Child 2: Have I, have I unlocked you?

Child 1: Um, no. (TD only pair)

ASD children were particularly prone to producing vague or incomplete descriptions, often compounded by problems with deixis, as in this example:

Child 1: Okay, Shaun, quick, open my gate.

Child 2: Where is it?

Child 1: Well, my starting place was right there and the gate's down there, quick.

Remember starting place was there up corner. (ASD-TD pair)

To verify coding by the first author, a research assistant blind-coded a reliability sample of 5 transcripts (~10% of all data) for semantic information; inter-rater agreement was .89, surpassing the lower limit (.81) for an almost perfect level of agreement (Landis and Koch, 1977).

*(iii.) Interactional co-ordination.*

There were two stages to coding interactional co-ordination in our transcripts, again following protocol from the Garrod and Clark (1993) study. First, we tagged all exchanges in which a child explicitly queried some aspect of their partner's previous location description (thereby signalling communicative breakdown). Then, we checked the next turn and determined whether the partner had successfully or unsuccessfully responded to that

query, based on the content and tone of the exchange. The pattern of a successful query exchange was that, following a query, there was a cycle of proposal and optional repair, ending in some indication that the children had mutually accepted the location description (as per Clark & Wilkes-Gibbs, 1986). For example:

Child 2: Okay, there's nowhere I can go but I've only got one spot I can go to.

Child 1: Okay, where's your grey dot?

Child 2: My grey dot is, go one place. Do we start in the same space? No we wouldn't. So you know the top left-hand corner?

Child 1: Yeah.

Child 2: I'm there, so if you go one to the right?

Child 1: Yeah.

Child 2: One down?

Child 1: Yeah.

Child 2: From there, from where I am, and then one to the left, that's my grey dot.

Child 1: Okay. (TD only pair)

The cycle of proposal and repair was not evident in query exchanges that we coded as unsuccessful. These exchanges terminated before there was any indication that a location description had been mutually accepted, or with an unambiguous indication that an interlocutor did not understand the description. In the example below, Child 2 makes it clear that Child 1 has not said enough to clear up his confusion:

Child 1: I'm near my star as possible.

Child 2: You're, so you're right underneath it?

Child 1: No, I'm, I'm below it.

Child 2: You're in a dead-end?

Child 1: No.

Child 2: You're in a dead- *Okay, never mind.* Can you, I need a grey circle, okay, I need you to go on a grey circle. (TD only pair)

Occasionally, in the ASD-TD pairs, the ASD child would not address the description query at all, as in this example:

Child 1: It's on the grey one. It's, it's, its, it's number four.

Child 2: Two, three. Oh, I can't get in number four. What does he mean by number four? What do you mean by number four?

Child 1: Just go three ahead and back to the grey circle.

Child 2: Okay, can you but -

Child 1: I'm trapped, I was going to say I'm trapped. (ASD-TD pair)

Coding the query exchanges in this way offered a measure of the overall communicative success of the children's interaction. This measure was preferable to alternatives (e.g., whether or not children completed each maze trial; time taken by children to complete each trial) because we imposed time limits on playing the game, meaning that not all pairs completed all maze trials in the experimental session. As before, a proportion of descriptions could not be classified as either successful or unsuccessful, according to our criteria, and these were excluded from our analyses.

Unclassifiable descriptions were again more common among ASD-TD pairs (19.6%) and TD only pairs in the VM age-matched group (20.69%), compared with TD only pairs in the chronological age-matched (15.69%) group. Coding of interactional co-ordination was again verified by a research assistant, who blind-coded a reliability sample of 5

transcripts; inter-rater agreement was .91, indicating an almost perfect level of agreement (Landis & Koch, 1977).

## Results

### *(i.) Syntactic and lexical alignment.*

#### *(a.) Alignment effects*

We ran a series of mixed ANOVAs on alignment scores generated by the NLP application (Table 2). We considered syntactic and lexical alignment scores separately, and on a trial-by-trial basis. Alignment (syntactic or lexical) was the dependent variable, with group (ASD versus chronological age-matched versus VM age-matched) as a between-participants factor and maze trial (1 versus 2 versus 3) and conversation type (control versus real) within-participants factors. We also computed interaction terms for these variables.

*Table 2: Mean syntactic and lexical alignment effect scores, by group and by maze trial*

Group	Alignment effect	Maze trial <sup>a</sup>		
		1.	2.	3.
		<i>M</i>	<i>M</i>	<i>M</i>
<i>ASD</i>	<i>Syntactic</i>	.09	.08	.09
	<i>Lexical</i>	.03	.03	.03
<i>Chronological age-matched controls</i>	<i>Syntactic</i>	.10	.09	.10
	<i>Lexical</i>	.03	.03	.03
<i>VM age-matched controls</i>	<i>Syntactic</i>	.10	.11	.09
	<i>Lexical</i>	.02	.03	.03

<sup>a</sup> Estimated marginal means, adjusted for chance level repetition in control dialogues.

With respect to syntactic alignment, we identified no main effect of group overall,  $F(2,42) = 1.26, p = .29$ , and group did not interact significantly either with trial,  $F(4,84) = .64, p = .64$ , or with conversation type,  $F(2,42) = .15, p = .86$ . The effect of trial was also non-significant,  $F(2,41) = .16, p = .86$ . We found a significant effect of conversation type overall,  $F(1,42) = 9.47, p = .004$ , and while this did not interact significantly with the effect of trial,  $F(2,41) = .27, p = .77$ , post hoc Bonferroni  $t$ -tests revealed that there was significantly more syntactic alignment in the real than in the control conversations only for maze games 2,  $t(44) = 2.20, p = .03$ , and 3,  $t(44) = 3.21, p = .003$ , and not for maze game 1,  $t(44) = 1.50, p = .14$ . A three-way interaction between group, conversation type, and trial was non-significant,  $F(4,84) = .16, p = .96$ .

The analysis of lexical alignment scores was consistent with that of syntactic alignment scores. There was no main effect of group on lexical alignment overall,  $F(2,42) = .19, p = .83$ , and the effect of group did not interact significantly with either trial,  $F(4,84) = .29, p = .89$ , or with conversation type,  $F(2,42) = 1.42, p = .25$ . The effect of trial was also non-significant,  $F(2,41) = .46, p = .64$ . We identified a significant effect of conversation type overall,  $F(1,42) = 16.28, p < .001$ , which did not interact significantly with trial,  $F(2,41) = .38, p = .69$ . Yet as before, post hoc Bonferroni  $t$ -tests revealed significantly more lexical alignment in the real than in the control conversations in maze games 2,  $t(44) = 2.71, p = .01$ , and 3,  $t(44) = 5.87, p < .001$ , but not maze game 1,  $t(44) = 1.53, p = .13$ . Again, a three-way interaction between group, conversation type, and trial was non-significant,  $F(4,84) = .74, p = .57$ .

The results of these analyses highlight two important findings. First, and consistent with past research (Allen et al., 2011; Hopkins et al., 2015), the ANOVAs show that ASD children aligned with an interlocutor, and to the same extent as both chronological and VM age-matched controls, across the maze game trials; this is shown by the absence of a



significant main effect of group, and by the absence of any significant interactions of group with trial and conversation type, for both syntactic and lexical alignment.

Secondly, the post hoc tests suggest that children's alignment evolved over the course of the game, irrespective of group. In maze trial 1, there was evidence of linguistic convergence in children's conversations; however, post hoc tests showed that both syntactic and lexical convergence was not more heightened than we would expect by chance at this stage in the game. Put simply, there was language repetition, but not alignment proper, in children's discussions of maze trial 1.

Yet significant post hoc tests on the effect of conversation type for maze trials 2 and 3 indicate that, after children had completed trial 1, they engaged in significantly more language repetition than would be expected by chance. Note that, as Table 2 shows, it was not the case that language repetition increased absolutely for the groups over time; language repetition increased relative to baseline levels across the three trials. Where language repetition was significantly above baseline level, this implicates external mechanisms (e.g., priming) and suggests that alignment occurred. These findings are novel in demonstrating a time shift effect in the alignment of TD and ASD children, and are broadly in line with previous research concerning the time course of alignment (Foltz et al., 2013).

*(b.) Correlations between syntactic, lexical, and semantic alignment scores*

There were significant correlations between syntactic and lexical alignment in all maze game trials: trial 1  $r = .74$ ,  $N = 45$ ,  $p < .001$ ; trial 2  $r = .35$ ,  $N = 45$ ,  $p = .02$ ; trial 3  $r = .76$ ,  $N =$ ,  $p < .001$ . Such close correlations reflect the interdependence of syntax and lexis, and demonstrate that alignment at one level of language is related to alignment at another level of language, as proposed by the IA account. We found no significant correlations between measures of syntactic/lexical and semantic alignment, however (all  $ps > .05$ ). This may be

because, contrary to Pickering and Garrod’s (2004) claim, lower level (syntactic; lexical) alignment doesn’t relate to higher level (semantic) alignment in conversation. It is also plausible that, if a relationship exists between lower and higher level alignment, this is less stable among less experienced communicators; as highlighted in the General Discussion, some children erroneously trust that superficial co-ordination signals deeper, conceptual co-ordination with an interlocutor.

*(ii.) Semantic information.*

The mean number of location descriptions produced by each group across the three maze trials are displayed in Table 3. Note that these values are substantially lower than those reported in Garrod and Clark’s (1993) study. We examine why this might be the case in our discussion, while considering here the distribution of descriptions by group and by trial.

*Table 3: Number of location descriptions observed in maze trial dialogues*

<b>Group</b>	<i>M</i>	<i>SD</i>
ASD	3.07	2.19
Chronological age-matched controls	3.33	3.79
VM age-matched controls	1.93	1.98

*(a.) Distribution of location description schemes by group.*

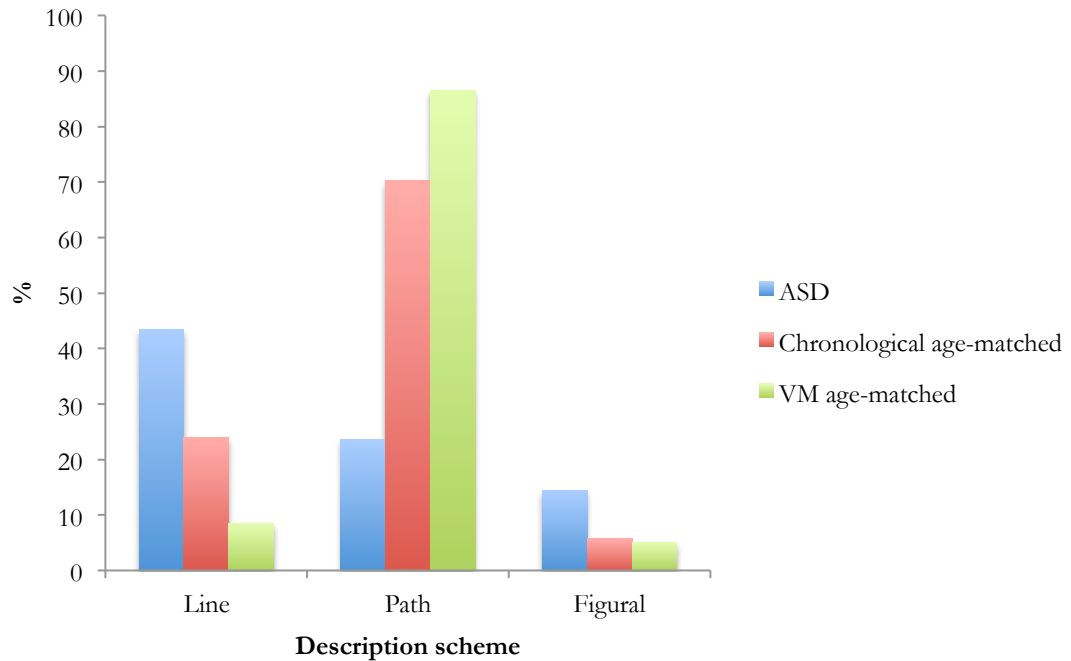
We conducted an ANOVA with group (ASD versus chronological age-matched versus VM age-matched) as a between-participants factor, and number of location descriptions as the dependent variable. This indicated that the ASD-TD pairs and both groups of TD only pairs did not differ significantly from each other in the total number of descriptions they produced,  $F(2, 42) = 1.08, p = .35$ .

Yet we also found that, while all groups used line, path, and figural descriptions, there were significant group differences in the distribution of descriptive schemes,  $\chi^2(4) = 31.21$ ,  $p < .001$  (see Figure 2). Specifically, the ASD-TD pairs used proportionally more line type descriptions, and proportionally fewer path type descriptions, than both groups of TD only pairs. ASD-TD pairs also produced proportionally more figural type descriptions than control pairs. It is difficult to conclude, however, that these differences depend on the ASD children, because we coded the descriptions of both the ASD and TD child in the ASD-TD pairs.

Thus we re-ran this analysis, including only the descriptions produced by the focal child in the pair, in order to isolate the effect of ASD on the distribution of description schemes. We found that, when examining only the location descriptions of focal children, the pattern of results held,  $\chi^2(4) = 11.76$ ,  $p = .02$ . Focal ASD children used proportionally more line and figural descriptions, and proportionally fewer path descriptions, than focal TD children, supporting the idea that there was something qualitatively different about the way ASD-TD pairs conceptualised the mazes. We find support in Garrod and Clark's (1993) study for this pattern of results.

ASD children's heightened tendency to use figural type descriptions might seem counterintuitive, given they are known to struggle with figurative language (e.g., Happé, 1993). Yet in Garrod and Clark's (1993) study, figural type descriptions were preferred by the youngest pairs of TD children, suggesting that these are a function of reduced communicative competence, and by extension of less mature social cognition. It is plausible that, in the current study and in Garrod and Clark's (1993), a relationship exists between children's use of figurative descriptions and their social cognitive ability. In a conversational context, figurative descriptions are effective only if they are intelligible to an interlocutor; it may be that less able communicators are more likely to produce such descriptions, because they are less constrained by pragmatic concerns.

Figure 2: Histogram showing by-group percentage use of location description schemes across maze games



It is a challenge to extend this logic to the distribution of line and path descriptions in our groups, however. Like Garrod and Clark (1993), we found that our older TD children (i.e., chronological age-matches) were more likely to produce line descriptions, and less likely to produce path descriptions, compared with the younger TD children (i.e., VM age-matches) in our study. This suggests that the tendency (or not) to produce line and path descriptions may be another function of communicative competence. Yet if so, it is surprising that ASD children were more likely to use line descriptions, and less likely to use path descriptions, compared with chronological age-matched controls in our study; as we shall see, the chronologically age-matched children were the most communicatively capable. We defer the matter of ASD children's use of location descriptions to future exploration and replication.

*(b.) Distribution of location description schemes by trial.*

Across the maze game trials, there were significant differences in the overall distribution of location descriptions,  $\chi^2(4) = 21.94$ ,  $p < .001$ , particularly where line and path type descriptions are concerned (see Figure 3). In all trials, path-type descriptions were the most commonly observed, although these were used with decreasing frequency as the experimental session progressed. Conversely, line type descriptions were used with increasing frequency over the course of the experimental session. These trends are consistent with the findings of Garrod and Anderson's (1987) study, which showed that typical adult speakers tended to adopt more abstract schemes (line and matrix) as the maze game proceeded.

*Figure 3: Histogram showing by-trial percentage use of location description schemes*

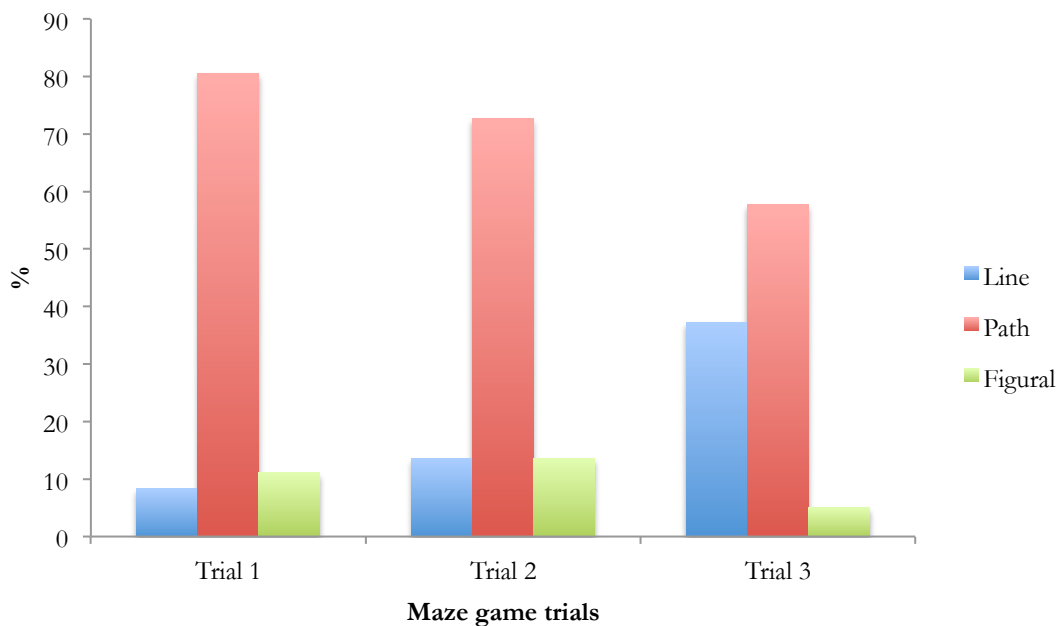


Figure 3 also illustrates how divergence as well as convergence of representations occurred across the maze game trials, with children increasingly adopting line descriptions at the expense of path descriptions as the game progressed. We now turn to consider divergence

at the conceptual level in the game, and how children managed to negotiate instances of this.

(c.) *Interactional co-ordination.*

The mean frequencies of clearly successful versus unsuccessful query exchanges observed in each group and across the maze game trials are presented in Table 4. We submitted these data to a mixed ANOVA, with group (ASD versus chronological age-matched versus VM age-matched) as a between-participants factor, and query exchange outcome (successful versus unsuccessful) as a within-participants factor.

Table 4: Mean frequencies of clearly successful and clearly unsuccessful query exchanges by group

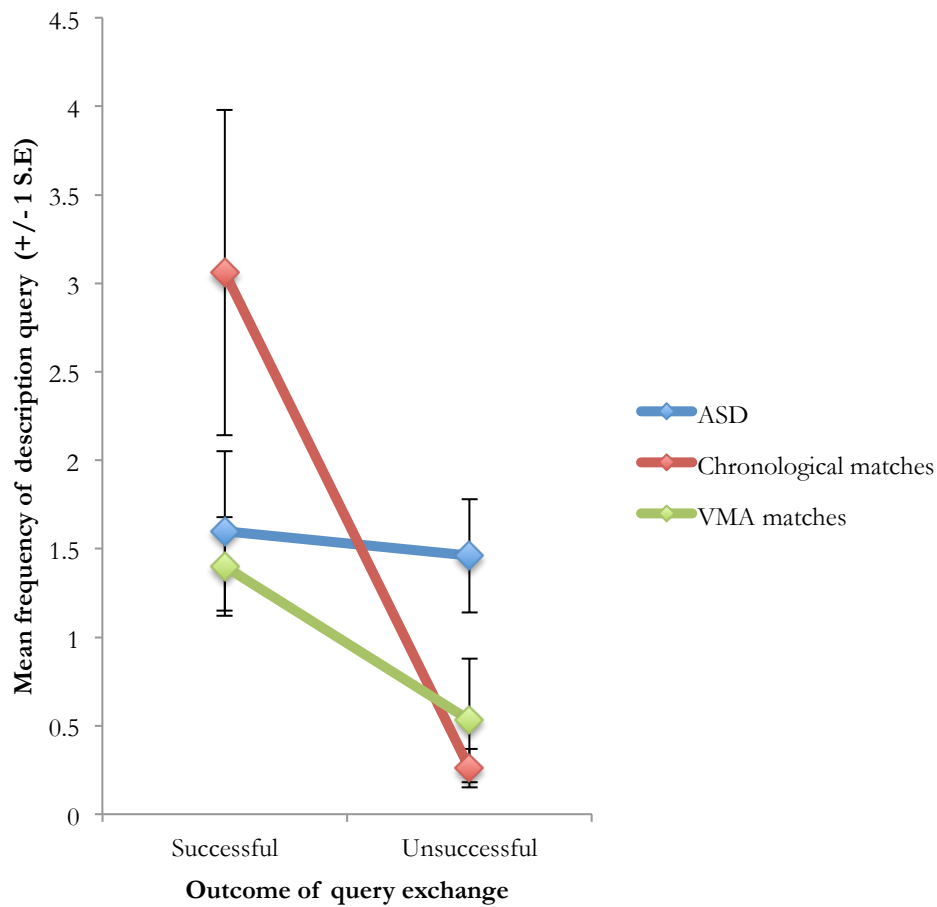
	Query exchanges			
	Successful		Unsuccessful	
Group	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
ASD	1.60	1.76	1.47	1.25
Chronological age-matched controls	3.07	3.58	.27	.46
VM age-matched controls	1.40	1.12	.53	1.36

The ANOVA revealed a main effect of query exchange outcome,  $F(1, 42) = 11.76$ ,  $p = .001$ , such that, overall, there were significantly more successful ( $M = 2.02$ ,  $SD = 2.45$ ) than unsuccessful ( $M = .76$ ,  $SD = 1.19$ ) query exchanges. Although we found no main effect of group in our data,  $F(1,42) = 1.08$ ,  $p = .35$ , there was a significant interaction between group and query exchange outcome,  $F(2,42) = 4.64$ ,  $p = .02$ . We therefore carried out post hoc tests to determine the source of this interaction.

We conducted two separate ANOVAs, for the two levels of the repeated measures factor. We found that the main effect of group was not significant in terms of successful

query exchanges,  $F(2, 42) = 2.17, p = .13$ . However, when considering unsuccessful query exchanges, we found a significant main effect of group,  $F(2, 42) = 4.96, p = .01$ . Post hoc Bonferroni  $t$ -tests on the factors in this model indicated ASD-TD pairs experienced significantly more unsuccessful exchanges ( $M = 1.47, SD = 1.25$ ) than TD only pairs in both the chronologically age-matched group ( $M = .27, SD = .46; t(42) = -3.0, p = .01$ ) and the VM age-matched group ( $M = .53, SD = 1.36; t(42) = 2.33, p = .02$ ), as shown in Figure 4. These results support our hypothesis that, despite being superficially as co-ordinated as TD only pairs, the ASD-TD pairs struggled to attain the same deeper level co-ordination in their discussions of the maze game.

Figure 4: Interaction plot for group and description query outcome



*(d.) Initiation of repair*

Given that the ASD-TD pairs experienced significantly more unsuccessful query exchanges than the TD only pairs while playing the maze game, we sought to determine which, if either, child in the ASD-TD pairs was more likely to initiate repair in conversation. If it were the case that the TD children initiated repair more often than ASD children, this could indicate that TD children have better awareness than their ASD interlocutors of the extent to which their conversations are semantically (mis)aligned. We found tentative evidence in support of this proposal. Overall, TD children ( $M = 2$ ,  $SE = .52$ ) initiated repair more often than did ASD children ( $M = 1.07$ ,  $SE = .40$ ), but this difference was not significant,  $t(28) = 1.43$ ,  $p = .16$ . In addition, since query exchanges could be successful or unsuccessful, we also examined whether there were differences in repair initiation across these categories. In successful exchanges, TD children ( $M = 1$ ,  $SE = .35$ ) initiated repair more often than ASD children ( $M = .60$ ,  $SE = .29$ ), and the same pattern held in unsuccessful exchanges (ASD  $M = .46$ ,  $SE = .19$ ; TD  $M = 1$ ,  $SE = .34$ ). Neither of these differences were at the level of significance, however (successful exchanges:  $t(28) = .88$ ,  $p = .39$ ; unsuccessful exchanges:  $t(28) = 1.37$ ,  $p = .18$ ). The failure of these results to reach significance could in part reflect the small size of the sample considered, and the low numbers of query exchanges observed overall (see General Discussion, for further consideration of this matter).

It is also possible that the distribution of repair initiations in the ASD-TD pairs reflects a more complex interplay between these children in conversation. Repair initiation indexes awareness of communicative breakdown, but the greater challenge for the interlocutor(s) lies in re-establishing mutual understanding, and this requires collaborative effort. It is interesting to note that repairs by ASD children occur more often in successful than unsuccessful exchanges, which is somewhat counterintuitive; this finding could suggest that



TD children make a concerted effort towards semantic realignment when the understanding of their ASD interlocutor is awry.

*(e.) Relationship between interactional co-ordination and semantic understanding*

The ASD group scored lower than both TD control groups in their performance on the ‘Ambiguous Sentences’ subtest of the TLC (Table 5), but not significantly so,  $F(2, 42) = 1.43$ ,  $p = .25$ . Nevertheless, we used ASD children’s scores on the TLC to examine the possibility that there was a relationship between the propensity of ASD-TD pairs to have unsuccessful query exchanges, and the slightly weaker semantic skills of the ASD children in those pairs.

*Table 5: Summary of performance on TLC ‘Ambiguous Sentences’ subtest*

<b>Group</b>	<i>M</i>	<i>SD</i>
ASD	9.13	3.36
Chronological age-matched controls	10.60	2.90
VM age-matched controls	10.73	2.91

Group-wise, we correlated individual children’s TLC scores with the frequencies of successful and unsuccessful query exchanges in their respective pairs. We found a marginally significant relationship between semantic ability and the frequency of unsuccessful communication exchanges ( $p = .06$ ), but in the VM age-matched group only (see Table 6).

*Table 6: Correlations of TLC scores with query exchange frequencies*

Group	N	Measure	Correlations	
			1.	2.
ASD	15	1. TLC score		
		2. Frequency of successful exchange queries	.15	
		3. Frequency of unsuccessful exchange queries	-.31	.03
Chronological age-matched controls	15	1. TLC score		
		2. Frequency of successful exchange queries	-.40	
		3. Frequency of unsuccessful exchange queries	-.18	.43
VM age-matched controls	15	1. TLC score		
		2. Frequency of successful exchange queries	-.18	
		3. Frequency of unsuccessful exchange queries	.51	.27

Overall, these correlational analyses do not suggest that ASD children's communicative breakdowns related to semantic impairment, and specifically to difficulties in resolving semantic ambiguities, as measured on the TLC. This implicates other factors in the pattern of our results.

*(f.). Relationship between interactional co-ordination and left-right awareness*

Since initially, not all children evidenced left-right awareness, we wished to examine whether left-right confusion was related to the number of query exchanges observed in each pair. We ran a two way ANOVA, with group (ASD versus chronological age-matched versus VM age-matched) and left-right awareness (yes versus no) as between-participants factors, and with pairs' total number of query exchanges as the dependent variable. We found no main effect of left-right awareness,  $F(1, 39) = 1.72, p = .20$ , group,  $F(2, 39) = 1.68, p = .20$ , and no interaction between these two variables,  $F(2, 39) = 1.25, p = .30$ . These results give us grounds to rule out the possibility that, across our groups, communicative breakdowns were related to left-right confusion.

## **General discussion**

Previous studies have reported that unmediated alignment mechanisms are intact in ASD, and that ASD children align linguistically with an interlocutor to the same extent as TD children (Allen et al., 2011; Osborne & Allen, 2012; Hopkins et al., 2015). The results of the current study support these past findings. We found that, in conversations prompted by a computerised referential communication task, ASD children were as likely to align syntax and lexis with a TD peer as were TD controls; this was also true whether the controls were matched for either chronological or VM age.

Nevertheless, our study also showed that ASD children's conversations with a TD peer were significantly less co-ordinated on a deeper (i.e., semantic) level, evidenced by the greater difficulties ASD-TD pairs experienced in dealing with communicative breakdowns. ASD-TD pairs were more likely than TD only pairs (in both the chronological and VM age-matched groups) to fail to resolve misunderstandings over interlocutors' descriptions of their location on a maze. This suggests that semantic misalignment was more common

in ASD-TD pairs. Yet the tendency of ASD-TD pairs to semantically misalign was unrelated to the ASD child's semantic abilities, which are commonly impaired (Boucher, 2003).

Taken together, our findings support the hypotheses laid out in our introduction, as well as the distinction made by Garrod and Clark (1993) between superficial and deep processes of co-ordination in children's conversations. Their study demonstrates that alignment on structural aspects of language (i.e., syntax, lexis) does not always promote alignment on aspects of language connected to meaning (semantics), especially among young TD children. A novel finding of our study is that ASD children experience similar disruptions to the alignment process: superficial co-ordination was less likely to prompt deep co-ordination in ASD children's conversations, compared with the conversations of chronological and VM age-matched controls. Worse, high levels of superficial co-ordination had the effect of duping some ASD children into thinking that they understood each other better than they actually did. This is illustrated by the following example:

Child 2: Joe, where's your purple star?

Child 1: Down one, and on top of it.

Child 2: OK Joe?

Child 1: Yes?

Child 2: Are you on top of the purple star?

Child 1: Yes.

Child 2: This is not happening, it's, it's not letting us win. We're on the purple star! Joe, are you, are you on your purple star?

Child 1: No.

Child 2: Then where are you?

Child 1: On top of it, like I said.

Child 2: No you didn't, you said, you're not on top of your purple star. Joe, tell me the truth! Are you on your purple star, yes or no?

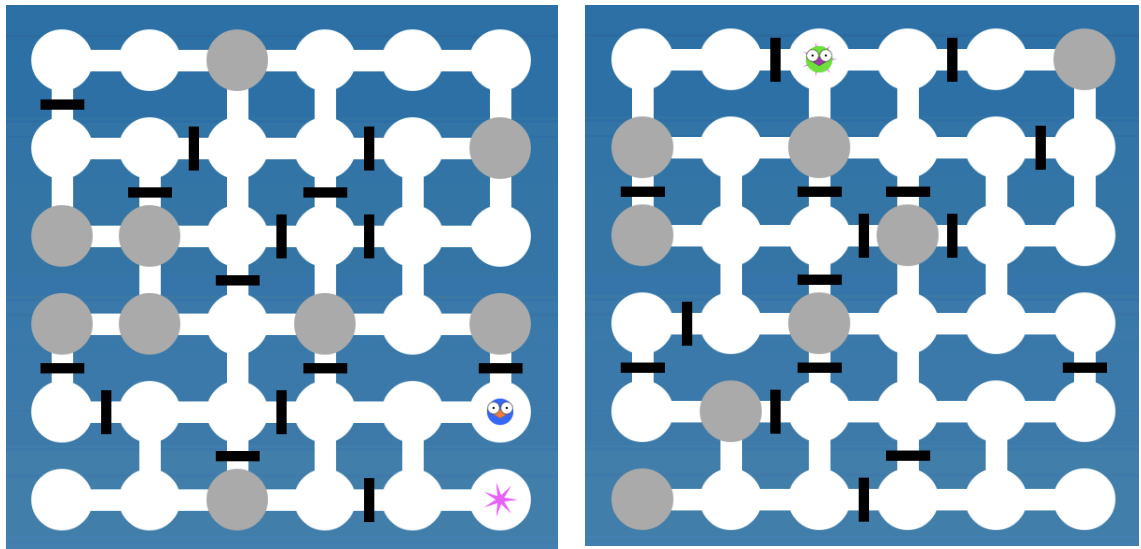
Child 1: On top of it!

Child 2: It's not happening!

(ASD-TD pair)

In this exchange, which occurred towards the end of a maze trial, both children converge on 'on top of it' to indicate their respective positions, relative to their end positions (i.e., the star). Their alignment on this expression convinces the children that they mean the same thing, even when the halted progress of the game signals that they did not.

*Figure 6: Screenshots taken from the maze trial of an ASD-TD pair*



As Figure 6 reveals, what Child 1 (left) intends by 'on top of it' is 'I'm in the node which is on top of my star'; Child 2 (right), however, intends his interlocutor to understand that he had reached his end position, and is thus physically on top of his star. This exchange proved so frustrating for the children that the experimenter had to intervene before an argument broke out. It highlights how superficially co-ordinated conversation can be,

without interlocutors' engaging with deeper co-ordination processes, and the potentially negative consequences of this.

The above example also underscores the importance of circumventing the alignment process when necessary. Because unmediated alignment occurs automatically, efforts must sometimes be made to resist the pressure towards superficial co-ordination in conversation, via repair strategies. As our results indicated, children in the ASD-TD pairs were not always able to resist alignment, even when description schemes were not working for them, and were less able to instigate repair in conversation. These are problems which, to our knowledge, have been neither identified nor measured in the wider literature on ASD children's conversational deficits. In accounting for our pattern of results, we propose different mechanisms that might underlie the deficits observed in our study.

To begin with, our results are compatible with the IA account of alignment. The IA account anticipates that the percolatory effect of alignment will be disrupted in the event of communicative breakdown, and this is borne out by our data. When misalignment occurs, interlocutors must rely on repair strategies to establish or re-establish alignment; however, as Pickering and Garrod (2004) acknowledge, people's capacity for repair may vary widely. They hypothesise that ToM ability may explain some of this individual variation, and we feel that this explanation characterises our results.

Hence we propose that the tendency of ASD-TD pairs towards semantic misalignment is at least in part a reflection of the poorer social cognitive abilities of the ASD child in those pairs. We suggested in the introduction that semantic language impairments and social cognitive deficits might separately influence the employment of repair strategies in the ASD-TD pairs. In cases of communicative breakdown, semantic impairments could make ASD children poorer at reformulating utterances, and social cognitive deficits could prevent them identifying and rectifying when mutual understanding was awry. In reality, it

seemed that social cognitive impairment undercut both types of repair strategy in the conversations of ASD-TD pairs. As expected, we observed query exchanges in which repair using full common ground was disrupted by shortcomings in the ASD child's mentalising skills, as in this example:

Child 1: Wait up, you say you can't get to the other one that's on the side of the star. So the one that's at the left of the star that'll free me, and then I can get to the star.

Child 2: What like, umm? I have no idea what you're really talking about.

Child 1: The left of the star, do you know which circle's to the left of the star?

Child 2: Is yours different from mine?

Child 1: No, no they're both exactly the same.

Child 2: No, I don't really get what you're talking about.

Child 1: Do you know which circle's next to the left of the star? You know which is left and right, yeah?

Child 2: Ummm. Hmmm. (ASD-TD pair)

In this exchange, Child 2 (TD) becomes aware that his situation model is not aligned with his interlocutor's, and he twice invites Child 1 (ASD) to help him re-establish their mutual understanding. Despite engaging in explicit negotiation over their situation models, the children are unable to repair using full common ground, because Child 1 does not tailor his utterances to the informational needs of Child 2.

Yet we also observed query exchanges in the ASD-TD pairs where repair using implicit common ground appeared to be disrupted by poor mentalising skills, on the part of the ASD child. For example:

Child 1: Can you go on your one?

Child 2: What, what? To my star?

Child 1: No, go on your thing, to open the gate.

Child 2: What, on your grey spot? On your grey spot, Ben?

Child 1: I just need to go one more space, to get to my star. (ASD-TD pair)

In this exchange, Child 2 (TD) keeps prompting Child 1 (ASD) to reformulate an unintelligible instruction for Child 2 to go somewhere on his maze ('what, what? To my star?; 'On your grey spot, Ben?'). Child 1 responds with another vague term ('thing'), however, even though a lack of referential clarity in his earlier utterance ('one') is the source of Child 2's confusion. Communicative breakdown occurs, not because Child 1 cannot reformulate his utterances, but because his reformulations contain language choices that are unintelligible to Child 2, without the contextual information required for 'one' and 'thing' to make sense (i.e., what Child 1 can see on his iPad screen). In overlooking this problem, Child 1 has committed a pragmatic error, which likely stems from his failure to recognise that Child 2 cannot know what he knows about his maze, without Child 1's telling him. This is consistent with the findings of Geller (1998), who noted that ASD children's lack of specificity when referring to items often led to listener confusion. If our ASD-TD pairs' struggle to repair using implicit common ground reflected social cognitive rather than linguistic deficits, then this could explain why query exchange measures were unrelated to ASD children's TLC scores; the failure to disambiguate meaning was not a manifestation of semantic language impairment (as assessed by the TLC), but of poor social cognitive understanding.

Of course, in making these evaluations, we are aware of the fact that no ToM measures were recorded in the current study. This was a conscious choice, motivated by our previous research (Hopkins et al. 2015; Article 2, this thesis), which failed to find a relationship



between alignment behaviour and classic measures of ToM. Relatedly, in a study which showed that ASD children have poorer communicative competence, false belief tasks neither discriminated ASD children from DD controls, nor predicted conversational ability, once language skills were taken into account (Capps et al., 1998). It is a task for future research both to develop and incorporate measures which validly test a role for social cognitive impairments in ASD children's conversational deficits. The conclusions of this study would clearly have been usefully informed by such a measure.

Although we have attributed our findings to social cognitive impairments among the ASD children, it is also possible that the propensity of the ASD-TD pairs to have unsuccessful query exchanges was related to the type of description schemes employed by these pairs. ASD-TD pairs were more likely to use line descriptions than other schemes, and since line descriptions are more abstract than path descriptions (which were preferred by TD children in both control groups), this raises the possibility that the way ASD-TD pairs conceptualised the mazes ran them into greater communicative difficulties. This seems an unlikely explanation for the present findings: we identified only one instance of an unsuccessful query exchange in which a line type description was implicated; by contrast, line descriptions were used in eight successful query exchanges. The communicative expediency of line descriptions could explain why these were preferred among the ASD-TD pairs.

So far, we have focused on why the ASD-TD pairs in our study were less able to repair communicative breakdown. An equally important question is why, in all groups, children were sometimes unable to resist aligning with an interlocutor, even when it was communicatively disadvantageous for them to do so. One possibility is that linguistic divergence depends on executive functioning (EF), an array of domain-general processes which regulate goal-directed behaviour, and which includes working memory, cognitive flexibility, and inhibitory control. It has been shown that EF is needed to inhibit

spontaneous motoric imitation (van Leeuwen, van Baaren, Martin, Dijksterhuis, & Bekkering, 2009); correspondingly, Kidd (2011) has suggested that children with developing EF skills might be unable to suppress production of familiar linguistic forms.

We have previously proposed a role in alignment for conflict IC, which involves suppressing a salient response to generate a novel, conflicting response; we suggested in Article 2 that IC might regulate communicative perspective-taking in alignment driven by mediated (e.g., audience design) mechanisms. It is plausible that IC, or a process similar to this, might also support children's ability to diverge in conversation. We base this supposition on research into echolalia, a language disorder associated with ASD, and which involves automatic, non-intentional mimicry of others' speech, often at great length. The disorder has been understood by researchers (e.g., Grossi et al., 2013) as an imitative behaviour resulting from IC deficits, as in patients with frontal lobe damage.

Despite its presentation, we do not regard echolalia as alignment *ad extremum*; it seems to deviate from processing models of language production, in that production appears to govern proposition encoding, rather than the other way round. Nevertheless, echolalia offers a helpful analogy for what happens when alignment becomes 'deadlocked' during conversation: speakers repeat utterances, but the content of those utterances is not processed in any meaningful way. By extension, if echolalia is a product of IC deficits, it could also be the case that children's failure to diverge is due to difficulties in inhibiting automatic repetition of what their interlocutor is saying. If this hypothesis is correct, then it may carry negative implications for ASD children, who have poorer response inhibition and interference control than TD controls (Geurts et al., 2014). ASD children could face a double bind in conversation: they might be more likely to converge on unworkable description schemes (as in the example above), as well as being less able to repair semantic misalignment.

Our study would have been enhanced by testing whether in ASD-TD pairs, the challenge of interactive repair was related to social cognitive deficits. It would also benefit from replication in a larger and more diverse sample. Recall that the children in our ASD group were all educated in a mainstream setting; ASD children educated in specialist settings tend to have more pronounced social and communication difficulties than their mainstream-educated counterparts, raising a question as to how our findings would generalise to them. The maze game might also require modification, to accommodate other deficits associated with a specialist education ASD profile (e.g., lower IQ).

As noted, our transcripts evidenced substantially fewer location and query exchanges than did those in Garrod and Clark's (1993) study. We suspect that, in our study, children engaged in less conversation because of the clicking sound effect they heard when they reached the location of their partner's switch nodes. Instead of talking to their partner, children would sometimes use the sound effect as an auditory cue for their partner's whereabouts on the maze, thereby negating the need to discuss this. We incorporated the clicking sound effect when adapting the maze game because, in piloting sessions, we felt that it improved children's grasp of the gate/switch mechanism. Although removing the sound effect from the application might improve data yield in a future replication of our study, we fear removal might also make the game harder and more frustrating for children, especially those with ASD.

## **Conclusions**

To conclude, this study has enquired as to how far unmediated alignment supports effective communication in ASD children, compared with TD controls. We found further evidence that unmediated alignment mechanisms are intact in ASD children, and demonstrated the novel finding that ASD children align syntax and lexis with a TD peer, to

the same extent as did TD children matched either for chronological or VM age. However, while ASD children were superficially as co-ordinated as TD children, their dialogues did not evidence the same level of deeper co-ordination as TD children in both control groups. We observed that pairs of ASD and TD children were less able than pairs of TD children to resolve communicative breakdown in conversation, suggesting that ASD-TD pairs did not align semantically to the same extent as TD only pairs.

These findings help to clarify the limits of automatic, priming-based (i.e, unmediated) alignment in explaining communication difficulties in ASD children. Consistent with the IA account, our study indicated that ASD children did not experience the same percolatory effect of alignment as did TD children, because they demonstrated reduced capacity in recognising and repairing instances of semantic misalignment. We contend that these conversational deficiencies, hitherto unexamined in ASD children, reflect social cognitive impairments common to ASD. Further research is necessary to lend empirical support to this assertion, and to specify which components of impaired social cognition prevent ASD children from achieving deeper co-ordination in conversation.

## 9. General discussion

This thesis has added to a small literature about language alignment in ASD, specifically in ASD children. Previous research had demonstrated that both syntactic and lexical alignment are intact in ASD children, who aligned with an interlocutor to the same extent as TD children matched either for chronological or VM age (Allen et al., 2011; Osborne & Allen, 2012). A single study of AS adults reported similar findings: AS adults aligned syntax, lexis, and spatial frame of reference with an interlocutor, and to the same extent as typical adults (Slocombe et al., 2012). The experiments presented in this thesis have both supported and extended previous research, by addressing some important outstanding questions. A summary of the hypotheses explored in each of the articles is provided in 9.1, which also interprets and synthesises the different study findings.

### *9.1. Summary of findings*

Article 1 reports two studies: the first is a partial replication of Allen et al.'s (2011) experimental investigation of syntactic alignment in ASD children; the second is a more naturalistic survey of syntactic alignment, based on real-life conversations between an ASD child and a peer. It was expected that Study 1 would replicate Allen et al.'s (2011) findings that (1) ASD children have intact syntactic alignment, and that (2) they align with an interlocutor to the same extent as TD children matched either for chronological or VM age. The primary hypothesis concerned the generalisability of these findings to non-experimental settings (Study 2). Specifically, it was predicted that ASD children would not maintain the level of alignment observed on an embedded priming paradigm (i.e., the Snap! game) when conversing in real-life interactions, which tend to be less structured and less goal-oriented. To address this hypothesis, alignment effects were calculated for ASD children and a group of VM age-matched controls, and compared across the experimental

task and real-life conversation. Study 1 yielded results consistent with Allen et al.'s (2011), as anticipated; however, there was no conclusive evidence to support the prediction that ASD children align less than TD controls in real-life conversation. This finding lends ecological validity to experimental data showing that ASD children are not significantly less likely to align than TD children with an interlocutor. It was noted, however, that the size of alignment effects were greater on the experimental task than in conversation, suggesting that such tasks may overstate children's tendency to align.

Article 2 also reports two studies, both of which seek to identify a mediated component to ASD children's lexical alignment, and to relate mediated alignment mechanisms (i.e., audience design) to measures of children's mentalising abilities. In this regard, Article 2 builds on work by Osborne and Allen (2012), which investigates whether ASD children's ToM understanding predicts their tendency to converge lexis with an interlocutor. The innovation of Article 2 was to draw on studies showing that communicative perspective-taking is related to IC in the typical population (Brown-Schmidt, 2009; Nilsen & Graham, 2009; Wardlow, 2013), and on theory proposing that IC regulates the use of mental state information in some ASD children (Nilsen & Fecica, 2011). The studies in Article 2 measured lexical alignment using an adapted version of the Snap! game used in Article 1, and compared ASD children's alignment effects with those of chronological and VM age-matched TD controls. Alignment effect scores were related to ToM and IC scores, obtained from all children. The first hypothesis of Article 2 was that, in line with previous research (Osborne & Allen, 2012), ASD children would demonstrate intact lexical alignment, and align with an interlocutor to the same extent as TD controls. The second hypothesis was speculative: it was suggested that, by accounting for IC abilities, a relationship could emerge between children's ToM understanding and their alignment, thereby implicating audience design mechanisms in the alignment process. However, it was also suggested that any such relationship might not be apparent in all groups, which could

help to address the question over whether the same or different mechanisms underpin alignment in ASD and typical development (Slocombe et al., 2012). The results of both studies in Article 2 support Osborne and Allen's (2012) findings that (1) lexical alignment is intact in ASD children, (2) that ASD children align with an interlocutor to the same extent as TD children matched for chronological and VM age, and (3) that ASD children's lexical alignment is not mediated by audience design mechanisms, which could not be pinpointed across multiple communicative perspective-taking measures. Further, the results suggest that ASD and TD children's lexical alignment is not driven by different mechanisms.

Article 3 reports a single study, which investigated the extent to which automatic, priming-based alignment promotes ASD children's communicative success, through the use of a collaborative maze game (adapted from Garrod and Anderson, 1987; Garrod and Clark, 1993). ASD children, along with groups of chronological and VM age-matched TD children, played the game with a TD peer. As in Article 1, real-life conversational data generated by the task was analysed for evidence of alignment (syntactic; lexical), and it was hypothesised that while ASD and TD children's conversations would be superficially co-ordinated to the same extent (as in experimental studies; Allen et al., 2011; Osborne & Allen, 2012), ASD children's conversations would lack deeper (i.e., semantic) co-ordination, as did the conversations of young TD children in Garrod and Clark's (1993) study. There was evidence in support of both hypotheses. ASD children aligned on syntax and lexis with a peer, and to the same extent as TD children in both control groups. Yet their conversations were less well co-ordinated on a deeper level, as indexed by the reduced likelihood of successful communicative repair in the ASD pairs. Although ASD individuals' impoverished repair strategies have been reported elsewhere in the literature (e.g., Volden, 2004), Article 3 is novel in relating repair to other aspects of ASD children's conversational behaviour. It highlights that ASD children's alignment may pose a risk to successful repair, because it can erroneously signal alignment of underlying referential interpretations. This

finding is consistent with Garrod and Clark's (1993) research, which emphasises the importance of divergence in conversation, and shows that less skilled communicators (i.e., young children) struggle to resist the pressure towards superficially co-ordinating with an interlocutor, in a way that can be communicatively maladaptive.

The studies reported in this thesis are coherent, not only with previous research, but with each other. In all studies, there is evidence that ASD children's syntactic and lexical alignment is intact, and that ASD children do not show atypical patterns of alignment, relative to TD children matched either for chronological or VM age. Moreover, this finding holds across experimental (Articles 1 and 2) and naturalistic conversational contexts (Articles 1 and 3). Based on the available evidence, therefore, ASD children's difficulties with conversation do not appear to result from a general deficit in language imitation. Further, the results of the studies suggest that ASD and TD children's alignment is predominantly unmediated; repeated attempts to identify a relationship between children's mentalising abilities and their tendency to align with an interlocutor were not successful (Articles 1 and 2).

This thesis also sought to identify the limits of unmediated alignment for ASD children (Article 3), given the central role of unmediated (priming) mechanisms in the alignment process. This was an attempt to reconcile conflicting psycholinguistic and psychological findings about conversation in ASD; ASD individuals struggle to align on situational models (e.g., Volden, 2002), when theoretically they should not, given their unmediated priming mechanisms are intact (cf., Allen et al., 2011). Hence by examining semantic alignment in Article 3, it was possible to identify where the alignment process becomes disrupted for ASD children, and to consider why disruption occurs. It was suggested that the percolatory effect of alignment is stymied by ASD children's difficulties with effecting repair in conversation, difficulties which were attributed to their social cognitive impairments, rather than to impaired semantic understanding. In this respect, the findings



of Article 3 support a distinction between structural and communicative language deficits in ASD (Boucher, 2003); while ASD children's alignment on structural aspects of language (syntax; lexis) is unimpaired, it does not automatically promote higher level alignment on aspects of language connected to meaning; this is at least partly owing to ASD children's underdeveloped repair skills, which relate to their reduced ability to diverge in conversation. Proficiency in both of these areas requires children to be sensitive to the success of communicative exchanges, in terms of fixing mutual intelligibility, and this likely implicates ToM.

### *9.2. Theoretical implications of findings*

This thesis contributes to questions of theoretical relevance to the study of alignment. First, it highlights the circumstances under which the unmediated alignment process is disrupted, by focusing on children with atypical communication skills. Pickering and Garrod (2004) predicted that, while alignment does not require complete ToM, it could be impaired in the presence of social deficits. The studies reported here revealed mixed support for this hypothesis. On the one hand, basic alignment mechanisms seem to be intact in ASD children, even those with ToM impairment. On the other hand, ASD children's impoverished repair strategies obstruct the alignment process for them, and such difficulties likely stem from mentalising deficits. Within Pickering and Garrod's (2004) framework, therefore, children's ability to model an interlocutor's mental state is both relevant and not relevant to alignment. Children with mentalising deficits are capable of aligning syntax and lexis in conversation, and to the same extent as speakers with intact mentalising abilities; yet children with mentalising deficits may not experience the percolatory effect of the alignment process if, by virtue of those deficits, they are unable either to detect or to respond to the need to repair communicative breakdown.

Secondly, the findings of this thesis must be reconciled with evidence in support of alternative theories of alignment, such as the audience design account (Branigan et al., 2011). It is already known that alignment can involve both mediated and unmediated components (Haywood, Pickering, & Branigan, 2005), but the separate accounts of alignment might also be viewed as complementary descriptions of a developmental trajectory. Alignment, like other aspects of communicative behaviour (Shatz and Gelman, 1978), may mature over time: it seems likely that alignment relies more heavily on priming mechanisms in early childhood (e.g., Messenger et al., 2012), while audience design mechanisms emerge later in development (cf., Branigan et al., 2011). The age effects recorded in Garrod and Clark's (1993) study lend tentative support to this explanation, which would also account for the stronger priming effects seen in children (Rowland et al., 2012). The automaticity of priming should diminish as children become increasingly able to exert control over the structural and communicative properties of their linguistic productions.

The findings of this thesis also carry theoretical implications for the literature on imitation in ASD. As noted, ASD individuals show an imitative deficit for motor actions, in particular for motor actions with high social processing demands (Vivanti & Hamilton, 2014). While Article 2 precludes firm conclusion as to whether and how social processing affects ASD children's alignment, this thesis overwhelmingly does not support the idea of a general deficit in linguistic imitation in ASD. ASD children demonstrated alignment, and typical levels of alignment, in all the studies of this thesis. The absence of impairment could reflect the non-social, unmediated nature of ASD children's alignment; note that intact automatic imitation of motor actions has been observed in ASD adults, when social processing demands are eliminated from an imitative task (Bird, Leighton, Press, & Heyes, 2007). The complementarity of such findings implies consistency between the literature on

non-linguistic versus linguistic imitation (i.e., alignment) in ASD, at least where automatic imitation is concerned.

### *9.3. Practical implications of findings*

While this thesis suggests that basic alignment mechanisms are intact in ASD (although see 9.4., for further discussion of this matter), and hence that these are not a target for improvement, it is clear that the alignment process runs less smoothly for ASD children than for TD children; the percolatory effect of alignment is weaker in the conversations of ASD children, who demonstrate less deeper level co-ordination with their interlocutor. Article 3 identifies two ways in which this facet of ASD children's alignment behaviour might be amenable to intervention.

First, ASD children lack the interactive repair strategies to rectify communicative breakdown, when unmediated syntactic and lexical alignment leads to misalignment of representations. Thus teaching the use of conversational repair strategies could indirectly expedite the alignment process for ASD children. Recall that, according to the IA account, alignment of situation models is achievable as long as speakers are able to deploy repair strategies whenever necessary (Pickering & Garrod, 2004). Of course, if ASD children's difficulties with repair stem from social cognitive impairment, as argued in Article 3, then there is a question about whether this aspect of their communicative functioning can be improved, simply by supporting repair strategies. A possible explanation for the failure of ToM training studies to enhance ASD children's conversational skills (cf., Hadwin et al., 1997) is that ToM cannot be taught, and neither by extension can the social skills which depend on it. Nevertheless, there is evidence that repair strategies can be therapeutically targeted in children with pragmatic language impairments (Merrison & Merrison, 2005), raising the possibility that, if ASD children were to be explicitly taught pragmatic skills, they could learn to manage communicative breakdowns more effectively. If so, it might

also follow that ASD children could become less prone to semantic misalignment, and more able to establish mutual understanding in conversation.

Developing ASD children's pragmatic skills might also increase their awareness of when it is necessary to resist the pressure to align; however, children must possess the skills to support such divergence (cf., Article 3, General Discussion). This is a difficult issue to target, since it is a challenge to alter behaviour which is unconscious and automatic in nature (Pickering & Garrod, 2004). In addition, too little is currently known about the mechanisms that drive priming, and hence unmediated alignment; further research must specify, not only the mechanisms which drive speakers to repeat a previously processed linguistic form (e.g., Kidd, 2011), but also which mechanisms support non-imitation of language (i.e., divergence). Identifying the underlying mechanisms of divergence could help to explain individual differences in children's ability to circumvent the alignment process. For example, and as suggested in Article 3, it could be that ASD children's difficulties with divergence relate to IC deficits; if so, improving their EF through training could help to reduce maladaptive alignment. These are all matters for future research.

#### *9.4. Unanswered questions and further directions*

This thesis has left some unanswered questions, particularly in Article 2. The results presented there, as well as in previous research (Osborne & Allen, 2012), converge on the conclusion that ASD children's alignment lacks a mediated component; this might not be the full story, however. It is argued in Article 2 that embedded priming paradigms (e.g., the Snap! game), might not prompt speakers to align in a communicatively strategic way, because there is no communicative cost to reduced alignment. As noted, it would be interesting to investigate the question of mediated alignment in ASD children by adopting a similar methodology to Branigan et al., (2011), who measured adults' tendency to align after experimentally manipulating their beliefs about an interlocutor. Although Article 2 did

not capture any communicatively strategic language production, Article 3 showed that (1) children can tailor their utterances to the informational needs of a listener, and (2) there are differences in ASD and TD children's capacity for this. Taken together, these findings suggest that, in a task which expressly elicited audience design-based alignment, there could be variability in the extent to which ASD and TD children align to enhance communicative success. In ASD children, who have impaired perspective-taking abilities (Nilsen & Fecica, 2011), the effects of priming might not be strengthened by the concurrent action of audience design mechanisms.

This relates to a second unanswered question in this thesis, which concerns the possibility that, while ASD and TD children's alignment appears superficially to be the same, the mechanisms underpinning it might be different (Slocombe et al., 2012). The results presented here offer insufficient evidence to settle the issue either way, although ASD children's difficulties with divergence (Article 3) suggests that the contribution of priming mechanisms to their alignment may be especially strong, and thus difficult to overcome. Slocombe et al., (2012) propose that, in future investigations, performance measures (e.g., processing speed; neurophysiological measures) should be collected during alignment tasks, to elucidate potential differences in the mechanisms underlying alignment in ASD and typical development. Yet it could be a challenge to collect such measures from children, especially ASD children, who may resist more intrusive measures of linguistic processing. Hence an alternative approach would be to conduct an investigation like Kidd's (2011), wherein measures of alignment could be correlated with a battery of other linguistic and non-linguistic measures, to see where any relationships might lie. Such an investigation could be extended across different communicative contexts, and to different levels of language (i.e., syntax versus lexis), where audience design considerations may be more or less salient.

Research on alignment in ASD could easily be extended beyond the scope of this thesis. Baron-Cohen (1988) has called for an integration of social cognitive and affective theories of ASD, in order to better understand the communicative deficits of the disorder. To date, however, there is no known work on the role of affective mechanisms in ASD children's alignment, making this an obvious direction for future research. The studies in this thesis have not considered affective alignment mechanisms, but there are grounds for suspecting that these are impaired in ASD children; ASD is associated with reduced social orientation and affiliative behaviour (cf., Chevallier et al., 2012), suggesting that ASD children would be less motivated to align in order to express affiliation or rapport. It would therefore be valuable to assess whether and how far affective mechanisms contribute to ASD children's alignment, especially in light of evidence attributing conversational impairment to affective deficits in ASD (3.1) This matter is also important because affective and audience design mechanisms may operate concurrently in conversation (Branigan et al., 2010): for example, the pursuit of communicative success could promote a better social relationship between participants in an interaction. Understanding the contributions of these mechanisms to alignment in ASD would help to establish how different aspects of impaired social understanding affect ASD children's communicative language processing; it would also help to develop and refine theoretical models of language alignment.

Examining alignment across a broader range of language phenotypes in ASD would also extend the work of this thesis. The ASD children sampled in the reported studies all had language within the normal range, in order that they were able to cope with the demands of the experimental paradigms. It is unlikely, therefore, that these samples captured the heterogeneity of language abilities within the autism spectrum (Boucher, 2003), raising the possibility that wider sampling could yield larger group differences than those detected here. Aptly, a new and unpublished study of 2-5 year olds with ASD (Fusaroli, Weed, Fein, & Naigles, in prep) reports significant differences in the alignment of ASD and matched

TD controls, but only when a subgroup of ASD children with low verbal ability (as measured on the Mullen Scales of Early Learning; Mullen, 1995) was included in analyses. This finding is consistent with Allen et al.'s (2011) discovery of a correlation between VM age and alignment effects in their ASD sample, which suggests that ASD children's alignment relates in some way to their language ability. Further, if alignment is considered less from the perspective of conversational behaviour (e.g., Pickering & Garrod, 2004), and more from the perspective of language acquisition (Chang et al., 2006), then it stands to reason that children with poorer language abilities will also have weaker priming mechanisms. Hence there is work to be done on the extent to which language impairment in ASD affects alignment, including the development of simpler experimental paradigms.

It is also worth investigating whether there are subtle differences in alignment among ASD children with higher verbal ability. As noted in the introduction, this thesis has adopted the single label of ASD, following clinical guidelines (American Psychiatric Association, 2013), and consent forms for studies did not probe the nature of each child's ASD (i.e., did the child have a subtype diagnosis of e.g., AS; HFA). It is plausible that variation in language ability, even among the most verbally able ASD children, could produce variations in alignment behaviour; for example, it has been shown that there are slight differences in the lexical processing systems of AS and HFA children, which could reflect the presence or absence of language delay in early development (Speirs, Yelland, Rinehart, & Tonge, 2011).

#### *9.5. Strengths and limitations of the present investigation*

A major strength of the work presented here has been that, through psycholinguistic experimentation, it has been possible to take a scientific approach to the study of conversation in ASD. The use of experimental techniques (Articles 1 and 2) has facilitated investigation of the mechanisms underlying ASD children's communicative language use,

in contrast to previous studies (e.g., Volden, 2002). Further, the present investigation has successfully generalised experimental findings about alignment to ASD children's real-life conversations (Articles 1 and 3); patterns of alignment identified through experimental methods have been readily identifiable in a unique corpus of dialogues, which transcribe the interactions of ASD children with their non-ASD peers. These dialogues have provided novel evidence which secures alignment as a real phenomenon, in the conversations of both ASD and TD children. Clearly, confirming the ecological validity of experimental findings is also of value to theoretical models of language alignment.

In addition, the present investigation has incorporated double matching procedures, which is not a feature of most previous studies on conversation in ASD (e.g., Capps et al., 1998). In the majority of studies reported in this thesis, ASD children were paired individually to two TD controls, one with the same chronological and one with the same VM age. This approach made it possible to examine the effects of age and language exposure on the alignment in ASD and TD children, and to identify when ASD children's alignment was age and/or language level appropriate or not. This is an important strength of the present investigation, in light of debates over whether ASD children are delayed or different in their social development (cf., Peterson, Wellman, & Liu, 2005; VanMeter, Fein, Morris, Waterhouse, & Allen, 1997).

Besides the unanswered questions outlined in 9.4, which could be seen as a limitation of the present investigation, the findings reported here should be interpreted within the context of commonly cited weaknesses in ASD research, such as sample size. While considerable efforts were expended in recruiting ASD children for studies, it was difficult to attract the higher numbers that would have increased the power of statistical analyses, and the generalisability of findings. It should be noted, however, that the ASD samples which took part in this research were of similar size to those involved in previous research on alignment in ASD (Allen et al., 2011; Osborne & Allen, 2012; Slocombe et al., 2012);



further, these studies reported similar patterns of results to those reported in Articles 1-3, which should inspire confidence in the robustness of findings.

Lastly, while matching procedures in the reported studies were rigorous, they could also have been more detailed. The BPVS-3 (Dunn et al., 2009) measures receptive vocabulary, and is widely used as a matching measure in ASD research (Motttron, 2004). However, and especially because this thesis investigated alignment on different aspects of language, the reported studies could have been strengthened by consistently matching ASD children on additional measures of language ability, such as syntactic and semantic knowledge. Although children were not matched according to TLC (Wiig & Secord, 1985) scores in Article 3, having this measure invited consideration of how semantic ability related to ASD children's semantic alignment, and whether structural language deficits were a plausible explanation for their difficulties with communicative repair.

#### *9.6. Concluding remarks*

This thesis doubles the number of studies on alignment in ASD, to consider ASD children's conversational deficits from a psycholinguistic perspective. Hence in contrast to previous research, this thesis is less concerned with psychological (i.e., ToM) explanations for conversational deficits in ASD, and more concerned with how linguistic processing mechanisms might contribute to these. The studies in this thesis consistently demonstrate that ASD children have intact syntactic and lexical alignment, and tend to align with an interlocutor as much as TD peers of either the same chronological or the same VM age. This means that ASD children's conversations appear superficially to be as co-ordinated as the conversations of TD children. However, this thesis also provides evidence for reduced deeper level co-ordination in ASD children's conversations, suggesting that the presumed percolatory effect of alignment is disrupted in ASD. In this regard, superficial (syntactic;

lexical) alignment can act as a communicative pitfall for ASD children, if they trust that having common ways of speaking with an interlocutor implies mutual understanding.

## References

- Allen, M. L., Haywood, S., Rajendran, G., & Branigan, H. (2011). Evidence for syntactic alignment in children with autism. *Developmental Science*, 14(3), 540–8. doi:10.1111/j.1467-7687.2010.01001.x
- American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders*. Arlington. doi:10.1176/appi.books.9780890425596.744053
- Anderson, D. K., Lord, C., Risi, S., DiLavore, P. S., Shulman, C., Thurm, A., Pickles, A. (2007). Patterns of growth in verbal abilities among children with autism spectrum disorder. *Journal of Consulting and Clinical Psychology*, 75, 594–604. doi:10.1037/0022-006X.75.4.594
- Astington, J. W., & Jenkins, J. M. (1995). Theory of mind development and social understanding. *Cognition & Emotion*, 9(2-3), 151–165. doi:10.1080/02699939508409006
- Bailey, A., Le Couteur, A., Gottesman, I., Bolton, P., Simonoff, E., Yuzda, E., & Rutter, M. (1995). Autism as a strongly genetic disorder: evidence from a British twin study. *Psychological Medicine*, 25(01), 63. doi:10.1017/S0033291700028099
- Baltaxe, C. A. M. (1977). Pragmatic Deficits in the Language of Autistic Adolescents. *Journal of Pediatric Psychology*, 2(4), 176–180. doi:10.1093/jpepsy/2.4.176
- Baron-Cohen, S. (1988). Social and pragmatic deficits in autism: Cognitive or affective? *Journal of Autism and Developmental Disorders*, 18(3), 379–402. doi:10.1007/BF02212194
- Baron-Cohen, S. (1989). The autistic child's theory of mind: a case of specific developmental delay. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 30(2), 285–297. doi:10.1111/j.1469-7610.1989.tb00241.x
- Baron-Cohen, S. (1997). Hey! It was just a joke! Understanding propositions and prepositional attitudes by normally developing children and children with autism. *Israel Journal of Psychiatry and Related Sciences*, 34, 174–178.
- Baron-Cohen, S. (2001). Theory of Mind in Normal Development and Autism. *Prisme*, 34, 174–183. Retrieved from <http://www.autism-community.com/wp-content/uploads/2010/11/TOM-in-TD-and-ASD.pdf>
- Baron-Cohen, S. (2008). Theories of the autistic mind. *Psychologist*, 21(2), 112–116. doi:http://dx.doi.org/10.1016%2F0010-0277%2885%2990022-8
- Baron-Cohen, S., Allen, J., & Gillberg, C. (1992). Can autism be detected at 18 months? The needle, the haystack, and the CHAT. *The British Journal of Psychiatry*, 161(6), 839–843. doi:10.1192/bjp.161.6.839

- Baron-Cohen, S., Campbell, R., Karmiloff-Smith, A., Grant, J., & Walker, J. (1995). Are children with autism blind to the mentalistic significance of the eyes? *British Journal of Developmental Psychology*, 13(4), 379–398. doi:10.1111/j.2044-835X.1995.tb00687.x
- Baron-Cohen, S., Jolliffe, T., Mortimore, C., & Robertson, M. (1997). Another advanced test of theory of mind: evidence from very high functioning adults with autism or asperger syndrome. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 38(7), 813–822. doi:10.1111/j.1469-7610.1997.tb01599.x
- Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a “theory of mind”? *Cognition*, 21, 37–46. doi:10.1016/0010-0277(85)90022-8
- Baron-Cohen, S., Wheelwright, S., Spong, A., Scahill, V., & Lawson, J. (2001). Are intuitive physics and intuitive psychology independent? A test with children with Asperger Syndrome. *Learning*, 5, 47–78.
- Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3), 255–278. doi:10.1016/j.jml.2012.11.001
- Bartolucci, G., & Albers, R. J. (1974). Deictic categories in the language of autistic children. *Journal of Autism and Childhood Schizophrenia*, 4(2), 131–141. doi:10.1007/BF02105366
- Bates, D., Maechler, M., & Bolker, B. (2011). lme4: Linear mixed-effects models using S4 classes. *R package version 0.999375-39*. Retrieved from <http://CRAN.R-project.org/package=lme4>.
- Bauminger, N., & Kasari, C. (2000). Loneliness and Friendship in High-Functioning Children with Autism. *Child Development*, 71(2), 447–456. doi:10.1111/1467-8624.00156
- Bennetto, L., Pennington, B. F., & Rogers, S. J. (1996). Intact and impaired memory functions in autism. *Child Development*, 67(4), 1816–1835. doi:10.1111/j.1467-8624.1996.tb01830.x
- Biber, D., Johansson, S., Leech, G., Conrad, S., & Finegan, E. (1999). Longman grammar of spoken and written English. *Tesol Quarterly*, 34, 1203. doi:10.2307/3587792
- Bird, G., Leighton, J., Press, C., & Heyes, C. (2007). Intact automatic imitation of human and robot actions in autism spectrum disorders. *Proceedings of the Royal Society B-Biological Sciences*, 274(1628), 3027–3031. doi:10.1098/rspb.2007.1019
- Bishop, D. V. M. (2005). Executive functions in children with communication impairments, in relation to autistic symptomatology: 2: Response inhibition. *Autism*, 9(1), 29–43. doi:10.1177/1362361305049028
- Bloom, L., Hood, L., & Lightbown, P. (1974). Imitation in language development: If, when, and why. *Cognitive Psychology*, 6, 380–420. doi:10.1016/0010-0285(74)90018-8

- Bloom, P., & German, T. P. (2000). Two reasons to abandon the false belief task as a test of theory of mind. *Cognition*, 77(1). doi:10.1016/S0010-0277(00)00096-2
- Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology*, 18(3), 355–387. doi:10.1016/0010-0285(86)90004-6
- Bock, K., & Griffin, Z. M. (2000). The persistence of structural priming: transient activation or implicit learning? *Journal of Experimental Psychology. General*, 129, 177–192. doi:10.1037/0096-3445.129.2.177
- Bock, M. A. (1996). Autism: An Introduction to Psychological Theory. *Focus on Autism and Other Developmental Disabilities*. doi:10.1177/108835769601100309
- Boddaert, N., Belin, P., Chabane, N., Poline, J. B., Barthélémy, C., Mouren-Simeoni, M. C., Zilbovicius, M. (2003). Perception of complex sounds: Abnormal pattern of cortical activation in autism. *American Journal of Psychiatry*, 160(11), 2057–2060. doi:10.1176/appi.ajp.160.11.2057
- Bodfish, J. W., Symons, F. J., Parker, D. E., & Lewis, M. H. (2000). Varieties of Repetitive Behavior in Autism: Comparisons to Mental Retardation. *Journal of Autism and Developmental Disorders*, 30(3), 237–243. doi:10.1023/A:1005596502855
- Borbély, T. (2014). *The role of inhibitory control in the co-operative play of high-functioning children with autism (Doctoral thesis)*. Retrieved from [http://sro.sussex.ac.uk/56521/1/Borb%C3%A9ly%2C\\_Tam%C3%A1s.pdf](http://sro.sussex.ac.uk/56521/1/Borb%C3%A9ly%2C_Tam%C3%A1s.pdf)
- Bortfeld, H., & Brennan, S. E. (1997). Use and acquisition of idiomatic expressions in referring by native and non-native speakers. *Discourse Processes*, 23, 119–147. doi:10.1080/01638537709544986
- Boucher, J. (2000). Time Parsing, Normal Language Acquisition, and Language-Related Developmental Disorders. In *New Directions In Language Development And Disorders* (pp. 13–23). doi:10.1007/978-1-4615-4157-8
- Boucher, J. (2003). Language development in autism. *International Journal of Pediatric Otorhinolaryngology*, 67, 159-63. doi:10.1016/j.ijporl.2003.08.016
- Boucher, J. (2012). Research Review: Structural language in autistic spectrum disorder - characteristics and causes. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 53(3), 219–233. doi:10.1111/j.1469-7610.2011.02508.x
- Bowler, D. M. (1992). “Theory of mind” in Asperger’s syndrome. *Journal of Child Psychology and Psychiatry*, 33(5), 877–893. doi:0021-9630/92
- Boyd, B. A., Conroy, M. A., Mancil, G. R., Nakao, T., & Alter, P. J. (2007). Effects of circumscribed interests on the social behaviors of children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 37, 1550–1561. doi:10.1007/s10803-006-0286-8

- Bradac, J., Mulac, A., & House, A. (1988). Lexical diversity and magnitude of convergent versus divergent style shifting perceptual and evaluative consequences. *Language and Communication*, 8(3-4), 213–228.
- Branigan, H., McLean, J. F., & Jones, M. (2005). A blue cat or a cat that is blue? Evidence for abstract syntax in young children's noun phrases. In A. Brugos, M. R. Clark-Cotton, & S. Ha (Eds.), *Proceedings of the 29th annual Boston University conference on language development*. Somerville, MA: Cascadilla Press.
- Branigan, H. P., Garrod, S. C., & Pickering, M. J. (2014). Alignment (interactive) in language development. In the *Encyclopedia of Language Development* (pp. 13-16). London: Sage Publications.
- Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition*, 75(2), B13–25. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/10771277>
- Branigan, H. P., Pickering, M. J., Pearson, J., & McLean, J. F. (2010). Linguistic alignment between people and computers. *Journal of Pragmatics*, 42(9), 2355–2368. doi:10.1016/j.pragma.2009.12.012
- Branigan, H. P., Pickering, M. J., Pearson, J., McLean, J. F., & Brown, A. (2011). The role of beliefs in lexical alignment: evidence from dialogs with humans and computers. *Cognition*, 121(1), 41–57. doi:10.1016/j.cognition.2011.05.011
- Branigan, H. P., Pickering, M. J., Stewart, A. J., & McLean, J. F. (2000). Syntactic priming in spoken production: linguistic and temporal interference. *Memory & Cognition*, 28(8), 1297–302. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/11219957>
- Brennan, S. E., & Clark, H. H. (1996). Conceptual pacts and lexical choice in conversation. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, 22(6), 1482–93. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/8921603>
- Brown-Schmidt, S. (2009). The role of executive function in perspective taking during online language comprehension. *Psychonomic Bulletin & Review*, 16(5), 893–900. doi:10.3758/PBR.16.5.893
- Bruinsma, Y., Koegel, R. L., & Koegel, L. K. (2004). Joint attention and children with autism: A review of the literature. *Mental Retardation and Developmental Disabilities Research Reviews*, 10(3), 169–175. doi:10.1002/mrdd.20036
- Capps, L., Kehres, J., & Sigman, M. (1998). Conversational Abilities Among Children with Autism and Children with Developmental Delays. *Autism*, 2(4), 325–344. doi:10.1177/1362361398024002
- Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, 72(4), 1032–1053. doi:10.1111/1467-8624.00333

- Carlson, S. M., Moses, L. J., & Hix, H. R. (1998). The role of inhibitory processes in young children's difficulties with deception and false belief. *Child Development*, 69, 672-92. doi:10.2307/1132197
- Carpenter, M., Uebel, J., & Tomasello, M. (2013). Being mimicked increases prosocial behavior in 18-month-old infants. *Child Development*, 84(5), 1511-8. doi:10.1111/cdev.12083
- Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review*, 113, 234-272. doi:10.1037/0033-295X.113.2.234
- Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: the perception-behavior link and social interaction. *Journal of Personality and Social Psychology*, 76(6), 893-910. doi:10.1037/0022-3514.76.6.893
- Cherry, E. C. (1956). *On human communication*. Cambridge, MA: MIT Press.
- Chevallier, C., Kohls, G., Troiani, V., Brodtkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Sciences*, 16(4), 231-9. doi:10.1016/j.tics.2012.02.007
- Chin, H. Y., & Bernard-Opitz, V. Teaching conversational skills to children with autism: effect on the development of a theory of mind. *Journal of Autism and Developmental Disorders*, 30(6), 569-583 (2000). doi:11261468
- Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.
- Clark, H. (1996). *Using Language*. Cambridge: Cambridge University Press.
- Clark, H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. *Cognition*, 22(1), 1-39. doi:10.1016/0010-0277(86)90010-7
- Clark, H., & Marshall, C. (1981). Definite reference and mutual knowledge. In A. K. Joshe, B. Webber, & I. A. Sag (Eds.), *Elements of discourse understanding*. Cambridge: Cambridge University Press.
- Cleland, A. A., & Pickering, M. J. (2003). The use of lexical and syntactic information in language production: Evidence from the priming of noun-phrase structure. *Journal of Memory and Language*, 49(2), 214-230. doi:10.1016/S0749-596X(03)00060-3
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2<sup>nd</sup> ed.) Hillsdale, NJ: Lawrence Erlbaum.
- Cowan, B. R., Branigan, H. P., & Beale, R. (2011). Investigating the impact of interlocutor voice on syntactic alignment in human-computer dialogue. *Proceedings of BCS HCI 2012*, Birmingham, UK, 39-48.
- Dale, R., & Spivey, M. J. (2006). Unraveling the Dyad: Using Recurrence Analysis to Explore Patterns of Syntactic Coordination Between Children and Caregivers in Conversation, *Language Learning*, 56(3), 391-430.

- Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the nature of face processing impairment in autism: insights from behavioral and electrophysiological studies. *Developmental Neuropsychology*, 27(3), 403–24. doi:10.1207/s15326942dn2703\_6
- de Villiers, J. (2000). Language and theory of mind: what are the developmental relationships? In S. Baron-Cohen, H. Tager-Flusberg, & D. Cohen (Eds.), *Understanding other minds: Perspectives from developmental cognitive neuroscience* (Second Edi., pp. 83–123). Oxford: Oxford University Press.
- de Villiers, J. (2007). The Interface of Language and Theory of Mind. *Lingua*, 117(11), 1858–1878. doi:10.1016/j.lingua.2006.11.006
- Delaney, H. D., & Maxwell, S. E. (1981). On Using Analysis Of Covariance In Repeated Measures Designs. *Multivariate Behavioral Research*, 16, 105–123. doi:10.1207/s15327906mbr1601\_6
- Dickson, W. P. (1982). Two decades of referential communication research: A review and meta- analysis. In C. J. Brainerd & M. Pressley (Eds.), *Verbal processes in children* (pp. 1–33). New York: Springer.
- Diehl, J. J., & Paul, R. (2012). Acoustic Differences In The Imitation Of Prosodic Patterns In Children With Autism Spectrum Disorders. *Research in Autism Spectrum Disorders*, 6(1), 123–134. doi:10.1016/j.rasd.2011.03.012
- Dijksterhuis, A., & Bargh, J. A. (2001). The perception-behavior expressway: Automatic effects of social perception on social behavior. *Advances in Experimental Social Psychology*, 33, 1–40. doi:10.1016/S0065-2601(01)80003-4
- Dixon, P. (2008). Models of accuracy in repeated-measures designs. *Journal of Memory and Language*, 59(4), 447–456. doi:10.1016/j.jml.2007.11.004
- Dunn, J., & Kendrick, C. (1982). The speech of two- and three-year-olds to infant siblings: “baby talk” and the context of communication. *Journal of Child Language*, 9(3), 579–595. doi:10.1017/S030500090000492X
- Dunn, L. M., Dunn, D. M., & Styles, B. (2009). *British Picture Vocabulary Scale*. London: GL Assessment.
- Eales, M. J. (1993). Pragmatic impairments in adults with childhood diagnoses of autism or developmental receptive language disorder. *Journal of Autism and Developmental Disorders*, 23(4), 593–617. doi:10.1007/BF01046104
- Eisenmajer, R., & Prior, M. (1991). Cognitive linguistic correlates of theory of mind ability in autistic children. *British Journal of Developmental Psychology*, 9(2), 351–364. doi:10.1111/j.2044-835X.1991.tb00882.x
- Emerich, D. M., Creaghead, N. a., Grether, S. M., Murray, D., & Grasha, C. (2003). The comprehension of humorous materials by adolescents with high-functioning autism and Asperger’s syndrome. *Journal of Autism and Developmental Disorders*, 33(3), 253–257. doi:10.1023/A:1024498232284



- Eskritt, M., Whalen, J., & Lee, K. (2008). Preschoolers can recognize violations of the Gricean maxims. *The British Journal of Developmental Psychology*, 26(3), 435–443. doi:10.1348/026151007X253260
- Field, T., Ezell, S., Nadel, J., Grace, A., Allender, S., & Siddalingappa, V. (2013). Reciprocal Imitation Following Adult Imitation by Children with Autism. *Infant & Child Development*, 22(6), 642–648. doi:10.1002/icd.1812
- Flavell, J. H., Green, F. L., & Flavell, E. R. (1986). Development of knowledge about the appearance-reality distinction. *Child Development*, 51(1), 1–87. doi:10.1037/0003-066X.41.4.418
- Fletcher-Watson, S., Leekam, S. R., Benson, V., Frank, M. C., & Findlay, J. M. (2009). Eye-movements reveal attention to social information in autism spectrum disorder. *Neuropsychologia*, 47(1), 248–257. doi:10.1016/j.neuropsychologia.2008.07.016
- Flynn, E., O'Malley, C., & Wood, D. (2004). A longitudinal, microgenetic study of the emergence of false belief understanding and inhibition skills. *Developmental Science*, 7(1), 103–115. doi:10.1111/j.1467-7687.2004.00326.x
- Francis, K. (2005). Autism interventions: a critical update. *Developmental Medicine and Child Neurology*, 47(7), 493–499. doi:10.1111/j.1469-8749.2005.tb01178.x
- Freitag, C. M. (2007). The genetics of autistic disorders and its clinical relevance: a review of the literature. *Mol Psychiatry*, 12, 2–22. doi:10.1038/sj.mp.4001896
- Frith, U. (1989). *Autism: explaining the enigma*. Oxford: Basil Blackwell.
- Frith, U., Morton, J., & Leslie, A. M. (1991). The cognitive basis of a biological disorder: autism. *Trends in Neurosciences*, 14(10), 433–438. doi:10.1016/0166-2236(91)90041-R
- Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development*, 10(4), 483–527. doi:10.1016/0885-2014(95)90024-1
- Fusaroli, R., Bahrami, B., Olsen, K., Roepstorff, A., Rees, G., Frith, C., & Tylén, K. (2012). Coming to Terms: Quantifying the Benefits of Linguistic Coordination. *Psychological Science*, 23(8), 931–9. doi:10.1177/0956797612436816
- Fusaroli, R., Weed, E., Fein, D., & Naigles, L. (in prep). Learning to Interact: Developmental trajectories of linguistic alignment in ASD.
- García-Pérez, R. M., Lee, A., & Hobson, R. P. (2007). On intersubjective engagement in autism: A controlled study of nonverbal aspects of conversation. *Journal of Autism and Developmental Disorders*, 37(7), 1310–1322. doi:10.1007/s10803-006-0276-x
- Garnham, A. (1985). *Psycholinguistics: Central Topics*. London: Routledge.
- Garrod, S., & Anderson, A. (1987). Saying what you mean in dialogue: a study in conceptual and semantic co-ordination. *Cognition*, 27(2), 181–218. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/3691025>

- Garrod, S., & Clark, A. (1993). The development of dialogue co-ordination skills in school children. *Language and Cognitive Processes*, 8, 101–26. doi:10.1080/01690969308406950
- Garrod, S., & Pickering, M. J. (2004). Why is conversation so easy? *Trends in Cognitive Sciences*, 8(1), 8–11. doi:10.1016/j.tics.2003.10.016
- Geller, E. (1998). An investigation of communication breakdowns and repairs in verbal autistic children. *The British Journal of Developmental Disabilities*, 44(2), 71–85.
- Gerard, J., Keller, F., & Palpanas, T. (2010). Corpus evidence for age effects on priming in child language. Paper presented at the 32nd annual conference of the Cognitive Science Society. Portland, OR.
- Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: performance of children 3 1/2–7 years old on a stroop- like day-night test. *Cognition*. doi:10.1016/0010-0277(94)90068-X
- Geurts, H. M., & Embrechts, M. (2008). Language profiles in ASD, SLI, and ADHD. *Journal of Autism and Developmental Disorders*, 38(10), 1931–43. doi:10.1007/s10803-008-0587-1
- Geurts, H. M., van den Bergh, S. F. W. M., & Ruzzano, L. (2014). Prepotent response inhibition and interference control in autism spectrum disorders: Two Meta-Analyses. *Autism Research*, 7(4), 407–420. doi:10.1002/aur.1369
- Ghaziuddin, M., & Gerstein, L. (1996). Pedantic speaking style differentiates Asperger syndrome from high-functioning autism. *Journal of Autism and Developmental Disorders*, 26(6), 585–595. doi:10.1007/BF02172348
- Giles, H., Coupland, J., & Coupland, N. (1991). Accommodation theory: communication, context, and consequence. In H. Giles, J. Coupland, & N. Coupland (Eds.), *Contexts of accommodation: Developments in Applied Sociolinguistics* (pp. 1–68). Cambridge: Cambridge University Press.
- Giles, H., & Powesland, P. (1975). *Speech Style and Social Evaluation*. London: Academic Press.
- Ginzburg, J. (2001). Clarification ellipsis and nominal anaphora. In H. Bunt (Ed.), *Computing Meaning, Volume 2*. Dordrecht: Kluwer.
- Gopnik, a, & Astington, J. W. (1988). Children's understanding of representational change and its relation to the understanding of false belief and the appearance-reality distinction. *Child Development*, 59(1), 26–37. doi:10.2307/1130386
- Grabrucker, A. M. (2012). Environmental factors in autism. *Frontiers in Psychiatry*, 3, 118. doi:10.3389/fpsy.2012.00118
- Grice, H. P. (1975). Logic and conversation. In *Syntax and semantics: Vol. 3., Speech acts* (pp. 41–58). New York: Academic Press.

- Gries, S. T. (2005). Syntactic priming: a corpus-based approach. *Journal of Psycholinguistic Research*, 34(4), 365–99. doi:10.1007/s10936-005-6139-3
- Griffith, E. M., Pennington, B. F., Wehner, E. A., & Rogers, S. J. (1999). Executive functions in young children with autism. *Child Development*, 70(4), 817–832. doi:10.1111/1467-8624.00059
- Gropen, J., Pinker, S., Hollander, M., Goldberg, R., & Wilson, R. (1989). The Learnability and Acquisition of the Dative Alternation in English. *Language*, 65(2), 203–257.
- Grossi, D., Marcone, R., Cinquegrana, T., & Gallucci, M. (2013). On the differential nature of induced and incidental echolalia in autism. *Journal of Intellectual Disability Research*, 57(10), 903–12. doi:10.1111/j.1365-2788.2012.01579.x
- Grzadzinski, R., Huerta, M., & Lord, C. (2013). DSM-5 and autism spectrum disorders (ASDs): an opportunity for identifying ASD subtypes. *Molecular Autism*, 4(1), 12. doi:10.1186/2040-2392-4-12
- Hadwin, J., Baron-Cohen, S., Howlin, P., & Hill, K. (1997). Does teaching theory of mind have an effect on the ability to develop conversation in children with autism? *Journal of Autism and Developmental Disorders*, 27(5), 519–37. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/9403370>
- Hale, C. M., & Tager-Flusberg, H. (2003). The influence of language on theory of mind: A training study. *Developmental Science*, 6(3), 346–359. doi:10.1111/1467-7687.00289
- Hale, C. M., & Tager-Flusberg, H. (2005). Social communication in children with autism: the relationship between theory of mind and discourse development. *Autism: The International Journal of Research and Practice*, 9(2), 157–178. doi:10.1177/1362361305051395
- Halladay, A. K., Bishop, S., Constantino, J. N., Daniels, A. M., Koenig, K., Palmer, K., Szatmari, P. (2015). Sex and gender differences in autism spectrum disorder: summarizing evidence gaps and identifying emerging areas of priority. *Molecular Autism*, 6, 36. doi:10.1186/s13229-015-0019-y
- Hanley, M., McPhillips, M., Mulhern, G., & Riby, D. M. (2013). Spontaneous attention to faces in Asperger syndrome using ecologically valid static stimuli. *Autism*, 17(6), 754–761. doi:10.1177/1362361312456746
- Happé, F., Ehlers, S., Fletcher, P., Frith, U., Johansson, M., Gillberg, C., Frith, C. (1996). “Theory of mind” in the brain. Evidence from a PET scan study of Asperger syndrome. *Neuroreport*, 8(1), 197–201. doi:10.1097/00001756-199612200-00040
- Happé, F. G. (1993). Communicative competence and theory of mind in autism: a test of relevance theory. *Cognition*, 48(2), 101–19. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/8243028>

- Happé, F. G. (1995). The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Development*, 66(3), 843–855. doi:10.1111/1467-8624.ep9506152729
- Happé, F., Ronald, A., & Plomin, R. (2006). Time to give up on a single explanation for autism. *Nature Neuroscience*, 9(10), 1218–1220. doi:10.1038/nn1770
- Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review*, 20(3), 290–322. doi:10.1007/s11065-010-9138-6
- Hartsuiker, R. J., & Kolk, H. H. (1998). Syntactic persistence in Dutch. *Language and Speech*, 41 (Pt 2), 143–184. doi:10.1177/002383099804100202
- Hartung, J. R. (1970). A review of procedures to increase verbal imitation skills and functional speech in autistic children. *Journal of Speech & Hearing Disorders*, 35, 203–217.
- Haywood, S. L., Pickering, M. J., & Branigan, H. P. (2005). Do speakers avoid ambiguities during dialogue? *Psychological Science*, 16(5), 362–366. doi:10.1111/j.0956-7976.2005.01541.x
- Healey, P. G. T., Purver, M., & Howes, C. (2014). Divergence in dialogue. *PLoS ONE*, 9(6). doi:10.1371/journal.pone.0098598
- Herbert, M. R., Russo, J. P., Yang, S., Roohi, J., Blaxill, M., Kahler, S. G., Hatchwell, E. (2006). Autism and environmental genomics. *NeuroToxicology*, 27(5), 671–684. doi:10.1016/j.neuro.2006.03.017
- Hill, E. L. (2004). Evaluating the theory of executive dysfunction in autism. *Developmental Review*, 24(2), 189–233. doi:10.1016/j.dr.2004.01.001
- Hill, E. L., & Bird, C. M. (2006). Executive processes in Asperger syndrome: Patterns of performance in a multiple case series. *Neuropsychologia*, 44(14), 2822–2835. doi:10.1016/j.neuropsychologia.2006.06.007
- Hilton, C., Graver, K., & LaVesser, P. (2007). Relationship between social competence and sensory processing in children with high functioning autism spectrum disorders. *Research in Autism Spectrum Disorders*, 1(2), 164–173. doi:10.1016/j.rasd.2006.10.002
- Hobson, P. (1989). Beyond cognition: a theory of autism. In *Autism: Nature, diagnosis, and treatment* (pp. 22–48). New York: Guilford Press.
- Hobson, R. P. (1986). The autistic child's appraisal of expressions of emotion: a further study. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 27(5), 671–680. doi:10.1111/j.1469-7610.1986.tb01836.x
- Hobson, R. P., Hobson, J. A., García-Pérez, R., & Du Bois, J. (2012). Dialogic linkage and resonance in autism. *Journal of Autism and Developmental Disorders*, 42(12), 2718–28. doi:10.1007/s10803-012-1528-6

- Hobson, R. P., & Hobson, J. A. (2008). Dissociable aspects of imitation: A study in autism. *Journal of Experimental Child Psychology*, 101(3), 170–185. doi:10.1016/j.jecp.2008.04.007
- Holler, J., & Wilkin, K. (2011). Co-Speech Gesture Mimicry in the Process of Collaborative Referring During Face-to-Face Dialogue. *Journal of Nonverbal Behavior*, 35(2), 133–153. doi:10.1007/s10919-011-0105-6
- Honey, E., Leekam, S., Turner, M., & McConachie, H. (2007). Repetitive Behaviour and Play in Typically Developing Children and Children with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, 37(6), 1107–1115. doi:10.1007/s10803-006-0253-4
- Hopkins, Z., Yuill, N., & Keller, B. (2015). Children with autism align syntax in natural conversation. *Applied Psycholinguistics*. Advance online publication. doi:10.1017/S0142716414000599
- Howes, C., Healey, P., & Purver, M. (2010). Tracking lexical and syntactic alignment in conversation. *Proc. of CogSci*, 9(2), 2004–2009. Retrieved from <http://mindmodeling.org/cogsci2010/papers/0484/paper0484.pdf>
- Howlin, P. (2000). Outcome in Adult Life for more Able Individuals with Autism or Asperger Syndrome. *Autism*, 4(1), 63–83. doi:10.1177/1362361300004001005
- Hughes, C., & Russell, J. (1993). Autistic children's difficulty with mental disengagement from an object: Its implications for theories of autism. *Developmental Psychology*, 29(3), 498–510. doi:10.1037/0012-1649.29.3.498
- Ingersoll, B. (2008). Imitation in Autism: Implications for the Treatment of Imitation Deficits and Social Communication. *Infants & Young Children*, 21(2), 107–119. doi:10.1097/01.IYC.0000314482.24087.14
- Jaeger, T. F. (2009). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, 59, 434–446. doi:10.1016/j.jml.2007.11.007
- Joseph, R. M., & Tager-Flusberg, H. (2004). The relationship of theory of mind and executive functions to symptom type and severity in children with autism. *Development and Psychopathology*, 16(1), 137–155. doi:10.1017/S095457940404444X
- Just, M. A., Keller, T. A., Malave, V. L., Kana, R. K., & Varma, S. (2012). Autism as a neural systems disorder: a theory of frontal-posterior underconnectivity. *Neuroscience and Biobehavioral Reviews*, 36(4), 1292–313. doi:10.1016/j.neubiorev.2012.02.007
- Kaminsky, L., & Dewey, D. (2001). Siblings relationships of children with autism. *Journal of Autism and Developmental Disorders*, 31(4), 399–410. doi:10.1023/A:1010664603039
- Kana, R. K., Maximo, J. O., Williams, D. L., Keller, T. A., Schipul, S. E., Cherkassky, V. L., Just, M. A. (2015). Aberrant functioning of the theory-of-mind network in children and adolescents with autism. *Molecular Autism*, 6(1), 1–12. doi:10.1186/s13229-015-0052-x

- Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, 2, 217–250.
- Kasari, C., Locke, J., Gulsrud, A., & Rotheram-Fuller, E. (2011). Social networks and friendships at school: Comparing children with and without ASD. *Journal of Autism and Developmental Disorders*, 41(5), 533–544. doi:10.1007/s10803-010-1076-x
- Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman Brief Intelligence Test* (Second edi.). Bloomington, IL: Pearson.
- Kenny, L., Hattersley, C., Molins, B., Buckley, C., Povey, C., & Pellicano, E. (2015). Which terms should be used to describe autism? Perspectives from the UK autism community. *Autism*, 55–59. doi:10.1177/1362361315588200
- Kidd, E. (2011). Individual differences in syntactic priming in language acquisition. *Applied Psycholinguistics*, 33(02), 393–418. doi:10.1017/S0142716411000415
- Kjelgaard, M. M., & Tager-Flusberg, H. (2001). An Investigation of Language Impairment in Autism: Implications for Genetic Subgroups. *Language and Cognitive Processes*, 16(2-3), 287–308. doi:10.1080/01690960042000058
- Kleinman, J., Marciano, P. L., & Ault, R. L. (2001). Advanced Theory of Mind in High-Functioning Adults with Autism. *Journal of Autism and Developmental Disorders*, 31(1), 29–36. doi:10.1023/A:1005657512379
- Klin, A. (1991). Young autistic children's listening preferences in regard to speech: A possible characterization of the symptom of social withdrawal. *Journal of Autism and Developmental Disorders*, 21(1), 29–42. doi:10.1007/BF02206995
- Klin, A., Jones, W., Schultz, R., & Volkmar, F. (2003). The enactive mind, or from actions to cognition: lessons from autism. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 358(1430), 345–60. doi:10.1098/rstb.2002.1202
- Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Defining and quantifying the social phenotype in autism. *The American Journal of Psychiatry*, 159, 895–908. doi:10.1176/appi.ajp.159.6.895
- Kreitmayer, S. (2014). *iPad maze game (unpublished manuscript)*. University of Sussex, School of Psychology.
- Kuhl, P. K., Coffey-Corina, S., Padden, D., & Dawson, G. (2005). Links between social and linguistic processing of speech in preschool children with autism: behavioral and electrophysiological measures. *Dev Sci*, 8(1), F1–F12. doi:10.1111/j.1467-7687.2004.00384.x
- Lakin, J. L., & Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychological Science*, 14, 334–339. doi:10.1111/1467-9280.14481
- Landa, R. J. (2008). Diagnosis of autism spectrum disorders in the first 3 years of life. *Nature Clinical Practice. Neurology*, 4(3), 138–147. doi:10.1038/ncpneuro0731

- Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33(1), 159–174. doi:10.2307/2529310
- Leekam, S. R., & Perner, J. (1991). Does the autistic child have a metarepresentational deficit? *Cognition*, 40(3), 203–218. doi:10.1016/0010-0277(91)90025-Y
- Leinonen, E. K., & Letts, C. (1997). Referential communication tasks: Performance by normal and pragmatically impaired children. *European Journal of Disorders of Communication*, 32, 53–65.
- Levelt, W. J. & Kelter, S. (1982). Surface form and memory in question answering. *Cognitive Psychology*, 14, 78–106. doi:10.1016/0010-0285(82)90005-6
- Lewis, M. H., & Bodfish, J. W. (1998). Repetitive behaviour disorders in autism. *Mental Retardation and Developmental Disabilities Research Reviews*, 4(2), 80–89. doi:10.1002/(SICI)1098-2779(1998)4:2<80::AID-MRDD4>3.0.CO;2-0
- Liebal, K., Colombi, C., Rogers, S. J., Warneken, F., & Tomasello, M. (2008). Helping and cooperation in children with autism. *Journal of Autism and Developmental Disorders*, 38(2), 224–38. doi:10.1007/s10803-007-0381-5
- Lind, S. E., & Bowler, D. M. (2009). Language and theory of mind in autism spectrum disorder: the relationship between complement syntax and false belief task performance. *Journal of Autism and Developmental Disorders*, 39(6), 929–37. doi:10.1007/s10803-009-0702-y
- Loveland, K. A., & Tunali, B. (1991). Social scripts for conversational interactions in autism and Down syndrome. *Journal of Autism and Developmental Disorders*, 21(2), 177–186. doi:10.1007/BF02284758
- Loveland, K. A., Tunalia, B., Mcevoy, R. E., & Kelley, M. L. (1989). Referential communication and response adequacy in autism and Down's syndrome. *Applied Psycholinguistics*, 10(3), 301-313. doi:10.1017/S014271640000864X
- Magonde, M., & Keller, B. (2014). Syntactic alignment software (unpublished manuscript). University of Sussex, Department of Informatics.
- Malle, B. F. (2002). The relation between language and theory of mind in development and evolution. In T. Givón & B. F. Malle (Eds.), *The evolution of language out of pre-language* (pp. 265-284). Amsterdam: Benjamins.
- Marsh, L., Pearson, A., Ropar, D., & Hamilton, A. (2013). Children with autism do not overimitate. *Current Biology*. doi:10.1016/j.cub.2013.02.036
- Matson, J. L., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorders. *Research in Autism Spectrum Disorders*, 5(1), 418–425. doi:10.1016/j.rasd.2010.06.004

- Matson, J. L., Wilkins, J., Sevin, J. a., Knight, C., Boisjoli, J. a., & Sharp, B. (2009). Reliability and item content of the Baby and Infant Screen for Children with aUtism Traits (BISCUIT): Parts 1-3. *Research in Autism Spectrum Disorders*, 3, 336–344. doi:10.1016/j.rasd.2008.08.001
- McEvoy, R. E., Rogers, S. J., & Pennington, B. F. (1993). Executive function and social communication deficits in young autistic children. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 34(4), 563–78. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/7685360>
- Menenti, L., Pickering, M. J., & Garrod, S. C. (2012). Toward a neural basis of interactive alignment in conversation. *Frontiers in Human Neuroscience*, 6(June), 185. doi:10.3389/fnhum.2012.00185
- Merrison, S., & Merrison, A. J. (2005). Repair in speech and language therapy interaction: Investigating pragmatic language impairment of children. *Child Language Teaching and Therapy*, 21(2), 191–212. doi:10.1191/0265659005ct288oa
- Messenger, K., Branigan, H. P., & McLean, J. F. (2011). Evidence for (shared) abstract structure underlying children's short and full passives. *Cognition*, 121(2), 268–74. doi:10.1016/j.cognition.2011.07.003
- Messenger, K., McLean, J. F., Branigan, H. P., & Sorace, A. (2012). Is young children's passive syntax semantically constrained? Evidence from syntactic priming. *Journal of Memory and Language*, 66(4), 568–587. doi:10.1016/j.jml.2012.03.008
- Militerni, R., Bravaccio, C., Falco, C., Fico, C., & Palermo, M. T. (2002). Repetitive behaviors in autistic disorder. *European Child and Adolescent Psychiatry*, 11, 210–218. doi:10.1007/s00787-002-0279-x
- Mitchell, P., Robinson, E. J., & Thompson, D. E. (1999). Children's understanding that utterances emanate from minds: Using speaker belief to aid interpretation. *Cognition*, 72, 45–66. doi:10.1016/S0010-0277(99)00030-X
- Mitchell, P., Saltmarsh, R., & Russell, H. (1997). Overly literal interpretations of speech in autism: understanding that messages arise from minds. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 38(6), 685–91. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/9315978>
- Mostert-Kerckhoffs, M. A., Staal, W. G., Houben, R. H., & Jonge, M. V. (2015). Stop and change: Inhibition and flexibility skills are related to repetitive behavior in children and young adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 45(10), 3148–3158. doi:<http://dx.doi.org/10.1007/s10803-015-2473-y>
- Mottron, L. (2004). Matching Strategies in Cognitive Research with Individuals with High-Functioning Autism: Current Practices, Instrument Biases, and Recommendations. *Journal of Autism and Developmental Disorders*, 34(1), 19–27. doi:10.1023/B:JADD.0000018070.88380.83



- Mullen, E. M. (1995). Mullen Scales of Early Learning, AGS Edition: Manual and Item Administrative Books. *American Guidance Services, Inc.*, 1–92.
- Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. *Journal of Autism and Developmental Disorders*, 20(1), 115–128. doi:10.1007/bf02206861
- Nassar, N., Dixon, G., Bourke, J., Bower, C., Glasson, E., De Klerk, N., & Leonard, H. (2009). Autism spectrum disorders in young children: Effect of changes in diagnostic practices. *International Journal of Epidemiology*, 38(5), 1245–1254. doi:10.1093/ije/dyp260
- Nation, K., & Penny, S. (2008). Sensitivity to eye gaze in autism: is it normal? Is it automatic? Is it social? *Development and Psychopathology*, 20(1), 79–97. doi:10.1017/S0954579408000047
- Nilsen, E. S., & Fecica, A. M. (2011). A model of communicative perspective-taking for typical and atypical populations of children. *Developmental Review*, 31(1), 55–78. doi:10.1016/j.dr.2011.07.001
- Nilsen, E. S., & Graham, S. a. (2009). The relations between children's communicative perspective-taking and executive functioning. *Cognitive Psychology*, 58(2), 220–49. doi:10.1016/j.cogpsych.2008.07.002
- Norbury, C. F. (2005). The relationship between theory of mind and metaphor: Evidence from children with language impairment and autistic spectrum disorder. *British Journal of Developmental Psychology*, 23(3), 383–399. doi:10.1348/026151005X26732
- Orsmond, G. I., Krauss, M. W., & Seltzer, M. M. (2004). Peer relationships and social and recreational activities among adolescents and adults with autism. *Journal of Autism and Developmental Disorders*, 34(3), 245–256. doi:10.1023/B:JADD.0000029547.96610.df
- Osborne, E., & Allen, M. L. (2012). Evidence for lexical alignment in children with autistic spectrum disorder. In *2012 BPS Developmental Section Annual Conference*. University of Strathclyde, Glasgow.
- Over, H., & Carpenter, M. (2009). Priming third-party ostracism increases affiliative imitation in children. *Developmental Science*, 12(3). doi:10.1111/j.1467-7687.2008.00820.x
- Ozonoff, S., & Jensen, J. (1999). Specific executive function profiles in three neurodevelopmental disorders. *Journal of Autism and Developmental Disorders*, 29(2), 171–177. doi:10.1023/A:1023052913110
- Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1990). Are there Emotion Perception Deficits in Young Autistic Children? *Journal of Child Psychology and Psychiatry*, 31(3), 343–361. doi:10.1111/j.1469-7610.1990.tb01574.x

- Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic individuals: relationship to theory of mind. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 32(7), 1081–1105. doi:10.1111/j.1469-7610.1991.tb00351.x
- Ozonoff, S., Rogers, S. J., & Pennington, B. F. (1991). Asperger's Syndrome: Evidence of an Empirical Distinction from High-Functioning Autism. *Journal of Child Psychology and Psychiatry*, 32(7), 1107–1122. doi:10.1111/j.1469-7610.1991.tb00352.x
- Ozonoff, S., & Strayer, D. L. (2001). Further evidence of intact working memory in autism. *Journal of Autism and Developmental Disorders*, 31(3), 257–63. doi:10.1023/A:1010794902139
- Ozonoff, S., Young, G. S., Carter, A., Messinger, D., Yirmiya, N., Zwaigenbaum, L., ... Stone, W. L. (2011). Recurrence risk for autism spectrum disorders: a Baby Siblings Research Consortium study. *Pediatrics*, 128(3), e488–95. doi:10.1542/peds.2010-2825
- Paul, R. (2005). Assessing communication in autism spectrum disorders. In F. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.), *Handbook of Autism and Pervasive Developmental Disorders, Volume 2* (3<sup>rd</sup> ed.) New York: Wiley & Sons.
- Pearlman-Avnion, S., & Eviatar, Z. (2002). Narrative analysis in developmental social and linguistic pathologies: dissociation between emotional and informational language use. *Brain and Cognition*, 48, 494–499. doi:10.1006/brcg.2001.1401
- Pellicano, E. (2007). Links between theory of mind and executive function in young children with autism: clues to developmental primacy. *Developmental Psychology*, 43(4), 974–990. doi:10.1037/0012-1649.43.4.974
- Pennington, B., Rogers, S., & Bennetto, L. (1997). Validity tests of the executive dysfunction hypothesis of autism. In J. Russell (Ed.), *Autism as an executive disorder* (pp. 143–178). Oxford: Oxford University Press.
- Perner, J. (1998). The meta-intentional nature of executive functions and theory of mind. In P. Carruthers & J. Boucher (Eds.), *Language and Thought: Interdisciplinary themes* (pp. 270–283). Cambridge: Cambridge University Press.
- Perner, J., & Wimmer, H. (1985). “John thinks that Mary thinks that...” attribution of second-order beliefs by 5- to 10-year-old children. *Journal of Experimental Child Psychology*, 39(3), 437–471. doi:10.1016/0022-0965(85)90051-7
- Persicke, A., Tarbox, J., Ranick, J., & St. Clair, M. (2013). Teaching children with autism to detect and respond to sarcasm. *Research in Autism Spectrum Disorders*, 7(1), 193–198. doi:10.1016/j.rasd.2012.08.005
- Peterson, C. C., Wellman, H. M., & Liu, D. (2005). Steps in theory-of-mind development for children with deafness or autism. *Child Development*, 76(2), 502–517. doi:10.1111/j.1467-8624.2005.00859.x

- Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: evidence from syntactic priming in language production. *Journal of Memory and Language*, 39, 633–651. doi:10.1006/jmla.1998.2592
- Pickering, M. J., & Branigan, H. P. (1999). Syntactic priming in language production. *Trends in Cognitive Sciences*, 3, 136–141.
- Pickering, M. J., & Ferreira, V. S. (2008). Structural priming: a critical review. *Psychological Bulletin*, 134(3), 427–459. doi:10.1037/0033-2909.134.3.427
- Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *The Behavioral and Brain Sciences*, 27(2), 169–90; discussion 190–226. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/15595235>
- Port, R. G., Gandal, M. J., Roberts, T. P. L., Siegel, S. J., & Carlson, G. C. (2014). Convergence of circuit dysfunction in ASD: a common bridge between diverse genetic and environmental risk factors and common clinical electrophysiology. *Frontiers in Cellular Neuroscience*, 8, 414. doi:10.3389/fncel.2014.00414
- Premack, D., & Woodruff, G. (1978). Does the Chimpanzee have a Theory of Mind? *The Behavioral and Brain Sciences*, 34(1), 1401–1407. doi:10.1016/j.celrep.2011.1011.1001.7.
- Putman, W. B., & Street, R. L. (1984). The conception and perception of noncontent speech performance: implications for speech-accommodation theory. *International Journal of the Sociology of Language*, 46, 97–114. doi:10.1515/ijsl.1984.46.97
- Quade, D. (1967). Rank analysis of covariance. *Journal of the American Statistical Association*, 62, 1187–1200. doi:10.1080/01621459.1967.10500925
- Rapin, I., & Dunn, M. (2003). Update on the language disorders of individuals on the autistic spectrum. *Brain and Development*, 25(3), 166–172. doi:10.1016/S0387-7604(02)00191-2
- Rapin, I., Dunn, M. A., Allen, D. A., Stevens, M. C., & Fein, D. (2009). Subtypes of language disorders in school-age children with autism. *Developmental Neuropsychology*, 34(1), 66 – 84. doi:10.1080/87565640802564648
- Reitter, D., & Moore, J. D. (2014). Alignment and task success in spoken dialogue. *Journal of Memory and Language*, 76, 29–46. doi:10.1016/j.jml.2014.05.008
- Robertson, K., & Murachver, T. (2003). Children's Speech Accommodation to Gendered Language Styles. *Journal of Language and Social Psychology*, 22(3), 321–333. doi:10.1177/0261927X03255304
- Rodgers, J., Glod, M., Connolly, B., & McConachie, H. (2012). The relationship between anxiety and repetitive behaviours in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 42(11), 2404–2409. doi:10.1007/s10803-012-1531-y

- Roland, D., Dick, F., & Elman, J. L. (2007). Frequency of basic English grammatical structures: A corpus analysis. *Journal of Memory and Language*, 57, 348–379. doi:10.1016/j.jml.2007.03.002
- Ronald, A., Happé, F., & Plomin, R. (2005). The genetic relationship between individual differences in social and nonsocial behaviours characteristic of autism. *Developmental Science*, 8(5), 444–458. doi:10.1111/j.1467-7687.2005.00433.x
- Ross, D. E. (2002). Replacing faulty conversational exchanges for children with autism by establishing a functionally equivalent alternative response. *Education and Training in Mental Retardation and Developmental Disabilities*, 37(4), 343–362.
- Rowland, C. F., Chang, F., Ambridge, B., Pine, J. M., & Lieven, E. V. M. (2012). The development of abstract syntax: evidence from structural priming and the lexical boost. *Cognition*, 125(1), 49–63. doi:10.1016/j.cognition.2012.06.008
- Russell, J. (1997). How executive disorders can bring about an adequate theory of mind. In J. Russell (Ed.), *Autism as an executive disorder* (pp. 256–304). Oxford: Oxford University Press.
- Russell, J., Jarrold, C., & Henry, L. (1996). Working memory in children with autism and with moderate learning difficulties. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 37(6), 673–686. doi:10.1111/1469-7610.ep9702145190
- Rutter Bailey, A., & Lord, C., M. (2003). Social Communication Questionnaire. Los Angeles, CA; Western Psychological Services.
- Rutter, M. (1978). Diagnosis and definition. In M. Rutter & E. Schopler (Eds.), *Autism: a reappraisal of concepts and treatment*. New York: Plenum Press.
- Rutter, M. (2000). Genetic studies of autism: From the 1970s into the millennium. *Journal of Abnormal Child Psychology*, 28(1), 3–14. doi:10.1023/A:1005113900068
- Saastasti, S., Lepistö, T., Toppila, E., Kujala, T., Laakso, M., Wendt, T. N. Von, Jansson-Verkasalo, E. (2008). Language abilities of children with Asperger syndrome. *Journal of Autism and Developmental Disorders*, 38(8), 1574–1580. doi:10.1007/s10803-008-0540-3
- Saulnier, C. a., & Klin, A. (2007). Brief report: Social and communication abilities and disabilities in higher functioning individuals with autism and Asperger syndrome. *Journal of Autism and Developmental Disorders*, 37(4), 788–793. doi:10.1007/s10803-006-0288-6
- Schaafsma, S. M., Pfaff, D. W., Spunt, R. P., & Adolphs, R. (2015). Deconstructing and reconstructing theory of mind. *Trends in Cognitive Sciences*, 19(2), 65–72. doi:10.1016/j.tics.2014.11.007
- Shallice, T., Marzocchi, G. M., Coser, S., Del Savio, M., Meuter, R. F., & Rumati, R. I. (2002). Executive function profile of children with attention deficit hyperactivity disorder. *Developmental Neuropsychology*, 21, 43–71. doi:10.1207/S15326942DN2101\_3

- Shatz, M., & Gelman, R. (1973). The development of communication skills: modifications in the speech of young children as a function of listener. *Monographs of the Society for Research in Child Development*, 38(5), 1–38. doi:10.2307/1165783
- Shatz, M., Wellman, H. M., & Silber, S. (1983). The acquisition of mental verbs: a systematic investigation of the first reference to mental state. *Cognition*, 14(3), 301–321. doi:10.1016/0010-0277(83)90008-2
- Shih, P., Shen, M., Öttl, B., Keehn, B., Gaffrey, M. S., & Müller, R. A. (2010). Atypical network connectivity for imitation in autism spectrum disorder. *Neuropsychologia*, 48(10), 2931–2939. doi:10.1016/j.neuropsychologia.2010.05.035
- Shriberg, L. D., Paul, R., McSweeney, J. L., Klin, a M., Cohen, D. J., & Volkmar, F. R. (2001). Speech and prosody characteristics of adolescents and adults with high-functioning autism and Asperger syndrome. *Journal of Speech, Language, and Hearing Research*, 44(5), 1097–1115. doi:10.1044/1092-4388(2001/087)
- Slocombe, K. E., Alvarez, I., Branigan, H. P., Jellema, T., Burnett, H. G., Fischer, A., Levita, L. (2012). Linguistic Alignment in Adults with and Without Asperger's Syndrome. *Journal of Autism and Developmental Disorders*. doi:10.1007/s10803-012-1698-2
- So, W.-C., Wong, M. K.-Y., Lui, M., & Yip, V. (2014). The development of co-speech gesture and its semantic integration with speech in 6- to 12-year-old children with autism spectrum disorders. *Autism: The International Journal of Research and Practice*, 1362361314556783–. doi:10.1177/1362361314556783
- Speirs, S., Yelland, G., Rinehart, N., & Tonge, B. (2011). Lexical processing in individuals with high-functioning autism and Asperger's disorder. *Autism: The International Journal of Research and Practice*, 15(3), 307–25. doi:10.1177/1362361310386501
- Sperber, D., & Wilson, D. (1986). *Relevance: communication and cognition*. Oxford: Blackwell.
- Spiker, M. A., Lin, C. E., Van Dyke, M., & Wood, J. J. (2012). Restricted interests and anxiety in children with autism. *Autism*, 16(3), 306–320. doi:10.1177/1362361311401763
- Stel, M., Van Baaren, R. B., Blascovich, J., Van Dijk, E., McCall, C., Pollmann, M. M. H., Vonk, R. (2010). Effects of a priori liking on the elicitation of mimicry. *Experimental Psychology*, 57(6), 412–418. doi:10.1027/1618-3169/a000050
- Stewart, S. L. K., Corcoran, R., & Drake, R. J. (2008). Alignment and theory of mind in schizophrenia. *Cognitive Neuropsychiatry*, 13(5), 431–448. doi:10.1080/13546800802405610
- Stockbridge, M. D., Happé, F. G. E., & White, S. J. (2013). Impaired Comprehension of Alternating Syntactic Constructions in Autism. *Autism Research*, 7(3), 314–21. doi:10.1002/aur.1348

- Stone, W. L., Ousley, O. Y., Yoder, P. J., Hogan, K. L., & Hepburn, S. L. (1997). Nonverbal communication in two- and three-year-old children with autism. *Journal of Autism and Developmental Disorders*, 27(6), 677–96. doi:10.1023/A:1025854816091
- Surian, L., Baron-Cohen, S., & Van der Lely, H. (1996). Are children with autism deaf to gricean maxims? *Cognitive Neuropsychiatry*, 1(1), 55–72. doi:10.1080/135468096396703
- Swettenham, J. G., Baron-Cohen, S., Gomez, J. C., & Walsh, S. (1996). What's inside someone's head? Conceiving of the mind as a camera helps children with autism acquire an alternative to a theory of mind. *Cognitive Neuropsychiatry*, 1(1), 73–88. doi:10.1080/135468096396712
- Tager-Flusberg, H. (1981). On the nature of linguistic functioning in early infantile autism. *Journal of Autism and Developmental Disorders*, 11(1), 45–56. doi:10.1007/BF01531340
- Tager-Flusberg, H. (1991). Semantic processing in the free recall of autistic children: Further evidence for a cognitive deficit. *British Journal of Developmental Psychology*, 9(3), 417–430. doi:10.1111/j.2044-835X.1991.tb00886.x
- Tager-Flusberg, H. (1993). What language reveals about the understanding of minds in children with autism. In S. Baron-Cohen, H. Tager-Flusberg, & D. J. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 138–157). Oxford: Oxford University Press.
- Tager-Flusberg, H. (2000). Language and understanding minds: Connections in autism. In *Understanding other minds: Perspectives from developmental cognitive neuroscience* (pp. 124–149). Oxford: Oxford University Press.
- Tager-Flusberg, H. (2006). Defining language phenotypes in autism. *Clinical Neuroscience Research*, 6(3–4), 219–224. doi:10.1016/j.cnr.2006.06.007
- Tager-Flusberg, H. (2011). False-belief tasks are distinct from theory of mind. *Spectrum*. Retrieved from <https://spectrumnews.org/opinion/viewpoint/false-belief-tasks-are-distinct-from-theory-of-mind/>
- Tager-Flusberg, H., & Anderson, M. (1991). The development of contingent discourse ability in autistic children. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 32(7), 1123–34. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/1838537>
- Tager-Flusberg, H., & Sullivan, K. (1994). A second look at second-order belief attribution in autism. *Journal of Autism and Developmental Disorders*, 24(5), 577–86. Retrieved from <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1201457&tool=pmcentrez&rendertype=abstract>
- Tager-Flusberg, H., & Sullivan, K. (2000). A componential view of theory of mind: evidence from Williams syndrome. *Cognition*, 76(1), 59–90. doi:10.1016/S0010-0277(00)00069-X

- Tia, B., Saimpont, A., Paizis, C., Mourey, F., Fadiga, L., & Pozzo, T. (2011). Does observation of postural imbalance induce a postural reaction? *PloS One*, 6(3), e17799. doi:10.1371/journal.pone.0017799
- Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. *Child Development*, 57(6), 1454–1463. doi:10.2307/1130423
- Trepagnier, C. Y., Olsen, D. E., Boteler, L., & Bell, C. A. (2011). Virtual conversation partner for adults with autism. *Cyberpsychology, Behavior and Social Networking*, 14(1-2), 21–7. doi:10.1089/cyber.2009.0255
- van Baaren, R. B., Fockenberg, D. a., Holland, R. W., Janssen, L., & van Knippenberg, A. (2006). The Moody Chameleon: The Effect of Mood on Non-Conscious Mimicry. *Social Cognition*, 24(4), 426–437. doi:10.1521/soco.2006.24.4.426
- van Baaren, R. B., Holland, R. W., Steenaert, B., & van Knippenberg, A. (2003). Mimicry for money: Behavioral consequences of imitation. *Journal of Experimental Social Psychology*, 39(4), 393–398. doi:10.1016/S0022-1031(03)00014-3
- van Baaren, R., Janssen, L., Chartrand, T. L., & Dijksterhuis, A. (2009). Where is the love? The social aspects of mimicry. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 364(1528), 2381–9. doi:10.1098/rstb.2009.0057
- van Leeuwen, M. L., van Baaren, R. B., Martin, D., Dijksterhuis, A., & Bekkering, H. (2009). Executive functioning and imitation: Increasing working memory load facilitates behavioural imitation. *Neuropsychologia*, 47(14), 3265–3270. doi:10.1016/j.neuropsychologia.2009.06.005
- VanMeter, L., Fein, D., Morris, R., Waterhouse, L., & Allen, D. (1997). Delay versus deviance in autistic social behavior. *Journal of Autism and Developmental Disorders*, 27(5), 557–569.
- Vivanti, G., & Hamilton, A. (2014). Imitation in Autism Spectrum Disorders. In F. R. Volkmar, R. Paul, S. J. Rogers, & K. A. Pelphrey (Eds.), *Handbook of Autism and Pervasive Developmental Disorders* (Vol. 1, pp. 278–301). Hoboken, NJ: Wiley.
- Volden, J. (2002). Features Leading to Judgements of Inappropriacy in the Language of Speakers with Autism: A Preliminary Study. *Journal of Speech-Language Pathology and Audiology*, 26, 138–146.
- Volden, J. (2004). Conversational repair in speakers with autism spectrum disorder. *International Journal of Language & Communication Disorders / Royal College of Speech & Language Therapists*, 39(2), 171–189. doi:10.1080/13682820410001663252
- Wald, A. (1943). Test of statistical hypotheses concerning several parameters when the number of observations is large. *Transactions of the American Mathematical Society*, 54, 426–482.

- Wardlow, L. (2013). Individual differences in speakers' perspective taking: the roles of executive control and working memory. *Psychonomic Bulletin & Review*, 20(4), 766–72. doi:10.3758/s13423-013-0396-1
- Warren, A., & Tate, C. (1992). Egocentrism in children's telephone conversations. In R. M. Diaz & L. E. Berk (Eds.), *Private speech: From social interaction to self-regulation* (pp. 245–264). NJ: Lawrence Erlbaum.
- Weatherholtz, K., Campbell-kibler, K., Jaeger, T. F., Hall, O., & Ave, N. (2014). Socially-Mediated Syntactic Alignment. *Language Variation and Change*, 26, 387–420. doi:10.1017/S0954394514000155
- Wheeldon, L., & Smith, M. (2003). Phrase structure priming: A short-lived effect. *Language & Cognitive Processes*, 18(4), 431–442. doi:10.1080/01690960244000063
- Wheelwright, S., Auyeung, B., Allison, C., & Baron-Cohen, S. (2010). Defining the broader, medium and narrow autism phenotype among parents using the Autism Spectrum Quotient (AQ). *Molecular Autism*, 1(1), 10. doi:10.1186/2040-2392-1-10
- Whitehouse, A. J. O., & Bishop, D. V. M. (2008). Do children with autism “switch off” to speech sounds? An investigation using event-related potentials. *Developmental Science*, 11(4), 516–524. doi:10.1111/j.1467-7687.2008.00697.x
- Wiggins, L. D., Bakeman, R., Adamson, L. B., & Robins, D. L. (2007). The Utility of the Social Communication Questionnaire in Screening for Autism in Children Referred for Early Intervention. *Focus on Autism and Other Developmental Disabilities*, 22(1), 33–38. doi:10.1177/10883576070220010401
- Wiig, E. H., & Secord, W. (1985). *Test of language competence*. San Antonio, TX: Psychological Corporation.
- Williams, J. H. G., Whiten, A., Suddendorf, T., & Perrett, D. I. (2001). Imitation, mirror neurons and autism. *Neuroscience and Biobehavioral Reviews*, 25(4), 287–295. doi:10.1016/S0149-7634(01)00014-8
- Wing, L. (1971). Severely retarded children in a London area: Prevalence and provision of services. *Psychological Medicine*, 1(5), 405–415.
- Wing, L. (2002). *The autistic spectrum: a guide for parents and professionals*. London: Constable and Robinson.
- Wing, L., & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: epidemiology and classification. *Journal of Autism and Developmental Disorders*, 9(1), 11–29. doi:10.1007/BF01531288
- Wolff, J. J., Botteron, K. N., Dager, S. R., Elison, J. T., Estes, A. M., Gu, H., Piven, J. (2014). Longitudinal patterns of repetitive behavior in toddlers with autism. *Journal of Child Psychology and Psychiatry*, 55(8), 945–953. doi:10.1111/jcpp.12207



- Yirmiya, N., Sigman, M. D., Kasari, C., & Mundy, P. (1992). Empathy and cognition in high-functioning children with autism. *Child Development*, 63(1), 150–160. doi:10.2307/1130909
- Yirmiya, N., Solomonica-Levi, D., & Shulman, C. (1996). The ability to manipulate behavior and to understand manipulation of beliefs: A comparison of individuals with autism, mental retardation, and normal development. *Developmental Psychology*, 32(1), 62–69. doi:10.1037/0012-1649.32.1.62
- Zaroff, C. M., & Uhm, S. Y. (2012). Prevalence of autism spectrum disorders and influence of country of measurement and ethnicity. *Social Psychiatry and Psychiatric Epidemiology*, 47, 395–398. doi:10.1007/s00127-011-0350-3
- Zelazo, P. D., Jacques, S., Burack, J. A., & Frye, D. (2002). The relation between theory of mind and rule use: Evidence from persons with autism-spectrum disorders. *Infant and Child Development*, 11, 171–195. doi:10.1002/icd.
- Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, 123(2), 162–185. doi:10.1037/0033-2909.123.2.162

**Appendix**

*Sample card game script for Study 1, Article 1*

A dog is biting a robber

A nurse is being squashed by a pig

A lion sends a girl a letter

A dog cuts a fireman a cake

A penguin throws a banana to a cowboy [SNAP!]

An elephant sings a song for a boy

A lion is hitting a fireman

A horse is pulling a clown

A queen is being carried by a cow

A crocodile is kicking a knight [SNAP!]

A soldier is being pulled by a tiger

A sheep sings a song to a queen

A horse reads a book to a nurse

A rabbit gives a clown a ball

A chef is being photographed by a dolphin [SNAP!]

A robber is being carried by an elephant

A bear is patting a girl

A king is being hit by a frog

A pig pours a drink for a witch

A pirate is being washed by a seal [SNAP!]

A frog reads a book to a fairy

A tiger gives a ball to a doctor

A cat is patting a witch

A bear sends a soldier a letter

A snake is painting a diver a picture [SNAP!]

A cat pours a robber a drink

A sheep is squashing a fairy

A doctor is being bitten by a rabbit

A cow cuts a king a cake

A giraffe is hugging a vampire [SNAP!]

*Sample images for card game (Study 1, Article 1)*





## DOES YOUR CHILD LIKE PLAYING GAMES?

The Children and Technology (ChaT) Lab at the University of Sussex is looking at new and exciting ways of helping children with autism to talk with others. Zoë, a researcher in the ChaT lab, is visiting [REDACTED] in April to try out a fun new maze game, which children play with a classmate on iPads. Zoë wants to understand how games can be used to support social communication between children.

To do this, she needs to tape record children as they play the maze game. She then analyses what they say in great detail, to see what supports positive outcomes. If you think your child would like to have a go at the game, then please return the form below to your child's teacher as soon as possible, along with the attached questionnaire (note that the questionnaire continues on the back of the page).

Children will play the maze game with a classmate (chosen by their teacher) in a one-hour session, which will also include a check of each child's language ability. This will involve children showing Zoë what words they know.

Zoë expects the children to enjoy all aspects of the session, but they only take part with your permission, and if they want to on the day: they are free to withdraw at any point in the research. If you would like more information, you can contact Zoë or her supervisor, Nicola, by email ([z.hopkins@sussex.ac.uk](mailto:z.hopkins@sussex.ac.uk), [nicolay@sussex.ac.uk](mailto:nicolay@sussex.ac.uk)), phone them on 01273 678630, or check the ChaT lab site: <http://www.sussex.ac.uk/psychology/chatlab/>

You can also email any questions you might have to the University of Sussex Sciences & Technology Cross-Schools Research Ethics Committee (C-REC), which has approved Zoë's study, on [crecscitec@sussex.ac.uk](mailto:crecscitec@sussex.ac.uk)

The findings of the study will be used to inform how games can be used in

the future to support children in talking with others.

## Thank you!

Please complete all parts and return to your child's teacher as soon as possible:

I am happy for my child to take part in the play session being carried out by the University of Sussex.

My child's name is \_\_\_\_\_

My child's class is \_\_\_\_\_

I am happy for my child to be video recorded during this study, for use only by the research team in the lab.

yes/no

I am happy that video recordings of my child playing the maze game may be used to describe the research to other researchers at:

- Meetings  
yes/no
- Conferences  
yes/no
- In published work, including our website  
yes/no

Please note that because the data we collect is precious, and involves extra effort for the schools, we generally keep video recordings in our secure lab for up to 10 years so that as new analysis software becomes available, we can look in more detail at the fine details of interaction. Be assured that personal information (i.e. name, class) about your child will be kept separately from video recordings, so s/he cannot be identified. Email or speak to us if you are unsure about any aspect of the study.

Signed \_\_\_\_\_ (parent/carer)



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- Meetings  
yes/no
- Conferences  
yes/no
- In published work, including our website  
yes/no

Please note that because the data we collect is precious, and involves extra effort for the schools, we generally keep video recordings in our secure lab for up to 10 years so that as new analysis software becomes available, we can look in more detail at the fine details of interaction. Be assured that personal information (i.e. name, class) about your child will be kept separately from video recordings, so s/he cannot be identified. Email or speak to us if you are unsure about any aspect of the study.

Signed \_\_\_\_\_ (parent/carer

