Simulations of language in individuals with and without Autism Spectrum Disorder (ASD)

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Declaration

The research presented in this thesis was conducted at the School of Psychology, University of Kent, whilst the author was a full-time postgraduate student. The theoretical and empirical work presented is original work completed by the author under the supervision of Dr Heather Ferguson and the experiments were conducted with limited assistance from others. The author has not been awarded a degree by this, or any other University for the work included in this thesis. The data reported in Chapters 2, 3, 4 and 5 has been presented at the following conferences:

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Abstract

The current thesis provides an exploration of mental simulations of language in individuals with and without Autism Spectrum Disorder (ASD). The experiential explanation of language proposes that language comprehension is facilitated through the construction of mental simulations of described events, which are embodied in cognition; grounded in action and perception. This high order cognitive process is thought to be underpinned by the mirror neuron system and other neural networks in the typically developed (TD) population. In a series of six experiments combining behavioural, EEG and eye-tracking measures with psycholinguistic paradigms, this thesis examines for the first time whether individuals with ASD activate mental simulations of language that are comparable to those of TD individuals. The main findings suggest that individuals with ASD are able to simulate written and spoken language, and do so in the same way as TD individuals; relying on the same neurological correlates. These simulations are activated in real-time as the described event unfolds and are constrained by the linguistic input. However, the findings point to a possible deficit or bias in interpreting prosodic content in ASD. Moreover, difficulties in simulating described events in ASD emerge when the temporal sequence of events are interrupted. Moreover, while individuals with ASD are able to simulate language online, subtle differences in processing compared to TD individuals may explain the social communication associated with the disorder. The findings offer support for a complex information processing explanation of ASD and are discussed in relation to existing cognitive theories of ASD and the impact of social skills and language ability on mental simulations.

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Table of Contents

Declaration 2

Abstract 4

Acknowledgements 5

Table of Contents 6

List of Figures 9

List of Tables 13

Chapter 1: Introduction 15

1.1 Overview 15

1.2 Theories of language 15

1.2.1 Schema theory 16

1.2.2 Situation models theory 16

1.3 The embodiment of language 17

1.4 Representations of the motor and spatial content of language 18

1.4.1 Motor simulations 19

1.4.2 Spatial representations 24

1.5 Simulations of speech 28

1.6 Autism Spectrum Disorder (ASD) 29

1.7 Cognitive theories of ASD 31

1.7.1 Theory of mind (ToM)/mentalising deficit 31

1.7.2 Weak central coherence theory (WCC)/Local bias 36

1.7.3 Executive dysfunction theory 42

1.7.4 Disordered complex information processing theory 48

1.7.5 The current cognitive theories of ASD 51

1.8 Language and communication impairments in ASD 51

1.8.1 Impairments at the phonological and morpho-syntactic levels 52

1.8.2 Semantic processing impairments 54

1.8.3 Deficits in pragmatics and comprehension 55

1.9 Action understanding and imitation in ASD 57

1.9.1 Mirror neuron dysfunction in ASD 60

1.10 Matching ASD and control participants 65

1.11 Chapter summary 67

1.12 Current research questions 68

Chapter 2 71

Behavioural signatures of motor simulations 71

Behavioural signatures of spatial simulations 75
Evidence for language simulation in ASD 78
The current experiments 80
Experiment 1A 80
Method 82
Results 89
Discussion 95
Experiment 1B 99
Method 99
Results 100
Discussion 104
Experiment 2 108
Method 110
Results 115
Discussion 117
Chapter Summary 120
Chapter 3 123
The N400 ERP component 124
Effect of ASD on language-induced N400 129
Contextual uncertainty 131
The current experiment 133
Method 134
Results 141
Discussion 152
Chapter Summary 158
Chapter 4 160
The prosodic components of reading and spoken language 160
Prosodic and pragmatic deficits in ASD 166
EEG event-related power 172
EEG power in the language processing network 175
The current experiment 179
Method 181
Results 187
Discussion 195
Chapter Summary 203
Chapter 5 205

Language mediates visual attention 205
Mapping language onto the mental world 209
Integration deficits in ASD 210
The current experiments 213
Experiment 5 214
Method 215
Results 219
Discussion 227
Experiment 6 230
Method 232
Results 237
Discussion 246
Chapter Summary 251
Chapter 6: General discussion 253
6.1 Overview 253
6.2 Summary of results 257
6.3 Interpretation of findings 263
6.3.1 Interpretation of findings in relation to the cognitive theories of ASD 270
6.4 Limitations and Future Research 277
6.6 Conclusions 283
References 286
Appendix A 316
Appendix B 323
Appendix C 328
Appendix D 355
Appendix E 374
Appendix F 376

List of Figures

Figure 1. Example of Titchener Circles used by Háppe (1996). 38

Figure 2. (a) Examples of puzzles used in the ToL task (b) Examples of cards used in WCST; taken from Hill (2004). 44

Figure 3. The three stimulus types taken from Williams et al. (2006): (a) animation, in which either index or middle finger were raised (b) symbolic cue, in which either the index or middle finger were marked (c) spatial cue, in which a cross was shown on either the left or right side of the screen. 62

Figure 4. Experiment set up. The keyboard was rotated 90º with the letter 'q' further from the participant and 'p' nearer. 88

Figure 5. Mean response accuracy for concrete transfer sentences collapsed across groups. Error bars show standard errors. 91

Figure 6. Mean response accuracy for abstract transfer sentences collapsed across groups. Error bars show standard errors. 91

Figure 7. Mean response time (in ms) for concrete transfer sentences (left) and abstract sentences (right) for the TD group (top) and ASD group (bottom). 94

Figure 8. Mean response accuracy for concrete transfer sentences. Error bars reflect standard errors. 101

Figure 9. Mean response accuracy for abstract transfer sentences. Error bars reflect standard errors. 101

Figure 10. Mean response time (in ms) for concrete transfer sentences. Error bars reflect standard errors...103

Figure 11. Mean response time (in ms) for abstract transfer sentences. Error bars reflect standard errors...103

Figure 12. Mean accuracy (%) for the TD and ASD groups, across conditions. Error bars show standard errors. 116

Figure 13. Mean reaction times for the TD and ASD groups, across conditions. Error bars show standard errors. 117

Figure 14. Example stimuli from West and Holcomb (2002). Following a pictorial story depicting a girl running in a hurdle race, the final frame was either congruous (left) or incongruous (right), with the story. 127

Figure 15. Electrode array. 64 active electrodes (62 scalp electrodes, 2 ocular electrodes) with regions of interest defined. 139

Figure 16. Mean accuracy (%) for TD and ASD groups, across all conditions. Errors bars show standard errors. 142

Figure 17. Mean reaction times for the TD ad ASD groups, across all conditions. Error bars show standard errors. 143

Figure 18. Grand average ERPs at critical word onset (i.e. the final word) for 'knows' and 'thinks' sentences, for TD and ASD groups, across selected central electrodes. 146

Figure 19. Grand average ERPs at picture onset for the four conditions: knows-match, knows-mismatch, thinks-match, thinks-mismatch, for the TD group (left) and ASD group (right). 151

Figure 20. Illustration of the between-condition differences in vividness and contextual congruency, taken from Yao, Belin and Scheepers (2012). 165

Figure 21. The EEG power spectrum. 174

Figure 22. Electrode array. 64 active electrodes (62 scalp electrodes, 2 ocular electrodes) with regions of interest defined. 186

Figure 23. Mean contextual congruency ratings for direct-monotonous, indirect-monotonous and direct-vivid speech types. Error bars show standard errors. 188

Figure 24. Mean response times for the direct-monotonous, indirect-monotonous and direct-vivid speech types. Error bars show standard errors..190
Figure 25. Change in power from context to speech in the TD group for the three speech type conditions; direct-monotonous (DM), direct-vivid (DV) and indirect-monotonous (IM), over ROIs (left/right frontal, central, parietal and occipital regions)..193
Figure 26. Change in power from context to speech in the ASD group for the three speech type conditions; direct-monotonous (DM), direct-vivid (DV) and indirect-monotonous (IM), over ROIs (left/right frontal, central, parietal and occipital regions). 194
Figure 27. Example visual display. 217
Figure 28. Time course of the mean proportion of fixations to the empty wine glass for each tense condition (past, 'has drunk' and future 'will drink') for TD and ASD groups. Note that the vertical lines indicate the average onset of words in the target sentence, as labelled......221
Figure 29. Time course of the mean proportion of fixations to the full beer glass for each tense condition (past, 'has drunk' and future 'will drink') for TD and ASD groups. Note that the vertical lines indicate the average onset of words in the target sentence, as labelled......222
Figure 30. Mean proportion of trials with fixations on the empty wine glass at the onset of 'will/has', the onset of 'the' and the onset of 'wine/beer'. Error bars show standard errors. ...224
Figure 31. Mean proportion of trials with fixations on the full beer glass at the onset of 'will/has', the onset of 'the' and the onset of 'wine/beer'. Error bars show standard errors. ...224
Figure 32. Example visual display. 235
Figure 33. Time course of the mean proportion of fixations to each container object as the critical 'And then...' sentence unfolds for the TD group (top) and the ASD group (bottom). Note that the vertical lines indicate the average onset of words in the critical sentence, as labelled and the solid vertical line indicates the onset of 'sweetcorn'..................................238

Figure 34. Time course of the mean proportion of fixations to each container object as the critical But first...' sentence unfolds for the TD group (top) and the ASD group (bottom). Note that the vertical lines indicate the average onset of words in the critical sentence, as labelled and the solid vertical line indicates the onset of 'sweetcorn'..................................239

Figure 35. Mean proportion of fixations for 'And then' on each of the four container objects during sentence-final 'sweetcorn', at the offset of 'sweetcorn', 500ms following the offset of the discourse final noun, and the time between 500ms and 1000ms after discourse final noun offset. Error bars show standard errors. 241

Figure 36. Mean proportion of fixations for 'But first' on each of the four container objects during sentence-final 'sweetcorn', at the offset of 'sweetcorn', 500ms following the offset of the discourse final noun, and the time between 500ms and 1000ms after discourse final noun. Error bars show standard errors. 241

List of Tables

Table 1. Assessment test results, with means and t values for the TD and ASD groups. Standard deviations are noted in parenthesis. 85

Table 2. Example experimental sentences showing sentence direction and sentence type counterbalanced. 87

Table 3. Assessment test results, with means and t values for the TD and ASD groups. Standard deviations are noted in parenthesis. 111

Table 4. Example experimental sentences and the associated visual display, as labelled. 113

Table 5. Assessment test results, with means and t values for the TD and ASD groups. Standard deviations are noted in parenthesis. 135

Table 6. Example experimental sentence and the associated visual display, as labelled. 137

Table 7. Example stimuli from Yao and Scheepers (2011); the stories contained either a direct or indirect speech quotation from a fictitious protagonist in the story, preceded by a context that either described a fast-speaking (1) or slow-speaking (2) protagonist 163

Table 8. Assessment test results, with means and t values for TD and ASD groups. Standard deviations are noted in parenthesis. 182

Table 9. Example items of the background and direct/indirect speech quotations............... 183

Table 10. Assessment test result results, with means and t values for the TD and ASD groups. Standard deviations are noted in parenthesis. 216

Table 11. Parameter estimates for each target object at each time point. (For analysis of fixations to the empty wine glass, random slopes included were verb on participants at the onset of ‘will/has’ and ‘the’ and verb on items and participants at the onset of ‘wine/beer’. For analysis of fixations to the full beer glass, random slopes included were verb on participants at the onset of ‘will/has’ and ‘the’ and verb on items and participants at the onset of ‘wine/beer’.) 226

Table 12. Assessment test results, with means and t values for TD and ASD groups. Standard deviations are noted in parenthesis. 233

Table 13. *Pairwise comparisons for container, group and the container by group interaction for 'And then...'* 243

Table 14. Pairwise comparisons for container, group and the container by group interaction for 'But first...' 244

Chapter 1: Introduction

1.1 Overview

The experiments presented in this thesis explore mental simulations of language in individuals with and without an Autism Spectrum Disorder (ASD). Specifically, I look at the time course, content and nature of simulations of written and spoken language. To do so I use a number of psycholinguistic paradigms in conjunction with cognitive neuroscience techniques to investigate whether adult individuals with ASD simulate language at all and if so, whether they simulate language in the same way as typically developing (TD) adults.

In this Chapter, I will start by reviewing theories of language and the theoretical background and studies on mental simulations of language. I will discuss the dynamic nature of simulations and how TD comprehenders represent the motor, spatial and perceptual properties of the linguistic input. Following this, I will present an overview of ASD and theories of the disorder. I then discuss communication, language and action understanding impairments in ASD, before introducing the experiments in this thesis and outlining the thesis structure.

1.2 Theories of language

There have been a number of attempts to explain the processes of language comprehension. In this thesis I focus on the experiential explanation of language; that language is embodied in action and cognition and comprehenders construct dynamic mental simulations of described events. Before I present this approach however, I will begin by briefly reviewing other dominant theories of language comprehension, namely the schema theory and the situational theory.

1.2.1 Schema theory

Schemas are mental representations of stereotypical situations (Zwaan, & Radvansky, 1998). For example, Schank and Abelson's (1977) restaurant script, which represents the actors, props, entry and exit conditions and action sequence typical of a restaurant visit. Emphasising the constructive character of remembering, Bartlett (1932) proposed the schema theory of language, with schemas being cognitive structures built up over the course of interactions with the environment to organise experiences. Comprehenders relate the current input of the text to some mental representation based on a bank of relevant prior knowledge and experiences stored in memory. That is, according to the schema theory the fundamental process of comprehension is the mapping of new information onto situation-specific knowledge, or schemas (Sanford, & Garrod, 1981). Schemas can be viewed as the building blocks for the construction of situation models of a text or story.

1.2.2 Situation models theory

More recent evidence suggests that comprehending a text entails the construction of mental models, or more specifically a 'situation model.' Comprehenders build up knowledge about the current status of specific entities and space-time coordinates of the text into a mental model (Sanford, & Emmott, 2012). When comprehending a text readers construct representations of the characters, events, states, goals and actions described by the story, with events and intentional actions of characters at the focal point of situation models. That is, readers are representing what the text is about as opposed to representing the features of the text itself (Glenberg, Meyer, & Lindem, 1987).

As new information is provided by the progressing text, comprehenders monitor and update their current situation model on a number of event indices; temporality, spatiality, protagonist, causality and intentionality. That is, when processing an event, readers construct a situation model that encompasses the time frame of the event, the spatial region in which it occurs, the protagonists involved, its causal status with regards to prior events and how it relates to the protagonist's goals (Zwaan, Langston & Graesser, 1995; Zwaan, Magliano & Graesser, 1995). In analysing the construction of a situation model and retrieval of situational information, three distinctions can be made; (1) the current model, the model that is currently under construction while the individual is reading a particular clause or sentence, (2) the integrated model of the situations, which is the global model constructed by one at a time integrating the constructed models at time t1 to tn-1 while the individual is reading and (3) the complete model of the situations store in long term memory. However, the complete model is not necessarily the final model as comprehenders may update or develop the model based on new information or after rumination (Zwaan, & Radvansky, 1998).

These theories have since been extended and demonstrate how mental models of described events are important to language understanding. More recent developments have shown how mental representations can relate to other cognitive processes, and the view that comprehension involves an embodied component has led to an embodied theory of language. The idea that language is embodied in cognition and action will be the focus of this thesis and will be discussed further in the following section.

1.3 The embodiment of language

Language is fundamentally a set of cues used by the comprehender to construct an experiential simulation of the described event (Zwaan, 2004). Communication and understanding are thought to be facilitated through the construction of mental simulations, which represent the state of affairs described by the linguistic input and activate the perceptual, motor and affective content (Zwaan, 2009; Barsalou, 2008). Simulations are formed as an individual interacts with and perceives their own environment; perceptions and actions are associated with words and stored in long term memory as mental representations or traces (Singh, & Mishra, 2010). During language comprehension these traces are reactivated to produce a simulation of the described event (Zwaan, Madden, Yaxley & Aveyard, 2004). This interaction between language and simulation is what makes language experiential in nature (Barsalou, 2008).

Language-induced sensorimotor effects can be considered evidence of the experience-based nature of language. When participants were asked to construct grammatically sound sentences using words associated with the elderly (such as *Florida, old, retired, wrinkles,* etc.), they subsequently walked significantly slower than those exposed to neutral words (Bargh, Chen & Burrows, 1996). It is suggested that the priming of elderly words activated an 'elderly stereotype' and primed participants to perform stereotype-consistent behaviour. Such language-induced sensorimotor effects have been described as the physical performance of mental simulations; individuals re-enact the perceptual, motor and introspective states (Barsalou, 2008).

Zwaan (2004; 2009) suggests that during language comprehension individuals simulate the event described by the linguistic input rather than merely representing the input in some arbitrary way, which makes the comprehender an 'immersed experiencer' (Zwaan, 2004). A large amount of behavioural and electrophysiological research supports the re-enactment of motor and perceptual linguistic content as evidence of motor and spatial simulations. In the following section I discuss such simulations.

1.4 Representations of the motor and spatial content of language

Research shows that comprehenders represent the motor and spatial content of the linguistic input in a simulation of the described event. Below, I review evidence of such representations in the typically developing (TD) population.

1.4.1 Motor simulations

When an individual observes another person performing an action, the neural substrates associated with the individual performing the action themselves are activated (Zwaan, & Taylor, 2006). This 'motor resonance' phenomenon has been observed in behavioural tasks. For example, Zwaan and Taylor (2006) presented participants with a rotating black cross in the centre of the screen and asked them to twist a knob in one direction if the cross changed colour. A facilitation effect (i.e. shorter reaction times) was observed when the manual response required was in the same direction as the visual rotation and an interference effect (i.e. longer reaction times) occurred when the two were incongruent. To comprehend an observed action, one mentally simulates the action using the neural substrates involved in performing the action (Zwaan & Taylor, 2006). It is this process that is thought to underpin language comprehension as the language-induced sensorimotor effects assist comprehension by enriching the abstract mental representations induced by the linguistic input (Zwaan, 2009). However, research has shown that motor simulations of actions are initiated even at the single word level of language. Here I review both the neurological correlates and behavioural impact of motor simulations of language.

Neurological correlates of motor simulations

Neuropsychological studies have shown that processing concepts and word meaning involves multiple cortical regions. Language processing activates core language areas in the left hemisphere for the storage of semantic information as well as complementary language processing areas that process information about objects and actions the words refer to (Pulvermüller, 2001). Differential neuronal activity has been observed between different lexical categories, such as nouns and verbs, related to the semantic associations of the word groups. For example, nouns with a strong visual association elicit activation in neurons of visual cortices, whereas verbs with a strong action association activate neurons in motor cortices (Pulvermüller, Lutzenberger & Preissl, 1999).

Even differences between semantic subcategories exist, with action verbs eliciting differential neural activation along the motor cortex. Activity is strongest at the cortical representation of the body part primarily used for performing the action implied by the verb (Pulvermüller, Härle & Hummel, 2001). Pulvermüller, Härle and Hummel (2001) compared behavioural and neurophysiological responses to German single word action verbs related to different body parts; namely face-related words (e.g. t*o bite, to smile*), arm-related words (e.g. *to lift, to applaud*) and leg-related words (e.g. *to walk, to kick*) during a lexical decision task. Face-related words were processed significantly faster than leg-related verbs and arm-related words in between, as well as topographical and time course differences in neurophysiological responses between the three word types. At 200ms after stimulus onset, activity over the face representation of the cortex was significantly stronger for face-related words compared to both arm-related and leg-related words. Likewise, though somewhat later at around 300ms post-stimulus onset, leg-related verbs elicited greater activation above cortical leg representations compared to both face-related and arm-related verbs. Interestingly, this shows initial evidence of motor simulations even at the single word level of language.

Likewise, when Transcranial Magnetic Stimulation (TMS) is applied to areas in the left language-dominated hemisphere during the processing of action words related to body parts, processing differences occur. Reaction times to words referring to movements by the leg (e.g. *kick*) or arm and hand (e.g. *pick*) were compared during a lexical decision task. Response times were faster to leg-related words when TMS was applied to leg representation areas of the left language-dominated hemisphere, while arm representation TMS resulted in faster reaction times to arm-related words. Interestingly, no TMS related differences between the two words groups were observed when stimulation was applied to leg and arm areas in the non-dominant right hemisphere or during sham stimulation, supporting the notion of category-specific functional links between action and language processing systems during language processing (Pulvermüller, Hauk, Nikulin & Ilmoniemi, 2005).

Neurophysiological studies have localised category-specific activations. Using magnetoencephalography (MEG) and objective source localisation, face-related words (e.g. *lick*) have been found to induce stronger activation in inferior frontocentral regions compared to leg-related words (e.g. *kick*). In comparison, activation in superior central sites is stronger following leg-related words (*kick*) compared to face-related words (*lick*) (Pulvermüller, Shtyrov & Ilmoniemi, 2005). This finding confirms that action words are related to different body parts in a somatotopic fashion during lexical processing.

Interestingly, cortical somatotopic activation by related action words can be suppressed when negation is introduced. Negation is a prevalent yet abstract aspect of human language that refers to the absence of a concept (e.g. *"I am not smiling"*) and is associated with an inhibition of motor system activation. During an electromyography (EMG) study activity of the zygomatic muscle (i.e. the smiling muscle) was continuously recorded as participants were presented with sentences that either mapped directly onto the zygomatic muscle (e.g. *"I am smiling"*) or did not (e.g. *"I am frowning"*). Additionally, the sentences were presented in an affirmative form (*"I am smiling"* or *"I am frowning"*) or a negated form (*"I am not smiling"* or *"I am not frowning"*). Reading the affirmative sentence (*"I am smiling"*) led to activation of the zygomatic muscle, but interestingly, reading the sentence involving the negation of the activity of the zygomatic muscle (*"I am not smiling"*) was associated with inhibition of this muscle. In addition to this, reading sentences unrelated to the zygomatic muscle (*"I am frowning"* or *"I am not frowning"*) produced no muscle activation (Foroni & Semin, 2013). This finding further supports simulations as underlying action-related language processing by demonstrating that negation also engages the motor system by rapidly inhibiting the relevant muscle action.

This inhibition effect has also been demonstrated in neuroimaging studies. Tettamanti et al (2010) presented participants with Italian action-related affirmative (e.g. *"I push the button."*) and negated action-related sentences (e.g. *"I do not push the button."*) and found inhibited activation of the left fronto-parieto-temproal areas for the latter. That is, negation of the action-related sentences induced weaker activation of the action-representation system involved in motor simulation of language (Tettamanti, et al, 2008). This finding provides further evidence for the activation of action representations in the motor cortex during lexical process in a somatotopic fashion.

Having demonstrated the neural correlates of motor simulation, I now move on to discuss the behavioural impact of motor simulations during sentence processing.

Behavioural impact of motor simulations during sentence processing

The neurological correlates of simulating action sentences are observable at the behavioural level. When participants read sentences that describe an action towards or away from the body (*"Courtney passed you the notebook"* versus *"You passed Courtney the notebook"*) a facilitation effect (i.e. shorter reading time) is observed when the implied direction of the sentence is the same as the actual response direction, and an interference effect (i.e. longer reading time) when they contrasted (Glenberg, & Kaschak, 2002). Glenberg and Kaschak (2002) termed this interaction the 'Action-Sentence Compatibility Effect' (ACE) and it was demonstrated for three sentence types; imperative sentences (e.g. *"Open the drawer"*), sentences describing the transfer of concrete objects (e.g. *"Open the drawer"*) and sentences describing the transfer of abstract entities (e.g. *"Liz told you a story"*). The facilitation and interference effects affirm the view that mental simulations of actions are central to the representation of meaning in language comprehension.

In an extension of Glenberg and Kaschak's (2002) ACE, and of their first experiment mentioned above, Zwaan and Taylor (2006) explored whether visual rotations produce motor resonance. In their second experiment Zwaan and Taylor (2006) presented participants with sentences describing a manual action (e.g. *"Eric turned down the volume."*) and asked them to make sensibility judgements (i.e. judge whether a sentence made sense or not) by turning a knob. Sensibility judgements were quicker when the manual response was in the same direction as the manual action implied in the sentence, which extends the ACE from simple away-from-the-body/towards-the-body actions and into the domain of manual rotation. This finding demonstrates that not only observing a visual rotation, but also comprehending a manual rotation sentence produces motor resonance.

In a third experiment, Zwaan and Taylor (2006) extended this finding further by demonstrating how observing a visual rotation affects comprehension of manual rotation sentences. Participants read sentences describing a manual rotation (e.g. *"Jenny screwed in the lightbulb."*) and made sensibility judgements whilst simultaneously monitoring for a rotating cross to change colour. An interaction between the visual stimulus and comprehension of the manual action sentences was observed, with comprehension easier when the visual stimulus was rotating in the same direction as the manual rotation implied in the sentence. Such language-induced motor effects suggest that both viewing a visual rotation and understanding a sentence describing a manual rotation activate neural substrates involved in performing an actual manual rotation. Such findings demonstrate the impact of motor simulations at the behavioural level during lexical processing.

However, when comprehending a sentence the motor properties implied are not the only aspects of the linguistic input that are simulated. Next, I present evidence to show how comprehenders also represent the spatial properties of language in a simulation of the described event.

1.4.2 Spatial representations

Another way that language can be experienced is in the spatial properties of referents implied by the linguistic input. The sentence-picture verification task is a paradigm that demonstrates support for the experiential nature of language. Participants are presented with sentences such as *"John put the pencil in the cup"* and subsequently make a mentioned/not mentioned judgement on an image that depicts the object mentioned in the preceding sentence (i.e. a pencil). Critically, the image either matches the physical state of the described object (a vertically orientated pencil) or mismatches (a horizontally orientated pencil). Response times reveal a facilitation effect (i.e. shorter reaction times and fewer errors) when the object matches the implied orientation, that is shorter reaction times and less errors to make the mentioned/not mentioned judgement and an interference effect (i.e. longer reaction times and more errors) when it mismatches (Stanfield & Zwaan, 2001). The degree of facilitation/interference is also influenced by the wider sentence context. Research has shown that comprehenders encode contextually modified aspects of referents and events described, including the shape of referents (Zwaan, Stanfield & Yaxley, 2002), which I will focus on in Chapter 2, as well as the implied visibility of objects (Yaxxley & Zwaan, 2007) and motion (Zwaan, et al, 2004).

The verbs used in sentences can implicate these changes in spatial properties. Research has shown that the spatial changes such as direction of motion implied by a verb impact participants' judgement in decision tasks. This would suggest language comprehension may affect visual representations of events. In a variation of the sentence-picture verification task participants heard sentences such as (1) and (2) followed by two images, the first depicting the described object (i.e. a ball) in a big or small size, and the second depicting the same object in a medium size (Zwaan, Madden, Yaxley & Aveyard, 2004). Participants are asked to judge whether the images depict the same object, but critically the images imply a direction of motion away from or towards the participants.

(1) "The shortstop hurled the softball at you."

(2) "You hurled the softball at the shortstop."

Response times were faster when the picture sequence matched the movement of the object (ball) implied in the sentence. This would support the theory that comprehension entails the activation of perceptual simulations of the referent's spatial properties implied by the linguistic input.

Similarly, verbs have also been shown to implicate the speed of agents or objects described by the event. In an eye tracking experiment participants heard sentences such as (3) and (4) while concurrently viewing a visual scene depicting the agent and a path leading to the described goal object (Lindsay, Scheepers & Kamide, 2013).

(3) "The student will stagger along the trail to the picnic basket."

(4) "The student will run along the trail to the picnic basket."

Results revealed that when the verb implied a slow manner of motion (i.e. *will stagger*), participants looked more often and for longer along the path to the goal object, whereas when the verb implied a fast manner of motion (i.e. *will run*) participants looked earlier at the goal object and less on the path. These findings would suggest participants mentally simulate the movement of the agent down the path to the goal object, consistent with the finding that participants map the event onto the visual scene.

Likewise, Kamide, Lindsay, Scheepers and Kukona (2015) showed that comprehension of a motion event involves the activation of a spatial simulation that integrates language with the visual world online. Using the same paradigm as Lindsay, Scheepers and Kamide (2013), sentences included a verb that implied a motion following an upper path (e.g. jump in *"Foodtock will jump onto the sofa."*) or a lower path (e.g. crawl in *"Foodtock will crawl onto the sofa."*), while viewing a concurrent visual scene of the agent, the goal and 'empty space' between the two. Results revealed a bias of visual attention to fixate upwards when the verb implied an upward motion (*jump*) and to fixate downwards when the verb implied downward motion (*crawl*). Additionally, a second experiment involved the same experimental stimuli as Experiment one, but visual scenes included an obstacle in the empty space between the agent and the goal object. Participants were asked to use the mouse to move the agent so as to perform the action described in the sentence, and again visual attention was biased upwards when the verb implied this direction of motion (i.e. *jump*) and biased downwards when the verb implied a downward path of motion (i.e. *crawl*). Interestingly, mouse tracking analysis revealed participants constructed the path of motion events. These studies support the simulation of spatial properties as details regarding spatial changes implicated by the verb are mapped onto the visual world through visual attention.

Experiences of the spatial properties of an utterance are also detectable in electroencephalography (EEG) and magnetoencephalography (MEG) studies. EEG refers to the recording of the brain's electrical activity as indicative of cognitive functions, while MEG is a functional neuroimaging technique that maps brain activity by recording magnetic fields produced by this electrical activity. Research on language processes emphasises the N400 ERP component in the EEG output. The N400 is an ERP component with a large negative deflection at around 400ms after stimulus onset (Kutas & Federmeier, 2000). It relates to violations of semantic expectancy during language comprehension and is accessed by both words and pictures (Nigam, Hoffman, & Simons, 1992).

In a sentence-picture verification task participants were presented with images of objects such as a flying duck, paired with three sentence conditions; feature matching (i.e. *"The ranger saw a duck in the air."*), feature-mismatching (i.e. *"The ranger saw a duck in the lake."*) or an unrelated sentence (i.e. *"The ranger prepared a sandwich."*) (Hirschfeld, Zwitserlood & Dobel, 2011). Presentation of the target image resulted in an N400 that was largest for the object that was not previously mentioned in comparison to when it was mentioned. That is, the component was not sensitive to the shape mismatch, reflecting activation of abstract lexical representations rather than gradual feature overlap. However, MEG results revealed increased brain activity in the occipital cortex, strongest when the object's state implied by the sentence matched that depicted in the image. In contrast, the feature-mismatched object was treated as a completely incongruent object, with reduced activation in the occipital cortex (Hirschfeld, Zwitserlood & Dobel, 2011).

The EEG effect was further demonstrated by Hirschfeld, Feldker and Zwitserlood (2012) who presented participants with an image of an object (e.g. a swimming duck) after the visual presentation of a noun phrase describing the object in the same shape (i.e. *"swimming duck"*), a shape-mismatching state (i.e. *"flying duck"*) or an incongruent object (i.e. *"sliced bread"*). The EEG findings replicated Hirschfeld, Zwitserlood and Dobel's (2011) observation of a larger N400 for the incongruent pairing (i.e. *"sliced bread"* followed by an image of a swimming duck), but no difference in N400 amplitude for the shape-matching (*"swimming duck"*) or shape-mismatching (*"flying duck"*) conditions. This would suggest the N400 is insensitive to shape mismatch, reflecting activation of abstract lexical representations as opposed to gradual feature overlap (Hirschfeld, Feldker & Zwitserlood, 2012). Thus, the large N400 effect for not-mentioned objects compared to mentioned objects reflects congruency between the linguistic context and the object. Whereas the brain responses in the occipital cortex found in the MEG study are thought to reflect the perceptual match between the expected shape implied in the sentence and the actual shape depicted. I will go on to investigate these neurological underpinnings of simulations of spatial properties in Chapter 3.

Thus far I have focused on simulations of written language; however mental simulations are also constructed to facilitate the comprehension of spoken language. In the following sections I discuss how TD individuals encode how the spoken linguistic input is delivered into a simulation of the event.

1.5 Simulations of speech

As well as representing the linguistic input in terms of simulating the described event, comprehenders also represent how the linguistic input is delivered; by encoding the speaker's (implied) voice. The speaker's voice is considered one aspect of the input's prosodic structure; the organisational structure of language (Beckman, 1996), providing information about the structure and pragmatic function of an utterance (Yao & Scheepers, 2015). When reading or listening to speech (i.e. speech quotations), prosody is a key feature that differentiates direct speech (*Mary said, "This dress is absolutely beautiful?"*) and indirect speech (*Mary said that the dress was absolutely beautiful*) (Yao & Scheepers, 2015). The pragmatic function of direct speech is to provide a demonstration that depicts the reported speech event and it is considered more 'vivid' than indirect speech. In contrast, indirect speech merely serves as a description of what has been said. For this reason, direct and indirect speech is thought to be differentially represented in language comprehension.

The mental simulation of the speaker's voice during silent reading of direct speech, compared to indirect speech, induces top-down activation of the auditory cortex. During silent reading, direct speech has been found to elicit a higher BOLD signal in voice-selective areas of the right auditory cortex, compared to indirect speech. This is alongside greater activation in brain regions distributed in the occipital lobes, superior parietal lobules and precuneus, thought to be associated with the enrichment of a multisensory perceptual simulation of the direct speech (Yao, Belin & Scheepers, 2011), evidence of an "inner voice" as readers engage in vivid perceptual simulation of the speaker's voice. I will discuss the nature of the inner voice and simulations of direct and indirect speech further in Chapter 4.

So far, I have presented theories of language, emphasising the embodied theory as the focus of this thesis. I have illustrated the dynamic nature of mental simulations of language and how TD individuals represent the motor, spatial and perceptual content of events described by the linguistic input. Now, I will present an overview of Autism Spectrum Disorders (ASD), focusing on the four main cognitive theories of the disorder. Following this, I will discuss specific impairments exhibited by individuals with ASD that are the focus of this thesis.

1.6 Autism Spectrum Disorder (ASD)

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder (PDD). In the DSM-V ASD is an umbrella term for autistic disorders, Asperger's Syndrome (AS) and Pervasive-Developmental Disorder – Not Otherwise Specified (PDD-NOS) (McPartland, Reichow & Volkmar, 2012). Autism is a neurodevelopmental disorder with largely genetic causes that persists throughout life. Those with ASD demonstrate impairments in two diagnostic domains; persistent deficits in social communication and interaction across contexts and restricted and repetitive behaviour, interests or activities.

The increasing body of research aimed at understanding the characteristics and manifestations of ASD are particularly timely given the increasing prevalence of the disorder.

Whilst it was once considered a relatively rare disorder with prevalence estimates of approximately four in 10,000 individuals (Prior, 2003), more recent investigations suggest a prevalence of around 157 per 10,000 individuals or one per cent of the general population, with a ratio of known:unknown cases at about 3:2 (Baron-Cohen, et al, 2009). There are a number of possible explanations for the increased prevalence in ASD, such as expanded and altered diagnostic criteria, heightened awareness, earlier diagnosis, increased support and commonality with other conditions (Prior, 2003; Matson & Kozlowski, 2011).

The disorder is also characterised by high clinical heterogeneity as there are varying manifestations of symptoms both between and within individuals. Indeed, the heterogeneous nature of the disorder has stimulated much debate among researchers and clinicians regarding the profile of social and cognitive deficits. Whilst ASD is comprised of deficits in social interaction, communication and restricted and repetitive interests, whether or not these impairments require a unitary explanation is questionable. Rather, the variability in severity between individuals would suggest a more fractionable explanation of the triad of impairments (Happé, Ronald & Plomin, 2006).

At the genetic level, distinct influences have been observed for the three components. Whilst high heritability has been found for the three core impairments (social, communication and restricted and repetitive behaviours and interests) in both the extreme population and measured on a continuum in the general population, this is not mediated by environment (Ronald, et al, 2006). This genetic component of ASD has an impact on the brain at the anatomical level. Individuals with ASD for example, have been found to have significant reductions in grey-matter volume in three large clusters in comparison to healthy controls; centred in the right cerebellum, right inferior temporal gyrus and left parahippocampal gyrus (Toal, et al, 2009).

1.7 Cognitive theories of ASD

Despite the non-homogenous nature of ASD, current theories attempt to explain the core deficits in unification. There are currently four main accounts of ASD; the Theory of Mind (ToM) and mentalising deficit theory, the Weak Central Coherence (WCC) theory, the Executive Dysfunction hypothesis and the Disorder Complex Information Processing theory. I now review each of these theories in turn.

1.7.1 Theory of mind (ToM)/mentalising deficit

The most dominant explanation of ASD is that the disorder is primarily a deficit in social cognition. TD children develop the ability to 'mind read' around four years old. That is, individuals have the unconscious, cognitively mechanistic ability to attribute mental states to oneself and others in order to explain and predict behaviour, as well as to produce appropriate emotional reaction to others' mental states (Frith & Happé, 1994; Baron-Cohen, 2004). This ability has been termed a 'Theory of Mind' (ToM). As a possible explanation of their deficits, Baron-Cohen, Leslie and Frith (1985) proposed that autistic children lack a theory of mind.

The precursor for this theory is Wimmer and Perner's (1983) research on how TD children understand false belief tasks. False (or wrong) belief understanding refers to the realisation that another's beliefs about a given real-world event may differ from reality and from one's own. Consequently, there is an understanding that the beliefs may be true or false and vary between people (Schaffer, 2004). In order to understand another person's belief, one must be able to suppress their own beliefs in favour of the others', implying the presence of theory of mind. To test TD children's ability to comprehend wrong beliefs, Wimmer and Perner (1983) showed TD children sketches of a protagonist putting an object into a location x and then, in the absence of the protagonist, showed the object being transferred form location x to location y. Since the transfer was assumed to be a surprise, it had to be implicit that the protagonist still believes that the object is in location x. Four year old TD children were able to suppress their own belief about the location of the object and constrain their interpretation of the protagonist's intention in terms of that person's beliefs; implicating the ability to attribute false beliefs and consequently implying the development of theory of mind understanding (Wimmer & Perner, 1983).

In a similar scenario, Frith (1989) provided children with a story acted out with dolls, Sally and Anne. Sally places a marble in a basket and leaves the room, after which Anne moves the marble to another location. Sally then returns to looks for the marble and the child is asked; where will Sally look for the marble? Frith (1989) also found TD children younger than four years old could not attribute a false belief to Sally and subsequently predict her appropriate behaviour.

Baron-Cohen, Leslie and Frith (1985) proposed that children with ASD have a deficit in this ability to attribute independent mental states to others, thus they lack a theory of mind. Those with ASD can therefore be considered 'mind blind'. Baron-Cohen, Leslie and Frith (1985) ran the Sally-Anne task with ASD children with an average age of 11 years, as well as TD preschool children, with a mean age of 4 years and a group of children with Down's syndrome and a mean age of 10 years. Again, TD preschool children were able to appreciate Sally's false belief regarding the marble's location and so too were Down Syndrome children (85% and 86% respectively). However, 80 percent of ASD children failed on the belief task, pointing to the real location of the marble. This would suggest that even at 11 years old, children with ASD cannot consider others' differing beliefs. That is, in comparison to those children with Down's Syndrome and TD preschool children, those with ASD were unable to appreciate that their own up-to-date knowledge of the marble's location and the knowledge attributed to the doll were different and to then use this to predict the dolls behaviour.

This inability to impute beliefs to others is further justified by performance on perceptual perspective-taking tasks. Whilst attributing mental states could be considered a conceptual perspective-taking skill, the distinct performance of individuals with ASD demonstrates how the inability to attribute mental states is specific to the disorder. In a perspective-taking task, Piaget, Inhelder and Mayer (1967) showed that while young TD children were able to identify their own viewpoint, they were unable to distinguish this from the viewpoint of other observers. However, by seven years old children were able to discriminate between and coordinate perspectives and this was mastered at around nine years old. Perspective-taking requires the child to consciously relate an object to their own viewpoint by distinguishing it, yet at the same time coordinating it with other viewpoints. Young TD children consider their own viewpoint as the only possible one and therefore cannot make further deductions regarding how it would change according to a change in position. However, as children develop, they transition from this egocentric realism to relational coordination, at which point they are able to master perspective-taking.

Nonetheless, some argue that given a simpler task, TD children develop perspective-taking earlier, at around four years old (Masangkay, et al, 1974; Flavell, Everett, Croft & Flavell, 1981). Young children are able to understand that what they see may be different from what another sees (Moll & Tomasello, 2006), but not until four years old do they have the ability to appreciate that they and another may simultaneously see the same thing from different perspectives.

Interestingly, individuals with ASD have been shown to succeed on such visuospatial perspective-taking tasks, but are unable to infer others' mental states. During a mentalising task where adult participants were asked to indicate their own and an agent's preference between two objects, those with ASD were slower than age and IQ matched controls at inferring the virtual character's preference. However, when asked to indicate which of two objects was elevated from their own and the agent's perspective during a visuospatial task, those with ASD performed as well as controls (David, et al, 2010). Similarly, Zwickel et al (2011) found that adults with Asperger's Syndrome could adopt the visuospatial perspective of a social agent to the same degree as TD adults whilst observing an interaction, but it seemed without necessarily understanding the nature of the interaction, as they were unable to attribute mental states to the agents. This is a very interesting difference as it would suggest differences in theory of mind use when a task involves mentalising compared to visual perspective-taking. Tracking and observing agents is highly distinguishable from attributing mental states to the agents, suggesting differences in how as opposed to what visual input is processed in ASD (Zwickel, et al, 2011). Nonetheless, visual perspective-taking is thought to develop later and perhaps differently in children with ASD in comparison to TD children (Warreyn, Roeyers, Oelbrandt & De Groote, 2005). This would suggest a specific deficit in ASD when inferring mental states that is unrelated to visuospatial perspective-taking, supporting a mind blind account of ASD.

It has been suggested that language impairments in ASD, particularly at the pragmatic level, are tied to theory of mind deficits (Oberman & Ramachandra, 2007), with the ability to make social inferences considered focal to the ability to effectively communicate with others (Martin & McDonald, 2003). Sperber and Wilson (1987) specifically implicated theory of mind in communication ability when they proposed their 'relevance theory', stating that *"communication exploits the well-known ability of humans to attribute intentions to each other"* (pp. 699). According to relevance theory then, ostensive-inferential communication is unattainable for individuals with ASD because it requires the communicator to recognise intentions (Happé, 1993). Whilst some children with ASD show first-order belief attribution (i.e. distinguishing one's own belief from someone else's belief) and may be employing a compensatory strategy to do so, they may lack second-order belief attribution. That is, they may not be attribute a belief to one person about another person's belief.

For example, using Wimmer and Perner's (1983) false-belief task, Baron-Cohen (1989) found that whereas TD and Down's Syndrome children could attribute a false belief to the character and use this to predict the character's behaviour, 80% of ASD participants showed no such ability. In a follow up study, Baron-Cohen (1989) tested the 20% of ASD children who did pass the first-order belief attribution task on a second-order attribution task. The author showed participants a toy village comprised of objects and dolls and told the participants a story while moving the characters (dolls) around the scene. Following the story, participants were given a series of questions, including a belief question (*"Where does Mary think John has gone to buy ice-cream?"*) and a justification question (*"Why?"*). Baron-Cohen (1989b) found that while TD and Down's Syndrome children could attribute beliefs to others about another person's belief, those with ASD could not engage in this advanced second-order attribution.

This inability to recognise intentions and to attribute beliefs at a higher, second-order level may account for the language impairments in ASD. In three experiments, Happé (1993) tested adolescents with ASD and TD individuals on their analysis of figurative language (similes, metaphors and irony) in terms of relevance and theory of mind. The author found that ASD participants who lacked a theory of mind could comprehend similes, but could not comprehend metaphors or irony. Happé argued that because similes like *"He was like a lion"* and *"He was like his father"* can be interpreted in a purely literal sense, individuals with ASD who lack a theory of mind are capable of using and comprehending them. However, metaphors requires some understanding of intention as the sentence is a loose interpretation of the speaker's thought, and so require a first-order theory of mind to be properly used and understand. While ironic utterances are more demanding as they reference an attributed quote, so relies on second-order intentions (i.e. what the speaker thinks the listener believes). More interestingly however, Happé (1993) also found that those ASD participants who did have first-order theory of mind ability were able to comprehend both similes and metaphors, but not irony, and individuals with second-order theory of mind could appropriately process all inferential language. These findings would suggest a strong association between theory of mind deficits and communication impairments in ASD.

However, one pitfall of the theory of mind explanation of language impairments in ASD is that the direction of the relationship between theory of mind and communication difficulties is unclear. Some researchers believe that theory of mind is a fundamental precursor for the development of social communication skills, while others suggest that it is experience of social communication that drives the development of theory of mind reasoning (Martin & McDonald, 2003).

Whilst the Theory of Mind approach has been successful in terms of predicting impairments in socialization, imagination and communication in people with ASD, it cannot account for many other aspects of ASD nor can it explain all people with ASD (Frith & Happé, 1994). Other aspects of the disorder include; preoccupations with sameness, hyper- and hypo-sensitivities, islets of ability, excellent attention to details, difficulties with coordination, muscle tone differences and rigid posture (Frith, & Happé, 1994; Baron-Cohen, 2004; Jaegher, 2013). However, not all of these symptoms of ASD are impairments, but are abilities superior to those in the general population.

1.7.2 Weak central coherence theory (WCC)/Local bias

Neurotypical individuals consistently show strong central coherence or Gestalt processing (Baron-Cohen, 2004). That is, they demonstrate a preference for processing at the global as opposed to the local level. Frith (1989) suggests this is because the normal cognitive system has an innate tendency to generalise over a wide range of stimuli and contexts, which compels individuals to prioritise understanding of meaning and gain high-level global cohesion of information. In contrast, people with ASD are thought to lack this capacity for global coherence, showing a bias to process featural and local information with an inability to understand the 'big picture'. This theory of a weak central coherence can explain the hyper-attention to detail characteristic of individuals with ASD and can account for the patterns of superior and poor performance within a single cognitive postulate. The theory can predict good performance in areas where local attention is advantageous and poor performance where global processing is more beneficial; thus, this account of ASD is better characterised in terms of cognitive bias or style as opposed to cognitive deficit (Happé & Frith, 2006).

Empirical support for a weak central coherence in individuals with ASD has shown that detail-focussed, local processing has been observed at the perceptual and visuospatial levels. At the perceptual level, individuals with ASD have the tendency to focus on individual elements without integrating them. Happé (1996) presented ASD children, TD children and children with developmental delay with Titchener Circles visual illusions (as in Figure 1). For TD individuals, the presence of the surrounding circles interferes with the ability to judge whether the two inner circles are the same size or not. However, Happé (1996) found that children with ASD did not succumb to the illusion and were successful in judging the size of the circles, compared to typically- and delayed-developing children. According to the WCC theory this was because the children with ASD perceived the figures in a less unified fashion, processing each part of the object in a fragmented way.

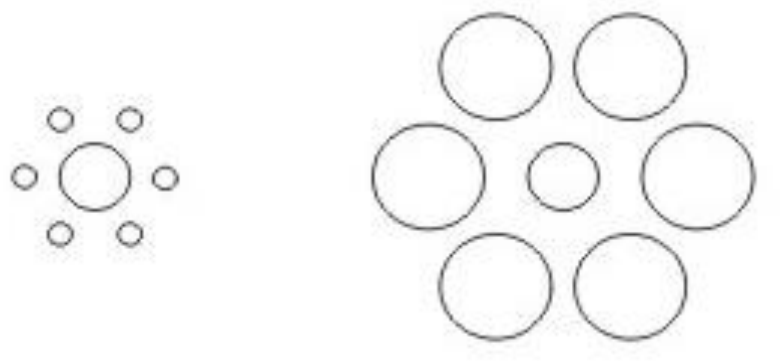


Figure 1. Example of Titchener Circles used by Háppe (1996).

In the same way, Jarrold and Russell (1997) showed children with ASD, in comparison to TD and developmentally delayed children, do not benefit from canonical presentations (versus distributed presentation) during a dot counting task. The authors suggested that in line with the WCC theory, ASD children did not consider the canonical dots as a global gestalt but rather counted the dots individually; the same processes required in the distributed condition. Autistic children also show a local perceptual bias in processing auditory stimuli. During a same-different judgement task of pairs of melodies, high functioning ASD individuals were superior at detecting changes in melodies at a local level in comparison to TD individuals (Mottron, Peretez & Ménard, 2000). The authors argued that this reflects a processing style as opposed to a cognitive deficit.

Bölte, Holtmann, Poustka, Scheurich and Schmidt (2006) examined gestalt perception in high functioning autistic (HFA) adult men and found that a decrease in such processing was indicative of a preference for local visual processing. They gave adult males with HFA, schizophrenia, depression and healthy controls a gestalt perception task and four global-local processing tasks (visual illusions, hierarchical letters, block design and the embedded figure test). It was found that the autistic participants perceived the gestalt stimuli less in accord with corresponding gestalt laws of similarity, proximity and closure compared to the clinical or control groups. The authors argued that the findings reflect altered gestalt perception in ASD.

This preferential processing style may explain the language impairments in ASD. The WCC theory explains that pragmatic language requires the ability to focus on the global context of the discourse, as opposed to simply attending to the specific semantics of the language, in order to comprehend the meaning (Oberman & Ramachandran, 2007). Evidence shows that while language use fundamentally relies on context, language is an early cognitive system to suffer as a result of WCC in ASD (Martin & McDonald, 2003). For example, children with ASD are less likely to spontaneously use the sentence context to provide the context-appropriate pronunciation of a homograph (e.g. *"There was a big* <u>*tear*</u> *in her dress."*) (Jolliffe & Baron-Cohen, 1999). Moreover, Jolliffee and Baron-Cohen (1999) asked participants to read aloud, sentence pairs (one describing a situation and one describing an outcome) such as *"George left his bath water running. George cleared up the mess in the bathroom"* and were asked which of three additional sentences would fit between the describing and outcome sentences to make them related and coherent (i.e. *"George cleared up the mess in the bathroom because: the bath had overflowed/his brother had left it untidy/the workman hadn't cleared up the mess"*). The authors found that the ASD group were impaired in their ability to identify the coherent inference. Since inference processing is central to language ability, these findings would support a WCC account of the language impairments of ASD

Face perception and WCC

Research on face processing by individuals with ASD provides further evidence of a weak central coherence theory of the disorder. High functioning autistic individuals have been found to be significantly slower at same/different discriminations between novel faces compared to TD individuals, and this impairment is emphasised when making individual discriminations versus gender discriminations (Behrmann, et al, 2006). Additionally, Behrmann and colleagues (2006) showed that relative to TD individuals, those with ASD showed configural processing biased to local processing in a Navon letter task; identifying local elements faster than global letters or shapes in comparison to TD adults. These observed difficulties in face processing and configural processing abilities would imply a preference for local processing and support a WCC account of ASD.

Interestingly however, individuals with ASD are able to recognise and process faces holistically when appropriately cued. In a whole versus part paradigm adolescents with and without ASD matched a target face to either a whole face or a face feature. On some trials participants were cued to a feature on which to make their matching judgement (i.e. *"Look at the mouth"*), while remaining trials were uncued (López, Donnelly, Hadwin, & Leekam, 2004). Compared to age matched typically developing adolescents, those with ASD were only able to process whole faces under a cued condition, but not under the uncued condition. In contrast, typically developing adolescents showed a whole face advantage under both cued and uncued conditions. This would suggest that holistic processing is intact in ASD, but only operates under certain conditions. Rather, individuals with ASD present superior processing of face parts and not necessarily a deficit in configural face processing, implying a processing style (Lahaie, et al, 2006).

Local processing as a systemising processing style

Local processing has been considered synonymous with the savant skills observed in many with ASD. At least one third of such individuals are thought to exhibit savant skills and most notably in areas of music, mathematics, art and memory for dates, places, routes and facts (Howlin, Goode, Hutton & Rutter, 2009). This predisposition for savant skills and attention to detail is thought to undermine hyper-systemising characteristic of the disorder (Baron-Cohen, Ashwin, Ashwin, Tavesolli & Chakrabarti, 2009; Happé, 1999).

Individuals with ASD are believed to have intact or even superior systemising that is at least in line with mental age (Baron-Cohen, 2004). Systemising refers to the drive to analyse and construct systems so that one can understand and predict the behaviour of inanimate events and can be technical, natural, numerical, motoric, collectible, abstract and social (Baron-Cohen, Richler, Bisarya, Gurunathan & Wheelwright 2002; Baron-Cohen, 2004; Baron-Cohen, 2009). Systemising is one dimension of the Empathising-Systemising Model (E-S Model) explanation of ASD; an approach that has emerged from within the Theory of Mind account (Lawson, Baron-Cohen & Wheelwright, 2004). The E-S Model posits that the social impairments observed in ASD are the result of a deficit in empathising, or the ability to attribute mental states and emotions to others, as discussed above. The areas of strength in ASD, such as hyper-attention to detail are explained by reference to intact or even superior systemising (Baron-Cohen, 2009).

Individuals with ASD have been found to score higher on the Systemising Quotient (SQ), but lower on the Empathising Quotient (EQ) in comparison to the general population (Baron-Cohen, et al, 2003). Children with ASD have also shown intact or superior systemising abilities. In comparison to older TD children, eight to 11 year old children with Asperger Syndrome (AS) scored higher on an intuitive physics tests but lower on an intuitive psychology test (Baron-Cohen, Wheelwright, Spong, Scahill & Lawson, 2001).

While some argue that behaviours and processing styles typical of those with ASD are the result of a weak central coherence, others suggest that symptoms such as restricted and repetitive behaviours are explained by impairments of executive functions. The Executive Dysfunction Hypothesis is the third explanation of ASD and I discuss this next.

1.7.3 Executive dysfunction theory

Executive function refers to the ability to shift one's mind set quickly and to adapt to diverse situations while also inhibiting inappropriate behaviour (Jurado & Rosselli, 2007). The general term includes abilities such as planning, working memory, mental flexibility, impulse control, inhibition and initiation and monitoring of actions (Hill, 2004). Executive dysfunction is linked to ASD and is thought to account for the repetitive behaviour and restricted interests characteristic of the disorder (Hill, 2004). Repetitive behaviours and restricted interests in ASD encompass a need for sameness, lack of impulse control, difficulty initiating new non-routine actions and difficulty switching between tasks (Robinson, Goddard, Dritschel, Wisely & Howlin, 2009).

However, executive dysfunction is thought to appear later on in development as ASD children do not show differences in executive function abilities compared to TD children at around four years old (Griffith, Pennington, Wehner & Rogers, 1999). Rather, TD children and children with ASD are thought to show different developmental trajectories of executive abilities, with executive deficits thought to become more prevalent in ASD with age, while TD children grow out of such a deficit (Griffith, et al, 1999).

Other neurodevelopmental disorders such as attention deficit hyperactivity disorder (ADHD) are also associated with deficits of executive functions; however dysfunction is thought to be more generalised and profound in ASD. Geutts et al (2004) asked groups of children aged six to 13 years old to complete a series of tasks relating to five major domains of executive functions; inhibition, working memory, planning, cognitive flexibility and verbal fluency. Differences between children with ADHD and children with high functioning ASD were reported; with ADHD children showing difficulties in inhibiting a prepotent response and verbal fluency. This is in contrast to the ASD children who exhibited difficulties with inhibiting a prepotent response as well as an ongoing response, alongside dysfunctions with planning, cognitive flexibility and verbal fluency. However, the ASD group did not show working memory impairments.

Disturbance of executive functions is also thought to underpin the characteristic repetitive behaviours and restricted interests of ASD. South et al (2007) asked a group of ASD adolescents and an age matched TD group to complete the Repetitive Behaviour Interview developed by Turner (1991, as cited in South, Ozonoff & McMahon, 2007) alongside tasks related to executive functions; namely the Wisconsin Card Sorting Task, which requires participants to match cards along different dimensions. The participants also completed two measures of central coherence; an Embedded Figure test measuring visual-spatial ability and attention to perceptual detail, and the Gestalt Closure test where participants identify degraded pictures of objects and animals. Interestingly, reports of repetitive behaviours positively correlated with measures of executive functions, whereas no correlation between repetitive behaviours and central coherence was observed (South, Ozonoff & McMahon, 2007). This would suggest that repetitive behaviours characteristic of the disorder are explained by executive dysfunction as opposed to a weak central coherence.

Research has also investigated specific domains of executive function in ASD, with difficulties reported in planning, mental flexibility and inhibition. I will now focus my review on these specific domains.

Planning

Planning is a cognitive skill that requires constant monitoring, evaluation and updating of actions (Hill, 2004). The ability to plan is generally assessed using the Tower of London (ToL) task (though there are variations of this paradigm), which involves participants moving disks from a prearranged sequence to match a goal state determined by the examiner in as few moves as possible (Hill, 2004). See Figure 2 for an example of the ToL task. Children with ASD have been found to be impaired on planning and this deficit has been found to be more profound in this group compared to age matched children with ADHD and Tourette's Syndrome (Ozonoff & Jensen, 1999).

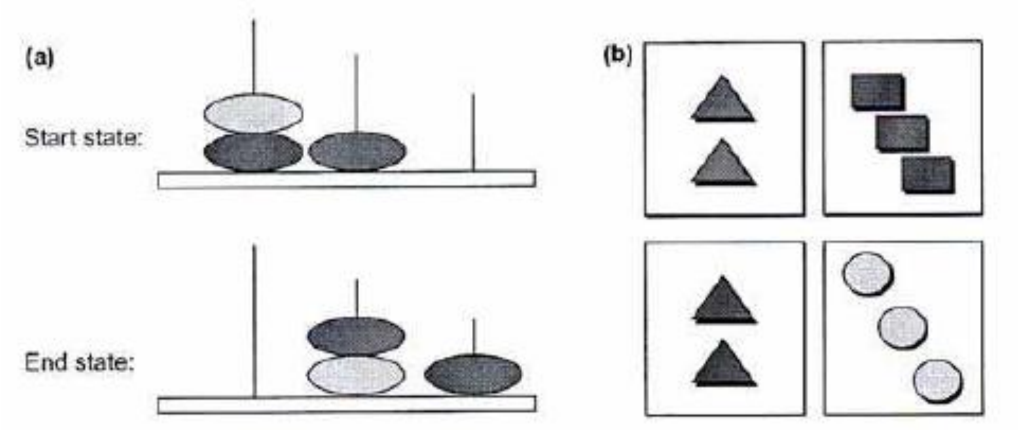


Figure 2. (a) Examples of puzzles used in the ToL task (b) Examples of cards used in WCST; taken from Hill (2004).

However, on a computerised version of the ToL task, called the Stockings of Cambridge, planning impairments were only evident when puzzles became more complex, requiring longer sequences of moves (Hughes, Russell & Robbins, 1994). Hughes et al (1999) compared the performance of ASD individuals with age matched children with moderate learning difficulties and a second TD group. The ASD group showed impairments in planning and set shifting, specifically related to internal controls of visual attention and coordination in comparison to both control groups.

Mental flexibility

Individuals with poor mental flexibility show repetitive, stereotyped behaviour and difficulties in regulating and modulating motor actions, indicating an impaired ability to shift to different thoughts or actions according to changing situations (Hill, 2004). Mental inflexibility, which may contribute to the restricted repetitive behaviours exhibited by those with ASD, has been assessed using the Wisconsin Card Sorting Task (WCST). In this task participants are presented with cards and are asked to sort them on one of three dimensions (colour, number or shape) without specific instruction. They are then required to shift rules and sort the cards along a different dimension, and the experimenter informs the participants on whether they have placed the cards correctly, but does not explicitly give the rule. Measures of scoring include total number of errors, categories completed and number of perseverative errors, with the latter reflecting a failure to shift set to a new sorting criterion.

Individuals with ASD experience difficulty in mental flexibility compared to TD individuals and people with other neurodevelopmental disorders such as ADHD, developmental language disorder and individuals with learning difficulties (Robinson, et al, 2009; Corbett, et al, 2009; Liss, et al, 2001). Interestingly, studies evaluating measures on the WCST have found deficits are maintained over time in ASD. Autistic adolescents performed significantly worse on mental flexibility and other assessments of executive function compared to matched participants with learning difficulties and reassessment three years later showed no improvement. In contrast, the control group did show changes on WCST performances developmentally, suggesting that while those without autism show improvements in executive functions, illustrated through measures on the WCST, those with ASD remain relatively static through development (Ozonoff & McEvoy, 1994)

On a computerised version of the WCST, adults with HFA and Asperger Syndrome proceeded through a number of shift sets with successful performance requiring the participants to determine the correct sorting criterion on the basis of computer feedback and then maintain this sorting principle. Although ASD participants performed below the TD matched participants on all measures of the WCST, differences were only significant on a measure of failure to maintain set (Kaland, Smith & Mortensen, 2008). Here, ASD participants seemed to recognise the sorting principle, but were unable to maintain the strategy of sorting throughout the study, which would imply a notable impairment on the WCST in ASD.

Inhibition

Response inhibition is the ability to suppress irrelevant or interfering information or impulses (Robinson, et al, 2009). Studies have shown that on classic inhibition tasks, such as the Stroop task (Stroop, 1935) where participants are required to name the colour that words are written in while ignoring the word representing colour itself (e.g. *"red"* written in blue colour), individuals with ASD are unimpaired (Hill, 2004). After administering a battery of executive function tasks to individuals with Asperger Syndrome and a group of matched TD adults, those with Asperger Syndrome participants were found to be unimpaired on 'classic' tests. Though, the lack of group difference may be due to the nature of the tasks. While the Stroop task is conceived as a test of inhibition; other tasks may require other attention processes, such as sustained attention, which may be impaired in ASD (Hill & Bird, 2006).

However, impaired response inhibition has been reported on the Windows task and Detour-Reaching task. In these tasks participants win a desired object visible in a box by inhibiting a prepotent response to point to the box with the object in it. Instead participants must point to an empty box beside the target box. Consistently poor performance on these tasks indicates an inability to inhibit prepotent responding (Robinson, et al, 2009), with difficulties shown by individuals with ASD in situations with and without a social component, as well as when the instructions are arbitrary or non-arbitrary (Hill, 2004).

Compared to children without autism and non-typical development, children with ASD have been found to perseveratively indicate the target box; the box with the object to be won inside. Interestingly, this performance is consistent regardless of whether participants are competing against an opponent or not, and when the task is designed to allow the participant to implement strategic deception. The authors argue that this reflects a difficulty for individuals with ASD to disengage from an object (Hughes & Russell, 1993).

The executive dysfunction account of ASD is supported by evidence of correlations between executive functioning and language ability (Oberman & Ramachandran, 2007). Liss et al (2001) examined executive functioning in children with ASD and matched children with developmental language disorder. Following a battery of assessments, the authors found a significant relationship between performance on the WCST and verbal IQ, suggesting that executive dysfunctions are mediated by verbal abilities. However, whilst deficits in executive functioning appear to play a role in the communication impairments of ASD, it is not clear whether its contribution is a causal factor (Oberman & Ramachandran, 2007).

Bishop (2005) compared children with HFA, pragmatic language impairments (PLI), specific language impairment (SLI) and TD children on two fluency tasks; the Use of Objects task, in which participants are presented with an object and asked to state uses to which it could be put, and the Pattern Meanings task, where participants are given meaningless line drawings and asked to think of as many different things as possible that each could be. Participants also completed the Children's Communicative Checklist (CCC), which focused on pragmatic aspects. Analysis revealed that children with HFA and PLI produced a lower percentage of correct responses that TD children and children with SLI, and a relationship between performance on the fluency task and communicative abnormality was found. The author argued that pragmatic language impairments in ASD are associated with impairments in executive functions, including a lack of flexibility of thought and weak generativity. Such dysfunction would account for the restricted conversation exhibited by individuals with ASD.

The research findings discussed thus far highlight an interesting pattern of performance in cognitive tasks by individuals with ASD, with some tasks highlighting deficits in such individuals, and others suggest a lack of impairment. Such differences could be due to the nature of the tasks and the abilities they tap into. One theory that attempts to account for this pattern of performance is the Disordered Complex Information Processing Theory, which emphasises the impact of task demand.

1.7.4 Disordered complex information processing theory

A contemporary theory proposes that ASD is underpinned by a reduced capacity to process complex information across cognitive domains (Minshew & Goldstein, 1998). For tasks that test basic or mechanical abilities, performance is intact or even enhanced in individuals with ASD, in comparison to TD individuals. It is when tasks test higher order cognitive processing that individuals with ASD show reduced performance in comparison to TD individuals (Minshew, Williams & McFadden, 2008). It is suggested that this is because complex information processing requires the integration of multiple features, speeded processing, and the processing of large amounts of often novel information (Minshew, Williams & McFadden, 2008).

Evidence for this account of ASD has largely come from eye tracking research, which more often than not has reported similarities between TD and ASD groups for simple processing demand tasks. For example, in a "spot the difference task", in which participants were asked to indicate which in a pair of images had a missing detail, no group effects were found. ASD participants were no different to TD participants in their ability to identify the target picture and there was no difference in eye movements between the groups (Au-Yeung, Benson, Castelhano & Rayner, 2011). Interestingly however, in a complex '"which ones weird" task, where participants were asked to identify which one of a pair of images looks "weird", although the ASD participants were able to identify the target picture, analysis of eye movements sequences revealed group differences in how participants were navigating the pictures. In this complex task, ASD participants took significantly longer to begin inspecting the target region, made more fixations before entering the target region and the first fixation to the "weird" region was significantly longer, suggesting the ASD participants did not immediately recognise the weird feature (Au-Yeung, Benson, Castelhano & Rayner, 2011).

Benson, Castelhano, Au-Yeung and Rayner (2012) ran a second analysis on the results found by Au-Yeung, Benson, Castelhano and Rayner (2011) to look at volitional eye movements by TD and ASD participants to test the disordered complex information processing theory. The authors found no group difference in the number of fixations or mean fixation durations in either the "spot the difference" or "which ones weird" tasks. Moreover, there were no group differences in any of the measures on the simple information processing task. However, analysis revealed processing differences between the ASD and TD participants for the complex information processing task. Despite ceiling level accuracy in both groups, the ASD participants took significantly longer to respond and this was reflected in the eye movement data where such individuals took longer to scan the scenes before fixating the target region, compared to TD participants. More interestingly, when the target was fixated, the ASD group did not immediately identify the "weird" target item when they first looked at it.

Complex information processing deficits are thought to occur across cognitive domains. Perspective- and non-perspective-taking tasks have revealed that individuals with ASD show a difficulty resolving ambiguity in comparison to TD individuals, and ambiguity may be a defining feature of complex information processing deficits in the disorder (Au-Yeung, Kaakinen & Benson, 2014). Eye movements were recorded as participants viewed a house scene, with objects such as a laptop, a printer, a broken curtain rail, a damaged radiator and other non-technological items including money, purses, handbags, etc., and were given either a perspective-taking or non-perspective-taking task. In the former task, participants were instructed to "look at the items of the house that are valuable" or "look at the features of the house that need fixing", whilst in the perspective-taking task they were instructed to "look at the pictures and imagine that you are a burglar" or "look at the pictures and imagine that you are a repairman". Analysis of eye movements revealed that in the "look for the valuable items" (non-perspective-taking) and burglar perspective-taking tasks, ASD participants performed comparably to TD participants. That is, they showed a relevance effect, fixating the schema-relevant (i.e. the laptop and printer) as opposed to schema-irrelevant (i.e. the curtain rail and radiator) items. Interestingly however, in the "look for features that need fixing" (non-perspective-taking) and repairman perspective tasks, no relevance effect was observed in the ASD group. It would seem that identifying the objects relevant to this schema was more difficult for ASD participants, possibly due to ambiguities in categorising relevant items (Au-Yeung, Kaakinen, & Benson, 2014). These patterns of behavioural and eye movement results fit with Minshew and Goldstein's (1998) complex information processing theory of ASD.

This theory can also account for the variable patterns of language ability in the ASD population. Despite intact verbal abilities, individuals with ASD display language impairments as a result of a generalised dissociation between basic and complex tasks in terms of information processing demands. This dissociation is evident in ASD performance on tasks comparing basic procedural linguistics with complex, interpretative linguistic skills. Minshew, Goldstein and Siegel (1995) asked HFA and TD participants to complete a battery of tests assessing; basic linguistic information processing, basic verbal learning, mechanical reading and phonetic skills, basic language fluency and comprehension of oral speech, and the use of language in communication and verbal problem solving. The authors found that the ASD participants performed as well as control participants on basic procedural language tests, but showed reduced performance on tests of complex interpretative language abilities. These findings would support a dissociation between basic mechanical and procedural language abilities, which are thought to be intact in ASD, and more complex language abilities, which are found to be impaired in ASD.

1.7.5 The current cognitive theories of ASD

Though the four most influential cognitive theories of ASD make a good attempt at explaining the characteristics of the disorder, none are able to comprehensively account for all behavioural manifestations or the high heterogeneity in ASD. However, it has recently been suggested that the high cognitive heterogeneity may be more characteristic of ASD than any single profile. In fact the high cognitive heterogeneity both between and within individuals with ASD has driven a new neuropsychological approach that is beginning to form the basis of theorising. The method entails administering tasks that tap different cognitive domains and differences within an individual, as opposed to across individuals. This approach put forward by Towgood et al (2009) effectively considers each ASD participant to be their own control. This single case study method was tested by running a series of neuropsychological assessments on a group of high functioning ASD adults, matched against a control group of TD adults on age, IQ and gender. Results were analysed between groups and by individual. Interestingly, while group-level analysis revealed limited deficits in the ASD group, single-case analysis revealed marked variation in performance both within and between the ASD participants on measures of processing and motor speed and measures of executive function. Participants with ASD performed at both an impaired and supra-normal level across tasks, with variability being the defining feature of the group. This would suggest that high cognitive heterogeneity could be considered a characteristic of ASD itself and therefore no single theory could account for the vast amount of variation.

1.8 Language and communication impairments in ASD

It is well-reported that the majority of those with autism suffer deficits not only in social reasoning as discussed, but also exhibit language development deficits. Deficits in language, much like many other symptoms of ASD vary greatly between individuals, ranging from muteness to no apparent delay and competent use of grammatically complex language. This heterogeneity in language skills is made evident when observing performance on standardised tests (Kjelgaard & Tager-Flusberg, 2001). Kjelgaard and Tager-Flusberg (2001) administered a battery of standardised language assessments to autistic and control children to test their phonological, lexical, and higher order semantic and grammatical abilities. It was found that although across all autistic children articulation skills were spared, there was significant heterogeneity in language skills, with different subgroups of children with ASD identified on the basis of vocabulary knowledge. Moreover, it is thought that over half of people with ASD exhibit some language impairment, many involving all aspects of language; pragmatics, lexical and semantic, syntactical, morphological, phonological and phonetic (Belkadi, 2006). Typical language abnormalities in ASD include echolalia, pronoun reversal, the production of utterances unrelated to the conversational context and a lack of drive to engage in communication (Asperger, 1991; Kanner, 1943 as cited in Groen, Zwiers, van der Gaag & Buitelaar, 2008).

1.8.1 Impairments at the phonological and morpho-syntactic levels

There is some debate as to whether children with ASD tend to be impaired in structural language form. One aspect of structural language form on which children with ASD are impaired involves the use of personal pronouns 'I' and 'you'; that is, many reverse these pronouns in speech production as least for a developmental period. This reversal is thought to stem from a difficulty in continuously remapping reciprocal relations (deictic shifting) necessary for pronoun use, which may have a neural basis in the right anterior insula and precuneus (Mizuno, et al, 2011). However, TD children have also been shown to reverse pronouns, most commonly within certain contexts when processing resources are strained (Dale & Crain-Thoreson, 1993). It is thought that like TD children, those with ASD eventually master pronominal deixis (Mizuno, et al, 2011), and such deficits disappears. Although, Mizuno et al ran a linguistic perception-taking task, in which HFA and control adults were asked to respond to questions that used personal pronouns (shift deixis) or names (fixed diexis), from either a first- (self) or second-person (other) perspective. Results revealed greater difficulty (i.e. slower and less accurate responses) by the ASD participants with deictic shifting compared to fixed deixis. Poor behavioural responses were accompanied by lower functional connectivity between the right anterior insula and precuneus in the deictic shift condition for ASD participants, in comparison to greater functional connectivity in the shift than fixed condition in the control group.

However, many consider the issue of pronoun reversal to be a functional semantic-pragmatic impairment, rather than an impairment in the morpho-syntax or phonology. Bishop et al (2004) used two phonological processing tests to explore whether language impairments form part of the broad autism phenotype. The first task was a nonword repetition task, in which participants heard nonwords such as *"nembid"* and were asked to immediately repeat back the word. The second task was a nonsense passage reading task, where participants read short passages such as, *"Once upon a time a tawndy rapsig named Gub found a tix of pertollic asquees."* The two tasks were selected because of their sensitivity to language and literacy difficulties, and reading nonsense words requires the comprehender to map letters to speech sounds, tapping phonological skills. The authors found that although those with autism were impaired relative to TD controls on the two tests of spoken and written word phonological processing, there was no indication of a disproportionate phonological deficit when they had normal verbal ability. Consequently, the authors argued that the structural language impairments seen in autism are similar to those observed in individuals with Specific Language Impairments (SLIs), but that this was not evidence for an underlying etiology between the two conditions.

1.8.2 Semantic processing impairments

A widely recognised language impairment in ASD is a semantic impairment; a difficulty understanding and expressing language meaning. Kjelgaard and Tager-Flusberg (2001) reported difficulties in lexical comprehension, using the Peabody Picture Vocabulary Test (PPVT) and expressive vocabulary, using the Expressive Vocabulary Test (EVT) in most of the autistic children. Similarly, Kamio et al (2007) found that, in comparison to controls, lexical/semantic processing was not facilitated by priming in autistic children and adolescents during a lexical decision task. Kamio and colleagues presented participants with pairs of letter strings (e.g. *'beef' 'chicken'*), where the first word presented was a prime and the second was a target. Participants were asked to judge whether the target word was a word or a nonword. Processing by control participants was facilitated when the preceding word was semantically related, however this was not the case for individuals with ASD. Lexical/semantic processing by the ASD was unaffected by when the target word was preceded by a semantically related word, despite reaction times being comparable to that of the control group. The findings would suggest that although the ASD participants showed impairments in automatic semantic processing, their lexical access was not slowed compared to control participants.

Such lexical comprehension (or semantic) difficulties have been associated with functional underconnectivity and underintegration of cortical regions (Kana, Keller, Cherkassky, Minshew & Just, 2006). Kana and colleagues presented high-functioning autistic adults and controls with high- *("The number eight when rotated 90 degrees looks like a pair of eye glasses"*) and low-imagery *("Addition, subtraction and multiplication are all math skills"*) sentences. For the former, the use of imagery is required, whilst this is not true of the latter. Analysis revealed that among cortical regions, language and spatial centres were not as integrated in ASD as for controls. The authors also found that when processing low-imagery sentences autistic participants activated parietal and occipital brain regions associated with imagery equivalent for high-imagery sentences. This finding is in contrast to control participants who only used imagery to process the latter, suggesting a reduced integration of language and imagery in autism as a possible explanation for semantic difficulties.

Similarly, Just, Cherkassy, Keller and Minshew (2004) found a lower degree of integration across large-scale cortical areas associated with language processing in adults with high-functioning autism. Participants took part in a comprehension task that involved reading and responding to active and passive sentences. The autistic group showed greater activation in Wernicke's area but less in Broca's area and functional connectivity between regions of interest (ROIs) was lower for autistic than control participants. A deficit was also evident in the behavioural data, with the autistic group, although performing more quickly, were far less accurate than the control group. The findings could be interpreted to imply a difficulty with semantically and syntactically integrating the words of a sentence (Just, et al, 2004), perhaps as a result of underconnectivity.

1.8.3 Deficits in pragmatics and comprehension

The most central difficulties children with autism exhibit are within the pragmatics of language; the ability to appropriately use language in social context and to produce appropriate discourse (Tager-Flusberg, 1999). Such deficits in the pragmatics and comprehension of speech are thought to be universal in children with autism (Rapin & Dunn, 2003), whilst other language impairments are not. Colle and Baron-Cohen (2008) showed that adults with HFA and AS with no history of language delay still exhibited pragmatic deficits during a narrative discourse task. Using a picture book, Colle and Baron-Cohen asked autistic and control adults to narrate a story and found that the groups did not differ in their use of appropriate phonology, syntax, ability to comprehend and extract the plot and story length and structure. The authors therefore argued that this implies intact narrative discourse production in autism. However, autistic participants used significantly less personal pronouns and referential and temporal expressions. Moreover, they produced less fluent and pedantic sentences that were unlinked, suggesting an impaired ability to link episodes with a global theme, evidence of a pragmatic language deficit.

Other areas of pragmatics that have been shown to be impaired in individuals with ASD include the use of structured coherent discourse, understanding implied meaning (irony, metaphors, etc.) and the use of non-verbal communication gestures (Groan, et al, 2008). Autistic children are worse at comprehending metaphors and metonymy in comparison to age matched TD children (Rundblad & Annaz, 2009). Using picture stories, Rubdblad and Annaz presented participants with a set of pictures where the final section of the story contained a target metaphor or metonym alongside the picture, and asked children to report what the character in the story sees. Whilst TD children improved on metaphor and metonym comprehension with increasing chronological age, children with autism did not. In contrast, there was no reliable relationship between performance and chronological age for either metaphor or metonym comprehension for ASD children, and their performance was poorer for metaphor comprehension than metonym comprehension. However, analysis did reveal that the two linguistic devices yielded different developmental trajectories in the ASD group. Children in the ASD group mostly performed at floor level on the metaphor comprehension task, but performance on the metonym comprehension task had no systematic relationship with chronological age. The authors also found a lack of variability in performance in the ASD group and concluded that figurative language comprehension affects most children with ASD in a similar way.

Autistic children with and without mental retardation are also less likely to spontaneously interact socially, they use less non-verbal gestures and are limited in their use of facial glance and speech when addressing others (Attwood, Frith & Hermelin, 1988). However, Attwood and colleagues reported that autistic individuals did have an understanding of gestures that was par with TD children and children with Down Syndrome, possibly demonstrating an expressive as opposed to instrumental deficit.

Another pragmatic ability that has been widely researched in autism is the ability to perceive and use prosody; intonation, rhythm, tone of voice and stress (Groan, et al, 2008). Rutherford, Baron-Cohen and Wheelwright (2002) asked participants to judge which of two mental state terms matched spoken phrases and found that autistic individuals were impaired in their ability to attribute emotions or mental states after hearing sentences spoken in an emotional voice. Moreover, Paul and colleagues showed that individuals with autism have difficulty with the perception and production of stress, intonation and phrasing (Paul, Augustyn, Klin & Volkmar, 2005). Additionally, Peppé et al (2006) found deficits in receptive and expressive prosody (Peppé, McCann, Gibbon, O'Hare & Rutherford, 2006). Specifically, autistic children showed particular impairments in intonation, accent and ability to disambiguate utterances using prosodic breaks. Autistic children were also found to judge question-type stimuli as statements.

As well as marked deficits in processing and utilising language, individuals with ASD also show impaired action understanding and imitation. Such impairments are believed to result from abnormal oscillations of mirror neurons in the sensorimotor cortex, which I will discuss next.

1.9 Action understanding and imitation in ASD

Understanding and predicting others' actions are crucial skills that underlie cognitive development, social learning and everyday interactions (Tomasello, 1999). TD children demonstrate an understanding of action as early as infancy and have been shown to distinguish three levels of others' actions in the first year of life; acting animately, pursuing goals and choosing plans (Tomasello, et al, 2005).

In addition to the ability to understand and predict others' actions, TD children also develop the capacity to imitate actions very early on in development. As early as 12 to 21 days old, infants have been shown to imitate facial expressions and manual gestures (Meltzoff & Moore, 1977) and infants younger than 18 months show the ability to reproduce modelled actions following a 24 hour delay (Barr, Dowden & Hayne, 1996). Imitation serves two distinct functions; a learning function through which infants acquire new skills and knowledge, and a social function as infants engage in social and emotional exchanges with others, from which they develop the social communication skills which are observed to be deficient in children with ASD (Ingersoll, 2008).

Research suggests a relationship between imitation abilities and social communication skills in ASD, including language, play and joint attention (Ingersoll, 2008). Social communication impairments may result from an inability to understand peoples' actions, which may originate from difficulties attending to and/or integrating information (Vivanti, et al, 2011). In terms of imitating observed actions, children with ASD show significantly more impairments in overall imitation abilities, oral-face imitation and imitation of actions on objects compared to age and IQ matched TD and developmentally delayed children, though there are differential impairments in simple imitation between ASD children (Rogers, Hepburn, Stackhouse & Wehner, 2003). Investigating the nature of motor imitation in young children with ASD, Stone, Ousley and Littleford (1997) asked young children with ASD and aged matched TD and developmentally delayed children to complete the Motor Imitation Scale (MIS); a series of single-step motor imitations where half involve the manipulation of an object and the other half involve body movements. The authors found ASD children to be significantly impaired at motor imitation compared to the other two groups, with deficits more pronounced for body movement imitation compared to imitation of actions with objects.

Problems with imitation extend into adulthood, with adolescents with ASD showing impairments across a range of imitation and pantomime tasks compared to age matched clinical groups (Rogers, Bennetto, McEvoy & Pennington, 1996). Tasks included imitation (e.g. hand tasks, such as extending the hand and arm straight out in front of the body, facial tasks (e.g. tongue protrusion with mouth open) and pantomime tasks (e.g. movements involving the use of common objects, such as a toothbrush or scissors). The high functioning ASD adolescents were found to have deficits across the experimental tasks.

More specifically, adults with high functioning autism and AS have been found to lack a natural preference for imitation in a mirror-image fashion. In one study, participants were asked to imitate the experimenter putting a pen with the left or right hand into either a blue or green cup using one of two possible grips; using the crossed hand (e.g. the participant's right hand corresponding to the experimenters right hand) or as if looking in a mirror (e.g. the participant's left hand corresponding to the experimenters right hand). Interestingly, ASD participants' performance did not differ from TD participants in the crossed hand condition, suggesting they understood the instructions. However, performance by ASD participants was significantly worse than TD participants in the mirror- image condition (Avikainen, et al, 2003). The findings would suggest that individuals with ASD are impaired in online imitation of goal-directed movements when imitation occurs in a mirror-image fashion. Notably, this form of imitation is most natural for TD individuals (Avikainen, et al, 2003).

The process of imitation involves translating a complex dynamic visual input pattern into motor commands so that self-performing the action resembles the model movement

(Avikainen, et al, 2003). The neural representations overlapping one's own and observing others' actions are thought to involve the Mirror-Neuron System (MNS). Consequently, the 'broken mirror' theory argues that it is the dysfunction of this neural system that results in impaired action understanding and imitation in ASD and is consequently the root cause of the characteristic social impairments.

1.9.1 Mirror neuron dysfunction in ASD

The MNS is thought to underpin action understanding and imitation in the neurotypical population (Rizzolatti, Fogassi & Gallese, 2001). Mirror neurons are a subset of visuomotor neurons in the cortex of human and monkey brains that respond when an individual performs certain actions as well as when the person observes others performing the same movements. Mirror neurons provide a direct internal experience and understanding of others' actions, intentions and emotions. It is the MNS that is also thought to underlie the ability to imitate actions (Rizzolatti, Fogassi & Gallese, 2006). This network of mirror neurons not only sends motor commands for the performance of action, but also enables people to detect actions and intentions of others by internalising and mentally simulating them. Humans perceive others using a distinct perspective that people are "like me" and as such, use the same systems that process information about self-performed actions, self-conceived thoughts and self-experienced emotions to understand others. Simulation mechanisms such as the MNS are important for the development of typical recognition, imitation, theory of mind, empathy and language (Oberman & Ramachandran, 2007). Dysfunction of the MNS may underlie the disruption of social and communicative abilities in ASD (Ramachandran & Oberman, 2006; Oberman & Ramachandran, 2007).

To determine whether action observation and imitation impairments are associated with atypical underlying neural mechanisms in ASD Théoret et al (2005) applied TMS over the primary motor cortex during observation of finger movements. They observed significantly lower primary motor cortex activation during action observation in the ASD group compared to matched TD participants. The authors suggested that dysfunction of the MNS could underpin the social deficits of ASD and lead to abnormal self-other representations.

Equally, Williams et al (2006) presented adults with ASD and matched TD participants with three stimulus-types illustrated in Figure 3. The first was an animation of a left hand, the second was a photograph of the hand and the final was a plain background with a cross marking the left or right side. In an execution task participants were instructed to raise their right index or middle finger to imitate according to the stimulus currently presented, while in an observation task participants were asked only to observe the three stimulus types. While both the ASD and TD groups showed activation in the right somatosensory cortex that was greater during imitation execution (i.e. animation stimuli), activity of mirror neuron areas was less extensive in the ASD group compared to the TD group for both imitative and non-imitative action execution. Additionally, secondary activation in the posterior parietal cortex that is expected during motor activity was observed in the TD group during non-imitative action execution, but this was diminished in the ASD group, perhaps reflecting poor thalamo-cortical connectivity in ASD (Williams, et al, 2006).

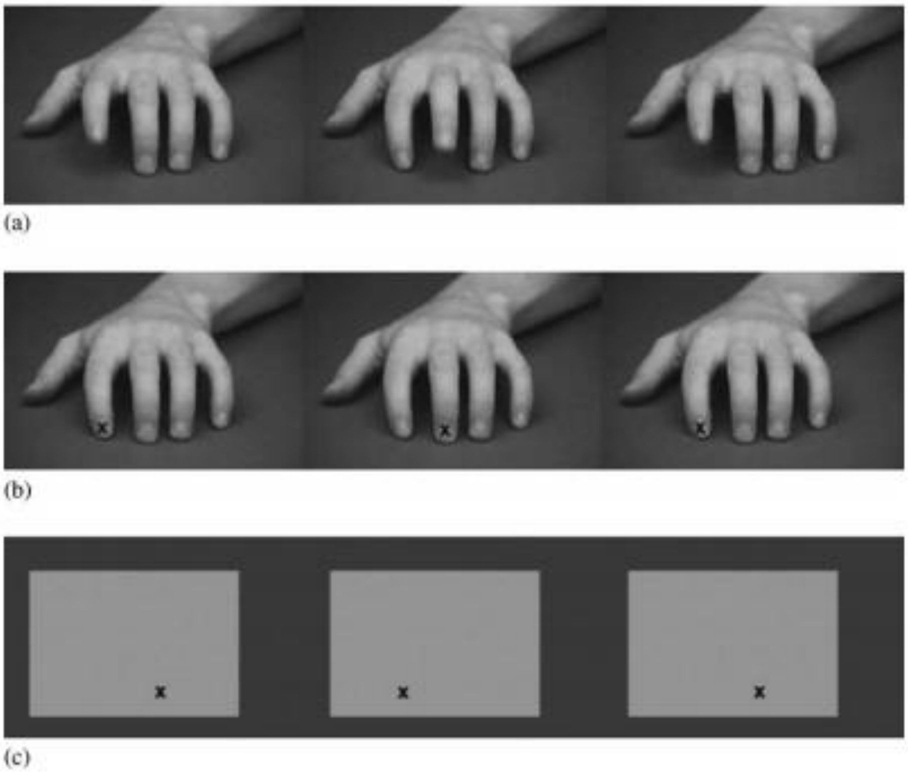


Figure 3. The three stimulus types taken from Williams et al. (2006): (a) animation, in which either index or middle finger were raised (b) symbolic cue, in which either the index or middle finger were marked (c) spatial cue, in which a cross was shown on either the left or right side of the screen.

Additionally, neuroimaging studies have reported anatomical differences in the MNS in ASD. Comparing HFA adults with TD matched individuals; neuroimaging has revealed significant thinning of cortical areas related to the MNS and other areas involved in social cognition in ASD participants (Hadjikhani, et al, 2006). Moreover, whole brain volumetric analysis of ASD children and matched TD children revealed significantly reduced overall grey matter in the former group and increased cerebrospinal fluid (CSF). Distribution differences of grey matter in cortical regions was also reported in the ASD group, further suggesting the disorder is associated with differences in anatomical and functional integration of large scale neural networks (McAlonan, et al, 2005).

EEG methods have also been used to investigate mirror neuron dysfunction in autism. Mu waves are EEG oscillations over the sensorimotor cortex with a large amplitude that are believed to reflect mirror neuron activity (Oberman, et al, 2005). Mu waves are interrupted when a voluntary action is made as the sensorimotor neurons are desynchronised by input from pre-motor neurons believed to house mirror neurons (Perkins, Stoke, McGillivray & Bittar, 2010). TD individuals show mu suppression both when they perform and observe actions, reflecting an execution/observation system that may play a critical role in action understanding and imitation (Oberman, et al, 2005; Muthukumaraswamy, Johnson & McNair 2004). Consequently, mirror neuron dysfunction in ASD may be observed as a lack of normal mu response (i.e. a lack of mu suppression in response to action performance or observation).

Oberman et al (2005) measured mu suppression in high-functioning autistic individuals and matched TD individuals while they watched videos of either a moving hand, a bouncing ball, visual noise or their own moving hand. As expected, TD participants showed significant mu suppression for observing both their own and another's hand movement. Interestingly however, ASD participants only showed mu suppression for self-performed hand movements, but not for observed hand movement. These findings would support a dysfunctional mirror neuron theory of ASD.

Similarly, Martineau et al (2008) showed ASD and TD children either a white screen, a no movement sequence (e.g. a lake surrounded by land), a non-human movement sequence (e.g. a waterfall) or a human performing a movement. TD children showed desynchronization of neurons in the motor cerebral cortex and frontal and temporal areas of the left hemisphere (i.e. MNS) during observation of biological movements. In contrast, ASD children showed inverse hemispheric activation, with increased activation in posterior regions of the right hemisphere. This would further support the hypothesis of a dysfunctional MNS in ASD, which may underlie the well-reported social deficits and impairments in action understanding and imitation.

However, research also suggests that individuals with ASD do show sensitivity of mu suppression to familiarity. Oberman, Ramachandran and Pineda (2008) presented ASD children and TD children with videos of a hand performing a grasping action. Critically, the hand either belonged to a stranger (unfamiliar), a parent or guardian (familiar) or was their own hand. Comparable to TD children, ASD children showed greater suppression to familiar hands than to unfamiliar hands. The finding suggests that the MNS does respond to observed actions in people with ASD, but only when those individuals can identify with the stimuli on a personal level, not just from an egocentric view point.

Thus far I have considered the impact of mirror neuron dysfunction on action understanding and imitation in the social domain in ASD. However, such mechanistic dysfunction is also believed to underlie the communication impairments characteristic of ASD. The observation and internalisation function provided by the MNS is thought to underpin the development of language from an early gestural communication system to dialogue (Ramachandran, 2000). Rizzolatti and Arbib (1998) examined monkeys and suggested that the part of the brain containing mirror neurons dealing with hand actions has evolved to sub-serve human speech as language builds on top pre-linguistic actions (or gestures). That is, the MNS is thought to serve as a bridge between perceived and performed action and speech, and consequently provides a foundation or the development of dialogue.

If the MNS does process auditory representations in the same way visual (action) representations, then the systems is most likely involved in representing the relationship between words and the speaker, and consequently impact the development of pragmatic and other complex aspects of language (Williams, Whiten, Sudendorf & Perrett, 2001). The 'Motor theory of speech perception' proposed by Liberman and Matingly (1985) claims that speech perception and speech production are closely linked. The phonetic gestures of the speaker are represented by the listener as invariant motor commands that signal the movement of the mouth, lips and tongue in specific configurations (Liberman & Mattingly, 1985; Oberman & Ramachandran, 2007), and speech production is the result of this simulation process.

The functional mechanism mirror neurons play in language can explain the communication impairments of ASD. In a linguistic multisensory-integration task, Ramachandran and Oberman (2006) presented children with ASD and TD children with two drawn shape, one jagged and one curvy and asked tem "Which of these shapes is *bouba* and which is *kiki*?" They found that 98% of the TD children labelled the curvy shape as *bouba* and the jagged shape as *kiki*, while only 20% of the ASD children showed the appropriate effect. The authors argued that the bouba/kiki effect reflects the typical brain's multisensory systems, including the MNS, integrate the visual shape with the sound (e.g. the jagged shape is embodied in both the drawing and the harsh sound of *kiki*). Dysfunction of the MNS in ASD would explain the impaired performance of the group in terms of reduced multisensory integration of information into an appropriate representation.

Given what is known about language impairments in ASD and the noted deficits in imitating actions, it is possible that the two are associated. Indeed, links have been drawn between imitation and language abilities in children with ASD. For example, motor imitation has been found to be a predictor of expressive language development in children with autism (Stone & Yoder, 2001). It could be that language impairments in ASD are related to impaired action understanding and the underlying brain mechanisms. The aim of this thesis is to investigate this possible explanation.

1.10 Matching ASD and control participants

Despite the well-documented impairments in ASD, some have begun to suggest that current matching tests between ASD and control groups are what underpin differences in performance. Mottron (2004) conducted a meta-analysis to compare the most common instruments used for level matching. At the time of publication, the prototypical cognitive neuroscience study on autism used individuals with high-functioning autism, a full scale IQ (FSIQ) of around 85 and a chronological age (CA) of 14 years. It was also found that CA and IQ (mostly verbal but also performance or full) are the most used matching variables.

Mottron found that verbal IQ is most commonly obtained through the Wechsler Scales VIQ or British Picture Vocabulary Scale (BPVS), whilst non-verbal (performance) IQ is obtained through the Raven Progressive Matrices (RPM) or the Wechsler PIQ. However, the three instruments result in significant differences when applied to the same population. For those with autism, there were discrepancies between the BPVS and Wechsler scales and between RPM and Wechsler FSIQ. For those with AS and the combined autism-AS group, the discrepancy was largest between the BPVS and Wechsler scales. Vocabulary-based scales and the RPM overestimate the general intelligence of autistic groups, making them unsuitable for matching with typically developing controls. In contrast, the Weschler scales were found to be a good indicator of general intelligence, with Mottron recommending that FSIQ or task-specific matching variables should be used to match groups.

The effects of poor matching are clearly evident in the literature. Take for example, Wang, Lee, Sigman and Dapretto (2006) and Colich, Wang and Dapretto (2012). Both examined the neural basis of irony processing in children and adolescents. The former reported that all participants were male, right handed and that the autistic and control groups did not differ significantly in CA or IQ. However, no significant difference does not imply that the two were similar. Although the control and autistic groups were matched on CA (Controls: M = 11.09, SD = 2.3; ASD: M = 11.09, SD = 2.8), VIQ (Controls: M = 108, SD = 13; ASD: M = 99, SD = 18) and FSIQ (Controls: M = 106, SD = 14; ASD: M = 102, SD = 18) (Wang, et al, 2006), the authors reported differences at the behavioural and neural level in how children with ASD and controls interpret irony. In contrast, Colich, et al (2012) matched groups on gender, handedness, age, amount of head motion and included ASD participants who had an IQ greater than 75 using the Wechsler Scale. Control and autistic groups were matched on FSIQ (Controls: $M = 109$, $SD = 13$; ASD; $M= 108$, $SD = 13$) and VIQ (Controls: $M = 111$, $SD = 16$; ASD; $M = 109$, $SD = 15$) and the authors found that autistic participants had intact interpretation of ironic remarks, with no difference between groups in terms of accuracy. Hence, many of the language impairments demonstrated may actually be the result of inadequate matching strategies, particularly with regards to HFA and AS, many of whom do not display a history of language delay.

1.11 Chapter summary

In the current Chapter I have presented the simulation model of language comprehension; the concept that language comprehension is facilitated through the construction of mental simulations. Language is embodied within cognition and simulations of events described by the linguistic input are enriched in perception and action. These simulations are constructed in real-time and constrained by characteristics of the input. As language becomes more complex and abstract, the comprehender must construct multiple and more complex simulations. This high-order cognitive process is believed to rely on neural networks including the mirror neuron system (MNS), also responsible for processes such as action understanding and imitation. Dysfunction of this neuron system is thought to underpin Autism Spectrum Disorder (ASD). Those with the disorder exhibit a heterogeneous array of characteristics and there are a number of theories that attempt to explain these. ASD is characterised by impairments in social communication, and the presence of repetitive and stereotyped behaviours. Such individuals also display marked impairments in imagination, action imitation and language production and comprehension; the latter being most notably within the domain of pragmatics and prosody, but also at lower level semantics and phonology.

1.12 Current research questions

So far, little is known about the nature of language simulation in the ASD population. In fact, whether such individuals simulate language at all remains unknown. Exploring simulations of language in ASD may provide insight into the social communication and language comprehension deficits associated with the disorder. As individuals with ASD show impairments in cognitive processes such as action understanding and imitation, which are thought to underpin simulations in the TD population, it may be that the disorder is also associated with a difficulty in simulating language and thus, comprehending language.

This thesis asks the question, what cognitive processes underlie the social communication impairments in ASD? Given the experiential nature of language and the marked deficits in imagination, action understanding and language in ASD, the research questions I aim to answer are; do individuals with ASD experience language at all? If so, is this experience the same as that of TD individuals? More specifically, in Chapter 2 I ask the following research questions; firstly, do individuals with ASD simulate the motor and spatial properties of language? If so, are these simulations activated as quickly and for as long as they are in TD individuals? I utilise two paradigms; the action-sentence compatibility effect (ACE) (Glenberg & Kaschak, 2002) and the sentence-picture verification task (Stanfield & Zwaan, 2001) alongside behavioural measures (i.e. reaction time and accuracy) to explore motor and spatial simulations of language by individuals with and without ASD. In Chapter 3, the research questions to be addressed are; what are the neurological mechanisms that underpin spatial simulations in individuals with and without ASD? Additionally, how are these simulations impacted by contextual uncertainty? To investigate this, I again employ the sentence-picture verification task (Stanfield & Zwaan, 2001), but with EEG event-related potentials (ERPs) to examine the neurological underpinnings of spatial representations of uncertain events.

Subsequent to exploring simulations of the motor and spatial properties of language, the remaining research questions focus on other forms of simulation. In Chapter 4 the research question moves to simulations of spoken language and asks; compared to TD individuals do individuals with ASD simulate the prosodic elements of language? Namely, are they able to simulate the speaker's tone of voice, emotions and intentions? To answer this question I use Yao, Belin and Scheepers' (2012) listening paradigm in conjunction with EEG event-related power change measures. The aim is to investigate the neural dynamics associated with simulations of spoken language in individuals with and without ASD.

The final research questions in Chapter 5 focus on the flexibility of mental simulations of language. Are individuals with ASD able to update their simulations of an event in time based on the unfolding linguistic input? And finally, are they able to undo simulations based on new information? Generally speaking, are ASD individuals able to simulate future and past events in real-time? In this final empirical Chapter I use the visual world paradigm (Altmann & Kamide, 2007; Kukona, Altmann & Kamide, 2014) alongside eye tracking measures to explore how individuals update and undo mental simulations of a spoken event in real-time. The paradigms and research methods utilised in this thesis will be introduced in more detail in the following chapters.

In summary, in the current thesis I will present six experiments that employ a number of psycholinguistic paradigms in conjunction with behavioural, EEG and eye tracking measures. The aim of this thesis is to provide new and valuable insight into simulations of language and comprehension capabilities in ASD, as a possible explanation of the social communication impairments characteristic of the disorder. In all the experiments presented, a sample of adults with HFA or Asperger's Syndrome recruited from the University of Kent will be tested. This sample was selected due to the nature of the cognitive tasks to be performed. Language simulation is a high-order cognitive task that requires intact verbal abilities comparable to TD adults. Since individuals with a diagnosis lower on the spectrum are more likely to have lower level language impairments, the decision was taken not to recruit from across the spectrum. Moreover, controlling for language abilities is advantageous as it will allow me to control for their effects on simulation ability.

The experiments proposed here will be the first to explore simulations of language in individual with ASD, which until now have only be explored in the TD population. Moreover, this thesis should contribute to the simulation literature generally, by offering insight into what it means to mentally simulate language. Furthermore, since simulations of language are the basis of language comprehension and thus social communication, at a theoretical level this research will provide further insight into the cognitive mechanisms that underpin communication impairments in ASD. At a practical level, this translates into a contribution to what is known about impairments in the domain of social communication in ASD and what the implications of these deficits are for such individuals in everyday interactions.

Chapter 2

Mental simulations of described events depict the perceptual, motor and affective content described by the linguistic input (Zwaan, 2009). In this chapter, psycholinguistic paradigms in conjunction with behavioural measures are used to investigate motor and spatial simulations of language comprehension by individuals with and without ASD. In this Introduction, I will present what is known about the behavioural signatures of motor and spatial simulations, discussing how such simulations work in the TD population. Following this, I will consider how individuals with ASD may be impaired in simulating language, or whether they represent language differently to TD individuals. Finally, I introduce the studies presented in this chapter.

Behavioural signatures of motor simulations

Motor simulations activate the neural substrates associated with performing a described action; when an individual observes another person performing an action, the neural substrates associated with actually performing the action are activated. It is also thought that when comprehending an action, one mentally simulates the action using the same neural substrates involved in performing the action (Zwaan & Taylor, 2006).

There is breadth of behavioural evidence to support this simulation theory of language comprehension. For example, Glenberg and Kaschak (2002) observed facilitation and interference effects when participants were asked to make judgements about sentences and respond by pressing a button in a position that required movement by the participant. Participants read sentences that described an action towards or away from the body (*"Courtney passed you the notebook"* versus *"You passed Courtney the notebook"*) and were asked to make sensibility judgements by pressing a button positioned away from the body or near to it. Response times were shorter when the implied direction of the sentence was the same as the actual response direction and an interference effect (longer response times) occurred when they contrasted. The authors termed this interaction between implied sentence direction and actual response direction as the 'Action-Sentence Compatibility Effect' (ACE). Comprehension of the sentences required the construction of simulations that reactivated patterns of brain activation associated with actually experiencing the event. When the motor action required a response that was in the same direction implied in the sentence, a facilitation effect (i.e. shorter reaction times) was observed and when the opposite motor action response was necessary an interference effect (i.e. longer reaction times) occurred. This was taken as evidence to support the notion that language comprehension is grounded in bodily action.

Borreggine and Kashchak (2006) sought to further extend understanding of the ACE interaction, arguing that in Glenberg and Kaschak's (2002) experiment participants knowledge of what motor action was required meant they could begin programming the correct motor response before the end of the sentence. They asked whether the ACE relies on this opportunity to prepare the required motor response during sentence processing by replicating the Glenberg and Kaschak's (2002) methodology, but manipulating the point at which participants became aware of which response direction was required to judge a sentence as sensible. In the first experiment, the response cue was presented at the onset of the sentence (as in Glenberg & Kaschak, 2002), while in the following three experiments the response cue was presented 50ms, 500ms and 1000ms respectively after the offset of the sentence. Interestingly, the ACE only arose in Experiment 1 when participants were able to prepare the required motor response while simultaneously processing the sentence. The effect was eliminated in the following three studies, suggesting that only during online processing of the sentence participants are activating relevant neural substrates. That is, the simulation process takes place during sentence processing, when participants can plan their motor response. This would explain the facilitation effects as the motor response is primed by the direction implied in the sentence.

Borreggine and Kaschak (2006) propose an account of the ACE and it's time course, based on the theory of event coding (TEC) (Hommel, Musseler, Aschersleben & Prinz, 2001). TEC is a theory of perception and action planning that posits action planning as a two-step process. Firstly, features associated with potential actions are activated and those features activated by more than one potential action receive more activation, which results in priming between the potential actions. Following this, the individual selects an action for execution, to which the relevant features are bound. Borreggine and Kaschak proposed this two-stage process during simulation of actions in language comprehension, suggesting features associated with the unfolding linguistic input are activated (e.g. whether the action described is away or towards) and these are then bound into a full simulation of the described action near or at the end of the sentence. The ACE occurs during preparation of the motor response for execution and preparation of the simulation. When participants know the direction of the motor response required, the directional feature (toward or away) is activated and simultaneously, as the sentence is being processed, a direction feature is activated for the simulation. Priming occurs between preparation of the motor response and preparation of the simulation when the directional feature activated by both is the same. It is this priming mechanism that drives the ACE, and as the feature binds to the simulation it becomes less available to execute the motor response, which is why the ACE then disappears if the response cue is presented after sentence offset.

Kaschak and Borreggine (2008) further supported this feature binding account of the ACE when they examined whether comprehenders simulate the described action before the end of the sentence. They manipulated the onset of the response to cue to be either 500ms, 1500ms or 2000ms after the onset of the sentence and only observed the ACE in the first instance. The authors argued that comprehenders are simulating the event prior to the completion of the sentence and they are doing so somewhere between 500ms and 1900ms before the end of the sentence.

These motor effects are also observed with different effectors. Scorolli and Borghi (2007) reported that when reading action sentences related to other effectors (mouth and foot), neural substrates associated with the execution of these actions are activated, again supporting the notion of simulation. Participants were presented with noun and verb pairs that referred to 'hand actions' and 'mouth actions' in one instance, and 'hand actions' and 'foot actions' in another. Half the participants responded to whether the combination made sense by using the microphone, while the other half responded using a foot pedal. 'Mouth action' sentences were processed faster than 'hand action' sentences when participants responded using the microphone rather than the foot pedal. This same facilitation effect was also observed with 'foot action' sentences compared to 'hand action' sentences when participants responded using the foot pedal, implying motor areas associated with performing the action are recruited during comprehension (Scorolli & Borghi, 2007).

Pulvermüller, Härle and Hummel (2001) state that action verbs induce differential neuronal activity along the motor cortex, with activity strongest at the cortical representation of the body part used in performing the implied action, demonstrating the occurrence of motor simulations. For example, during TMS of the left language-dominated hemisphere during action word processing, reaction times were shorter to words referring to leg movements (e.g. *"kick"*) compared to arm and hand (e.g. *"pick"*) when stimulation was focused on the leg representation area, and vice versa when stimulation was focused on the arm and hand representation area. This would support category-specific functional links between action processing and language processing (Pulvermüller, Hauk, Nikulin & Ilmoniemi, 2005). Such action understanding is believed to be underpinned by the mirror neuron system (MNS) in the TD population; the neuron system that is not only involved in performing actions, but also internalising and mentally simulating them (Rizzolatti, Fogassi & Gallese, 2001). For a full discussion of the neurological correlates of motor simulations and the MNS, refer back to Chapter 1.

Having presented the behavioural signatures of motor simulations in the TD population, I now move on to consider the behavioural signatures of spatial simulations of language.

Behavioural signatures of spatial simulations

Language is also experienced through spatial properties of the linguistic input, as comprehenders activate spatial simulations that integrate language with the visual world during the online processing of a sentence (Kamide, Lindsay, Scheepers & Kukona, 2015). The verb used in a sentence implicates changes in spatial properties and such changes impact participants' judgement in decision tasks, consequently affecting visual representations of events. Recall from Chapter 1 for example, Lindsay, Scheepers and Kamide (2013) who found that when participants heard a sentence where the verb implies a slow motion (e.g. *"The student will stagger along the trail to the picnic basket"*) they consequently looked more often and longer along the path to the goal object depicted in the accompanying visual scene. Whereas when the verb implied a faster motion (e.g. *"The student will run along the trail to the picnic basket"*), participants looked at the goal object on the path earlier and for less time. This suggests participants activate a spatial simulation of the movement and integrate this with the visual scene.

People have also been found to simulate other spatial properties of language, such as the shape of referents described by the linguistic input. In one behavioural task, called the Sentence-Picture Verification Task, participants are presented with sentences such as *"The* *ranger saw an eagle in the sky"* and subsequently make a mentioned/not mentioned judgement on an image that depicts the object mentioned in the preceding sentence (i.e. an eagle). Critically, the image either matches the physical state of the described object (an eagle with outstretched wings) or mismatches (an eagle with folded wings). When the object matches the implied shape a facilitation effect (i.e. shorter response times) is observed and when it mismatches, an interference effect (i.e. longer response times) has been found (Zwaan, Stanfield & Yaxley, 2002). That is, participants set up a spatial simulation of the event (i.e. an eagle with outstretched wings) and map this onto the subsequently presented visual scene. Responses are facilitated when the visual scene matches the simulation set up by that participant, but interference occurs when the two mismatch, supporting the notion of spatial simulations of language.

This paradigm has been widely applied using behavioural measures to demonstrate the nature and content of spatial simulations of language comprehension. Yaxley and Zwaan (2007) presented sentences of varying visual acuity such as *"Through the (fogged/clean) goggles, the skier could (hardly/easily) identify the moose"* and observed the same facilitation effects when the visual resolution implied in the sentence matched that depicted in the proceeding image, suggesting the perceptibility of referents is encoded in these simulations. Other perceptual aspects that are simulated during comprehension are orientation (Stanfield & Zwaan, 2001) and also the direction of motion of referents (Zwaan, Madden, Yaxley & Aveyard, 2004) suggesting these simulations are dynamic in nature.

Moreover, spatial simulations of implied shape and orientation are thought to be retained over a long period of time. During a sentence-picture verification task, Pecher, et al (2009) found that the match effect can be observed when sentence reading and picture recognition are separated in time. When recognition is both immediate and when it is delayed (by 45 minutes), recognition was better if the depicted object matched the shape or orientation of the object implied in an earlier sentence. Pecher et al explain this as a larger overlap between the simulation formed during sentence comprehension and the image presented when the two match as opposed to when they mismatch, supporting the notion of sensorimotor experiences of language.

Regarding the time course of spatial simulations, evidence suggests that a full simulation is rapidly set up and available to be mapped onto the visual world. Take for example, Kaup et al's (2007) work on simulations of negation. They presented participants with sentences such as *"The eagle is not in the sky"* and then following a 250ms delay, presented an image that depicted the object in the negated state (i.e. an eagle with outstretched wings) or mismatched the negated state (i.e. an eagle with wings folded). Participants were asked to make a mentioned/not-mentioned judgement on the image, and Kaup and colleagues found that participants were faster to respond when the object depicted matched the negated state implied in the preceding sentence, than when it mismatched the negated shape. That is, comprehenders mentally simulated the negated state and did so within this 250ms. This would imply that a simulation of an event is readily available within 250ms of the event, suggesting the simulation is constructed online during sentence processing.

In a similar paradigm, Kaup, Lüdtke and Zwaan (2006) presented sentences such as *"The door was open"* and *"The door was not open"*. Following a delay of either 750ms or 1500ms, an image that either matched or mismatched the state implied in the sentence and participants were asked to name the depicted object. Following the 750ms delay participants had access to a simulation of the negated simulation (i.e. a closed door), evident in faster response times when the image matched the negated form. Furthermore, by 1500ms after sentence offset, participants had access to simulations of both the negated state and the affirmative state (i.e. an open door).

Moreover, Ferguson, Tresh and Leblond (2013) investigated the time course of spatial simulations. They presented participants with sentences such as *"The old lady knows/thinks that the picnic basket is open"* and following a delay of 250ms or 1500ms asked them to make a mentioned/not-mentioned judgement of an image that either matched or mismatched the physical state implied in the preceding sentence. Interestingly, results revealed a facilitation effect for matching images (i.e. an open picnic basket) as well as an interference effect for mismatching images (i.e. a closed picnic basket) following a delay of 250ms for *'thinks'* compared to *'knows'* sentences. However, this effect disappeared following a 1500ms delay. Alongside Kaup et al (2007), this would suggests that comprehenders have available, a simulation of the described event within 250ms of the sentence offset. More interestingly however, is that Ferguson et al (2013) have shown that not only do these simulations remain active following a longer delay of 1500ms, but that multiple simulations can be activated and held.

Above, I have presented what is known about motor and spatial simulations of language in the TD population. I now move on to consider evidence that would suggest individuals with ASD may be impaired in simulating language, or at least construct simulations that differ from those of TD individuals.

Evidence for language simulation in ASD

To date, these behavioural paradigms have been widely used, their effects well established and a vast amount of evidence supports the notion of mental simulations of language in TD individuals. However, these paradigms have never been used to explore language comprehension in individuals with ASD. Recall, that simulations of language in the TD population are thought to be the result of interaction with and perception of the environment. Individuals associate perceptions and actions with words in the linguistic input and these combine to produce a simulation of the described event (Zwaan, Madden, Yaxley & Aveyard, 2004). Moreover, simulations are thought to be underpinned by the MNS, responsible for internalising experiences and comprehension of actions, intentions and emotions (Rizzolatti, Fogassi & Gallese, 2006).

However, as discussed in detail in Chapter 1 (section 1.9.1), dysfunction of the MNS is thought be the cause of impairments in ASD. Such individuals have been shown to have difficulty with motor imitation (see Rogers, Bennetto, McEvoy & Pennington, 1996) alongside difficulties attending to and/or integrating information (Vivanti, et al, 2011). A dysfunction of the MNS is thought to explain the prevalent deficits in action understanding, imitation and social communication in ASD.

Although, it should be noted that research has shown appropriate activation of the MNS by individuals with ASD that is comparable to TD individuals, but which is supressed. For example, in an execution task that required participants to imitate a hand action, both TD and ASD participants showed activation in the right somatosensory cortex that was greater during imitation execution (i.e. animation stimuli) (Williams, et al, 2006). Although mirror neuron activity was less extensive in the ASD group compared to the TD group, they still demonstrated appropriate neuron activation, implying some internalisation of the observed action.

In sum, motor and spatial simulation of language rely on the integration of sensorimotor experiences, underpinned by the MNS that internalises perception and action. However, deficits in action understanding, imitation and social communication in ASD are thought to be the result of a dysfunctional MNS and an inability to internalise actions. Given this, it may be that prevalent language comprehension deficits in individuals with ASD are the result of impaired or different motor and spatial simulations of language. Therefore, the aim of the studies presented in the current chapter is to investigate the nature of motor and spatial simulations of individuals with and without ASD.

The current experiments

To establish the behavioural signatures of mental simulations of language by individuals with ASD, two questions will be addressed; first whether individuals with ASD simulate the motor and spatial properties of language. Second, if it is the case that they simulate language, are these simulations activated as quickly and for as long as they are in TD individuals. These questions are addressed in the following experiments using behavioural measures in conjunction with two psycholinguistic paradigms; the action-sentence compatibility effect (ACE) to investigate motor simulations, and the sentence-picture verification paradigm to look at spatial simulations. Both paradigms have demonstrated evidence for sensorimotor simulations of described events during sentence comprehension and replication of the effects by individuals with and without ASD would at least suggest those with ASD do simulate language.

Experiment 1A

Experiment 1 set out to examine whether people with ASD simulate the motor properties of language in the same way that TD individuals do. More specifically, do individuals with ASD employ the same action simulations to facilitate language comprehension that have been extensively reported in the literature for TD adults? The experiment used the same Action-Sentence Compatibility Effect (ACE) paradigm as in Glenberg and Kaschak (2002), whereby participants made sensibility judgements about sentences that described actions either towards or away from the body and responded by pressing a button whose position required a movement towards or away from the body. As in Glenberg and Kaschak, participants were informed prior to the onset of each block which direction (towards or away-from the body) they would press to judge the sentence as sensible. This was done based on the evidence that suggests the ACE occurs only when participants are given the opportunity to plan their motor action (Borreggine & Kashchak, 2006). However, imperative sentences (e.g. *"close the drawer"*) were not included in the current experiment, the reason being that Glenberg and Kaschak (2002) found no ACE effect on such sentences. That is, in comparison to the two types of transfer sentences, there was a weaker interaction between implied sentence direction and response direction for imperative sentences. Thus the current experiment examined understanding for concrete transfer sentences and abstract transfer sentences.

If indeed individuals with ASD do simulate language, then they should display the same ACE interaction between implied sentence direction and actual response direction as previously observed in TD individuals, and this may be the case for both concrete and abstract transfer sentences. That is, they should demonstrate a facilitation effect (shorter response times) when the direction implied in the sentence (away-from-the-body or towards-the-body) is the same as the direction they should use to respond (i.e. whether participants should press the button furthest from them or nearest them), and an interference effect (longer response times) when the two are opposing.

However, there is evidence to suggest that individuals with ASD struggle with abstract language understanding. For example, children with ASD have been shown to have difficulty comprehending a number of forms of figurative language including hyperbole, indirect requests, irony, metonymy, rhetorical questions and understatements compared to age matched peers without ASD (MacKay, & Shaw, 2004). For this reason, it may be that in the current experiment that individuals with ASD only demonstrate impairment for abstract sentence processing; evident in an absence of the ACE interaction for abstract transfer sentences, but not for concrete transfer sentences.

Method

Participants

Participants were 22 adults with ASD (14 males and 8 females, ratio 7:4; *M* age = 20.28, *SD* age = 2.05; age range18 – 27) and 22 TD participants (4 males and 18 females, ratio 2:9; *M* age = 21.36, *SD* age = 5.50; age range 18 – 43 age range). All had English as their native language and none reported other language or neurological/neurodevelopment disorders. All participants were students at the University of Kent.

ASD students, with a formal diagnosis (DSM-IV, 1994) were recruited through the University's Disability and Dyslexia Support Services (DDSS), who forwarded the study information onto eligible students. Individuals in the ASD group received cash for their participation. The formal diagnosis of individuals in the ASD group ranged from moderate to high functioning ASD and Asperger's Syndrome (AS), and was confirmed prior to recruitment and was supplemented at the point of testing by scores on the Autism Quotient (AQ) (Baron-Cohen, Wheelwright, Skinner, Martin & Clubley, 2001). The TD group were undergraduate students at the University of Kent. They were recruited through the School of Psychology's online Research Participation Scheme (RPS) and were awarded course credits.

All participants completed a battery of IQ, language and autistic trait assessment measures outlined below. ASD participants scored significantly higher on the number of self-reported autistic traits of the Autism Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and had a significantly higher full IQ score, compared to TD participants. Means for IQ, AQ and the remaining assessments as well as comparison statistics between the two groups, are reported in Table 1.

Assessment Measures. Measures of IQ, language ability and autistic traits took approximately 90 minutes to administer and participants were offered a break if necessary.

Full IQ was measured using the Wechsler Adult Intelligence Scale (WAIS-III) (Wechsler, 1997). This provides a measure of an adult's intellectual ability through a series of eleven tasks. The assessment takes approximately 60 minutes to administer and as well as providing a full IQ measure, it also provides a verbal IQ and Performance IQ score.

Verbal IQ was measured using Vocabulary, Similarities, Arithmetic, Digit span, Information and Comprehension. The Vocabulary subtest measures expressive word knowledge by asking participants to describe the meaning of 33 words (e.g. audacious). Similarities measures abstract verbal reasoning as participants describe how two given words are alike (e.g. table and chair). Arithmetic assesses concentration and numerical reasoning. Here, participants are asked to solve 14 mental arithmetic problems without the use of pen and paper. Digit span assesses participants' attention, concentration and mental control. Digits are spoken by the experimenter at a rate of one per second and participants are asked to repeat the sequence. Information measures general knowledge as participants are asked to answer 28 questions about common events, objects, places and people (e.g. *"Who wrote Hamlet?", "Name all the continents"*). Finally, Comprehension assesses participants' understanding of concepts and social practices and their ability to solve everyday problems through 18 questions such as *"What is the thing to do if you find an envelope in the street that is sealed, addressed, and has a new stamp on it?"*

Performance IQ was measured using Picture completion, Digit symbol-coding, Block design, Matrix reasoning, Picture arrangement. Block design requires participants to use 4-8 blocks to form designs. For the first instance, the experimenter constructs the design and from then on the participant is asked to replicate designs shown in picture format. The aim is to assess spatial reasoning and abstract problem solving. Digit symbol-coding measures visual-motor coordination and visual working memory. In this sub-test, each digit is associated with a symbol and participants are asked to write the correct symbol under each number in a grid. Matrix reasoning assesses nonverbal abstract problem solving and spatial reasoning as participants are required to select which of five designs completes the pictorial pattern. Picture completion requires participants to arrange 10 sets of small pictures into a sensible order, the aim being to assess logical sequencing ability. Finally, in picture completion participants are given eleven sets of picture cards that tell a story. Cards are presented in a mixed order and the participant is required to rearrange the cards into a logical order within a specified time limit.

Understanding of grammar was measured using the *Test for Reception of Grammar (TROG-2)* (Bishop, 2003). The TROG-2 is a multiple choice test that assesses participants' understanding of English grammatical contrasts marked by inflections, function words and word order and is restricted to the simple vocabulary of nouns, verbs and adjectives (Bishop, 2003). There are 80 four-choice items, where a picture depicting the target sentence is grouped with three other pictures that depict the sentence if it were altered by a grammatical or lexical element (e.g. *"The sheep is running"* accompanied by four pictures depicting a sheep, one matching the target sentence).

Receptive vocabulary was assessed using the *British Picture Vocabulary Scale: 3rd Edition (BPVS-III).* The BPVS-III is a one-to-one test whereby participants are shown four images and asked to indicate which of these depicts a word spoken by the experimenter (e.g. the word *"oasis"* accompanied by four pictures, one depicting an oasis and three depicting unrelated objects/scenes).

Autism traits of both groups were measured at the point of testing using the short form of the *Autism Quotient (AQ)* (Baron-Cohen, et al, 2001). The AQ is a self-assessment screening instrument to test whether adults with high-functioning ASD or AS are simply extremes on dimensions of autistic traits that run through the general population. The questionnaire consists of 30 statements such as *"I prefer to do things with others than in my own"* and *"I tend to notice details that others do not"*. Participants indicate whether each statement is a reflection by selecting whether they "definitely agree" "slightly agree" "slightly disagree" or "definitely disagree" with each. One point is given for each question answered in a way that reflects autistic traits (e.g. answer "definitely agree" or "slightly agree" to the statement *"I tend to have very strong interests which I get upset about if I can't pursue"*). Baron-Cohen et al (2001) cite a score of 21 or more in this short form of the AQ as indicating clinically significant levels of autistic traits.

Table 1. *Assessment test results, with means and t values for the TD and ASD groups. Standard deviations are noted in parenthesis.*

	TD	ASD	Difference
WAIS			
Full IQ	101.14 (6.12)	107.86 (10.35)	$t(21) = -2.8$*
Verbal IQ	99.73 (5.67)	108.73 (10.07)	$t(21) = -4.64$***
Performance IQ	102.14 (9.11)	104.96 (14.36)	$t(21) = 0.72$
TROG	99.32 (6.89)	99.95 (7.5)	$t(21) = -.40$
BPVS	106.00 (8.51)	115.55 (11.09)	$t(21) = -3.04$**
AQ	12.94 (4.63)	32.67 (9.46)	$t(17) = -8.34$***

*Significant at ***.001 **.01 *.05*

Design

The experimental conditions gave rise to a 2 (Sentence type: concrete vs. abstract) x 2 (Sentence direction: away vs. towards) x 2 (Response direction: away vs. towards) x 2 (Group: ASD vs. TD control) mixed measures analysis of variance (ANOVA). Sentence type, sentence direction and response direction were manipulated within participants, and group was between participants. Response time and accuracy were dependent measures.

Response time was recorded in milliseconds and was measured from the onset of the sentence (i.e. when participants pressed a key to show the sentence) until their sensibility response (when participants pressed ‘q’ or ‘p’). Accuracy was defined as the percentage of trials accurately judged as sensible or nonsense.

Materials

The critical sentences were 60 transfer sentences of the same structure as those used in Glenberg and Kaschak’s (2002) study. Thirty of the sentences described a concrete transfer (e.g. *“You handed Courtney the notebook”*) and the other 30 described an abstract transfer (e.g. *“Liz told you the story”*). In addition, every critical sentence had an away-from-the-body form (*“You handed Courtney the notebook”* and *“You told Liz the story”*) and a towards-the-body form (*“Courtney handed you the notebook”* and *“Liz told you the story”*). See Table 2 for further examples of each type, and see Appendix A for a full list of the experimental items. There were also 60 filler sentences that served as nonsense items (e.g. *“Joe sang the cards to you”*). Half of all of the sentences (critical and filler) were of the dative form (e.g. *“You delivered the pizza to Andy”*), whilst the other half were written in the double-object form (e.g. *“You invited Aaron to lunch”*). Twenty additional practice items were generated; 10 were presented at the beginning of the experiment and another 10 were presented midway through the experiment when response instructions for the participants changed. Each practice session was made up of five sensible and five nonsense sentences and these were counterbalanced in terms of form (dative vs. double-object).

The critical items were equally divided into four conditions (away sentence-away response, away sentence-towards response, towards sentence-away response, towards sentence-towards response). These conditions were then used to create four counterbalanced lists that comprised a total of 120 items; 60 experimental items from the four conditions and 60 filler items. Experimental sentences were assigned to lists within the constraint that each item could only appear once in each list. That is, one sentence per item was assigned to each list. During the experiment, items appeared in four blocks of 30 trials, in a pseudorandom order.

Table 2. *Example experimental sentences showing sentence direction and sentence type counterbalanced.*

		Sentence Type	
		Concrete Transfer	Abstract Transfer
Sentence Direction	Away from the body	*"You handed Courtney the notebook."*	*"You told Liz the story."*
		"You threw the Frisbee to Dave."	*"You pitched the idea to Larry."*
	Towards the body	*"Courtney handed you the notebook."*	*"Liz told you the story."*
		"Dave threw the Frisbee to you."	*"Larry pitched the idea to you."*

To counterbalance response direction (i.e. whether participants responded away- or towards- when the sentence was sensible vs. nonsense), the four lists were duplicated so that for four of the lists participants responded to a 'sensible' sentence by pressing the button away from them for the first two blocks of the experiment and pressed the button closest to them (towards-) for the last two blocks. For the other four lists participants responded to 'sensible' sentences towards- for the first two blocks and away- for the last two blocks. In each list there was an equal number of concrete and abstract transfer sentences, and an equal number of dative and double-object forms.

Procedure

Participants were randomly assigned to one of the eight counterbalanced lists and told that they would read sentences that appear in the centre of the screen and should judge whether or not the sentence makes sense. Participants sat at the computer with the keyboard in front of them on the table at a 90 degree angle from its normal orientation. The keyboard was placed such that the 'q' key was situated furthest away from the participants' body and the 'p' key was closest (see Figure 4 for diagram of experiment set up). For the sentence to appear, participants had to press the 'y' key in the centre of the keyboard. They were told to hold down this key while reading the sentence and until they made their response (i.e. until they pressed either 'q' or 'p').

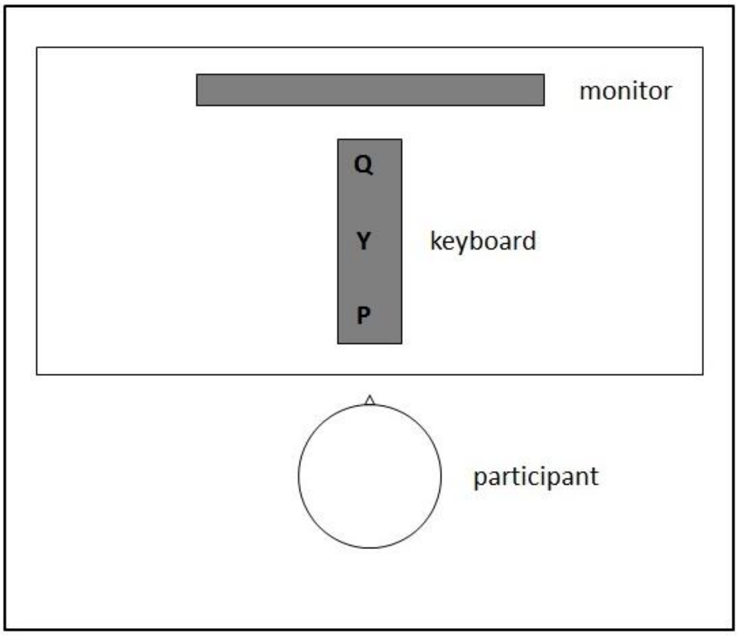


Figure 4. Experiment set up. The keyboard was rotated 90º with the letter 'q' further from the participant and 'p' nearer.

For four of the eight lists, participants were instructed to press the ‘q’ key if the sentence made sense and ‘p’ if it did not. Midway through the experiment participants were then instructed to switch their response, pressing ‘p’ if they judged the sentence as sensible and ‘q’ if it did not. This order was then reversed for the other four lists, such that in the first half of the experiment participants pressed ‘p’ if the sentence was sensible and ‘q’ if it was nonsense and then vice versa in the second half of the experiment. Participants were given 10 practice items at the beginning and midway through the experiment in order to familiarise them with the keys. Note that a ‘q’ response involved a response away from the body and a ‘p’ response involved a response towards the body. The ‘q’, ‘y’ and ‘p’ keys had small stickers placed over them to facilitate responding.

Results

Accuracy

Filler and practice trials were discarded. Response accuracy was analysed using a 2 (Sentence type: concrete vs. abstract) x 2 (Sentence direction: away vs. towards) x 2 (Response direction: away vs. towards) x 2 (Group: ASD vs. TD) mixed analysis of variance (ANOVA). Analysis revealed no main effect of group (p = .71), sentence type (p = .38), sentence direction (p = .66) or response direction (p = .68). However, the ACE interaction between sentence direction and response direction was significant [$F(1, 42) = 5.55$, $p < .05$, $\eta_p^2 = .12$] suggesting the ACE had no influence on accuracy in either the ASD or TD group. All other interactions were non-significant at $p > .1$.

Follow up analyses of the ACE interaction revealed that when the response required was far (i.e. participants had to press q for a yes response), both groups were more accurate at responding to sentences describing an action away-from-the-body (M = 0.98, SD = 0.03), compared to sentences describing an action towards-the-body (M = 0.97, SD = 0.04) [$t(43) = 2.79$, $p < .01$]. However, when the motor response required was near (i.e. participants had to press p for a yes response), there was no difference in response accuracy for sentences describing an action away-from-the-body or those describing an action towards-the-body (*M* = 0.97, *SD* = 0.06, vs. *M* = 0.98, *SD* = 0.04) (p = .29). Follow up analyses also revealed that there was no difference in response accuracy for away-from-the-body sentences when the motor response required was far (*M* = 0.98, *SD* = 0.03) versus near (*M* = 0.97, *SD* = 0.06) (p = .26). Although, both groups were marginally more accurate at responding to towards-the-body sentences when the required response was near (*M* = 0.97, *SD* = 0.04) compared to far (*M* = 0.98, *SD* = 0.04) [$t(43) = -1.97$, p = .06]. Overall response accuracy for concrete and abstract sentences are presented in Figures 5 and 6, collapsed across groups.

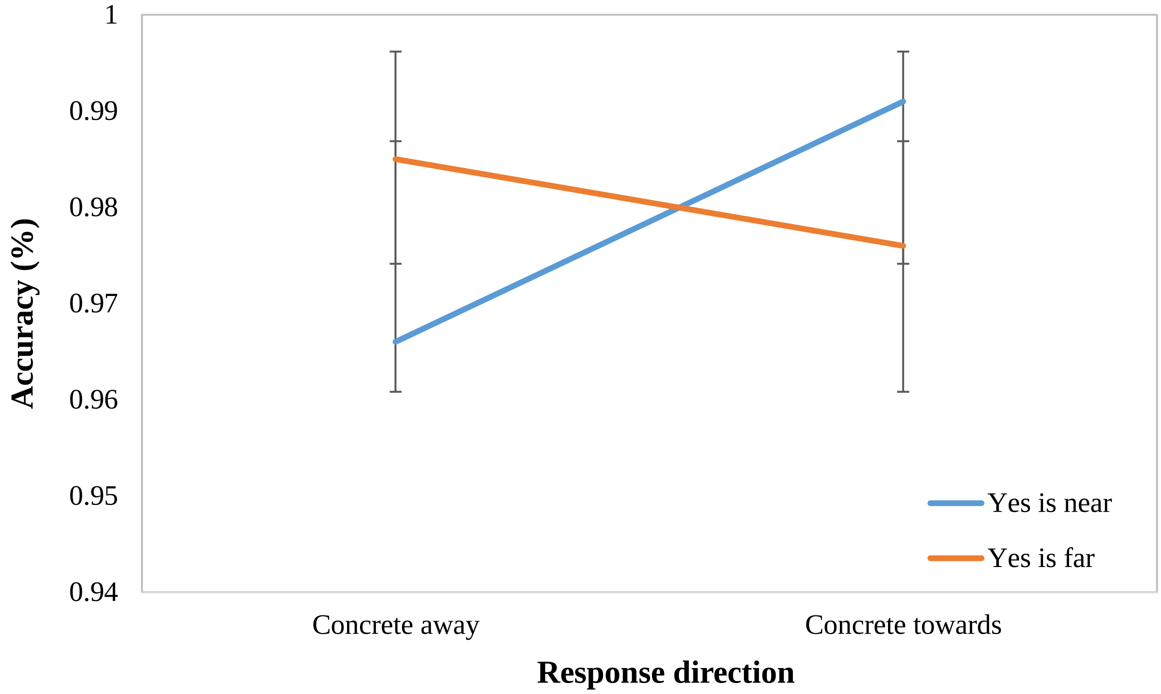


Figure 5. Mean response accuracy for concrete transfer sentences collapsed across groups. Error bars show standard errors.

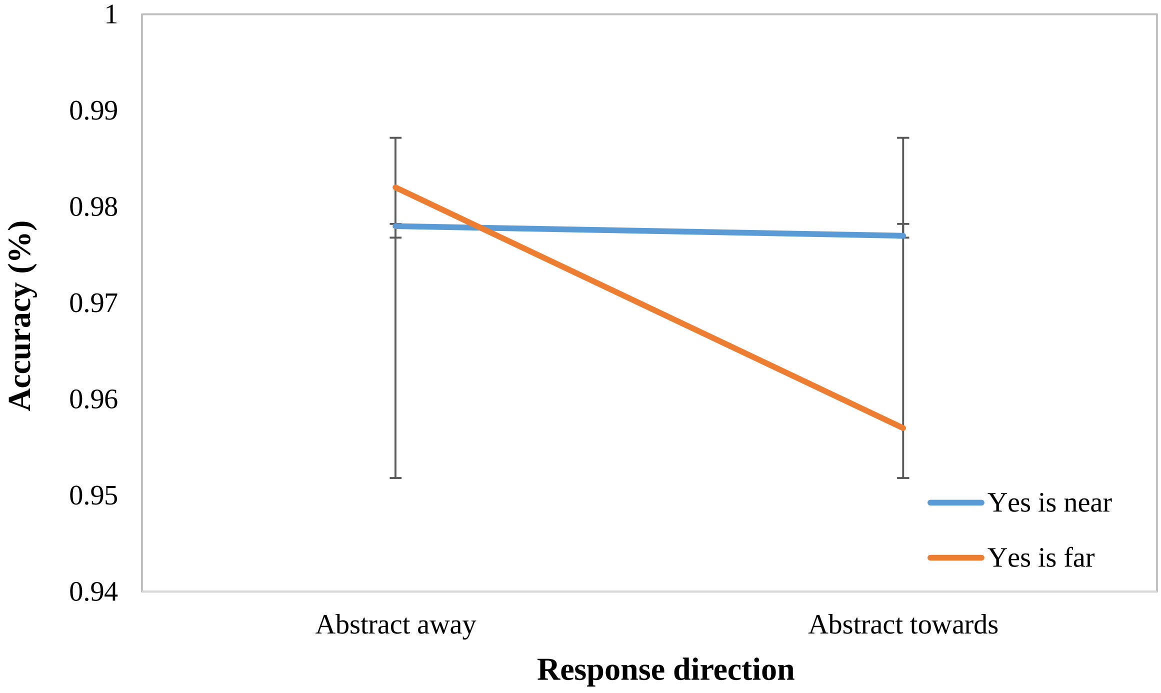


Figure 6. Mean response accuracy for abstract transfer sentences collapsed across groups. Error bars show standard errors.

Response time

Reaction time data were pre-processed and analysed using identical procedures to those used by Borreggine and Kaschak (2006) Experiment 1. Incorrect responses were removed prior to analysis of response time. Response time was calculated as the sum of the sentence reading time (i.e. time between pressing and releasing 'y') and the reaction time (i.e. time taken to make a judgement by pressing 'q' or 'p'). To reduce the effects of outliers, response times that fell more than 2 *SD*s from each participant's mean response time in each of the four conditions (away sentence-far response, away sentence-near response, towards sentence-far response, towards sentence-near response) were removed. Response times for concrete and abstract sentences are presented for the TD group and the ASD group in Figure 7.

As with accuracy, reaction times were analysed using a 2 (Sentence type: concrete vs. abstract) x 2 (Sentence direction: away vs. towards) x 2 (Response direction: away vs. towards) x 2 (Group: TD vs. ASD) mixed ANOVA). There was a marginally significant main effect of group [$F(1, 42) = 3.37$, $p = .07$, $\eta_p^2 = .07$], with TD participants responding faster than ASD participants (*M* = 2108ms, *SD* = 152.96 vs. *M* = 2505ms, *SD* = 152.96 respectively). There was also a main effect sentence type [$F(1,42) = 11.10$, $p < .001$, $\eta_p^2 = .22$] with participants responding faster to concrete transfer sentence in comparison to abstract transfer sentence (*M* = 2249ms, *SD* = 103.3 vs. *M* = 2364ms, *SD* = 115.2 respectively). There was a marginally significant sentence type by group interaction [$F(1, 42) = 3.60$, $p = .065$, $\eta_p^2 = .08$]. Follow up analyses of this interaction revealed no difference in response times for concrete versus abstract sentences for the TD group ($p = .13$), however the ASD group were significantly faster to respond to concrete sentences than abstract sentences [$t(21) = 3.08$, $p > .01$].

A main effect of sentence direction was observed [$F(1, 42) = 24.57$, $p < .001$, $\eta_p^2 = .37$], with shorter response times for sentences that required an away response compared to sentences that required a towards response (*M* = 2240ms, *SD* = 103.3 vs. *M* = 2372ms, *SD* = 114.4 respectively). Sentence direction also significantly interacted with Group [F(1, 42) = 10.56, $p < .01$, $\eta_p^2 = .2$], and follow up analyses revealed no difference in response times between away-from-the-body sentences and towards-the-body sentences for the TD group ($p = .1$). However, the ASD group were quicker to respond to away-from-the-body sentences than towards-the-body sentences [*t*(21) – 4.73, $p < .001$].

The main effect of response direction was not significant ($p = .77$) and neither was the ACE interaction between implied sentence direction and response direction observed in either group ($p = .33$). None of the remaining interactions, including that between implied sentence direction, response direction and group, reached significance (*p*'s > .2). That is, response direction did not have the expected interference/facilitation effect in either group.

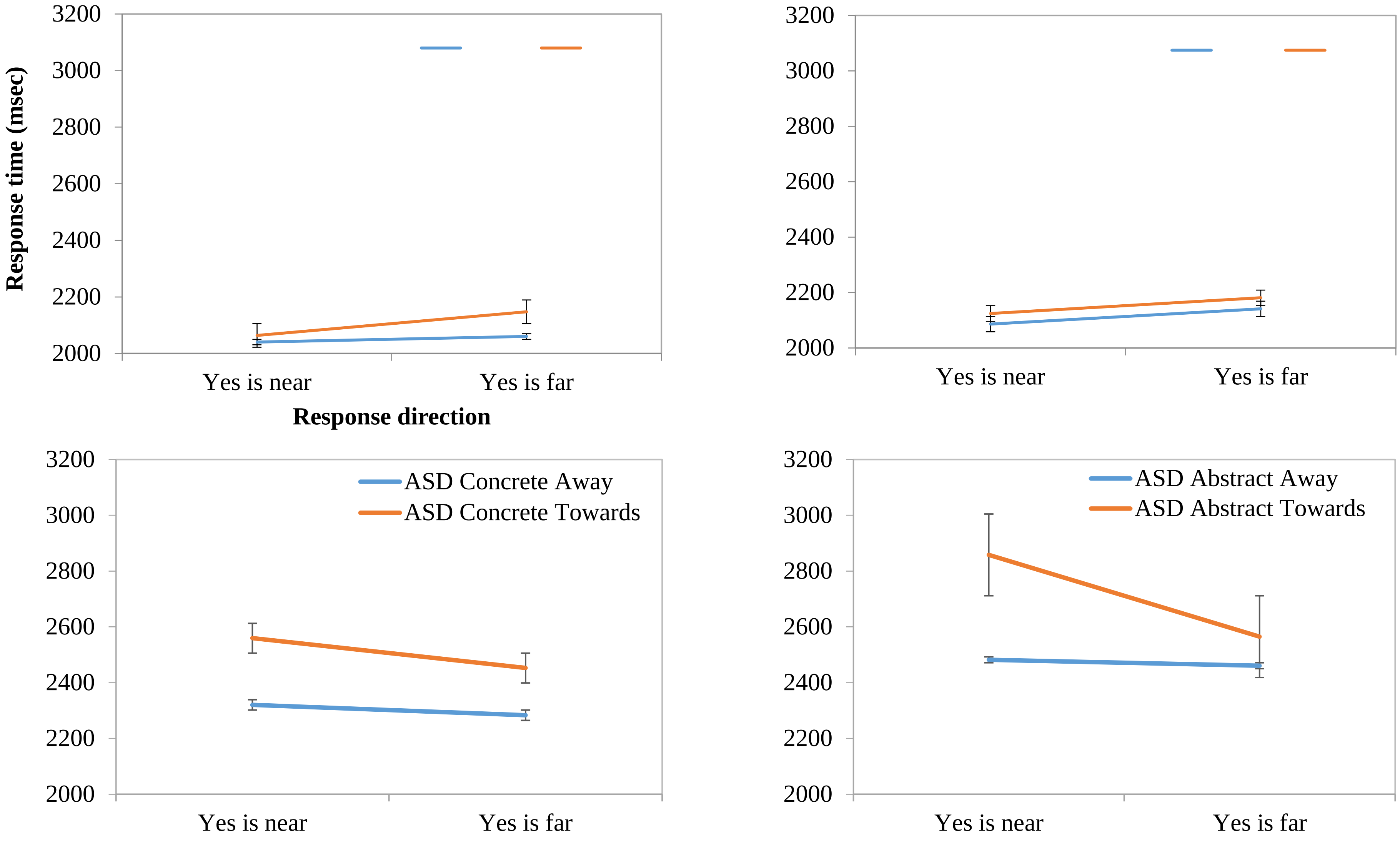


Figure 7. Mean response time (in ms) for concrete transfer sentences (left) and abstract sentences (right) for the TD group (top) and ASD group (bottom).

Discussion

The aim of the current experiment was to examine motor simulations in language comprehension, replicating the ACE interaction that has been well-documented in the literature for TD adults, and to test whether the effect is also observed in individuals with ASD. If so, this could be taken as evidence of language-activated motor simulation by such individuals. However, the experiment did not demonstrate the replicability of the ACE for either the TD control group or for the ASD group.

Recall that the ACE, first observed by Glenberg and Kaschak (2002) and replicated by a number of other researchers (e.g. Borreggine & Kaschak, 2006; Kaschak & Borreggine, 2008; Glenberg, et al, 2008; Aravena, et al, 2010; Diefenbach, et al, 2013) is an interaction between the implied sentence direction and the actual response direction. When the implied sentence direction is the same as the required motor response direction, a facilitation effect is observed, while an interference effect is observed when the two are in contrast. In terms of action simulations, the ACE is evidence that at least some language understanding taps into an action-based system as language is grounded in bodily action. Processing both concrete and abstract action sentences calls upon the same cognitive mechanisms as those used in planning and carrying out the action. Consequently, when the direction implied in the sentence contrasts with the actual motor response, there is interference (Glenberg & Kaschak, 2002). Due to the apparently high replicability of the ACE interaction in previous studies, it could be considered a robust effect. However, the current experiment did not replicate the effect even among the TD participant group. There are a number of possible reasons as to why the effect was not captured.

First, it may be that the ACE interaction is not as robust an effect as it first appears. For example, it is already known that the ACE is time sensitive, only occurring during sentence processing and when participants are aware of the motor action required to make a sense judgement. When the response cue is given after sentence offset, the effect disappears (Borreggine, & Kaschak, 2006). Similar findings have been reported by Diefenbach, et al (2013) who found that the timing between sentence comprehension and response preparation affects whether the ACE is present at all, and if it is, it affects whether the effect is positive or negative. Using the ACE paradigm, Diefenbach et al (2013) manipulated the time at which the direction of the required motor response was cued to be either at the onset of the sentence or at different points in time before and after sentence onset. When the response cue was presented at sentence onset, the (positive) ACE occurred, however, the effect became negative when the response cue was delayed 500ms after sentence onset. That is, participants were slower to respond when the implied sentence direction matched the direction of the required motor response. More interestingly, is the findings that when the response cue is presented 1000ms or 500ms prior to sentence onset, the ACE was absent, and this was also the case when the response cue was presented at the end of the sentence. This would suggest that people do not simulate language at all when the response cue is given 1000ms and 500ms before onset, highlighting the time-sensitive nature of the effect.

The current study controlled for temporal effects by presenting participants with knowledge of the required motor action response prior to the onset of the sentence (in fact, at the start of each block and this was consistent within each block). Given this, the ACE should have been present in the current experiment. One possible explanation is that participants were simply not simulating the motor information of the sentences, but this would have to be the case for both the TD and ASD groups, as neither group showed the expected ACE effect.

Previous studies looking at the ACE have shown either a facilitation or interference effect, however, the current study failed to find either. This would suggest a problem with the paradigm, therefore further inspection of the paradigm used in the current experiment is required. Glenberg and Kaschak employed 40 imperatives sentences, 20 concrete transfer sentences and 20 abstract sentences, alongside 80 filler items. As mentioned previously, imperative sentences were excluded from the current study as the ACE interaction was found to be weaker for these sentence forms in comparison to concrete and abstract transfer sentences (see Glenberg & Kaskak, 2002). The current study therefore included 30 concrete transfer sentences and 30 abstract transfer sentences, alongside 60 filler items. Although fewer items were used in comparison to Glenberg and Kaschak, the number of concrete and abstract transfer sentences was greater; yet the ACE did not replicate.

In both the current experiment and Glenberg and Kaschak (2002), visual presentation of each item was initiated by pressing the middle button with the right index finger. However, in the current study participants used the keyboard placed at 90 degrees to respond, whereas Glenberk and Kaschak used a specially constructed response box. Although, Borreggine and Kaschak (2006) also had participants responding using a keyboard placed at 90 degrees and they too observed the ACE interaction. Initially, in both experiments participants were randomly assigned to the yes-is-far or yes-is-near response direction condition and midway through were instructed to switch the direction of response (from yes-is-far to yes-is-near or vice versa). Participants were also given additional practice trials at the beginning of the experiment and midway through so as to become familiarised with the response method.

Response measures vary across studies investigating the ACE. Some have taken the time between sentence onset and release of the middle button, corresponding to the time taken to read and understand the sentence and begin to make a sensibility judgement (see Glenberg & Kashak, 2002; Glenberg, et al, 2008). Others have used a combination of sentence reading time and response time; the time between the onset of the sentence to pressing a response button (near or far) (see Borreggine & Kaschak, 2006 Experiment 1; Diefenbach, et al, 2013). The final response measures observed in the literature is the time to press the response key from the onset of the response cue, with the response cue varied across experiments (see Borreggine & Kaschak, 2006 Experiments 2, 3 and 4; Kaschak & Borreggine, 2008). In the current experiment, the combination of sentence reading time and response time was used as the dependent measure and data were processed and analysed using the same procedure as Borreggine and Kaschak (2006) Experiment 1, as described above.

One difference between the current study and previous research on the ACE is that others have included much larger sample sizes (Glenberg & Kaschak, 2002 Experiment 1 N = 44, Experiment 2 N = 70 Experiment 3 N = 72; Borreggine & Kaschak, 2006 N = 48; Kaschak & Borreggine, 2008 N= 144). Given that it is known that the ACE is time sensitive, it may also be the case that it is power sensitive. Small effects require a larger investment of resources than larger effects in order to yield power. One such way to increase resources is to increase the sample size. Thus, previous studies may have captured the small effect of the interaction between implied sentence direction and response direction in the ACE paradigm by using a large sample.

To investigate whether the ACE did not replicate in the current study due to a lack of power, a follow up study was conducted. The same paradigm and experimental stimuli were rerun on a new larger sample of TD adults to test this possibility and to validate the experimental paradigm used. If indeed the paradigm is power sensitive, the ACE should replicate with an increased sample size. Experiment 1B used a sample of TD individuals. An ASD group was not included because perhaps in Experiment 1A this group added noise to the data, even if it was not strong or consistent enough to elicit a significant group effect.

Experiment 1B

In Experiment 1B the same paradigm and experimental items used in Experiment 1A were utilised, however the task was completed by a larger sample of TD individuals. This was done to test whether the paradigm, as opposed to differences between the groups, could explain why the ACE interaction was not observed in Experiment 1A. The aim of Experiment 1B was therefore to validate the experimental design. As the effect has been well documented in the literature on typically developed individuals, it seemed suitable to remove the ASD group and attempt to replicate the paradigm with only a control group.

If the ACE is power sensitive and the lack of replicability in Experiment 1A was caused by small group sizes, then increasing the power should draw out the interaction. That is, the ACE should be observed if the sample size is increased. In Experiment 1B, the sample was increased to 48 TD adults, this is comparable to the sample size in Glenberg and Kaschak's (2002) Experiment 1 (N = 44) where the ACE interaction was observed using concrete and abstract transfer sentences.

Method

Participants

49 participants (6 males and 43 females) completed the experiment, however one participant was removed prior to analysis for having a mean response time that fell more than 2.5*SD* above the group average. Thus, the final group consisted of 48 TD adults (6 males and 42 females; *M* age = 21.36, *SD* age = 6.19; age range 18 – 49). All participants were undergraduate students at the University of Kent and were recruited through the School's Research Participation Scheme (RPS). Participants were award course credits for their participation.

Design

As in Experiment 1, the same experimental conditions were used, giving rise to a 2 (Sentence type: concrete vs. abstract) x 2 (Sentence direction: away vs. towards) x 2 (Response direction: away vs. towards) repeated measures design. However, as the aim of this experiment was to assess the sensitivity of the ACE only a sample of TD adults was used, meaning no group effects were examined. Sentence type, sentence direction and response direction were manipulated within participants. Response time and accuracy were dependent measures, as described in Experiment 1A.

Materials

Experimental and filler items were identical to those described in Experimental 1A.

Procedure

The Procedure was identical to that in Experiment 1A.

Results

The data was pre-processed and analysed using the same methods as described in Experiment 1A.

Accuracy

As in Experiment 1A, analysis of response accuracy revealed no main effects of sentence type ($p = .33$), sentence direction ($p = .29$) or response direction ($p = .62$). The ACE interaction between sentence direction and response direction was also not significant for response accuracy ($p = .36$), implying the ACE had no influence on participants' accuracy. Response accuracy for concrete and abstract sentences are presented in Figures 8 and 9.

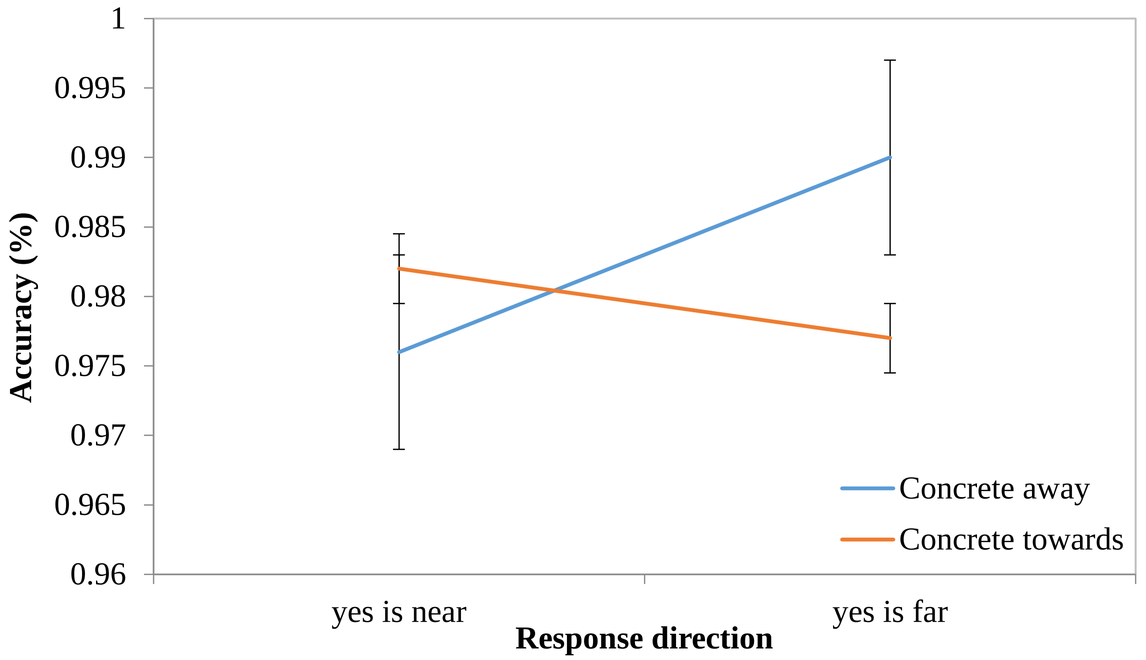


Figure 8. Mean response accuracy for concrete transfer sentences. Error bars reflect standard errors.

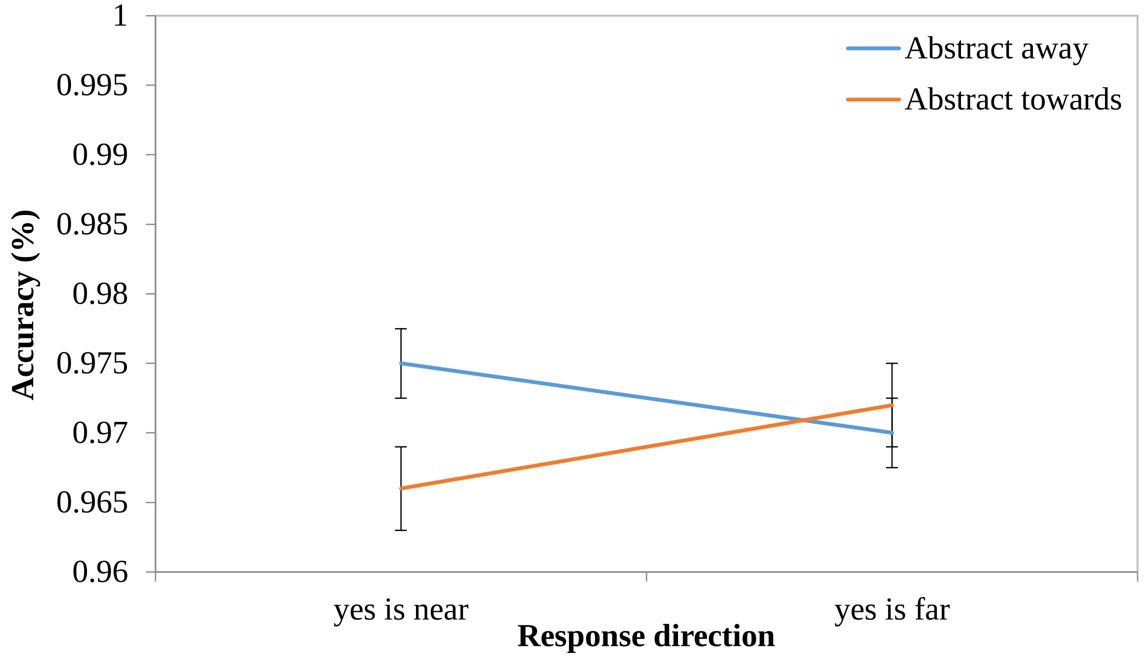


Figure 9. Mean response accuracy for abstract transfer sentences. Error bars reflect standard errors.

Response time

Similarly to Experiment 1A, analysis of response times revealed a main effect of sentence type [$F(1, 47) = 23.15$, $p < .001$, $\eta_p^2 = .33$], with participants responding faster to concrete transfer sentences compared to abstract transfer sentences (*M* = 2021ms, *SD* = 52.9 vs. *M* = 2126ms, *SD* = 57.09 respectively). In addition, there was again a main effect of sentence direction [$F(1, 47) = 10.54$, $p <.01$, $\eta_p^2 = .18$], with shorter response times for away sentences versus towards sentences (*M* = 2034ms, *SD* = 56.0 vs. *M* = 2112ms, *SD* = 54.47 respectively). Interestingly however, we failed again to observe a main effect of response direction ($p = .23$) or the ACE interaction between implied sentence direction and response direction ($p = .92$). See Figures 10 and 11 for response times for concrete and abstract sentences.

To rule out the possibility that switching response direction midway through the experiment impeded participants' responses in the second half of the experiment and thus masked the ACE interaction, separate analysis was conducted on trials in the first two blocks only (i.e. before the response switch). However, again the ACE interaction was not significant ($p = .83$).

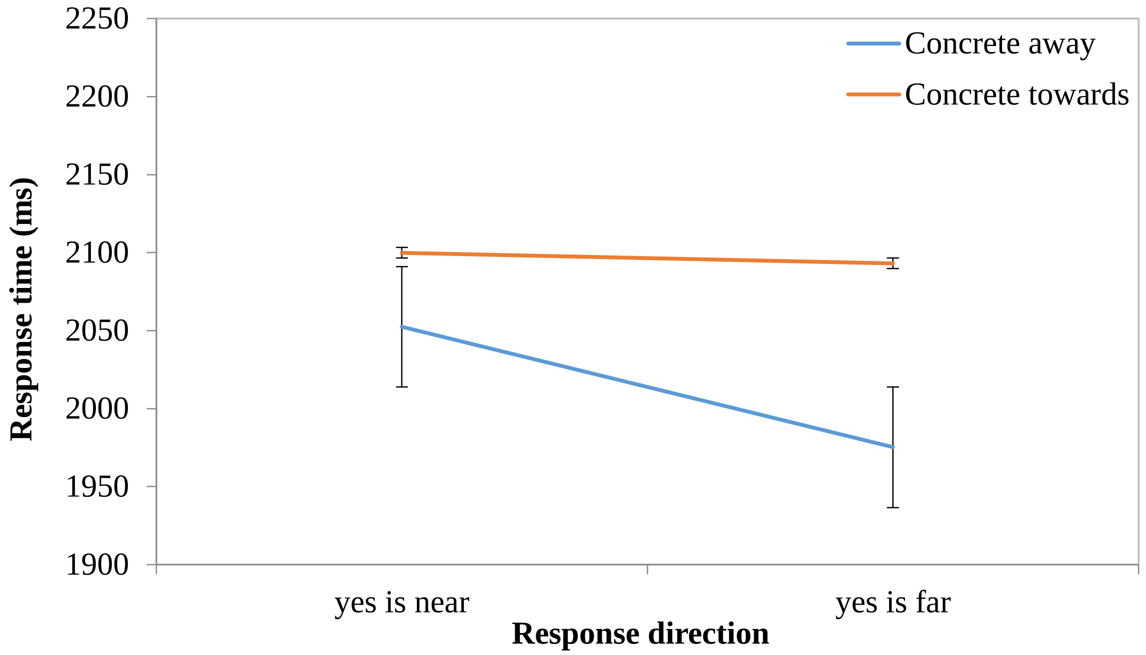


Figure 10. Mean response time (in ms) for concrete transfer sentences. Error bars reflect standard errors.

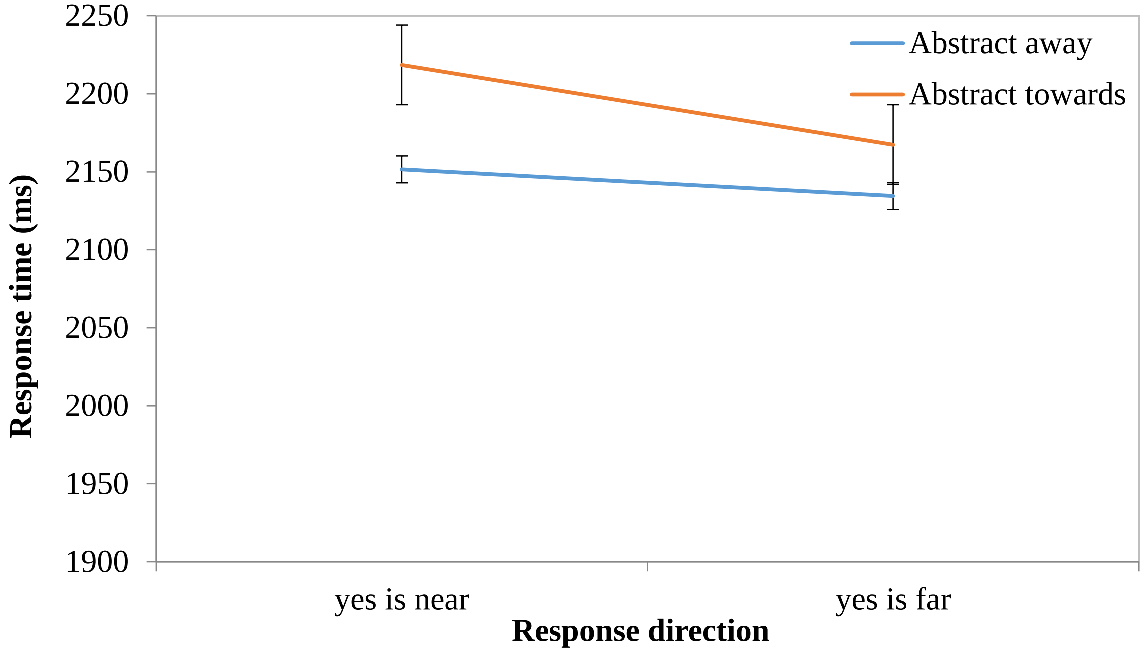


Figure 11. Mean response time (in ms) for abstract transfer sentences. Error bars reflect standard errors.

Discussion

The aim of Experiment 1B was to investigate why the ACE did not replicate in Experiment 1A, either in the group of TD individuals, or the individuals with ASD. Specifically, we tested the possibility that too few participants were used in Experiment 1A, meaning that the study suffered from a lack of power. The same ACE paradigm used in Experiment 1A was used here and it was tested on a new, larger, sample of TD adults.

Interestingly, the ACE failed to replicate again. That is, the expected interaction between implied sentence direction and actual response direction was not observed, even with a new larger sample. The expected facilitation effect when the implied sentence direction is the same as the required motor action and interference effect when the two are in opposite directions, has been well documented as evidence of motor simulations of language that are grounded in bodily action. However, this interaction was not observed in the current study. In fact, the findings replicated those of Experiment 1A; suggesting that the inability to capture of the effect could be an indicator of the sensitivity of the ACE paradigm. Even when the sample size was increased, the expected interaction did not emerge, which would imply that the lack of replication in Experiment 1A was not due to the groups. But still, this does not fully explain why the ACE did not replicate.

One possibility is that switching response direction half way through the task affected performance and resulted in the ACE being lost in the second half of the experiment. To investigate this, data from the second half of the experiment were removed and only the first half was analysed. This meant that participants were only making a motor action response in one direction to indicate when the sentence made sense, which would control any effect response direction switching and could possibly uncover the ACE in the first half of the experiment. However, the ACE failed to emerge (p = .83), suggesting that switching response midway through the experiment did not mask the interaction effect, but rather the ACE was not present at all.

As previously noted, it is well documented that the ACE is time sensitive. In these two experiments the response cue was presented to participants prior to the onset of the sentence (i.e. at the start of each block), allowing ample time for participants to simulate the event and program an appropriate motor response, but the ACE has failed to emerge. This would suggest that perhaps the paradigm is more sensitive than initially thought. It could be then, that the techniques used to trim the data prior to analysis impact the occurrence of the ACE. A number of different data trimming and analysis methods have been presented in the ACE literature. Glenberg and Kaschak (2002) analysed the sentence reading time (i.e. the time between sentence onset and when the participant released the middle button), with the rationale being that the ACE occurs early on. To trim the data and reduce the effects of outliers for each participants, Glenberg and Kaschak (2002) eliminated practice trial and discarded the fastest and slowest reading times for each of the 12 conditions (defined by the combination of two implied sentence directions, two response directions and three sentence types). Glenberg et al (2008) also analysed sentence reading time, but trimmed the data by first removing the longest 1% and shortest 1%, then eliminated the first 12 trials with each response assignment, considered to be practice effects. Errors were then eliminated and for each participant in each of the six conditions (defined by the two sentence types and three implied sentence directions – towards, away and no-transfer), reading times longer than 2.5 SDs over the mean were discarded.

Others have analysed the combination of sentence reading time and response time (i.e. the time between the onset of the sentence to pressing the near or far response button) (see Borreggine & Kaschak, 2006 Experiment 1; Diefenbach, et al, 2013). The justification for the inclusion of the response time being that participants may not always have selected a response before releasing the middle button, but instead only made a response decision after the movement had already been initiated. Analysing sentence reading time alone would not capture this part of the response preparation that occurs during movement time (Diefenbach, et al, 2013). In their Experiment 1, Borreggine and Kaschak (2006) then trimmed the data by removing incorrect responses and then discarding outliers that were more than 2 SDs from each participants' mean response time in each of the four conditions (defined by two implied sentence directions and two response directions). Diefenbach et al (2013) also discarded incorrect trials, and then trimmed the data by eliminating 0.5% of the longest and shortest responses across participants. Then for each participant, in each condition, response times that were more than 2.5*SD*s from the condition mean were also removed.

The final measure that has been used in previous research is the time to press the response key from the onset of the response cue, where the response cue varied across experiments (see Borreggine & Kaschak, 2006 Experiments 2, 3 and 4; Kaschak & Borreggine, 2008). The rationale for this measure was the prediction that the ACE will only arise when the direction of the required motor response is known, while the sentence is being processed (Borreggine & Kaschak, 2006). In all four of their experiments, Borreggine and Kaschak (2006) used the same data trimming method, outlined above. In contrast, Kaschak, & Borreggine (2008) trimmed the data by first removing incorrect trials and then eliminating response times longer than 3000ms. The data were then further screened for outliers by removing response times more than 2*SD*s from each participant's mean response time in each of the four conditions (defined by two implied sentence directions and two response directions).

In Experiments 1A and 1B, I used the combined sentence reading time and response time measure used by Borreggine and Kaschak (2006; Experiment 1) and Diefenbach et al (2013). I then trimmed the data according to the method used by Borreggine and Kaschak

(2006). It seems then, that there is no standardised way in which the ACE should be trimmed and analysed. So given this, it is possible that the ACE effect is very sensitive and previous papers have adjusted their choice of data trimming and analysis according to which gives the best results.

Another possible explanation as to why the ACE interaction did not appear in Experiments 1A and 1B is due to the nature of the experimental items used. Instead of using the same transfer sentences employed in Glenberg and Kaschak's (2002) original ACE study, new concrete and abstract transfer sentences that described actions away-from and towards-the-body were constructed. It may have been the case that the new items were not sensitive enough to capture the compatibility effect. Indeed, some studies such as Borreggine and Kaschak (2006) did use Glenberg and Kaschak's original experimental items and successfully replicated the ACE interaction. Therefore, rerunning the paradigm using Glenberg and Kaschak's (2002) original items may yield different results to Experiments 1A and 1B. However, it should be noted that not all previous studies that have successfully found the ACE interaction have used the same experimental materials. For example, Diefenbach et al (2013) used a set of German transfer sentences and successfully observed the ACE interaction, and Aravena et al (2010) employed Spanish hand-action sentences.

Given the failure to demonstrate evidence of motor simulations in language comprehension using the ACE paradigm, it may be that the effect requires a number of conditions to be met in order to be captured. As well as providing participants with knowledge of the required motor action direction prior to simulation completion, it may be that a relatively large sample is required to draw out the effect (perhaps even larger than that tested here in Experiment 1B). In addition to this, the number of data trimming and analysis techniques that have thus far been discussed could impact the prevalence of the ACE in the simulation literature. In addition to this is, of course, is the publication bias for positive effects, with null effects seldom being published. This bias may skew the prevalence of the ACE in the simulation literature further. All of this would suggest that testing motor simulations that access an action-based system are difficult to capture, at least with behavioural evidence. Instead it may be more suitable to test a different aspect of language; so I now move on to look at spatial simulations of language, which is assessed using a different paradigm.

Experiment 2

The aim of Experiment 2 is to examine a different kind of language simulation, one that is not based on motor representations, but instead on spatial representations. Recall that language-induced motor simulations entail the activation of the neural substrates involved in performing the action (Zwaan & Taylor, 2006). In contrast, spatial simulations entail the activation of perceptual representations and are mapped onto the visual world through visual attention (Scheepers & Kamide, 2013).

Comprehenders activate spatial simulations of different contextually modified aspects of the event and referents described by the linguistic input. As discussed in more depth in Chapter 1, individuals have been found to simulate the orientation of referents (Stanfield & Zwaan, 2001), the shape (Zwaan, Stanfield & Yaxley, 2002), implied perceptibility (Yaxley & Zwaan, 2007) and also the motion implied (Zwaan et al, 2004). Moreover, it is the verbs used in sentences that implicate these changes in spatial properties, resulting in the activation of relevant spatial simulation that is mapped onto the visual world.

Examining motor simulations relies on a motor action response as an indication of event simulation. In contrast, the mapping of a spatial simulation onto the visual world is implicitly captured by behavioural measures. One paradigm that tests spatial simulations of language is the sentence-picture verification task, which uses pictorial stimuli on which comprehenders map the simulation of the linguistic input. Participants are presented with sentences such as *"The ranger saw an eagle in the sky"* followed by and image that depicts the described object (i.e. an eagle). Critically, the object either matches or mismatches the physical state described in the preceding sentence (an eagle with outstretched wings vs. an eagle with folded wings). The participants' task is to judge whether the object depicted was mentioned in the preceding sentence or not. A facilitation effect (i.e. shorter reaction times) is typically demonstrated as participants are faster to respond when the physical state depicted in the image matches that described in the preceding sentence. In contrast, an interference effect (i.e. longer reaction times) is typically observed when these mismatch (Zwaan, Stanfield & Yaxley, 2002).

The first question the current study intends to address is again, do individuals with ASD simulate spatial properties of language at all. As motor representations of language were not replicated by either group in Experiment 1A or by the large control sample in Experiment 1B, it seems reasonable to address the related concept of spatial representations of language using a different, yet still well-established behavioural paradigm. In addition to this, the current study also aims to investigate the nature of language simulations by individuals with ASD. So the second question to be addressed is if indeed individuals with ASD do simulate language, are these simulations activated as quickly and for as long as they are in TD individuals.

In order to examine the question of the timing of language simulations, the current study manipulated the interstimulus interval (ISI); the time between the offset of the sentence and the onset of the image, to be either 250ms or 1500ms. This time can be considered the time given for the comprehender to simulate the event described in the preceding sentence, before the image appears. These timings were used as previous research suggests that within 250ms comprehenders have access to a full simulation of the described event (Kaup, et al, 2007; Ferguson, Tresh & Leblond, 2013). Moreover, simulations remain active even 1500ms after the sentence has ended (Ferguson, Tresh & Leblond, 2013). In the current study, ISI was manipulated so as to investigate how long spatial simulations take to set up and how long they remain accessible to individuals with and without ASD.

In the following study the sentence-picture verification paradigm used by Zwaan, Stanfield and Yaxley (2002) was utilised. It was predicted that the facilitation/interference effects observed in the TD population in previous research would be replicated by the TD group at both the short ISI (250ms) and long ISI (1500ms). Additionally, if individuals with ASD do simulate the spatial properties of language in the same way as TD individuals, then it was predicted that the facilitation effect for matching sentence-image pairs would occur at both the short and long ISI, with no effect of group across these two ISIs. That is, the ASD group, like the TD group should show shorter reaction times when the physical state of the object depicted in the images matches that described in the preceding sentence and longer reaction times when they mismatch.

Method

Participants

Participants were 22 adults with ASD (14 males and 8 females, ratio 7:4; *M* age = 20.32, *SD* age = 1.10; age range18 – 27) and 22 typically developing (TD) control participants (3 males and 19 females, ratio 3:19; *M* age = 20.64, *SD* age = 5.25; age range 18 – 43 age range). As in Experiment 1A, all had English as their native language and none reported other language or neurological/neurodevelopment disorders. All participants were students at the University of Kent.

As in Experimental 1A, ASD students were recruited through the University's Disability and Dyslexia Support Services (DDSS), who forwarded our study information onto eligible students. Individuals in the ASD group received £40 for their participation. The control group were Psychology undergraduate students at the University of Kent. They were recruited through the School of Psychology's online Research Participation Scheme (RPS) and were awarded course credits.

All participants completed the same series of assessment measures outlined in Experiment 1A. ASD participants scored significantly higher on the AQ and had a significantly higher full IQ score, compared to TD participants. Means for IQ, AQ and the remaining assessments as well as comparison statistics between the two groups, are reported in Table 3.

Table 3. *Assessment test results, with means and t values for the TD and ASD groups. Standard deviations are noted in parenthesis.*

	TD	ASD	Difference
WAIS			
Full IQ	100.64 (7.03)	108.68 (9.12)	$t(21) = -3.21$**
Verbal IQ	99.36 (6.66)	109.09 (9.8)	$t(21) = -3.51$**
Performance IQ	101.77 (9.56)	106.82 (12.47)	$t(21) = -1.88$
TROG	98.27 (10.78)	100.59 (7.2)	$t(21) = -1.48$
BPVS	105.64 (8.23)	116.27 (10.96)	$t(21) = -3.61$**
AQ	13.85 (5.15)	34.54 (8.47)	$t(12) = -7.23$***

*Significant at ***.001 **.01 *.05*

Design

A 2 (Image: match vs. mismatch) x 2 (ISI: 250ms vs. 1500ms) x 2 (Group: ASD vs. TD control) mixed measures design was used. Both image and ISI were manipulated within participants. Accuracy and reaction time (RT) were dependent measures. Accuracy was the percentage of trials on which participants correctly identified the object as being mentioned (or not mentioned) in the preceding sentence. Reaction time was the time taken, from picture onset, for participants to judge whether or not the object pictured was mentioned in the preceding sentence.

Materials

Forty-eight experimental sentence pairs (so 96 experimental sentences in total) and 48 filler sentences were created. The sentences were of the form *"The [object X] is Y/Z"*, with Y and Z being opposing predicates of Object X and were paired such that the two sentences described different physical states of the same object (e.g. *"The eagle is in the sky/nest"*).

One hundred and forty four colour images, 200x200 pixels in size, were used to accompany the sentences. Of these, 48 were paired with the filler items and depicted an object that was not mentioned in the accompanying sentence (e.g. the sentence *"The cat is in the living room"* followed by an image of a bike). The remaining 96 images formed 48 pairs, with each image in the pair depicting the same object in one of two different physical states (e.g. one image of an eagle with outstretched wings and another of an eagle with drawn in wings). These experimental images depicted the same objects mentioned in the 96 experimental sentences and either a matched or mismatched the described physical form. This resulted in four sentence-picture pairs for each of the 48 experimental items; two matched sentence-picture pairs and two mismatched (see Table 4). See Appendix B full list of the experimental sentences used.

From this, four counterbalanced lists were created. Each list contained a total of 96 trials; one sentence-picture pair from each of the 48 experimental items, plus all of the 48 filler items. During the experiment, items appeared in four blocks of 24 trials, in a random order. Participants were assigned to one list and therefore only saw one of the four sentence-picture pairings per experimental item. All filler items required a 'not mentioned' response and all experimental items required a 'mentioned' response.

Table 4. *Example experimental sentences and the associated visual display, as labelled.*

	Match	Mismatch
The eagle is in the sky.		
The eagle is in the nest.		

The interstimulus interval (ISI) – the interval between sentence offset and picture onset – was manipulated between blocks and the order was counterbalanced across lists. To do this, the four experimental lists were duplicated. For four of the lists, the first half of the experiment (i.e. the first two blocks) had an ISI for 250ms and the second half (last two blocks) had an ISI of 1500ms. For the other four lists this order was reversed, such that for the first half of the experiment the ISI was 1500ms and for the second half the ISI was 250ms. This resulted in a total of eight lists and participants were assigned to one list only.

Ten practice items of the same *"The [object X] is Y/Z"* form were presented at the beginning of the experiment. Five of the items required a 'not mentioned' response and the other five required a ‘mentioned’ response. ISI was also manipulated for practice items, such that half used an ISI of 250ms and half used an ISI of 1500ms.

Twenty-four experimental trials and 12 filler trials were followed by a comprehension question. These required a binary ‘true/false’ or ‘yes/no’ response and were included to ensure participants were reading and understanding the sentences.

Procedure

Participants were randomly assigned to one of the eight experimental lists and were seated in the lab in front of the screen and keyboard. Sentences were presented in the centre of the screen in black font on a white background. Participants were instructed to read the sentence and then to press the ‘spacebar’ key. A blank screen then appeared for either 250ms or 1500ms, followed by an image. Participants’ task was to indicate as quickly and accurately as possible whether the object depicted had been mentioned in the preceding sentence or not. They were instructed to press the ‘m’ key if they believed the object was mentioned and ‘n’ if it was not.

For 36 of the trials the picture was followed by a comprehension question about the preceding sentence (e.g. *“Is the egg in the frying pan?”*). This question was presented in the centre of the screen in black font on a white background. Participants were instructed at the beginning of the experiment to press the ‘m’ key if the answer to the comprehension question was on the right and ‘n’ if the answer was on the left.

The experiment began with 10 practice trials. Participants completed 96 experimental and filler items in four blocks of 24 items. The experiment took approximately 15 minutes to complete.

Results

Accuracy on the comprehension questions was 96.2% for the TD group and was also 96.2% for the ASD group

Accuracy

Responses accuracy was analysed using a 2 (Image: match vs. mismatch) x 2 (ISI: 250ms vs. 1500ms) x 2 (Group: TD vs. ASD) mixed measures ANOVA. Analysis revealed a main effect of Image [F(1, 42) = 9.1, $p < .01$, $\eta_p^2 = .18$], with participants more accurate at identifying a picture as mentioned when the physical state matched that implied in the preceding sentence compared to when the physical state mismatched that implied in the preceding sentence (*M* = 0.99, *SD* = 0.003 vs. *M* = .98, *SD* = 0.004). There was no main effect of group (*p* = .34) and this did not interact with image (*p* = .09), thus, this facilitation was present in both the TD and ASD groups. However, no main effect of interstimulus interval (ISI) was observed (*p* = .67), nor was there an interaction between ISI and Image (*p* = .99), or ISI, image and group (*p* = .27). Average response accuracy for the TD and ASD group are presented in Figure 12.

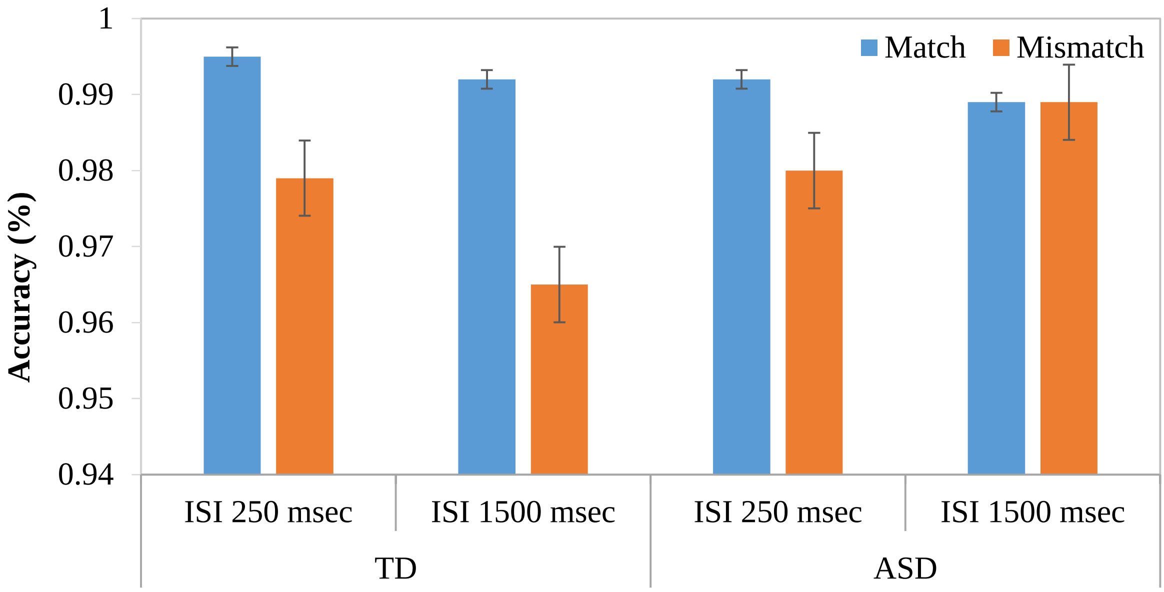


Figure 12. Mean accuracy (%) for the TD and ASD groups, across conditions. Error bars show standard errors.

Reaction Time

Incorrect responses were removed prior to analysis of reaction times; less than 2% of the data was excluded for this reason. To reduce the effect of outliers, participants' reaction times were transformed into z-scores and those corresponding to z-scores greater than 3.29 (i.e. $p < .001$) were removed. This procedure removed 12 responses (1.08% of all responses). The resulting means per condition are plotted in Figure 13.

Again, results were analysed using a 2 (Image: match vs. mismatch) x 2 (ISI: 250ms vs. 1500ms) x 2 (Group: TD vs. ASD) mixed measures ANOVA. There was a main effect of Image [$F(1,42) = 6.29$, $p < .05$, $\eta_p^2 = .13$], with participants responding faster when the image matched the physical state implied in the sentence than when it mismatched (M = 934ms, SD = 31.6 vs. M = 980ms, SD = 32.9). As before, there was no main effect of group ($p = .36$) and this did not interact with image ($p = .36$), thus, this facilitation was present in both the TD and ASD groups. However, there was no main effect of ISI ($p = .097$), nor a reliable interaction between ISI and image in either group (p = .53), or between ISI, image and group (p = .75). That is, both control and ASD participants activated comparable simulations of the described event within the given ISI.

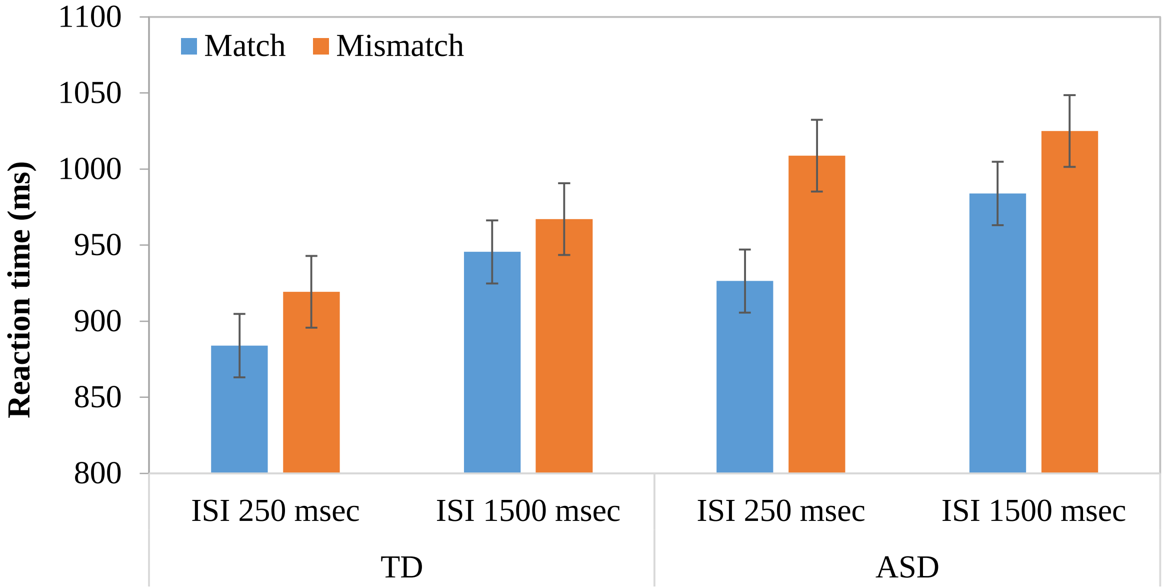


Figure 13. Mean reaction times for the TD and ASD groups, across conditions. Error bars show standard errors.

Discussion

The aim of Experiment 2 was to investigate whether individuals with ASD simulate the spatial properties of language, and if so, whether they activate these spatial simulations as quickly and for as long as TD individuals do. In a sentence-picture verification task participants were presented with sentences such as *"The eagle is in the sky"* and were asked to make a mentioned/not mentioned judgement on a subsequently presented image. Critically, when the following image depicted the object mentioned in the preceding sentence (i.e. an eagle), it either depicted the object in a physical state that matched that implied in the sentence (i.e. outstretched wings) or mismatched the physical state implied (i.e. closed wings). Recall that in the sentence-picture verification paradigm, a facilitation effect is observed when the physical state of the object depicted matches that described in the preceding sentence and an interference effect occurs when it mismatches. These effects occur as individuals activate perceptual representations of referents during language comprehension. Moreover, these representations are activated even when the perceptual characteristics are merely implied, as opposed to explicitly stated (Zwaan, Stanfield & Yaxley, 2002). These perceptual representations allow for the construction of a spatial simulation of the event described by the linguistic input, which is then mapped onto the visual world.

This paradigm has been used extensively in the simulation literature to demonstrate how TD individuals activate spatial simulations and map them onto the visual world during comprehension (see Stanfield & Zwaan, 2001; Zwaan, Stanfield & Yaxley, 2002; Yaxley & Zwaan, 2007; Zwaan, et al, 2004). Of interest in the current study was whether this would replicate with individuals with ASD. If so, this would be taken as evidence that individuals with ASD do in fact simulate the spatial properties of language.

As predicted, this mismatch effect was replicated in the current study, but more interestingly it was done so by both the TD participants and those with ASD. Research has shown that during sentence processing comprehenders represent perceptual aspects of referents, including shape (Zwaan, Stanfield & Yaxley, 2002), orientation (Stanfield & Zwaan, 2001) and visibility (Yaxley & Zwaan, 2007). The current study extends these findings by suggesting that those with ASD also simulate language. The lack of group by match/mismatch interaction in the current study shows that individuals with ASD are also representing the implied physical state of the object described during processing of the sentence. So when the depicted object matched the physical state implied in the preceding sentence, responses were quicker and when the physical shape mismatched that which was implied, responses were slower. However, an interesting observation to note is that although no group effect was found, the reaction time data does suggest a trend for those with ASD to be slower than TD individuals. In terms of spatial simulations of language, this would imply a very subtle group difference in processing. Nevertheless, response accuracy shows that the ASD group were just as accurate as the TD group at making judgements, which would imply that the groups accessed comparable simulations of the described event.

Having found evidence to support language simulation in ASD, the next question I addressed here was whether these simulations are activated as quickly and for as long as they are in TD individuals. In the current study the ISI; the interval between sentence offset and picture onset, was manipulated to be either 250ms or 1500ms. Previous research has shown that within 250ms comprehenders are able to set up a simulation of a described event (Kaup, et al, 2007; Ferguson, Tresh & Leblond, 2013). Moreover, by 1500ms they not only maintain this simulation, but also set up and hold additional simulations if required (Ferguson, Tresh & Leblond, 2013).

No effect of ISI was observed in the current study; participants were just as quick to respond to the preceeding image following a 250ms time delay as they were a 1500ms delay. This suggests that within 250ms of reading a sentence, participants have constructed a simulation of the described event, which can then be checked against the available image. In addition, the fact that the mismatch effect was still present with an ISI of 1500ms shows that these spatial simulations remain active for a prolonged time. Importantly, neither the TD participants nor the ASD participants showed an interaction between the mismatch effect and ISI, showing that the mismatch effect was comparable across the two ISI conditions. Thus, the ASD participants not only simulated the described event, but they did so as quickly and the simulation lasted as long as those of TD participants.

In conclusion, the findings of the current study provide behavioural evidence to suggest that individuals with ASD do simulate language and they do so at the same rate as

TD adults. The findings also point to the sentence-picture verification task as an effective paradigm for investigating mental simulations of language.

Chapter Summary

The aim of this chapter was to investigate motor and spatial simulation of language by individuals with and without ASD. In Experiment 1A, I set out to explore whether individuals with ASD make use of motor simulations that have been well documented in the simulation literature with TD individuals. To do so, a group of TD individuals and a group of individuals with ASD completed the ACE task, whereby participants made sensibility judgements on sentences describing an action away-from-the-body or towards-the-body and respond by pressing a button position either near or far. Previous research has shown a facilitation effect (i.e. short reading times and response times) when the direction implied in the sentence is the same as the required motor response, and an interference effect (i.e. longer reading and response times) when the two are opposed (see Glenberg, & Kaschak, 2002; Borreggine, & Kaschak, 2006; Kaschak, & Borreggine, 2008, Glenberg, et al, 2008, Diefenback, et al, 2013). However, Experiment 1A was apparently unsuccessful in demonstrating motor simulations of action sentences in TD adults or individuals ASD. It was argued that the lack of effect could be due to the small sample size used in Experiment 1A compared to previous literature, resulting in less power.

Therefore, Experiment 1B was run in order to test this possibility and to validate the ACE paradigm. The exact paradigm and stimuli used in Experiment 1A were completed by a larger sample of TD individuals; however, again the ACE interaction between implied sentence direction and response direction did not emerge. Discussion focused on possible explanations of the lack of replicability of the effect. The data trimming and analysis methods used in Experiments 1A and 1B were compared to those used in previous research, and it was concluded that perhaps the ACE effect is particularly sensitive and requires a number of conditions be met in order to be captured. Therefore, it seemed appropriate to move away from motor simulations and to focus on another type of language simulation.

Having been unable to demonstrate motor simulation of language using a behavioural paradigm, I moved on to look at another type of language simulation. The aim of Experiment 2 was to investigate spatial simulations of language in individuals with and without ASD. Participants completed the sentence-picture verification task, whereby they are presented with sentences describing an object and are asked to make a mentioned/not-mentioned judgement on a subsequently presented image. Critically, when the depicted object is mentioned in the preceding sentence, it is depicted in a way that either matches the physical state implied in the sentence, or mismatches. Previous research has shown a facilitation effect when the physical state of the object matches that implied in the sentence and an interference effect when it mismatches (see Stanfield, & Zwaan, 2001; Zwaan, Stanfield, & Yaxley, 2002; Yaxley, & Zwaan, 2007; Zwaan et al, 2004). Moreover, the time delay between the sentence offset and the image onset; considered the time for the participant to simulation the event, was manipulated in the current chapter to be 250ms or 1, 500ms.

Interestingly, it was found that individuals with ASD do simulate the spatial properties of language. Moreover, they activate spatial simulations at the same rate as TD individuals and keep them active for as long. These findings extend previous research on spatial simulations of language, showing that like TD individuals, those with ASD have access to a full simulation of the described event within 250ms of the sentence being complete, and are able to check this simulation against the subsequent image. Furthermore, the findings show that such individuals also maintain a spatial simulation of a described event for as long as TD individuals. Previous research has suggested that language comprehension is a perceptual simulation of the described situation (Barsalou, 1999). Individuals routinely activate representations of the perceptual information described by the linguistic input

(Zwaan, & Yaxley, 2004). Moreover, these representations are activated in implicit tasks even when the perceptual characteristics are merely implied (Zwaan, Stanfield, & Yaxley, 2002). Experiment 2 extends this further, with a lack of interaction between group, ISI and image implying that individuals with and without ASD construct comparable simulations. That is, those with ASD also represent perceptual properties of referents described by the linguistic input and integrate these into a simulation of the event.

In the current chapter I have found behavioural evidence that individuals with ASD are not only able to simulate the spatial properties of language, but they do so at the same rate as TD adults. Of interest next is to investigate the neural mechanisms that underlie spatial simulations of language in TD individuals and those with ASD. The next question to ask is what are the neurological correlates that underlie spatial simulations of language and do individuals with ASD rely on the same neural mechanisms as TD individuals? This is studied in Chapter 3 again through the use of the sentence-picture verification task, but with the addition of EEG measures.

Chapter 3

In Chapter 2 I demonstrated through use of psycholinguistic paradigms and behavioural measures that individuals with ASD are able to simulate the spatial properties of language, and appear to do so at the same speed as TD adults. The findings also highlighted the sentence-picture verification task as an effective paradigm for investigating simulations of language. In the previous experiment, both TD and ASD participants showed the expected mismatch effect when sentence and picture mismatched, suggesting both groups were comparing the image presented with the one they had simulated via the preceding linguistic input. Of interest now is to investigate the neural mechanisms that underlie spatial language simulation in TD and ASD adults. Moreover, the current experiment will investigate how these spatial simulations are affected by contextual uncertainty. Uncertainty is a pervasive component of language, so of interest is how this might impact the construction of spatial simulations by individuals with and without ASD.

Recall that understanding a sentence entails the meshing of affordances, guided by the sentence syntax. The use of behavioural measures has shown that comprehenders construct mental simulations of the described event; these simulations encompass properties of the event or object including the timing, spatial information, perspective and focal and background entity, conveyed by an attentional frame (Zwaan & Madden, 2005). As described in Chapter 1, evidence for this embodied simulations theory of language processing has been found using a variety of other experimental techniques including event-related potentials (ERPs) – the technique that I use in the current experiment. ERPs can provide online information about language processing well in advance of behavioural measures. The benefit of the ERP technique is that it allows us to examine how language is processed in real-time, as well as to monitor 'covert' processes in the absence of an 'overt' response (i.e. reading). Moreover, employing the technique means ERP effects found in the data can be mapped onto the vast literature to understand underlying mechanisms, which makes ERPs an effective technique to further investigate spatial simulations of language in the current Chapter.

In this Introduction I will first define the ERP component of interest in the current experiment – the N400 – and describe the linguistic structures that have been shown to give rise to N400 effects. Next, I will consider how language-based N400 effects might be influenced by ASD, then introduce the uncertainty paradigm that I implemented in the current experiment, and finally present my hypotheses.

The N400 ERP component

The two most commonly studied language-induced ERP components are the P600 and the N400. The P600 is linked to syntactic violations such as between the subject and verb, whereas the N400 is related to semantic violations and semantically less expected stimuli (van Herten, Kolk & Chwilla, 2005). Focus in the current Chapter will be on the N400 component, which was first reported by Kutas and Hillyard (1980). This ERP wave is a negative voltage deflection occurring around 400 msec post-stimulus onset, and is related to violations of semantic and pragmatic expectancy during language comprehension as well as to plausibility, word frequency and subjective predictability (cloze probability) (Nigam, Hoffman, & Simons, 1992; van Herten, Kolk & Chwilla, 2005). The N400 is elicited for every meaningful stimulus (both words and pictures) and the N400 effect refers to the difference between two conditions, demonstrating its relevance to the current experiment. Though the component peaks around 400ms, differential responses to sentential incongruous words begins at around 250ms (Halgren, et al, 2002). Words and pictures that change the veracity of a single sentence elicit consistently larger N400 amplitudes (Hagoort, Hald, Bastiaansen & Petersson, 2004). The larger the semantic mismatch, the larger the N400 amplitude.

The ERP component varies systematically with the processing of semantic information (Kutas & Federmeier, 2000) and is modulated not only by the sentence context, but at a lower level by the frequency of words in the sentence and also their lexical class (Halgren, et al, 2002). In addition, the modality of the sentence has also been found to modulate the N400. Modality switching involves presenting participants with two sentences, each associated with a different modality. Switching from processing a sentences describing a fact presented in one modality (e.g. visual; *"A cellar is dark"*), to processing a second sentence describing a fact presented in a different modality (e.g. tactile; *"A mitten is soft"*) results in a modality switch effect, evident in a larger N400 amplitude. This is in comparison to when the second sentence is grounded in a modality matching the first sentence (i.e. visual) (e.g. *"Ham is pink"*) and no modality switching effect occurs (Hald, Marshall, Janssen & Garnham, 2011).

Hald et al (2011) presented participants with true modality-matched *("Ham is pink" – "A cellar is dark"*) and -mismatched sentence pairs (*"A mitten is soft" – "A cellar is dark"*) and false modality-matched (*"A mitten is soft" – "A cellar is light"*) and –mismatched (*"Ham is pink" – "A cellar is light"*) sentence pairs. Participants were asked to make true/false judgement on each sentence. For true sentences, a larger N400 effect is found for the second (target) sentence in comparison to modality-matched sentence pairs. Moreover, false modality-mismatched sentences elicited a greater N400 compared to true modality-mismatched sentences. Assuming the ongoing simulation is embodied, the N400 is modulated by the integration of new incoming information into the ongoing simulation. As the integration becomes more difficult (e.g. as when the modality switches from visual to tactile, for example) the modulation of the N400 produced is greater (Hald, et al, 2011) and this modulation by the effects of the sentence is indicative of embodied language processing. Comprehenders construct a simulation of the described event as the sentence unfolds; when incoming information is incongruent with the simulation processing costs are incurred, evident in a larger N400.

The N400 for the final word in *"He took a sip from the transmitter"* (strong semantic incongruity) is significantly larger than that elicited by the final word in *"He took a sip from the waterfall"* (moderate semantic incongruity) (Kutas & Hillyard, 1980). Moreover, sentences such as *"The Dutch trains are sour and very crowded"* elicit a larger N400 at critical word onset when the critical word is semantically anomalous (sour) compared to when it matched real world expectations (*"The Dutch trains are yellow and very crowded"*) (Hagoort, et al, 2004). This would suggest that not only semantics, but also effects of pragmatics (i.e. real-world knowledge) elicit the same effects on the N400 as effects of semantics. In fact, the magnitude of the N400 varies in such a way that it reflects the interaction between real-world knowledge and discourse context (Hald, Steenbeek-Planting & Hagoort, 2007).

Van Berkum, Hagoort and Brown (1999) (see also Van Berkum, Zwitserlood, Hagoort & Brown, 2003) presented short stories made up of a local sentence (1) and a final target sentence (2), where the final critical word was either contextually coherent (2a) or anomalous (2b) to the wider discourse, though it fit the local sentence context. The semantic anomaly elicited a larger N400 and this amplitude was reduced when the sentence containing the critical anomalous words was presented in isolation (without the original context).

(1) *"As agreed upon, Jane was to wake her sister and her brother at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed."*

(2) *a. Discourse-coherent: "Jane told the brother that he was exceptionally quick."*

b. Discourse-anomalous: "Jane told the brother that he was exceptionally slow."

This effect is also observed when stories are presented as a series of pictures, with the final picture of story inducing a larger N400 when it is incongruous with the preceding context

(West & Holcomb, 2002). Participants were presented with a sequence of pictures of four to ten frames and were cued at the offset of the final frame to judge whether the story made sense or not. Critically, the final frame was either congruous or incongruous (see Figure 14) with the preceding context (e.g. the preceding frames depicting a girl running and falling during a hurdles race). Readers (and listeners) relate the unfolding information to the wider discourse context very rapidly, which his reflected in the sensitivity of the N400 to the wider context and to semantic anomalies (Van Berkum, et al, 2003).

Figure 14. Example stimuli from West and Holcomb (2002). Following a pictorial story depicting a girl running in a hurdle race, the final frame was either congruous (left) or incongruous (right), with the story.

ERPs have been used in conjunction with the sentence-picture verification task to observe in real time, the simulation of spatial properties of language during sentence processing. Presentation of a depicted object (e.g. a swimming duck) that follows the visual presentation of a noun phrases describing an incongruent object pairing (e.g. *"sliced bread"*) elicits a larger N400 compared to when the image is preceded by a noun phrase describing the depicted object in a shape-matching state (i.e. *"swimming duck"*) or a shape-mismatching state (i.e. *"flying duck"*) (Hirschfeld, Feldker & Zwitserlood, 2012). This was also observed in an MEG study where an image (e.g. a flying duck) was preceded by a sentence describing an object either feature-matching the object depicted (i.e. *"The ranger saw a duck in the* *air."*), feature-mismatching the depicted object (i.e. *"The ranger saw a duck in the lake."*) or the sentence was unrelated (i.e. *"The ranger prepared a sandwich."*) (Hirschfeld, Zwitserlood & Dobel, 2011). Presentation of the target image resulted in an N400 that was largest for the object that was not previously mentioned in comparison to when it was mentioned, regardless of whether the shape matched or mismatched. That is, the N400 is insensitive to shape mismatch, reflecting the activation of an abstract simulation as opposed to gradual feature overlap (Hirschfeld, Feldker & Zwitserlood, 2012). Thus, the large N400 effect for not-mentioned objects compared to mentioned objects reflects congruency between the linguistic context and the object.

Furthermore, self-rated vividness affects response and modulates the N400 effect. Hirschfeld, Feldker and Zwitserlood (2012) asked participants complete the Vividness of Visual Imagery Questionnaire (VVIQ), which requires participants to imagine four different scenes and rate the vividness of aspects of each scene on a 5-point Likert scale (1 = No picture at all; you merely know that you are thinking about the object, 5 = perfectly clear; as vivid as normal vision). Interestingly, participants with high self-reported vivid imagery showed larger context effects related to stronger N400 effects, compared to participants low in imagery. The authors proposed that these differences reflect general comprehension differences, with low vividness ratings reflective of poor or shallow comprehension. Alternatively, participants with high vivid imagery may represent described referents in great details (Hirschfeld, Feldker & Zwitserlood, 2012). This would further suggest readers are activating simulations of the described event.

Having presented the ERP component of interest (the N400) and described the linguistic structures that give rise to N400 effects, I now move on to consider how ASD may influence the language-based N400 effect.

Effect of ASD on language-induced N400

Studies have shown that individuals with ASD who have intact language skills show deficits in processing linguistic information in context (Háppe, 1997). Despite being relatively able, participants with ASD show an inability to use the sentence context to process target homographs (e.g. pronouncing tear in *"In her eye/dress there was a big tear."*) and derive their correct pronunciation (Háppe, 1997). However, there are differences between subgroups of autism, with high functioning autism (HFA) showing greater difficulty using contextual information than individuals with Asperger's Syndrome (AS) (Pijnacker, et al, 2010).

This difficulty in processing words in context has been hypothesised to derive from weak central coherence in language processing in ASD and a deficit in binding words in context (Brock, et al, 2002). In a series of studies testing homograph processing, local coherence inferences and ambiguous sentence processing, Jolliffe and Baron-Cohen (1999) showed that individuals with ASD are impaired in achieving local coherence. Additionally, they showed that such individuals also demonstrate a preference not to strive for coherence unless instructed to do so. In addition to this, ASD individuals show difficulty in processing non-literal utterances (e.g. *"He drew a gun"* where the verb could mean 'drawing' or 'pulling out'), which may again be explained by a weak central coherence and also deficits in theory of mind (Martin & McDonald, 2004). Such individuals demonstrate a preference for local processing, without utilising the wider context or meaning (Martin & McDonald, 2004). Háppe (1994) and Jolliffee and Baron-Cohen (1999) gave ASD and TD participants short stories describing an agent saying things they did not literally mean. In both studies it was found that individuals with ASD gave more context-inappropriate mental state justifications than context-appropriate justifications compared with TD controls, with focus kept on the utterance in isolation. Háppe (1994) presented short stories such as (3), which describes a pretend scenario, followed by two questions; *"Is it true what Emma said?"* and *"Why does Emma say this?"*.

(3) Katie and Emma are playing in the house. Emma picks up a banana from the fruit bowl and holds it up to her ear. She says to Katie, "Look! This banana is a telephone!"

ASD participants were impaired in providing context-appropriate mental state explanations for the non-literal utterances of characters in the stories compared to TD and another clinical group. The motivations underlying utterances are generally distinguished by the preceding context, the speaker's emotional expression and the relationship between agents (Jolliffee & Baron-Cohen, 1999).

This inability to process language in context is emphasised by the finding that the N400 in ASD is not influenced by semantic congruence in a word categorization task. Although behavioural measures show no difference between ASD and TD children in terms of word categorization accuracy, children with ASD show no difference in N400 amplitudes for semantically incongruous and congruous words (e.g. animal and non-animal words) (Dunn, Vaughan, Kreuzer & Kurtzberg, 1999). Children and young adolescents with ASD have been shown to process words in isolation, detached from context, even when they are given explicit categorical context (Dunn & Bates, 2005). Interestingly, individuals with ASD show a typical N400 effect for single word recognition (i.e. words presented in isolation without a context), with a larger amplitude to auditory names that mismatched the picture presented, relative to those that did match (Van Droof, et al, 2010). Whilst AS individuals, like TD controls, have shown a typical N400 ERP effect when processing sentences such as *"Finally the climber reached the top of the <u>tulip/mountain</u>"*, HFA individuals do not show this effect. However, the HFA do show a late positive component, larger for semantically anomalous sentences, like TD and AS participants (Pijnacker, et al, 2010).

It could be that the effect found in the previous Chapter; that individual with ASD do simulate the spatial properties of simple language at the same speed as TD adults, may not mean there are no processing differences at the neurological level between the two groups. It is for this reason that the current study aims to investigate the neural underpinnings of spatial simulations in ASD. Moreover, the experiment in the current Chapter aims to investigate whether such individuals simulate the spatial properties of language in context. Specifically, the experiment in the current Chapter examines whether individuals with ASD simulate the spatial properties of language within a context of uncertainty in the same way TD adults do, and whether simulations rely on the same neural mechanisms for the two groups.

Contextual uncertainty

Uncertainty is a pervasive component of language, detected through prosodic cues, body language, facial gestures and word choice (Litman, Rotaru & Nicholas, 2003; Krahmer & Swerts, 2005; Pon-Barry & Schrieber, 2011), such as conditional terms, e.g. *maybe*, *often*, *perhaps, likely, typically, usually, possibly*. Understanding uncertainty, like other complex language structures, is likely to involve the construction of multiple representations of the described and implied states. For example, it has been shown that when processing negated sentences, comprehenders must simulate the two proposed states of affairs; the negated argument and the affirmative argument. It has been suggested that individuals activate both states and then reject the former in favour of the later (Kaup, Lüdtke & Zwaan, 2006; Kaup, Yaxley, Madden, Zwaan & Lüdtke, 2007; but see Nieuwland & Kuperberg, 2008; Tian, Breheny & Ferguson, 2010). This process of accessing and holding multiple simulations has been found to be cognitively demanding, evident in delayed responses on comprehension measures.

Ferguson, Tresh and Leblond (2013) propose that comprehending uncertainty also requires additional processing costs. During a sentence-picture verification task they visually presented participants with sentences of varying contextual uncertainty (e.g. a certain sentence such as *"The student* knows *that the textbook is open"* vs. an uncertain sentence *"The student* thinks *that the book is open"*) followed by an image that either matched or mismatched the physical state implied in the preceding sentence. The interstimulus interval (ISI) was manipulated such that the image was presented either 250ms or 1500ms after the sentence. They observed the well-established mismatch effect; a facilitation effect when the image matched the physical state implied in the preceding sentence compared to when it mismatched. But more interestingly, the authors also found evidence to suggest different processing strategies for certain and uncertain sentences, which differentially influenced response speed at short versus long ISIs. Following the short 250ms ISI, reaction times to the target image were significantly shorter when the preceding sentence included the verb *'knows'* compared with *'thinks'*. However, this effect of verb disappeared at the longer ISI. The authors proposed that this difference at the shorter ISI reflects extra processing steps required to construct and map a simulation onto the available image in the uncertain condition that have not yet been completed following 250ms. However, this effect disappears following the longer ISI as participants are given adequate time to set up the appropriate simulations, making uncertain events no more difficult to comprehend than certain events. It is thought that the cognitive slowdown observed following *'thinks'* is due to a delay in accessing multiple versions of the world (i.e. all possible versions implied in the sentence; an open picnic basket and a closed picnic basket) at the shorter ISI, as opposed to a delay in setting them up.

Equally, research on the comprehension of negation, another complex language structure that requires the retention of multiple simulations that differ from reality, shows that individuals with ASD have difficulty processing the associated ambiguity. The sentence *"Every horse did not jump over the fence"* can be processed with the negation taking scope over the quantifier, resulting in the interpretation "not every horse jumped over the fence". But when the quantifier takes scope over the negation, the sentence can be interpreted as "all horses are such that they did not jump over the fence" (Noveck, et al, 2007). Whilst healthy adults are efficient at exploiting the context in order to come up with a consistent preference for "Not every" interpretations, children and verbally competent autistic adults are seemingly more random with their reading, reflecting the difficulty of processing the ambiguity of the sentences. This inability by individuals with ASD to exploit the context and instead process sentences in isolation may also be observed in their comprehension of language in other contexts, such as uncertainty.

The current experiment

Having established in Chapter 2 that individuals with ASD do simulate the spatial properties of language and appear to do so at the same speed as TD adults, the aim of the current experiment is to investigate the neural mechanisms that underlie these simulations. To further examine the neural mechanisms of simulating language, the current study manipulated the contextual uncertainty of sentences in a sentence-picture verification task by comparing *'knows'* and *'thinks'*, and recording ERP responses (the N400 effect). In this way, I hope to explore the neural mechanisms underlying simulations of the spatial properties of certain and uncertain events in TD and ASD participants.

The following study made use of the same sentence-picture verification paradigm used by Ferguson, Tresh and Leblond (2013). Based on the findings in Chapter 2 it was predicted that the facilitation/interference effect will again be replicated by both TD and ASD groups. That is, both groups should show shorter reaction times following a matched image and longer reaction times following a mismatched image. It is also predicted that there will be no difference in N400 amplitude for matched and mismatched images at final word or picture onset. This is justified by previous research suggesting the ERP component is insensitive to shape mismatch (see Hirschfeld, Zwitzerlood & Dobel, 2011; Hirschfeld, Feldker & Zwitserlood, 2012).

In relation to the effects of contextual uncertainty, recall that Ferguson et al (2013) only observed an effect of uncertainty following an ISI of 250ms and that participant were able to set up appropriate mental simulations following 1500ms ISI. Once participants are given time to construct and map the appropriate simulations of the spatial properties of the event, uncertain events become no more demanding to simulate than certain events. In the current experiment, the ISI was set at 500ms. If this is enough time for comprehenders to simulate the uncertain event, there should be no effect of verb (*'knows'* vs. *'thinks'*) for either group at final word onset or picture onset.

However, previous research does suggest individuals with ASD are unable to exploit sentence context; they have difficulty integrating information in context and in processing ambiguous language (see Dunn, Vaughan, Kreuzer & Kurtzberg, 1999). For this reason, a difference in N400 amplitude between ASD and TD groups may be expected following *'thinks'*.

Method

Participants

Participants were 23 adults with ASD (15 males and 8 females, ratio 15:8: *M* age = 20.22, *SD* age = 2.07; 18 – 27 age range) and 23 typically developed (TD) adults (6 males and 17, ratio 6:17 females; *M* age = 20, *SD* age = 2.89; 18 – 30 age range), all students at the University of Kent. All participants were native English speakers and none reported other language or neurological/neurodevelopmental disorders.

ASD students met the criteria outlined in Chapter 2 (page 76) and were recruited through the University's Disability and Dyslexia Support Service (DDSS), who forwarded our study information onto eligible students. Individuals in the ASD group received payment for their participation. The TD participants were undergraduate students and were recruited through the School of Psychology's online Research Participant Scheme (RPS) and were either awarded course credits or paid for their participation.

All participants completed the same battery of assessment measures outlined in Chapter 2. ASD participants scored significantly higher on the number of self-reported autistic traits of the Autism Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) and had a significantly higher full IQ score, compared to TD participants. Means for IQ, AQ and the remaining assessments as well as comparison statistics between the two groups, are reported in Table 5.

Table 5. *Assessment test results, with means and t values for the TD and ASD groups. Standard deviations are noted in parenthesis.*

	TD	ASD	Difference
WAIS			
Full IQ	101.74 (9.02)	107.78 (10.12)	t(22) = 2.09*
Verbal IQ	101.87 (8.48)	108.48 (9.94)	t(22) = 2.17
Performance IQ	100.78 (10.48)	105.87 (13.88)	t(22) = 1.54*
TROG	99.57 (9.61)	100.13 (7.38)	t(22) = 0.22
BPVS	107.7 (9.59)	115.57 (10.91)	t(22) = 2.49*
AQ	11.96 (4.41)	31.87 (9.96)	t(22) = 8.07***

*Significant at ***.001 **.01 *.05*

Design

The experimental conditions gave rise to a 2 (Verb: knows vs. thinks) x 2 (Image: match vs. mismatch) x 2 (Group: ASD vs. TD control) mixed measures design. Both verb and image were manipulated within participants. Reaction time and accuracy were the dependent measures for behavioural responses.

Reaction time was recorded in milliseconds as the speed with which participants judged whether the object depicted was mentioned or not mentioned in the preceding sentence. Accuracy was the percentage of trials on which participants correctly identified the depicted object as being mentioned or not mentioned in the preceding sentence. Mean ERP amplitudes were examined in the electrophysiological data, as described in detail below.

Materials

One hundred and sixty experimental sentences of the form *"[Character] knows/thinks that the X is Y/Z"*, where X is an object and Y/Z are opposing predicates of this object, were constructed. Each sentence had four forms; two for each form of X (e.g. open/closed), crossed with two that included knows and two that included thinks. Each of these sentences was paired with one of two 200x200 pixel colour images (so 320 experimental colour images in total), each depicting object X in a different physical state (e.g. an open picnic basket vs. a closed picnic basket). Half of the experimental sentences were paired with an image that matched the physical state implied in the sentence and the other half were paired with an image that mismatched. This resulted in eight sentence-picture pairs for each of the 160 experimental items (see Table 6 for an example), with one of each being assigned to one of the eight lists in a latin-square design. Participants saw one of these lists and therefore saw all 160 experimental items, but only one sentence-picture pairing condition per item. For all experimental items, the subsequent image always required a 'mentioned' response.

An additional 160 filler items were added to each list to balance the ‘mentioned/not mentioned’ responses. These were of the same sentence-picture structure as experimental items but included various other verbs (e.g. *hopes, wishes, noticed*) and states (e.g. *alive, nervous, broken*). Furthermore, the filler items were all incorrectly matched sentence-picture pairings (e.g. *“Julie noticed that the nightclub is closing”* followed by an image of a car) and required a ‘not mentioned’ response. All the filler items were distributed randomly with each list to create a single random order. Therefore, in total each participant saw 320 sentence-picture pairings throughout the experiment.

Table 6. *Example experimental sentence and the associated visual display, as labelled.*

	Match	Mismatch
The old lady [knows/thinks] that the picnic basket is closed.		
The old lady [knows/thinks] that the picnic basket is open.		

Half of the trials in the experiment were followed by a comprehension question, which required a ‘true/false’ or ‘yes/no’ response. These were included to test participants’ memory and to ensure that they understood the preceding sentence.

Procedure

Participants were seated in the lab in front of the PC. They were informed of the EEG procedure and experimental task and then the electrodes were set up (see full details below).

Each trial began with a blank screen for 500ms, followed by a fixation cross in the centre of the screen for 500ms. The sentence was then presented word-by-word in the centre of the screen. Each word was displayed for 300ms with a 200ms blank screen between each word. After the final word of the sentence a blank screen appeared for 500ms, followed by an image. Participants' task was to indicate as quickly and accurately as possible whether the object depicted was mentioned in the preceding sentence or not. They were instructed to press the 'm' key if the object was mentioned and 'n' if it was not mentioned. Participants were given explicit instructions to ignore the form of the object depicted and to make a judgement based wholly on the object itself, not its physical state.

For half of the trials, the image was followed by a comprehension question about the preceding sentence appeared in the centre of the screen. Participants were instructed at the beginning of the experiment to press 'm' if the answer to the question was on the right side of the screen and 'n' if the answer was on the left side of the screen.

The experiment began with 10 practice trials. Participants then completed 320 experimental and filler trials in eight blocks of 40 trials. The entire testing period lasted approximately 90 minutes.

Electrophysiological Measures

A Brain Products ActiCap system was used for continuous recording of electroencephalographic (EEG) activity from 62 Ag/AgCl scalp electrodes. Recording was taken over midline electrodes AFz, Fz, FCz, Cz, CPz, Pz, POz, Oz, lateralised electrodes over the left hemisphere from electrodes Fp1, AF7, AF3, F7, F5, F3, F1, FT9, FT7, FC5, FC3, FC1, T7, C5, C3, C1, TP7, CP5, CP3, CP1, P7, P5, P3, P1, PO9, PO7, PO3 and O1 and homologue electrodes over the right hemisphere from electrodes Fp2, AF4, AF8, F2, F4, F6, F8, FC2, FC4, FC6, FT8, FT10, C2, C4, C6, T8, CP2, CP4, CP6, TP8, P2, P4, P6, P8, PO4, PO8, PO10 and O2 (see Figure 15 for electrode arrangement). Ground was placed at AFz and all electrodes were references online to electrode FCz. HEOG activity (horizontal eye movements) was recorded from an electrode on the outer canthus of the left eye, and VEOG activity (vertical eye movements) was recorded from an electrode placed under the right eye and referenced to electrode Fp2. EEG and EOG activity was recorded at a sampling rate of 500Hz.

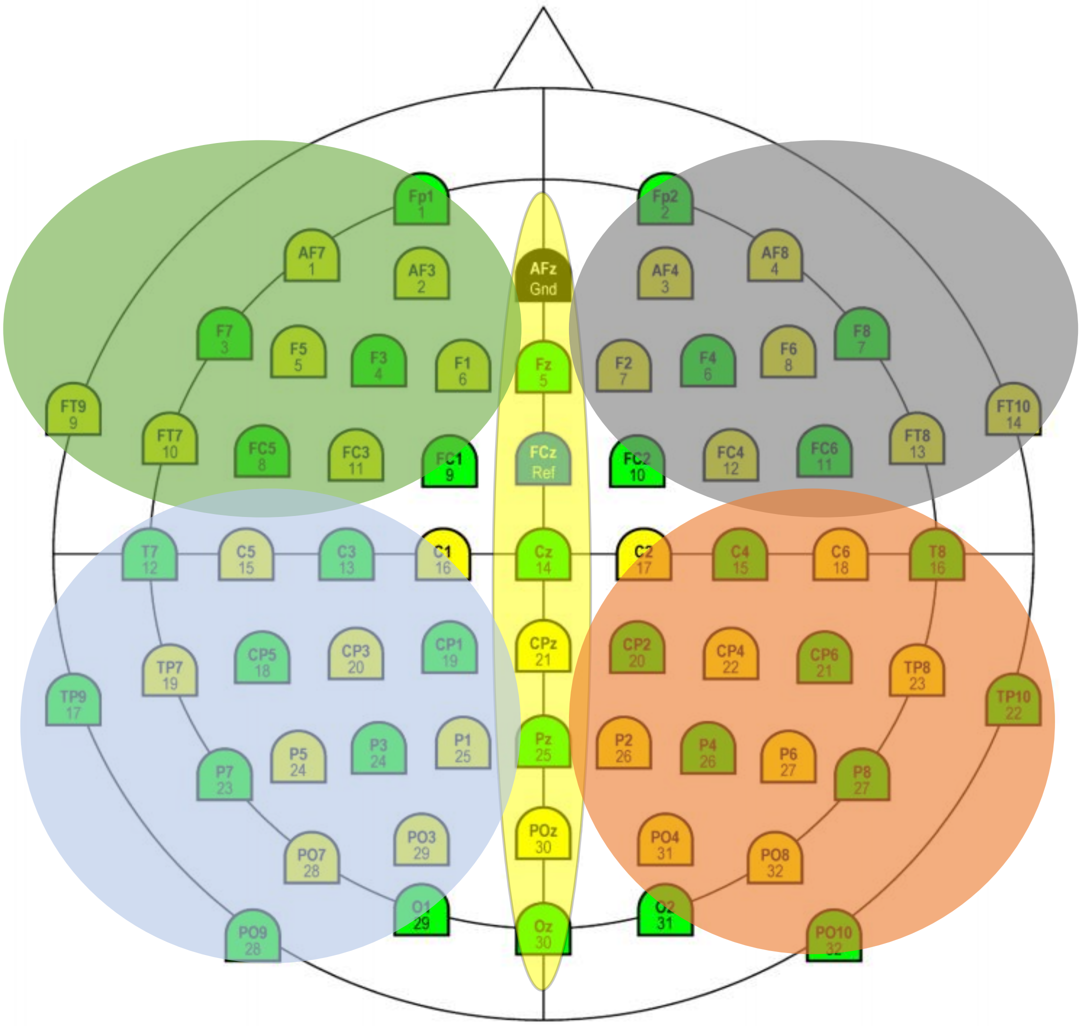


Figure 15. Electrode array. 64 active electrodes (62 scalp electrodes, 2 ocular electrodes) with regions of interest defined.

BrainVision Analyzer 2 Software was used to prepare the data prior to analysis. First, all channels were re-referenced offline to an average of the two mastoid electrodes (TP9 and

TP10) and the EEG signal was filtered between 0.05 – 30 Hz. Data containing blinks and horizontal eye movements was corrected using ocular correction with Independent Components Analysis (ICA) then the data was segmented separately around the final word onset and picture onset (-200 – 1000ms). Since analysis was only to be conducted on correct trials (i.e. correct picture judgements), all incorrect trials were removed at this point. A semi-automatic artifact rejection algorithm was then used to identify and discard trials with other artefacts such as drift and muscle activity. Finally, the remaining segments were aligned to a baseline period from -200ms to 0ms, and averaged for each of the four conditions (knows-match, knows-mismatch, thinks-match, thinks-mismatch) and fillers at picture onset, and for the two verb conditions (thinks vs. knows) critical word onset.

ERP Data Analysis

Grand averages combined the EEG signal at the critical word and picture onset for each participant and group. A pre-defined analysis interval of 300-450ms was used to examine mean ERP amplitudes in the N400 time-window. Upon visual inspection of the ERP grand averages, analyses for the image also examined the N1 (50 – 180ms) time window.

ERP amplitudes at midline electrodes (Fz, Cz, CPz, Pz, POz, Oz) were analysed separately from data recorded over lateral electrodes. ERP amplitudes across lateral electrodes were compared across both anterior-posterior electrode sites and across hemispheres, resulting in four regions of analysis using a repeated measures ANOVA (anterior-left: AF7, AF3, F7, F5, F3, F1, PT7, FC5, FC3, F1; anterior-right: AF4, AF8, F2, F4, F6, F8, FC2, FC4, FC6, FT8; posterior-left: TP7, CP5, CP3, CP1, P7, P5, P3, P1, PO7, PO3, O1; posterior-right: CP2, CP4, CP6, TP8, P2, P4, P6, P8, PO4, PO8, O2) (see Figure 20 for electrode array with regions of interest defined).

To analyse the ERP data time-locked to the critical word onset, two ANOVAs were performed. Mean amplitudes from the midline electrodes were analysed using a mixed ANOVA crossing electrode (Fz, Cz, CPz, Pz, POz, Oz), verb (thinks vs. knows) and group (ASD vs. TD). For the analysis of lateral ERP deflections at critical word onset, a second mixed ANOVA was run crossing anterior-posterior (anterior vs. posterior), hemisphere (left vs. right), verb (thinks vs. knows) and group (ASD vs. TD).

To analyse ERPs time-locked to the image onset over midline electrodes, a mixed ANOVA with variables electrode (Fz, Cz, CPz, Pz, POz, Oz), verb (knows vs. thinks), image (match vs. mismatch) and group (ASD vs. TD) was performed. Analysis of ERPs over lateral electrodes time-locked to image onset was conducted using a mixed ANOVA with variables anterior-posterior (anterior vs. posterior), hemisphere (left vs. right), verb (knows vs. thinks), image (match vs. mismatch) and group (ASD vs. TD).

Results

Accuracy on the comprehension questions averaged 76.7% for the ASD group and 75.4% for the TD controls.

Accuracy

Image response accuracy was analysed using a mixed 2 (Image: match vs. mismatch) x 2 (Verb: knows vs. thinks) x 2 (Group: ASD vs. TD) ANOVA. Mean response accuracies for the ASD and TD group are displayed in Figure 16. There was no main effect of group ($p = .2$). A main effect of image was observed [$F(1, 44) = 6.98$, $p < .05$, $\eta_p^2 = .14$], with participants more accurate at judging whether an object was mentioned in the preceding sentence when the physical state of the depicted object matched that described compared to when it mismatched. Image did not interact with group ($p = .15$), suggesting this facilitation effect was present in both the TD and ASD groups. There was also a main effect of verb [F(1,

44) = 6.46, $p < .05$, $\eta_p^2 = .13$], and again this did not interact with group ($p = .28$). That is, both ASD and TD participants were more accurate at judging the image when the preceding sentence was uncertain ('*thinks*') than when the sentence was certain ('*knows*'). The image by verb interaction was not significant ($p = .1$) and neither was the three-way interaction with group ($p = .43$).

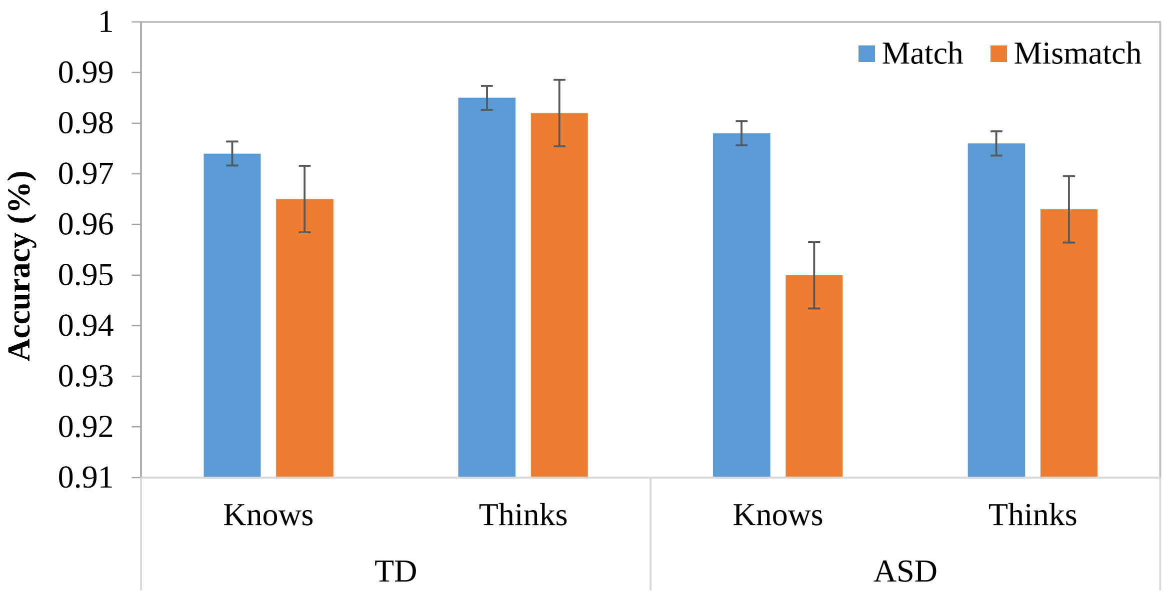


Figure 16. Mean accuracy (%) for TD and ASD groups, across all conditions. Errors bars show standard errors.

Reaction Time

Prior to analysis, incorrect responses were removed; this made up 2.93% of the data. To reduce the effects of outliers, participants' reaction times were transformed into z-scores and those corresponding to z-scores greater than 3.29 (i.e. $p < .001$) were removed. The trimmed means per condition are plotted in Figure 17.

Reaction times were then analysed using a 2 (Image: match vs. mismatch) x 2 (Verb: knows vs. thinks) x 2 (Group: ASD vs. TD) mixed ANOVA. There was no effect of group ($p = .12$). Analysis revealed a main effect of image [$F(1, 44) = 32.13$, $p < .001$, $\eta_p^2 = .42$], with participants faster to respond to the image when it matched the physical state described in the preceding sentence compared to when it mismatched (*M* = 934ms, *SD* = 47.04 vs. *M* = 1050ms, *SD* = 55.12 respectively). As with accuracy, image did not interact with group (*p* = .21), implying this facilitation effect was present in both the TD and ASD groups. However, there was no main effect of verb (*p* = .33), or interaction between verb and group (*p* = .42). Thus, both ASD and TD groups were just as fast to respond to the image when the preceding image was uncertain ('*thinks*') compared to certain ('*knows*'). There was also no reliable interaction between image and verb (*p* = .86), or a three-way interaction between image, verb and group (*p* = .15). That is, both the TD and ASD participants activated comparable simulations of the described event for both certain and uncertain events.

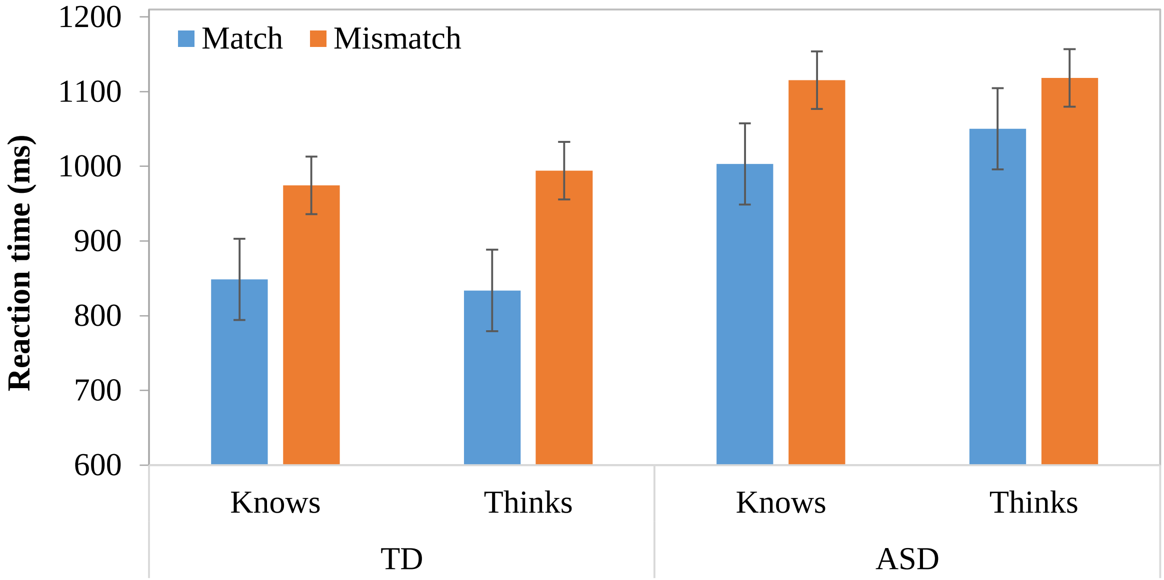


Figure 17. Mean reaction times for the TD ad ASD groups, across all conditions. Error bars show standard errors.

ERPs Evoked by Critical Word

The critical word was the last word of the sentence (e.g. '*open/closed*'), which described the physical state of the object. Recall that the physical state of the object could either be described as certain ('*knows*') or uncertain ('*thinks*'). Figure 18 shows the grand average

ERPs elicited by verb (*'knows'* vs. *'thinks'*) averaged over mismatch conditions (i.e. analyses were collapsed over matched and mismatched condition), time-locked to critical word onset, for both the ASD and TD groups.

The presentation of the critical word was associated with a negative deflection peaking around 400ms post-stimulus onset (N400). Effects over midline electrodes were examined using a mixed 6 (Electrode: Fz, Cz, CPz, Pz, POz, Oz) x 2 (Verb: knows vs. thinks) x 2 (Group: ASD vs. TD) ANOVA for a 150ms time window between 300 and 450ms after critical word onset. The main effect of group showed a trend for greater negativity in the TD group compared to the ASD group (p = .07) (TD = -1.18 Hz vs. ASD = 0.26 Hz). A main effect of electrode was observed [F(5, 220) = 4.65, $p < .001$, $\eta_p^2 = .1$], with maximal negativity across central-posterior midline electrodes (Fz = -0.47 Hz, Cz = -1.02 Hz, CPz = -1.25 Hz, Pz = -0.95 Hz, POz = -0.66 Hz, Oz = -0.58 Hz). This pattern reflects the typical N400 topography. There was no significant interaction between electrode and group ($p = .17$). There was also no main effect of verb ($p = .37$), but there was a marginal verb by group interaction [F(1, 44) = 3.65, $p = .063$, ηp2 = .08]. Follow up analyses revealed the main effect of verb was marginally significant in the ASD group [F(1, 22) = 3.38, $p = .079$, $\eta_p^2 = .13$] with greater difference between *'knows'* and *'thinks'* (*M* = -0.03 Hz vs. *M* = -0.62 Hz respectively). However there was no main effect of verb in the TD group (p = .45) (*'knows'* = -1.43 vs. *'thinks'* = -1.23). There was also no reliable interaction between electrode and verb ($p = .99$) nor electrode by verb by group ($p = .33$).

In order to assess the distribution of the N400 effect across lateral scalp electrodes, a second mixed 2 (Anterior-posterior: anterior vs. posterior) x 2 (Hemisphere: left vs. right) x 2 (Verb: knows vs. thinks) x 2 (Group: ASD vs. TD) ANOVA was conducted in the same 150ms time window. There was a main effect of group [F(1, 44) = 4.09, p < .05, $\eta_p^2 = .09$], with the TD group showing a significantly more negative deflection than the ASD group (*M*

= -0.76 Hz vs. *M* = 0.00 Hz respectively). The anterior-posterior main effect was not significant (p = .96) and this did not interact with group (p = .12). There was also no main effect of hemisphere (p = .88), however hemisphere did reliably interact with group [$F(1, 44) = 4.7$, $p < .05$, $\eta_p^2 = .1$]. Further analysis revealed that this interaction was driven by a partially significant right lateralised N400 compared to left in the TD group (*M* = -0.92 Hz vs. *M* = -0.59 Hz) [$F(1, 22) = 3.83$, $p = .06$, $\eta_p^2 = .15$] but no difference in the ASD group (p = .22). There was also no main effect of verb (p = .6) and this did not interact with group (p = .18). The anterior-posterior by hemisphere interaction was also not significant (p = .11), however anterior-posterior and hemisphere did interact with group [$F(1, 44) = 18.54$, $p < .001$, $\eta_p^2 = .3$]. Further analysis revealed that this was driven by a significant anterior-posterior by hemisphere interaction in the ASD group [$F(1, 22) = 19.95$, $p < .001$, $\eta_p^2 = .48$], but not in the TD group (p = .09). All other interactions were not significant (all p's > .11).

Visual examination of the ERP plots (Figure 18) suggests a group difference in a later time window (i.e. 600 – 700ms). However, since group differences have already been detected in the earlier 300 – 450ms time window it is not possible to examine these later effects since they are likely to be driven by the earlier effect.

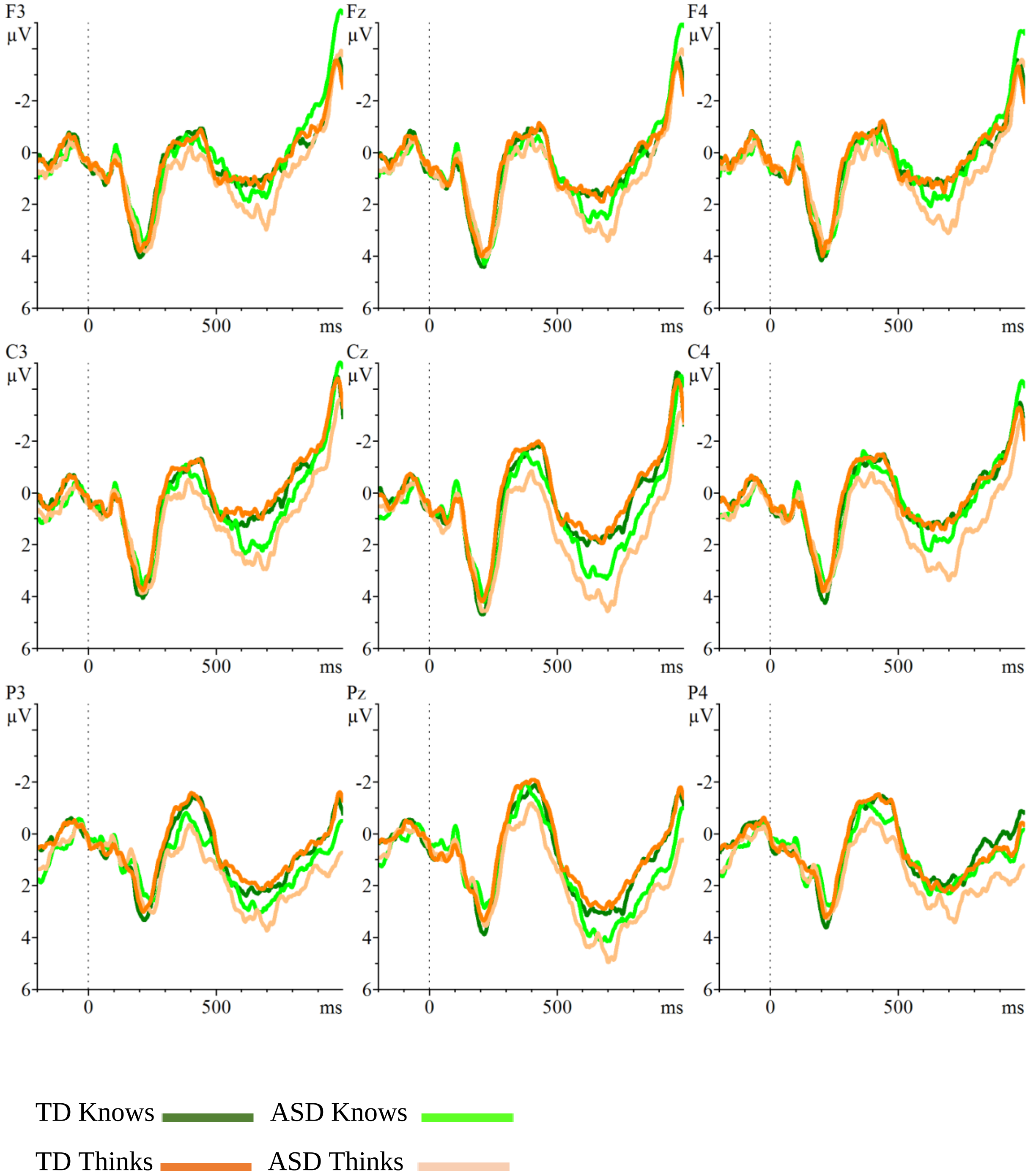


Figure 18. Grand average ERPs at critical word onset (i.e. the final word) for 'knows' and 'thinks' sentences, for TD and ASD groups, across selected central electrodes.

ERP Evoked by Picture

The target image was presented after the last word of the sentence and either matched or mismatched the physical state implied in the preceding sentence. Figure 19 shows the grand average ERPs elicited by the four conditions (knows-match, knows-mismatch, thinks-match, thinks-mismatch) and filler trials, time-locked to image onset, for the TD and ASD groups respectively. The presentation of the image was associated with deflections on the N1 and N400 ERP components.

N1 (50 – 180 msec). A mixed 6 (Electrode: Fz, Cz, CPz, Pz, POz, Oz) x 2 (Verb: knows vs. thinks) x (Image: match vs. mismatch) x 2 (Group: ASD vs. TD) ANOVA was conducted on midline electrodes for a 130ms time window between 50 and 180ms after image onset. There was no main effect of group (p = .22). In line with typical N1 topography, there was a main effect of electrode [$F(5, 225) = 38.08$, $p < .001$, $\eta_p^2 = .46$] with negativity maximal at central electrodes (Fz = -3.3 Hz, Cz = -3.49 Hz, CPz = -3.29 Hz, Pz = -2.37 Hz, POz = -0.9 Hz, Oz = 0.32 Hz). This significantly interacted with group [$F(5, 225) = 3.53$, $p < .01$, $\eta_p^2 = .07$], with both the TD and ASD group showing maximal negativity over central midline electrodes (TD group Fz = -2.25 Hz, Cz = -2.79 Hz, CPz = -2.81 Hz, Pz = -2.19 Hz, POz = -0.92 Hz, Oz = 0.1 Hz; ASD group Fz = -4.35 Hz, Cz = -4.19 Hz, CPz = -3.78 Hz, Pz = -2.55 Hz, POz = -0.87 Hz, Oz = 0.54 Hz). Post hoc analyses revealed a significantly larger N1 for the ASD group compared to the TD group over frontal electrode Fz [$t(22) = -2.51$, $p < .05$], with all other midline electrode comparisons non-significant at $p > .09$.

However, there was no main effect of verb (p = .43) or of image (p = .43) and neither interacted with group (p's = .59 and .41 respectively). Thus, contextual uncertainty (*'thinks'* vs. *'knows'*) and sentence-picture match/mismatch did not impact N1 processing of the image in either the TD or ASD group. Electrode did significantly interact with image [F(5, 225) = 3.66, $p < .01$, $\eta_p^2 = .08$], however all other interactions were not significant (all *p*'s > .31)

To examine any lateralised N1 effects a 2 (Anterior-posterior: anterior vs. posterior) x 2 (Hemisphere: left vs. right) x 2 (Verb: knows vs. thinks) x 2 (Image: match vs. mismatch) x 2 (Group: TD vs. ASD) mixed ANOVA was conducted in the same 130ms time window. There was no effect of group ($p = .19$). There was a main effect of anterior-posterior [F(1,45 = 37.29, $p < .001$, $\eta_p^2 = .45$], with greater negativity at posterior electrode sites compared to anterior sites (*M* = -2.93 Hz vs. *M* = -0.77 Hz respectively) and this interacted with group [F(1, 44) = 9.36, $p < .01$, $\eta_p^2 =.17$]. Further analysis revealed a main effect of anterior-posterior in both the TD and ASD groups [F(1,23) = 5.05, $p < .05$, $\eta_p^2 = .18$ vs. F(1,23) = 38.67, $p < .001$, $\eta_p^2 = .64$], with the N1 peaking over anterior electrodes in both groups. Moreover, the N1 was larger over anterior sites for the ASD group (*M* = -3.79 Hz) compared to the TD group (*M* = -2.16 Hz) [t(22) = -2.33, $p < .05$], but N1 amplitudes did not differ between the groups at posterior sites ($p = .42$).

No main effect of hemisphere was observed ($p = .21$), however this did interact with group [F(1, 45) = 9.97, $p < .01$, $\eta_p^2 = .18$]. Further analysis revealed an effect of hemisphere in the TD group [F(1, 23) = 13.16, $p < .01$, $\eta_p^2 = .36$] with the N1 deflection larger over the right hemisphere compared to left (*M* = -1.88 Hz vs. *M* = -1.19 Hz respectively), but no effect of hemisphere in the ASD group ($p = .25$).

As in the midline analysis, no effect of verb ($p = .54$) or image ($p = .3$) occurred and neither verb nor image reliably interacted with group (*p*'s = .45 and .28). Contextual uncertainty had no effect on the N1 elicited at picture onset for either TD or ASD participants and neither did the physical state of the depicted. None of the remaining interactions reached significance (all *p*'s > .15).

N400 (300 – 450 msec). A 6 (Electrode: Fz, Cz, CPz, Pz, POz, Oz) x 2 (Verb: knows vs. thinks) x 2 (Verb: knows vs. thinks) x 2 (Group: TD vs. ASD) mixed ANOVA was conducted on midline electrodes for a 150ms time window between 300 and 450ms after image onset. There was no main effect of group (p = .42). There was a main effect of electrode [F(5, 220) = 32.32, p < .001, ηp2 = .42] with negativity maximal at POz (Fz = -1.26 Hz, Cz = 0.4 Hz, CPz = 1.57 Hz, Pz = 3.45 Hz, POz = 4.91 Hz, Oz = 4.78 Hz). This significantly interacted with group [F(5, 220) = 5.96, p < .001, η_p^2 = .12]. There was no main effect of verb (p = .35) or image (p = .08) and neither interacted with group (p = .96).

However, there was a significant verb by match interaction [F(1, 44) 5.31, p <.05, η_p^2 = .11], but this did not further interact with group (p = .07). Post hoc analysis of the verb by match interaction revealed a significant more negative-going N400 amplitude for the mismatch versus match condition following *'knows'* [t(45) = -2.51, p < .05], but no match/mismatch difference following *'thinks'* (p = .82). The N400 amplitude was also significantly more negative-going for the knows-mismatch than the thinks-mismatch condition [t(45) = -2.69, p < .05], but knows-match and thinks-match conditions did not differ (p = .53). This suggests that both TD and ASD participants simulated the described events and were exhibiting notable interference from mismatched images in the certain *'knows'* condition, but were not sensitive to the mismatch following the uncertain verb. *'thinks'*. All other interactions were not significant (all p's > .15).

To determine any lateralised N400 effects, a 2 (Anterior-posterior: anterior vs. posterior) x 2 (Hemisphere: left vs. right) x 2 (Verb: knows vs. thinks) x 2 (Image: match vs. mismatch) x 2 (Group: ADD vs. TD) mixed ANOVA was conducted in the same 150ms time window. There was no effect of group (p = .69). There was a main effect of anterior-posterior [F(1,44 = 61.5, p < .001, η_p^2 = .58], with greater negativity at posterior electrode sites compared to anterior (M = -1.61 Hz vs. M = 3.47 Hz respectively). A main effect of hemisphere was also observed [F(1, 44) = 28.14, $p < .001$, $\eta_p^2 = .39$], with the N400 lateralised to the right hemisphere (right *M* = 0.39 vs. left *M* = 1.47). However, neither anterior-posterior nor hemisphere interacted with group (*p*'s = .2 and .06 respectively), suggesting no difference in the N400 topography between the TD and ASD groups.

Once again, no effect of verb (*p* = .65) or image (*p* = .35) occurred and neither verb nor image reliably interacted with group (*p*'s = .73 and .89). The hemisphere by verb by group interaction was significant [F(1, 44) = 4.40, $p < .05$, $\eta_p^2 = .09$], but further analysis revealed no significant hemisphere by verb interaction in either the ASD group (*p* = .22) or the TD group (*p* = .09). This suggests both TD and ASD participants are simulating the events using the same underlying neural mechanisms.

However, similar to the midline analysis, an interaction between verb and image was observed [F(1, 44) = 4.2, $p < .05$, $\eta_p^2 = .09$], which did not further interact with group (*p* = .08). Post hoc analysis of the verb by match interaction revealed that the mismatch difference was only significant following *'knows'* [t(45) = -2.03, $p < .05$], but not following *'thinks'* (*p* = .52). In addition, the N400 was significantly larger for the mismatch condition following 'knows' compared to *'thinks'* [t(45) = -2.15, $p < .05$], but did not differ between the two match conditions (*p* = .41). Once again, this suggests that both groups of participants simulated the described event following the certain verb *'knows'* and detected the mismatching image, but did not experience the same interference following the uncertain verb *'thinks'*. None of the remaining interactions were significant (all *p*'s > .12).

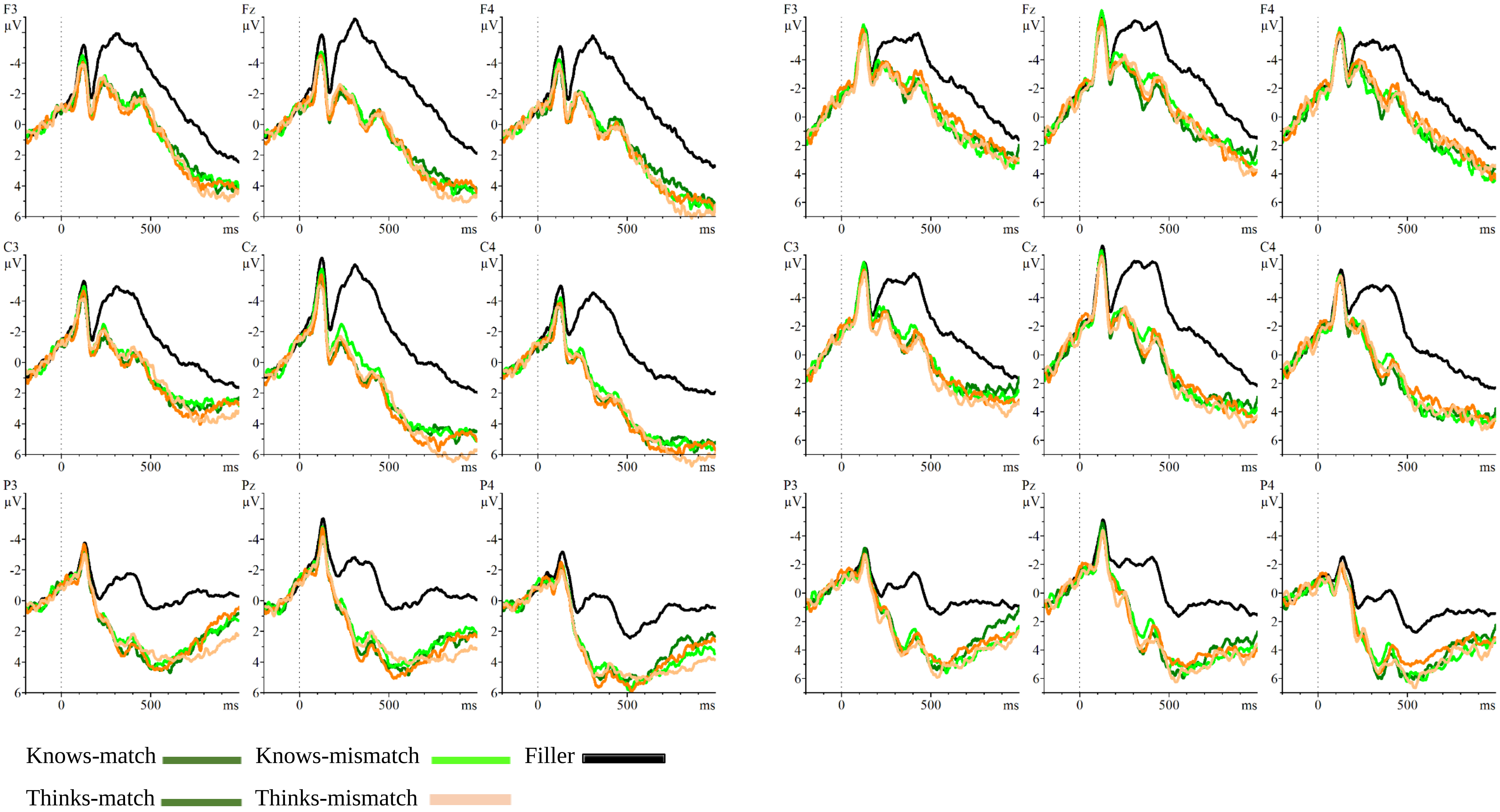


Figure 19. Grand average ERPs at picture onset for the four conditions: knows-match, knows-mismatch, thinks-match, thinks-mismatch, for the TD group (left) and ASD group (right).

Discussion

The aim of the current study was to investigate the neural mechanisms underlying spatial language simulation in TD and ASD adults using the sentence-picture verification task. The second aim was to explore these spatial language simulations and their neural underpinnings within a context of uncertainty. ERPs and behavioural measures were recorded as participants read sentences such as *"The old lady [knows/thinks] that the picnic basket is open"* and made a subsequent mentioned/not mentioned judgement for an image. The object depicted either matched or mismatched the physical state implied in the preceding sentence. In the following, effects on the behavioural measures and ERPs for sentence reading and picture verification are discussed.

Behavioural Findings

It was first hypothesised that the mismatch effect found in Chapter 2, Experiment 2, and observed countless times in the TD literature (e.g. Stanfield & Zwaan, 2001; Zwaan, et al, 2002; Zwaan, et al, 2004; Yaxley & Zwaan, 2007) would replicate in both groups. That is, it was expected that both TD and ASD participants would show a facilitation effect (i.e. shorter reaction times) when the pictured object matched the physical shape implied in the preceding sentence and an interference effect (i.e. longer reaction times) when the pictured object mismatched the physical shape implied in the preceding sentence. This hypothesis was supported in the current study. Both TD and ASD participants were quicker to make a mentioned judgement on the image when the physical state of the object matched that implied in the preceding sentence. Interestingly, despite the lack of group effect, visual inspection of the response time plots shows a trend for the ASD group to be marginally slower, suggesting the mismatch effect seen in the TD group may occur later in the ASD group. These findings can be taken as further evidence that individuals with ASD are able to simulate the spatial properties of language, but may do so later than TD individuals.

It was also hypothesised that contextual uncertainty would not affect reaction times for either group. This hypothesis was also supported; both TD and ASD participants were just as fast to respond to the image when the preceding sentence was certain (*'knows'*) compared to when it was uncertain (*'thinks'*). This not only replicates the findings of Ferguson et al (2013), but also extends them. Recall that Ferguson et al (2013) only observed an effect of uncertainty in the shorter ISI condition (250ms; knows < thinks), but not following the longer ISI (1500ms). The authors explained this in terms of differential processing steps for comprehending certain and uncertain sentences; with more time required to access multiple simulations when processing an uncertain event compared to a certain event. When participants in Ferguson et al's (2013) study were given sufficient time to access and map the appropriate simulations, any processing difficulty that had been observed at the shorter ISI was eradicated. In the current study, recall that the ISI was set to be 500ms and no effect of contextual uncertainty was observed. It should also be noted that in the current experiment the sentences were presented word-by-word, which probably gave participants even more time to begin activating an appropriate simulation of the event. This would suggest that within 500ms of reading a sentence, whether certain or uncertain, participants construct a simulation of the described event and can check these against the available image.

Importantly, neither the TD nor the ASD participants showed a reliable interaction between mismatch effect and contextual uncertainty. Thus, the TD and ASD participants activated simulations of the certain and uncertain events and are equally sensitive to mismatches between this mental simulation and a subsequent image. The fact that this effect occurred within 500ms of the sentence offset demonstrates that any difficulty in setting up mental representations of uncertain events can be overcome even earlier than the 1500ms shown in Ferguson et al (2013). However, an interesting observation is the current experiment is the subtle delay for ASD participants to respond. This mirrors the response time findings in the previous experiment, where ASD participants were slightly slower than TD participants, and could point towards very subtle processing differences between the groups. Examination of the ERP findings may will provide more insight into the processing strategies used by the TD and ASD groups.

ERP Findings

ERP findings centred on the N400 ERP component (300 – 450ms time window) at critical word onset (i.e. the final word of the sentence, e.g. '*open/closed*') and for picture onset separately.

Effects observed during sentence reading. It was hypothesised that there would be no difference in N400 at the critical word onset (i.e. the final word in the sentence, e.g. '*open/closed'*) for certain (*'knows'*) and uncertain (*'thinks'*) sentences for either groups. Recall, the N400 is an ERP that reflects unexpected semantic and pragmatic violations and is elicited by all stimuli; words and pictures (Nigam, Hoffman & Simons, 1992). The N400 effect has been observed numerous times in research on TD individuals (e.g. Kutas, & Hillyard, 1980; Hagoort, et al, 2004; Kutas & Federmeier, 2000). It was hypothesised that contextual uncertainty would not impact the N400 amplitude as enhancement of the ERP is associated with the wider discourse/sentence context (see Van Berkum, et al, 1999; Van Berkum, et al, 2003; West & Holcomb, 2002). Since both *'knows'* and *'thinks'* require the comprehender to relate the congruous final word (i.e. *open/closed*) to the preceding context, no difference in N400 amplitude was expected.

The current study supported this hypothesis, as no effect of contextual uncertainty on the ERP evoked at critical word onset was found for either TD or ASD participants (since there was no verb by group interaction). That is, the amplitude of the N400 did not differ for uncertain compared to certain sentences. These results would suggest that neither group had difficulty interpreting the event (i.e. whether the picnic basket was open or closed) relative to the certain event. There was however, a group effect which would suggest that although the ASD participants were simulating the spatial properties of certain and uncertain events in the same way as TD participants and therefore utilising the same underlying neural mechanisms, there was slight delay generally to do so in the ASD group. Furthermore, visual inspection of the ERP plots seem to suggest a group difference at a later time window (600 – 700ms). As explained above, since this later effect could have been driven by the earlier group difference (in the 300 – 450ms time window) it was not possible to examine it. However, this later effect mirrors that in the response time findings, and serves as further possible evidence that the timing of effects seen in the TD population might actually occur later in individuals with ASD.

Effects observed during picture verification. Visual inspection of the ERP wave following picture onset suggested that some condition effects may have already emerged on the N1 (50 – 180ms) component. While statistical analysis revealed no effect involving verb or image, effects involving group revealed subtle differences in the topography of the N1 between groups. The N1 is an ERP component that reflects stimulus discrimination. It is generally augmented at frontal electrode sites during attentional stimulus processing and is larger towards task-relevant target stimuli (Baruth, Casanova, Sears & Sokhadze, 2010). The subtle group difference found in the current study, where ASD participants showed greater negativity at anterior than posterior sites compared to the TD group, is interesting given other subtle group differences that have been observed in the behavioural and ERP data. That is, given the pattern of late effects that have emerged in the ASD group, the greater N1 amplitude for this group at picture onset may reflect subtle differences in processing strategies by the two groups.

Baruth, Casanova, Sears and Sokhadze (2010) found similar group differences in the visual N1 during a visual oddball task, in which participants were asked to identify a rare Kanizsa square among Kanizsa triangles and non-Kanizsa figures. The results revealed that ASD participants exhibited greater N1 negativity to target stimuli than the control group. The authors argued that this group difference reflects visual hypersensitivity and increased general arousal in individuals with ASD in comparison to TD individuals, which may disrupt or at least delay the processing of the target stimuli. This would suggest that in the current study, the subtle group differences of the N1 ERP reflects a delay in processing the picture, which consequently impacts stimulus processing in comparison to TD participants. This pattern would again suggest that although individuals with ASD, like TD individuals, are able to simulate the spatial properties of certain and uncertain events, there seems to be a subtle delay in doing so.

The following discussion on the ERPs associated with picture onset focuses on the N400 (300 – 450ms) time window. Based on behavioural evidence, it was hypothesised that there would be no difference in N400 amplitude for the TD and ASD groups for matched versus mismatched images. Based on behavioural findings by Ferguson et al (2013) and behavioural predictions of the current experiment, it was also predicted that there would be no difference in the N400 amplitude at picture onset following a certain (*'know'*) or uncertain (*'thinks'*) event for either group. However, as previous research suggests individuals with ASD have difficulty exploiting sentence context, differences in the N400 amplitude following 'think' between TD and ASD participants was also expected.

In the current study, there was no overall mismatched effect in either the TD or ASD group. That is, neither group showed an increased N400 for mismatched pictures compared to matched images. Recall, that the N400 is insensitive to object shape, further suggesting that both groups are simulating certain and uncertain events in the same way. However, there was a significant interaction between contextual uncertainty (whether the preceding sentence includes *'knows'* or *'thinks'*) and mismatch. In both groups, the N400 was only significantly different between the matched and mismatched images when the preceding sentence was certain. When the sentence included the certain verb *'knows'* both TD and ASD participants activated only one simulation of the described event. Both groups were then able to rapidly map the depicted object onto this single representation and thus detect the mismatch immediately; or at least within 500ms. Consequently, the mismatched image is incongruent with that implied in the preceding sentence and an increased N400 is observed.

However, when the sentence is uncertain (*'thinks'*) participants activate both the described and implied state of the object. Both the match and mismatch image can map onto each of the mental simulations, meaning that neither elicits a mismatch detection response. This is supported by the significantly smaller N400 following *'thinks'* compared to *'knows'* for the mismatched image. As the mismatched image is not incongruent with either simulation in the *'thinks'* condition no N400 effect is observed. This would suggest that TD and ASD participants are utilising the same neural mechanisms to simulate spatial properties of language, even within the context of uncertainty. Both groups are rapidly constructing relevant simulations of certain and uncertain events, albeit individuals with ASD may be somewhat delayed in doing so.

The behavioural findings would suggest then that both TD and ASD participants are unaffected by contextual uncertainty when given sufficient time to construct and map the appropriate simulations. This is particularly interesting when compared with previous research that has found individuals with ASD are impaired at processing language in context (Háppe, 1997), including difficulty processing non-literal sentences (Martin & McDonald, 2004). Given that it has already been established in the previous chapter that individuals with ASD simulate language at the same rate as TD individuals, it could be argued that in the current experiment both groups were not processing uncertain sentences in context, but rather in isolation. That is, they were processing sentences such as *"The student thinks that the book is open"* without the contextual uncertainty and therefore only simulating the open book as an isolated event.

However, the ERP findings would discredit this interpretation and as discussed above show that both TD and ASD participants treat mismatches of certain and uncertain events differently. If the groups were employing the same isolated processing strategy for both certain and uncertain events, there would be no difference the N400 for the two verb types. Comprehending an uncertain event requires individuals to construct and map multiple appropriate simulations, or at least one additional simulation; the objects implied alternative state (Ferguson, et al, 2013). So when processing *"The student thinks that the book is open"* the comprehender must activate a simulation of the described event (an open book), but also the alternative implied state (a closed book). This means that when participants are presented with an uncertain sentence, a mismatched image is not an unexpected violation as the participant has an active simulation that includes that mismatched image.

Chapter Summary

The experiment reported in this chapter provides further behavioural evidence that individuals with ASD simulate language in a similar way to TD participants. Moreover, the current results show that these mental simulations extend to both certain and uncertain events, which are activated within the same time course as TD participants. Here we recorded ERPs to elucidate the neural mechanism that underlie these mental simulations, and to examine the implicit responses that are activated by language users with and without ASD. In contrast to previous research that suggests that ASD individuals are unable to exploit the sentence context. ERP findings from the current study suggests that individuals with ASD do make use of the same underlying neural mechanisms as TD adults to simulate the spatial properties of language, but generally require more processing steps. Notably, both groups of participants activated different responses for comprehending certain and uncertain events.

Now having established in the last two chapters that individuals with ASD are able to simulate written language, next I turn to investigate simulations of spoken language. Of interest is whether non-linguistic cues about the context of language are represented in mental simulations of described events by individuals with and without ASD.

Chapter 4

In the previous Chapters I have demonstrated that individuals with ASD are able to simulate the spatial properties of language in a comparable way, and within the same time-course, as TD adults. Similarly, using ERP methods I found that people with ASD presented no apparent deficit in processing contextual uncertainty; they are able to activate simulations of both certain and uncertain events (e.g. *"The student thinks that the book is open"* vs. *"The student knows that the book is open")*. Thus, the experiments presented so far have employed psycholinguistic paradigms that elicited mental simulations of written information. In the current chapter I turn to investigate simulations of spoken language to examine how ASD and TD comprehenders represent the speaker's emotions and intentions, expressed through the speaker's tone of voice.

This Chapter introduction will be set out as follows; I will first define prosodic elements of language and how they are simulated in the TD population, before going on to present the prosodic and pragmatic processing deficits prevalent in ASD. Next, I will present the current study's methodology and justify the use of EEG and specifically event-related power change as a means of measuring the covert processes activated during spoken language comprehension. Finally, EEG power in the ASD population will be considered, before the paradigm and hypotheses of the current study are introduced.

The prosodic components of reading and spoken language

Prosody can be considered the organisational structure of language (Beckman, 1996). The prosodic form used by the speaker is dependent upon the utterances syntactic structure, semantic relations, phonological rhythm and pragmatic considerations (Wagner & Watson, 2010). It is a component in the overall formedness of a sentence that provides information about the structure and pragmatic function of an utterance as well as the source of the utterance (e.g. the speaker and their intentions and emotions) (Yao & Scheepers, 2015).

Auditory imagery experiences (AIEs) (or auditory perceptual simulations (APSs), which occur when readers simulate characters' voices while reading, are considered evidence of the simulation of sound and speech. During reading, individuals re-experience characters' voices they have previously heard by reactivating memories of the characteristics (such as the speech rate, gender, prosody, timbre and pitch) of the voice. Interestingly, readers transfer such perceptual features to unfamiliar situations, given sufficient prior exposure (Kurby, Magliano & Rapp, 2009), and mentally simulate the implied properties of an auditory characteristics of a sentence. For example, readers are faster to correctly categorise sounds as real (vs. fake, computer generated) when the sound had been implied in a preceding sentence (e.g. *"The engine clattered as the truck driver warmed up his rig"*), demonstrating the spontaneous activation of perceptual properties (Brunyé, Ditman, Mahoney, Walters & Taylor, 2010). Similarly, auditory perceptual simulations enrich mental simulations with an elaborated prosodic representation during silent reading of speech (Zhou & Christianson, 2015). This is evident in faster reading speed when the implied speaker is a native-English speaker compared to when the implied speaker is a non-native English speaker (Zhou & Christianson, 2015).

When reading or listening to speech (i.e. speech quotations), prosody is a key feature that differentiates direct speech (*Mary said, "This dress is absolutely beautiful?"*) and indirect speech (*Mary said that the dress was absolutely beautiful*) (Yao & Scheepers, 2015). The pragmatic function of direct speech is to provide a demonstration that depicts the reported speech event, while indirect speech merely serves as a description of what has been said (Clark & Gerrig, 1990). For this reason, direct and indirect speech are thought to be differentially represented in language comprehension. Recall that language comprehension is facilitated through the construction of mental simulations that activate the perceptual, motor and affective content of the described event (Barsalou, 2008; Zwaan, 2009). Consequently, individuals are more likely to incorporate the reported speaker's voice into a perceptual simulation of the event when reading direct speech as opposed to meaning-equivalent indirect speech (Yao, Belin & Scheepers, 2011).

Furthermore, simulations of the reported speaker's voice when reading direct speech are modulated by the properties of the voice. Oral and silent readers modulate their reading rate in relation to the contextually implied speech rate of direct speech quotations as opposed to meaning-equivalent indirect speech quotations (Yao & Scheepers, 2011). While reading short stories, Yao and Scheepers (2011) found that direct speech was read significantly faster when the context implied a fast speaking protagonist compared to a slow speaking protagonist (see table 7 for an example of the stories used). More interesting was the finding that reading rate was not modulated by the preceding context for indirect speech. These findings demonstrate that readers engage in spontaneous vocal re-enactment of the reported speech act when reading direct but not indirect speech by adjusting their reading rate to the contextually implied speech rate. This implies that a highly enriched simulation of the reported speech is constructed during reading of direct speech. So it is the distinction in vividness of direct and indirect speech that underlies language comprehension of the two reporting styles in written text.

Table 7. *Example stimuli from Yao and Scheepers (2011); the stories contained either a direct or indirect speech quotation from a fictitious protagonist in the story, preceded by a context that either described a fast-speaking (1) or slow-speaking (2) protagonist*

Background	Direct speech	Indirect speech
1) Fast-speaking context:		
It was a typical British day, rainy and gloomy. Sixteen year-old pianist Bobby was going to play in the quarter-finals of a local talent competition. He was extremely nervous before his performance.	His mother encouraged him but he was all shaking and said: "No! I can't do it! **This is the end of the journey because it is unlikely that I will make it this time**."	His mother encouraged him but he was all shaking and said that he couldn't do it and that **it was the end of the journey because it was unlikely that he would make it this time**. His mother tried to calm him down, saying that it's not the winning that counts, but the taking part.
2) Slow-speaking:		
It was a typical British day, rainy and gloomy. At Glasgow Royal Infirmary, an old man was dying, and too weak to sit up. His family members were sitting around the bed, feeling sad. He wanted to say something, so his daughter placed a cushion under his head.	Slowly, he looked around and said: "I'm grateful you're all here. **This is the end of the journey because it is unlikely that I will make it this time**."	Slowly, he looked around and said that he was grateful for their coming and that **it was the end of the journey because it was unlikely that he would make it this time**. Then he closed his eyes and everyone burst into tears.

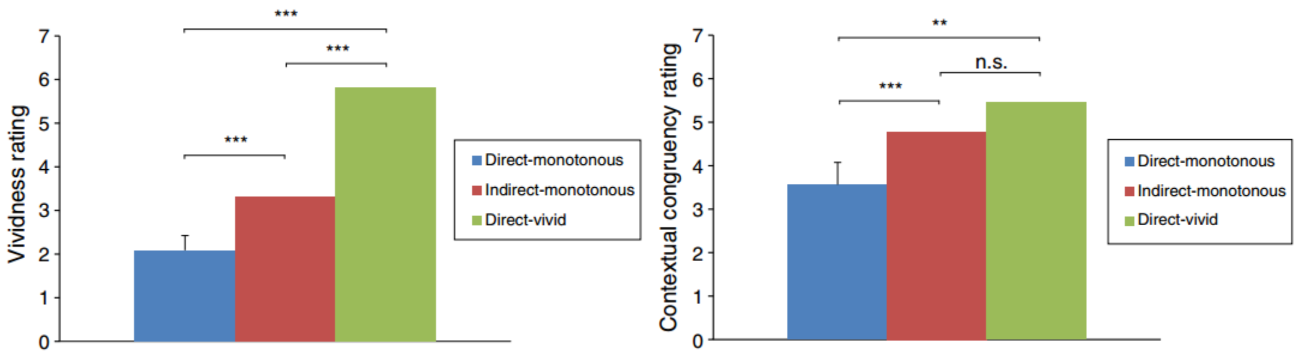
The mental simulation of the speaker's voice during silent reading of direct speech, compared to indirect speech, induces top-down activation of the auditory cortex. During silent reading, direct speech has been found to elicit a higher BOLD signal in voice-selective areas of the right auditory cortex, compared to indirect speech, alongside greater activation in brain regions associated with the enrichment of a multisensory perceptual simulation of the direct speech (Yao, Belin & Scheepers, 2011). Multiple brain structures distributed across both the left and right hemisphere are believed to be activated during recognition of emotional prosody (Adolphs, 2002). Voice sensitive temporal cortices have been found to react stronger to angry compared to neutral prosody, irrespective of the task (Ethofer, Kreifelts, Wiethoff, Wolf, Grodd, Vuilleumier & Wildgruber, 2009). Likewise, part of the auditory cortex is activated by processing of the speaker's voice, but not by verbal content (Von Kriegstein, Eger, Kleinschmidt & Giraud, 2003). This activation of voice-selective areas of the auditory cortex during silent reading of direct speech is evidence of an "inner voice" as readers engage in vivid perceptual simulation of the speaker's voice during silent reading of direct speech compared to reading meaning-equivalent indirect speech stories.

The nature of the "inner voice" experience and what constitutes simulations of the quoted speaker's voice are speculated to be the supra-segmental acoustic information. That is, speaker-unspecific aspects of the voice including emotional prosody, speech melodies and intonations (Yao, Belin & Scheepers, 2011). This was further explored by Yao, Belin and Scheepers (2012) who recorded short stories in which direct and indirect speech were spoken in a monotonous tone, such that supra-segmental acoustic information was minimalised, while sub-segmental information (such as phonological information) was intact. They found that listening to monotonous-direct speech elicited higher brain activity in temporal voice areas of the right auditory cortex compared to monotonous-indirect speech and vivid-direct speech.

Additional participants were recruited to rate the vividness and contextual congruency of the speech (see Figure 20 for vividness and contextual congruency ratings found by Yao, Belin & Scheepers, 2012). Yao, Belin and Scheepers (2012) presented participants with the same direct and indirect speech quotations, without the context and asked them to indicate how vivid and engaging the utterance they had just heard was. Participants responded on a 7-point scale by pressing number keys on the keyboard, where 1 meant "extremely monotonous" and 7 meant "very vivid and engaging". Another group of participants were recruited to rate the contextual congruency of the direct and indirect speech. Here, participants were presented with the whole story (i.e. context and direct and indirect speech quotations) and had to indicate the contextual congruency on a 7-point scale. That is, participants rate whether the speech utterances matched the context in terms of how vivid and engaging they were, where 1 meant "does not fit in the context at all" and 7 meant "fits in the context extremely well".

In terms of vividness it was found that the control condition of direct speech spoken in a vivid tone (direct-vivid) was perceived as more vivid than both direct speech spoken in a monotonous tone (direct-monotonous) and indirect-monotonous speech. Moreover, the direct-monotonous speech was rated as significantly less vivid than the indirect-monotonous speech, while direct-vivid and indirect-monotonous speech were rated as equally congruent with the preceding linguistic context. Direct-monotonous speech was considered significantly less congruent with the context that both direct-vivid and indirect-monotonous speech. This would suggest that listeners expect vivid vocal descriptions for direct speech but not for indirect speech. Consequently, listeners must supplement the monotonously spoken direct speech (contextually incongruent), by simulating vivid depictions of the reported speaker's voice. However, this is not necessary for indirect speech sentences or the direct-vivid speech sentences (contextually congruent).

Figure 20. Illustration of the between-condition differences in vividness and contextual congruency, taken from Yao, Belin and Scheepers (2012).



Taken together, this suggests listeners engage in top-down simulations of enriched supra-segmental acoustic representations while processing monotonous-direct speech. As direct speech is simulated in terms of enriched supra-segmental acoustic information of the speaker's voice, individuals have to mentally simulate this information when the direct quotation is spoken monotonously as the information is not available. In contrast, as indirect speech is merely a description of what has been said it is not represented in a vivid simulation of the voice. Thus, there is no need to simulate the supra-segmental acoustic information of indirect speech spoken in a monotonous tone. Having discussed the nature of prosodic simulations in the TD population, we now discuss the nature of pragmatic and prosodic deficits in ASD.

Prosodic and pragmatic deficits in ASD

Recall that prosody provides information about the structure and pragmatic function of a sentence, but it is at this pragmatic level that individuals with ASD show the most marked and universal impairments in language. Prosody is often atypical in individuals with ASD, even in those with no marked structural language impairments (Tager-Flusberg, Paul & Lord, 2005). Deficits in the ability to perceive and use prosody, intonation, rhythm, tone of voice and stress are well documented in the ASD population, although there some conflicting results.

Research suggests that prosodic comprehension deficits in ASD extend beyond its use as a pragmatic cue. Children with ASD have shown atypical processing of acoustic correlates, evident in deficits in pitch tracking compared to age-matched TD children (Russo, et al, 2008). Moreover, individuals with ASD have been found to show impaired perception and production of stress, intonation and phrasing when speaking (Paul, Augustyn, Klin & Volkmar, 2005). However, Chevallier, Noveck, Happé and Wilson (2009) argue for the importance of checking for disorder at this level (i.e. inabilities in perceiving differences in pitch, intensity and duration), before assessing perception of grammatical prosody.

Research that has explored the use of prosodic stress for lexical identification suggests that grammatical prosody is intact in ASD. During a lexical stress task, individuals with Asperger Syndrome and TD participants were asked to select the appropriate pronunciation of a sentence based on the stress pattern assigned to a noun or verb (e.g. *"He got the best PREsent he could dream of."* vs. *"I preSENT the late night news."*). The same sentence was presented twice – once with the correct stress placement and once with an incorrect stress placement – and participants indicated which was pronounced best (Chevallier, Noveck, Happé & Wilson, 2009). Interestingly, the AS group performed comparable to the TD group, indicating individuals with AS are able to use intonation to detect grammatical categories in the same way as TD individuals. Likewise, Grossman et al (2010) found individuals with ASD could use lexical stress to disambiguate the meaning of same word pairs (e.g. *PICKup* – a type of truck vs. *pick UP* – taking an item off the floor).

Chevallier and colleagues (2009) also found evidence that individuals with AS are as able as TD individuals at taking prosody into account when chunking word sequences, implying an appreciation of grammatical rhythm. Participants heard groups of compound word (e.g. *dragonfly* and *carrot*), split-compound (e.g. *dragon*, *fly* and *carrot*) and control (e.g. *fly*, *apple* and *carrot*) words, followed by pictures that matched (i.e. *dragon* and *carrot*, followed by pictures of a dragonfly and a carrot) or mismatched (i.e. *dragon* and *carrot*, followed by pictures of an elephant and a carrot) the preceding words. In a third, ambiguous mismatch condition, participants heard split-compound words and saw the pictures corresponding to the compound words (i.e. *dragon*, *fly* and *carrot*, followed by pictures of a dragonfly and a carrot) (or vice versa). Similarly, Grossman, et al (2010) found adolescents with HFA could produce appropriate differentiated lexical stress patterns. Participants heard short narratives to elicit two possible meanings of ambiguous word pairs (e.g. *"Kate calls Tom on his cell phone. When Tom doesn't answer, Kate wishes he would (pick up)*"), paired with an image of Tom picking up the phone. Participants' task was to listen to the discourses and to say the missing words, which was always in the sentence-final position and illustrated and written in the image in front of them. Interestingly however, while participants with HFA were able to appropriately disambiguate word pairs through differentiated production stress patterns, these productions were significantly different to those of TD participants. HFA participants produced atypically long lexical stresses, which would suggest an impairment in natural prosody production.

Although, Chevallier, et al (2009) assessed participants' ability to distinguish questions from declaratives based on prosodic and syntactic cues. Participants were presented with sentences where either, intonation and word order indicated the utterance as a question (e.g. *"Is this a dog?"*) or declarative sentences whereby the intonation was the only clue that the utterance was a question (e.g. *"This is a dog?"*). Participants' task was to judge whether the speaker sounded 'sure' or 'unsure'. Results revealed that individuals with AS are able to use intonation to detect question contour in the same way as TD individuals. Taken together, this series of experiments would suggest that grammar is generally spared in ASD and such individuals are able to process grammatical prosody.

It may be that age and developmental level play a role in differences in prosodic ability in ASD. Diehl, Friedberg, Paul and Snedeker (2015) used an eye-gazing paradigm to investigate whether children and adolescents with ASD can use prosodic cues to disambiguate the syntactical structure of a sentence. Participants heard instructions that were syntactically ambiguous which were resolved by placement of appropriate prosodic boundaries (e.g. *"You can feel the frog…with the feather"* indicating a reading vs. *"You can feel…the frog with the feather"* indicating an instrument reading). The relevant props, which included a target instrument, a target animal, a distractor instrument and a distractor animal, were laid out and participants were asked to complete the spoken command. Interestingly, ASD participants were as sensitive as TD participants to the prosodic cue presented and were able to use this to interpret syntactic ambiguity. Moreover, the ASD participants were able to utilise prosodic cues as rapidly as TD participants, suggesting both groups used similar comprehension mechanisms.

A block design was employed, such that only instrument prosody trials were presented in Block 1 and modifier prosody trials in Block 2 (or vice versa). Block analysis revealed developmental changes in both ASD and TD participants, with children initially misinterpreting ambiguous sentences in Block 2 due to interference from critical sentences in Block 1. In contrast, adolescents in both the ASD and TD group showed no interference effect; using the prosodic cue to quickly shift their interpretation of the utterances. Interestingly, it was also found that whilst children did eventually overcome this interference in Block 2, children with ASD were less able to do so (Diehl, Friedberg, Paul, & Snedeker, 2015). This would suggest that individuals with ASD do have strong expectations about syntactical structure based on prosodic information, but have difficulty overriding these expectations when prosody changes.

Mixed findings have also been reported on whether individuals with ASD are able to use prosody to interpret the affective content of utterances. Grossman, Bemis, Skwerer and Tager-Flusberg (2010) examined perception of affective prosody in children and adolescents with high functioning autism (HFA) and found such individuals performed comparably to TD individuals. That is, HFA individuals were able to determine affect in sad, happy and neutral spoken sentences. However, other research has observed deficits in processing affective prosody in ASD. Such individuals have shown impairments in matching mental state terms to spoken phrases, as well as an inability to attribute emotions of mental states to sentences spoken in emotional voices (Rutherford, Baron-Cohen & Wheelwright, 2002). Here, participants heard acoustic segments of dramatic performances and were asked to select between two adjectives, which best described the speaker's mental attitude or emotion (e.g. adjectives irritated and surprised for the spoken phrase *"Keep the damn thing!"*). This would imply a deficit in the use and perception of prosody to make social inferences.

Nevertheless, children with ASD have been found to display no impairment on assessments of familiar voice-face and sound-object matches, familiar voice recognition and unfamiliar voice recognition compared to those with Specific Language Impairments (SLI), and are superior to children with SLI on vocal affective naming and vocal-facial affect matching tasks. Nonetheless, ASD children do show impairment on affect matching relative to TD children (Boucher, Lewis & Collis, 2000), highlighting a deficit in processing emotional information when listening to speech.

Other high-level pragmatic impairments include an inability to interpret the communicative intent of others, such as with irony. High functioning ASD children listened to short stories and judged whether the speaker was sincere or ironic. Critically, the level of information available to guide this decision was varied such that scenarios included: knowledge of the event outcome and strong prosodic cues (sincere or sarcastic intonation), prosodic cues only, or knowledge of the event outcome only. Results showed that although ASD children performed above chance, they were less likely to take advantage of the available contextual information and were less accurate than TD children at interpreting the communicative intent behind ironic remarks (Wang, et al, 2006). Interestingly, other studies have shown that individuals with ASD performed as well as TD participants on comprehension accuracy of ironic and non-ironic written statements, and eye-tracking data have shown that both groups are able to use contextual information to infer non-literal interpretations of ironic statements. Moreover, processing ironic statements is more effortful non-ironic statements for those with and without ASD (Au-Yeung, Kaakinen, Liversedge & Benson, 2015).

Though, an important observation in the eye-tracking data is that although both groups spent longer reading the iron compared to non-ironic statements, the ASD participants spent more time overall rereading passages. The authors argue that this either reflects extra time taken to construct a discourse simulation of the linguistic event, or individuals with ASD take longer to make the decision that their representation of the text is reasonable, given their world knowledge (Au-Yeung, et al, 2015).

In summary, individuals with ASD show marked impairments at the pragmatic level of language, notably in their use and perception of prosody. Such individuals demonstrate a significant inability to attribute mental states and emotions to speakers during listening tasks, which in the current study, may impact their ability to differentiate between monotonous and vivid spoken direct speech. To date, no one has tested speech simulation of reading in ASD so as yet it is unknown whether such individuals would show the same voice selective brain activation that has been reported in the TD population. It is also unknown whether individuals with ASD would show the distinction in activation between processing direct speech and indirect speech quotations.

EEG event-related power

In the current experiment, I will use EEG to supplement behavioural measures and investigate the online simulation of spoken language in individuals with and without ASD. In the previous Chapter, an EEG event-related potential (ERP) approach was effective in demonstrating covert processes that occur during language comprehension that are not marked in behavioural results. However, this ERP approach does not allow for the extraction of non-phase-locked responses from the raw EEG signal (Luck & Kappenham, 2013). Thus, whilst ERPs can provide rich information about the time course of subcomponents of language comprehension, ERPs can only be extracted from the EEG data by averaging over individual time-locked events. This process removes any temporal structure of the signal not phased locked to the experimental event. Consequently, non-phase-locked oscillatory phenomena are significantly reduced or cancelled out when the average ERPs are extracted (Luck & Kappenham, 2013). Since interest in the current study is focused on what processes occur over a period of time as participants are listening to direct or indirect speech, an ERP approach is not appropriate and instead the EEG power change approach will be employed.

Oscillatory activity is the rhythmic, repetitive firing of neurons across time. EEG power reflects this synchronised neuron discharge and consequently, the capacity of cortical information processing (Klimesch, 1999). Individual cortical and sub-cortical areas are recruited dynamically in more than one functional network (Mesulam, 1998) and the synchronisation and desynchronization of neuronal activity reflects the coupling and uncoupling of these functional networks in the brain (Singer, 1999). It is this synchronous, repetitive firing of neurons at a given frequency that facilitate activation of a functional network, and the frequency specificity allows neurons or neuron pools to be recruited for different networks at different times (Bastiaansen, Mazaheri & Jensen, 2012).

Oscillatory neuronal synchrony in a wide range of frequencies is important for linking neuron pools that are part of the same functional network, therefore oscillatory activity dominates raw EEG recording. Consequently, event-related, non-phase-locked oscillatory EEG responses provide a window onto the functional network dynamics of the brain (Bastiaansen, Mazaheri & Jensen, 2012). Oscillatory activity changes according to the task being performed, with these changes classified into frequency bands that make up the EEG power spectrum (Ahirwal & Londhe, 2012). The EEG power spectrum is made up of five frequency bands; Delta (< 4Hz), Theta (4 – 7Hz), Alpha (8-14Hz, Mu 8 – 12Hz), Beta (14 – 30Hz) and Gamma (> 31Hz), each associated with specific cognitive functions (see Figure 21 for illustration of the EEG power spectrum). Generally, delta has been observed during sleep and during some continuous-attention tasks, while theta is associated with drowsiness and associated with the inhibition of elicited responses. Alpha occurs when an individual is in a relaxed state, generally when the eyes are closed, while Mu waves are more specifically associated with the motor neurons in the sensorimotor cortex at resting state. Beta waves occur during periods of alertness, such as during active thinking and focused attention. Finally, Gamma waves are present during cross-modal sensory processing and are displayed over the somatosensory cortex.

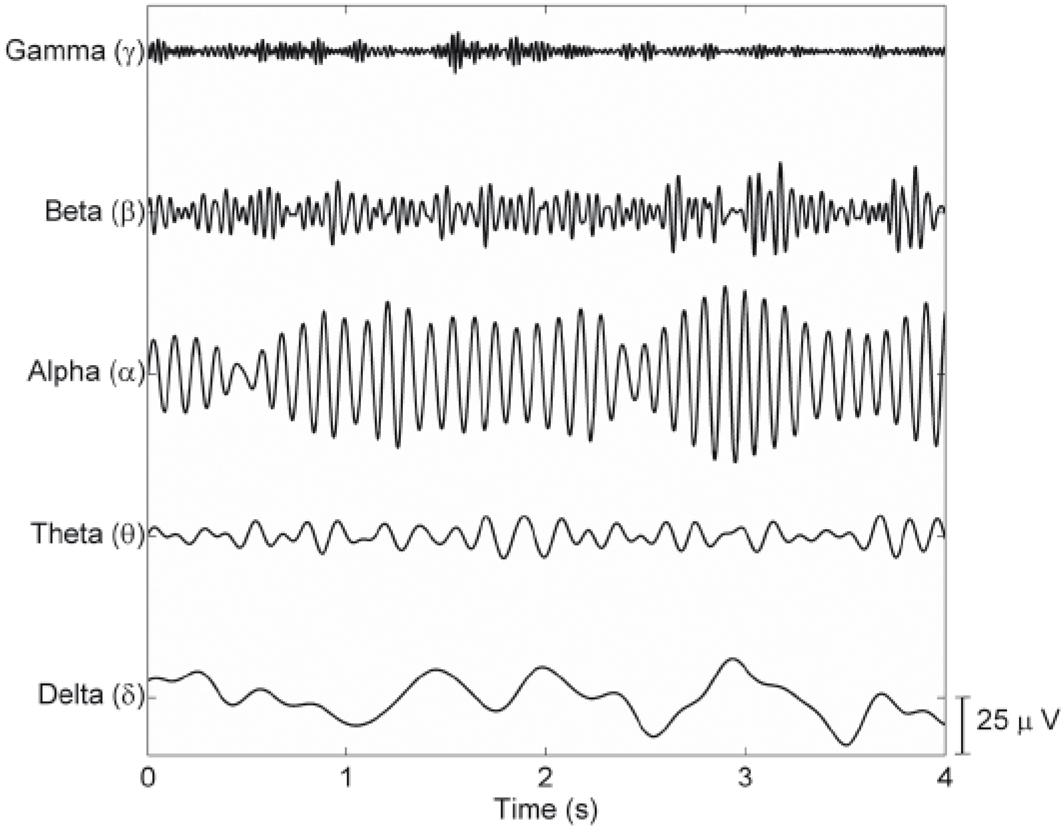


Figure 21. The EEG power spectrum.

Investigation of local oscillatory synchrony (i.e. synchrony within a functional network) within the brain's language network and the changes in oscillatory synchrony within the network requires the analysis of power changes within the network (Bastiaansen & Hagoort, 2006). Measures like EEG and MEG allow for understanding of the oscillatory neural dynamics of these language networks continuously on a millisecond time scale, making it a suitable method for observing the power changes that occur during spoken language comprehension over a period of time.

EEG power in the language processing network

In their review of literature on the oscillatory changes present in EEG and MEG signals during language comprehension tasks, Batinaansen and Hagoort (2006) conclude a distinction in language network dynamics between memory-related processes in the theta and alpha frequency bands, and information unification-related processes in the beta and gamma bands. Oscillatory power changes in the theta and alpha bands are thought to reflect cognitive and memory performance, with the two responding in different and opposite ways. As task demands increase, theta is found to synchronize (increase in theta power), while alpha desynchronizes (suppression of alpha power) (Klimesch, 1999). For example, during a sentence processing task, phasic power was found to increase in theta but decrease in alpha following the presentation of words in a sentence (Bastiaansen, van Berkum & Hagoort, 2002), reflecting aspects of either lexical or sentential context word processing.

Importantly, Bastiaansen, van Berkum and Hagoort (2006) also reported a slow increase in theta power as the sentence unfolds, possibly reflecting the formation of a memory trace as the individual words in the sentence converge into an overall understanding of the event described by the utterance. Theta power is also sensitive to syntactic violations (Bastiaansen, van Berkum & Hagoort, 2002b). When participants read sentences that were either correct, or contained a gender or number violation, words that constituted a violation elicited larger theta power increases than non-violation. Such differences were restricted only to oscillatory activity in the theta power band. This suggests that oscillatory dynamics in the theta frequency band during language comprehension are involved in the retrieval of lexical semantic information (Batinaansen & Hagoort, 2006).

Theta increases are observed over left temporal areas during the processing of open class (OC; such as nouns, verbs and adjectives) versus closed class words (CC; such as determiners, conjunctions and prepositions) (Bastiaansen, van der Linden, ter Keurs, Dijkstra

& Hagoort, 2005), and during lexical decision tasks that involve visual (i.e. referring to colours and shapes) and auditory nouns (i.e. referring to sounds) (Bastiaansen, Oostenveld, Jensen & Hagoort, 2008). This may reflect the activation of networks involved in retrieval of lexical-semantic properties of language. The double dissociation in topography of the theta response is produced exclusively by the semantic properties of the stimuli, thus supporting the argument that oscillatory dynamics in the theta band are related to the retrieval of lexical-semantic information.

However, some argue that increases in power may also reflect demands on working memory. The slow increase in theta power reported by Bastiaansen, van Berkum and Hagoort's (2002a) for example, may relate to incremental verbal working memory load as the sentence unfolds. This working memory link is supported by results from an n-back task, which showed that theta increased and alpha decreased as working memory load increased (Gevins, Smith, McEvoy & Yu, 1997). The association of increased theta power to the retrieval of lexical-semantic information and to demands on working memory suggest that in general, oscillatory dynamics in theta reflect the encoding of new information into episodic memory (Klimesch, 1999). This would further support Bastiaansen, van Berkum and Hagoort's (2002) claim that oscillatory patterns of theta over the period of time in which a sentence unfolds reflects the formation of a simulation of the described event. This is further supported by the fact that theta power increases have been reported in a variety of different tasks, so may relate to the many components (such as attentional demands, task difficulty and cognitive load) utilised during the construction of a mental simulation. Taken together, these findings provide electrophysiological evidence for the activation of mental simulations of events described by the linguistic input.

Differing patterns of desynchronization have also been noted in response to language stimuli in the lower (in the 6 – 10 Hz) and upper alpha bands (in the 10 – 12 Hz) (Klimesch, 1999). Lower alpha desynchronization reflects general task demands and attentional processes, while upper alpha desynchronization develops during the processing of sensory-semantic information (Klimesch, 1999). Upper alpha desynchronization is thought to be reflective of a complex sensory-semantic long-term memory system and is associated with different types of cognitive processes, memory performance, perceptual performance and intelligence (Klimesch, Doppelmayr & Hanslmayr, 2006). Moreover, upper alpha desynchronization has been shown to distinguish semantic and episodic language processing (Klimesch, Schmike & Schwaiger, 1994), with desynchronization larger in a semantic task compared to an episodic task. However, episodic tasks are more difficult than semantic tasks, suggesting upper alpha selectively reflects semantic processing and not general tasks demands (Klimesch, Schmike & Schwaiger, 1994; Klimesch, Doppelmayr & Hanslmayr, 2006).

Upper alpha may also reflect semantic retrieval during sentence comprehension (Röhm, Klimesch, Haider & Doppelmayr, 2001). When participants completed a comprehension task and a semantic task on sentences presented visually in four chunks (e.g. /A rabbit/is in/the box/hiding./), upper alpha showed greater desynchronization for the semantic task than the comprehension task during the processing of the second and third chunks compared to the simple comprehension task. This is alongside an increase in theta power over the course of the sentence, reflecting the processing demands on working memory). The authors proposed that this difference in upper alpha between the two tasks reflects the retrieval of semantic information that does not draw on working memory in the semantic task.

In summary, oscillatory changes in the theta band are thought to reflect the retrieval of lexical-semantic information and demands on the working memory system. In general, theta synchronization reflects the encoding of new information as a memory trace in episodic memory. That is, theta synchronization is electrophysiological evidence of the setting up of a simulation of the language input. In addition, differing patterns of alpha desynchronization have been observed in the literature, with lower alpha changes associated with attentional processes and general task demands, while upper alpha changes are believed to specifically reflect semantic processing and retrieval. However, research has not yet looked specifically at oscillatory activity when individuals mentally simulate linguistic events of either action or spatial information or speech quotations. Therefore, the aim of the current study is to investigate this, both in individuals with and without ASD.

At the neurological level ASD is considered a disorder of neural synchrony, with studies reporting differences in power spectra in ASD (Tierney, et al, 2012). Differences in oscillatory dynamics have even been identified in infants as young as 6 months old at high-risk of ASD (Tierney, et al, 2012). Such differences are thought to be underlined by differential brain anatomy in ASD. Recall, that anatomical differences in the MNS (Hadjikhani, et al, 2006) and anatomical and functional differences in the integration of large scale neural networks (McAlonan, et al, 2005) have been reported in ASD (see Chapter 1, section 1.9 for an extended discussion of brain activity and mirror neurons in ASD). These findings suggest differing resting state power between individuals with and without ASD, which should be considered during analysis of experimental data.

Studies of EEG power during resting have highlighted specific group differences such as excessive theta primarily in right posterior regions in children with ASD compared to TD children, as well as patterns of limited delta over frontal cortex and excessive midline beta in ASD (Coben, Clarke, Hudspeth & Barry, 2008). Differences in power between ASD and TD individuals have also been found in adults, with those with ASD showing less alpha desynchronization for eyes-open during rest compared to TD participants (Mathewson, et al, 2012). Additionally, electrocortical measures have been associated with behaviours considered typical of the disorder, with ASD adults showing decreased resting alpha power associated with greater allocation of attention to detail. This is in contrast to TD adults where no such relationship was found (Mathewson, et al, 2012). Moreover, EEG complexity, the presence of non-random fluctuations over time in the irregular dynamics of electrophysiological output is reduced in adults with ASD in comparison to TD adults over temporal-parietal and occipital regions (Catarino, et al, 2011).

In conclusion, individuals with ASD demonstrate differing baseline oscillatory dynamic patterns that emerge from early in development and are considered endophenotypes of the disorder. Such individuals exhibit overall lower baseline power across all bands of the spectrum, but specifically in the theta and alpha bands and this should be taken into consideration when calculating EEG power between individuals with and without ASD.

The current experiment

The current experiment used the same design and stimuli as Yao et al (2012), whereby participants listened to short stories, which contained direct-vivid, direct-monotonous, and indirect- monotonous speech. Participants judged how well they thought the speech component fitted with the wider sentence context, based on how vivid and engaging it sounded. EEG was recorded throughout the task to measure the change in EEG event-related power between the background context and the speech portion of stories in each condition. By analysing the change in power from context to speech, baseline differences in EEG activity between ASD and TD individuals should be eliminated, thus findings can be more directly attributed to specific processing strategies in each group during the comprehension of spoken direct and indirect speech.

Given the marked pragmatic and prosodic deficits that are characteristic of ASD, we might expect individuals with ASD to show difficulty detecting the inappropriate prosody in the direct- monotonous speech condition. That is, participants with ASD may judge direct-monotonous speech to be as congruent as direct- vivid and indirect-monotonous speech, while TD participants should show significantly lower congruency ratings for direct-monotonous speech compared to direct- vivid and indirect-monotonous speech (as in Yao et al., 2012). In terms of neurological findings, if indeed participants with ASD demonstrate difficulty distinguishing between direct- monotonous, indirect- monotonous and direct- vivid speech, this may be evident in no oscillatory power change from processing context to speech in either the direct-monotonous, direct-vivid or indirect-monotonous conditions. That is, direct-monotonous speech may have no effect on oscillatory power change in the ASD group. This is in contrast to TD participants who are expected to show greater oscillatory power change in the direct-monotonous condition in comparison to both the direct-vivid and indirect-monotonous conditions. Furthermore, it may be that overall activation is reduced across all condition in those with ASD in comparison to TD participants.

However, the experiments presented in this thesis thus far have suggested that individuals with ASD are able to simulate language in the same way as TD individuals. Findings in Chapter 3 suggest that individuals with ASD are able to effectively process contextual information during comprehension and make use of the same neural systems used by TD adults. Given this, it may be that individuals with ASD do not exhibit any impairment in simulating the prosodic elements of spoken speech either. In fact, it may be that such individuals are able to simulate such properties in the same way as TD participants. If this is the case, we would predict that ASD participants would detect the inappropriate prosody in the direct- monotonous speech condition, and thus rate congruency in the same way as TD participants, replicating Yao and Scheepers (2012) findings. At the neurological level, I would therefore expect no difference in in oscillatory power change between the TD and ASD groups.

Method

Participants

Participants were 23 adults with ASD (14 males, 9 females, ration 14:9; *M* Age = 20.30, *SD* Age = 1.99, 18 – 27 Age range) and 24 typically developing participants (4 males, 19 females, ratio 4:19; *M* Age = 23.30, *SD* Age = 9.71, 18 – 50 Age range). All were students at the University of Kent. All participants were native English speakers and none reported any other language or neurological/neurodevelopmental disorder.

ASD students were recruited through the University's Disability and Dyslexia Support Service (DDSS), who forwarded our study information onto eligible students. Individuals in the ASD group were paid for their participation. The TD participants were recruited through the School of Psychology's online Research Participant Scheme (RPS) and were awarded course credits.

ASD participants scored significantly higher on the number of self-reported autistic traits of the AQ, but there was no difference in full IQ score between the ASD group and ASD group. Means for IQ, AQ and the remaining assessments as well as comparison statistics between the two groups, are reported in Table 8.

Table 8. *Assessment test results, with means and t values for TD and ASD groups. Standard deviations are noted in parenthesis.*

	TD	ASD	Difference
WAIS			
Full IQ	103.74 (9.26)	108.52 (8.93)	t(22) = -1.74
Verbal IQ	101.91 (8.37)	108.96 (9.6)	t(22) = -3.03**
Performance IQ	105.26 (11.19)	106.74 (12.19)	t(22) = -0.39
TROG	95.65 (11.07)	100.96 (7.25)	t(22) = -2.35*
BPVS	110.78 (11.18)	116.13 (10.73)	t(22) = -1.74
AQ	13.96 (5.73)	30.77 (11.09)	t(22) = -6.33***

*Significant at ***.001 **.01 *.05*

Materials

The same ninety short stories developed by Yao, Belin and Scheepers (2012) were used as stimuli in this experiment. The stories described different protagonists and were three sentences long, consisting of two declarative sentences which set the scene, followed by either a direct or indirect speech quotation sentence (see Table 9 for examples and Appendix D for a full list of the experimental items). Importantly, the linguistic content was equal across conditions, apart from the use of quotation marks in the two direct speech conditions, and the additional *'that'* preceding the speech content in the indirect condition. The prosody of the spoken sentences was manipulated such that in one condition the direct speech sentence was deliberately spoken in a monotonous tone (direct-monotonous condition), as in the indirect sentences (indirect condition), such that there were no vivid depictions of the reported speaker's voice. In the third condition, "normal" (i.e. vivid) prosody was used for the direct speech sentences (direct-vivid condition), such that a vivid depiction of the speaker's voice was evident. The stories were spoken by a professional actress. Examples of the short stories used are in Table 9, and the full set of items are shown in Appendix D.

Comprehension questions followed 25% of the stories to ensure participants listened to the stories attentively, and to assess overall comprehension accuracy. These were visually presented on the screen.

The ninety items were counterbalanced into three lists using a Latin-square, such that each list contained 30 direct-monotonous trials, 30 indirect trials and 30 direct-vivid trials. This meant that each item appeared only once in each list, but in different conditions across the three lists. The items were presented in a random order within each list and participants completed only one list.

Table 9. *Example items of the background and direct/indirect speech quotations.*

Background	Direct-vivid /Direct-monotonous	Indirect
Luke and his friends were watching a movie at the cinema. Luke wasn't particularly keen on the romantic comedies, and was complaining a lot after the film…	He said "God, that movie was terrible! I've never been so bored in my life."	He said that the movie was terrible and that he had never been so bored in his life.
Julie and Mark had been classmates and had not seen each other for years. Today they met in a local supermarket and Julie started a conversation about career paths…	She said "My life has been amazing! After nearly three years I'm now a solicitor."	She said that her life had been amazing and that after nearly three years she now is a solicitor.

Design

The experimental conditions gave rise to a 3 (Speech: Direct-monotonous vs. Direct-vivid vs. Indirect-monotonous) x 2 (Group: ASD vs. TD) mixed measures design. The behavioural dependent variables were the rating scores given to each utterance when judging how well the final speech sentence fits the wider context of the story, and the time taken to make this response in milliseconds, from the story offset.

Procedure

Participants were seated in front of the computer and the EEG electrodes were set up (see below for full details). Each trial began with a fixation cross in the centre of the screen, which remained onscreen throughout the auditory presentation of the short story. Participants were instructed to listen to each story carefully. At the end of each story, the screen changed and participants were visually prompted to decide whether or not the final speech sentence fitted with the wider context of the story, based on how vivid and engaging it sounded, using a 7-point Likert scale (1 = did not fit the context at all; 7 = definitely fits the context), displayed horizontally across the screen. Participants responded using the numbers on the keyboard. Twenty-five percent of the items were followed by a visually presented comprehension question, such as *"Did Jason try to phone Melanie in the morning?"* Comprehension questions required a 'yes/no' or 'true/false' response and participants responded by pressing the '1' key for the former and '2' for the latter. All responses during the experiment were made using the keyboard. The stimuli were presented in a random order over three blocks and the experiment took approximately 30 minutes to complete.

Electrophysiological Measures

The Brain Products ActiCap system was used for continuous recording of electroencephalographic (EEG) activity from 62 Ag/AgCl scalp electrodes. Recording was taken over midline Fz, Cz, CPz, Pz, POz, Oz, lateral electrodes over the left hemisphere Fp1, AF7, AF3, F7, F5, F3, F1, FT7, FC5, FC3, FC1, T7, C5, C3, C1, TP7, TP9, CP5, CP3, CP1, P7, P5, P3, P1, PO9, PO7, PO3 and O1, and homologue electrodes over the right hemisphere Fp2, AF4, AF8, F2, F4, F6, F8, FC2, FC4, FC6, FT8, C2, C4, C6, T8, CP2, CP4, CP6, TP8, TP10, P2, P4, P6, P8, PO4, PO8, PO10 and O2 (see Figure 22 for electrode arrangement). HEOG activity (horizontal eye movements) was recorded from an electrode placed on the outer cathus of the left eye, and VEOG activity (vertical eye movements) was recorded from an electrode placed underneath the right eye. EEG and EOG activity was recorded at a sampling rate of 500Hz, with AFz as the Ground and FCz the recording reference.

BrainVision Analyzer 2 software was used to prepare the EEG data prior to statistical analysis. First, all channels were re-referenced offline to an average of the two mastoid electrodes (TP9 and TP10) and the EEG signal was filtered using 0.1 – 70 Hz and a notch filter at 50Hz. Data containing blinks or eye movements was corrected using ocular correction Independent Components Analysis (ICA). The data was then divided into segments, two for each item, defined by the onset and offset of the context, and the onset and offset of the speech. An automatic artifact rejection algorithm was used to discard individual segments that contained artifacts, such as drift and muscle activity. A Fast Fourier Transformation (FFT) with a 10% Hanning window was applied to convert the data from the time domain to the frequency domain. Finally, the FFT data for each participant was averaged for each speech condition (direct-vivid, direct-monotonous and indirect) and each audio segment (context and speech).

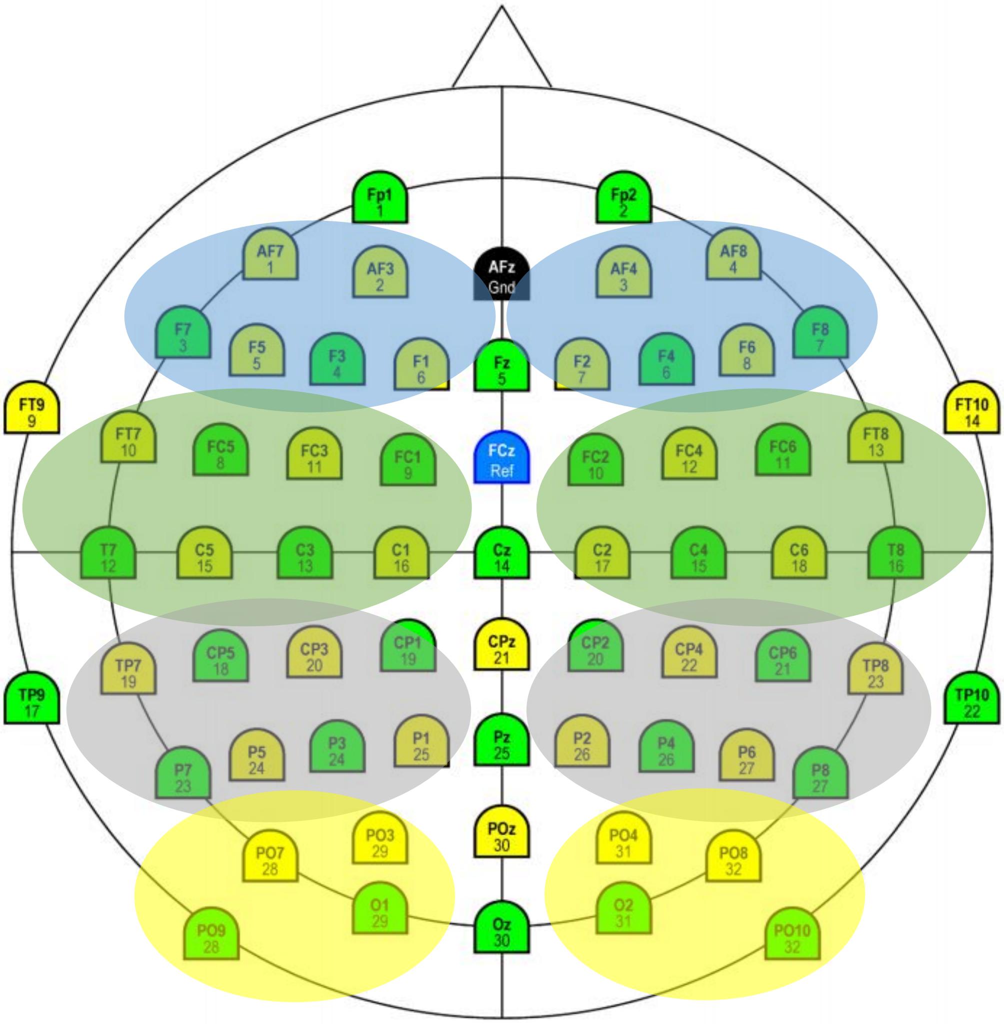


Figure 22. Electrode array. 64 active electrodes (62 scalp electrodes, 2 ocular electrodes) with regions of interest defined.

EEG Data Analysis

Raw power values during the context (which was identical across speech condition) and speech periods were used to calculate the change in power between these two periods, at each electrode site for each participant and condition, by subtracting the amplitude of the EEG signal during the context from the amplitude during the speech. This power change value was chosen over raw power changes in each speech condition because of baseline differences in oscillatory dynamic patterns between individuals with ASD and TD individuals (see Caterino, et al, 2011; Tierney, et al, 2012; Mathewson, et al, 2012). Analyses focused on three windows of the power band: upper theta (6 – 8 Hz), lower alpha (8 – 10 Hz) and upper alpha (10 – 12 Hz). The power change for each speech condition in the three power bands (upper theta, lower alpha and upper alpha) was analysed over eight regions of interest (ROIs): Left/Right Frontal (Af3/Af4, Af7/Af8, F1/F2, F3/F4, F5/F6. F7/F8), Left/Right Central (FC1/FC2, FC3/FC4, FC5/FC6, FT7/FT8, C1/C2, C3/C4, C5/C6, T7/T8), Left/Right Posterior (CP1/CP2, CP3/CP4, CP5/CP6, TP7/TP8) and Left/Right Occipital (PO3/PO4, PO7/PO8, PO9/PO10, O1/O2). Thus, the change in power for each band was averaged across electrodes in each ROI for each participant and condition.

Results

Accuracy on the comprehension questions averaged 83.6% for the ASD group and 85.1% for the TD group. Contextual congruency ratings and response times were analysed using separate 3 (Speech: Direct-monotonous vs. Direct-vivid vs. Indirect) x 2 (Group: ASD vs. TD) mixed measures ANOVAs.

Contextual congruency ratings

The mean ratings for the TD and ASD groups are illustrated in Figure 23. Analysis revealed a main effect of group [F(1, 44) = 13.21 $p < .001$, $\eta_p^2 = .23$], showing that the ASD group judged the final speech sentence as overall more fitting with the wider context than the TD group (ASD group: *M* = 5.22; TD group: *M* = 4.53). There was also a main effect of speech [F(2, 88) = 57.68, $p < .001$, $\eta_p^2 = .57$] and a significant group by speech interaction [F(2, 88) = 3.65, $p < .05$, $\eta_p^2 = .08$]. Further analysis of this interaction revealed a main effect of speech in both the TD group [F(2, 44) = 41.29, $p < .001$, $\eta_p^2 = .65$] and ASD group [F(2, 44) = 18.16, $p < .001$, $\eta_p^2 = .45$].

Follow-up analyses were conducted using paired t-tests to further investigate the effect of speech type in each group. In the TD group, direct-vivid speech (*M* = 5.8) was judged to be a better fit with the preceding context than both direct-monotonous [*M* = 3.12; t(22) = 7.25, $p < .001$] and indirect speech [*M* = 4.69; t(22) = 4.00, $p < .001$]. In addition, indirect speech was rated as a better fit with the preceding linguistic context than direct-monotonous speech [t(22) = 7.06, $p <.001$]. Similarly, participants in the ASD group perceived direct-vivid speech (*M* = 5.9) to be a better fit with the preceding context than direct-monotonous [*M* = 4.31; t(22) = 2.99, $p < .05$] and indirect speech [*M* = 5.45; t(22) = 4.51, $p < .001$] . They also perceived indirect speech to be a better fit with the preceding linguistic context than direct-monotonous speech [t(22) = -4.17, $p < .001$]. These results suggest that, at the behavioural level, TD and ASD participants distinguish the different speech types in the same way.

Further independent sample t tests examined group differences in ratings for each speech type, and revealed that the ASD group gave higher ratings than the TD group for direct-monotonous speech [t(44) = 3.067, $p < .05$], and indirect speech [t(44) = 2.97, p < .05]. There was no difference between the groups' ratings of direct-vivid speech ($p = .63$).

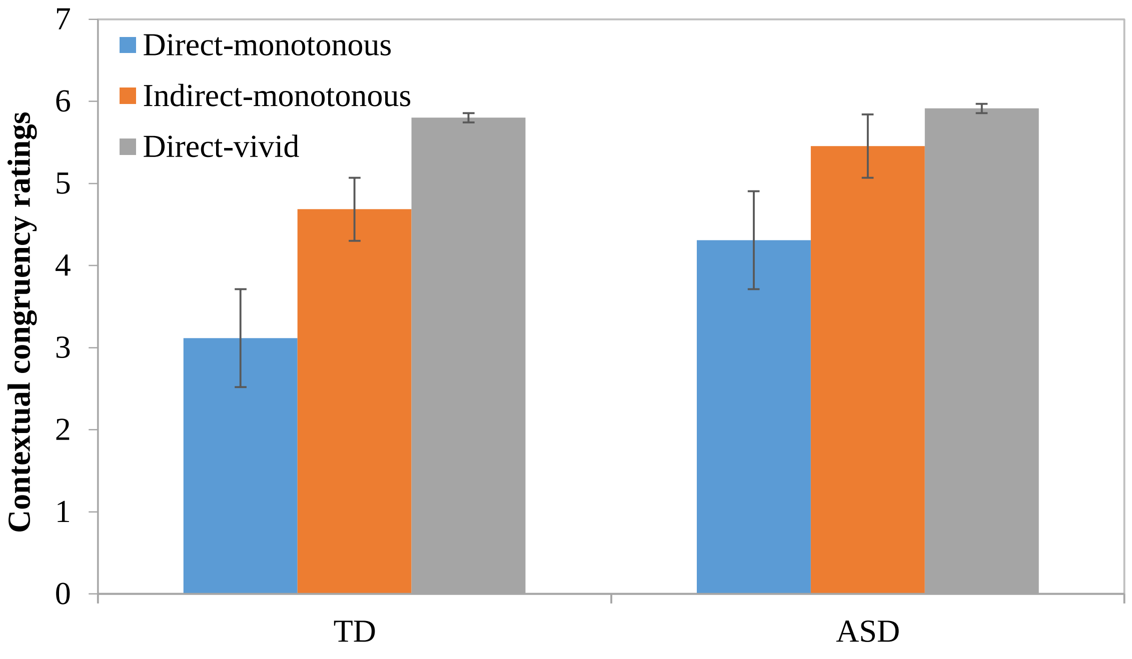


Figure 23. Mean contextual congruency ratings for direct-monotonous, indirect-monotonous and direct-vivid speech types. Error bars show standard errors.

Response times

To reduce the effect of outliers on response time analysis, participant's response times were transformed into z scores using the grand mean for each group averaged over the three conditions prior to analysis. Response times that had a z score corresponding to 3.29 (i.e. $p < .001$) were removed prior to analysis. This removed 23 data points from the ASD group (10 from the direct-monotonous condition, 8 from the indirect-monotonous condition ad 5 from the direct-vivid condition) and one data point from the TD group (one from the direct-vivid condition, none from the direct-monotonous or indirect-monotonous conditions).

Average response times are illustrated in Figure 24. No effect of group was found ($p = .22$), however a main effect of speech was found [$F(2,88) = 28.12$, $p < .001$, $\eta_p^2 = .39$] and the group by speech interaction showed a trend towards significance [$F(2, 88) = 2.58$, $p = .081$, $\eta_p^2 = .06$]. Further analysis revealed a main effect of speech in the TD group [$F(2, 44) = 17{,}79$, $p < .001$, $\eta_p^2 = .45$] and the ASD group [$F(2, 44) = 12.46$, $p < .001$, $\eta_p^2 = .36$]. To further explore these effects, paired t tests examined differences between speech conditions for each group. TD participants were significantly slower to judge indirect speech (M = 2804ms) than direct-monotonous [*M* = 2010ms; t(22) = 7.05, $p < .001$] and direct-vivid speech [*M* = 2218 msec; t(22) = 3.57, $p < .01$]. TD participants were also marginally slower to judge direct-vivid speech compared to direct-monotonous speech [t(22) = 1.87, $p = .075$]. The ASD group showed a similar response pattern. They were significantly slower to respond following indirect speech (*M* = 3200ms) than direct-monotonous [*M* = 2733ms; t(22) = 4.02, $p < .001$] and direct-vivid speech [*M* = 2613ms; t(22) = 4.48, $p < .001$], but were just as fast to judge direct-monotonous and direct-vivid speech ($p = .35$).

Independent samples t tests examined group differences in response times for each speech type, and revealed that the TD and ASD groups were equally fast to judge direct-vivid ($p = .43$) and indirect speech ($p = .33$). However, the TD group were marginally faster than the ASD group to judge the contextual congruency of direct-monotonous speech [t(44) = 1.85, *p* = .07].

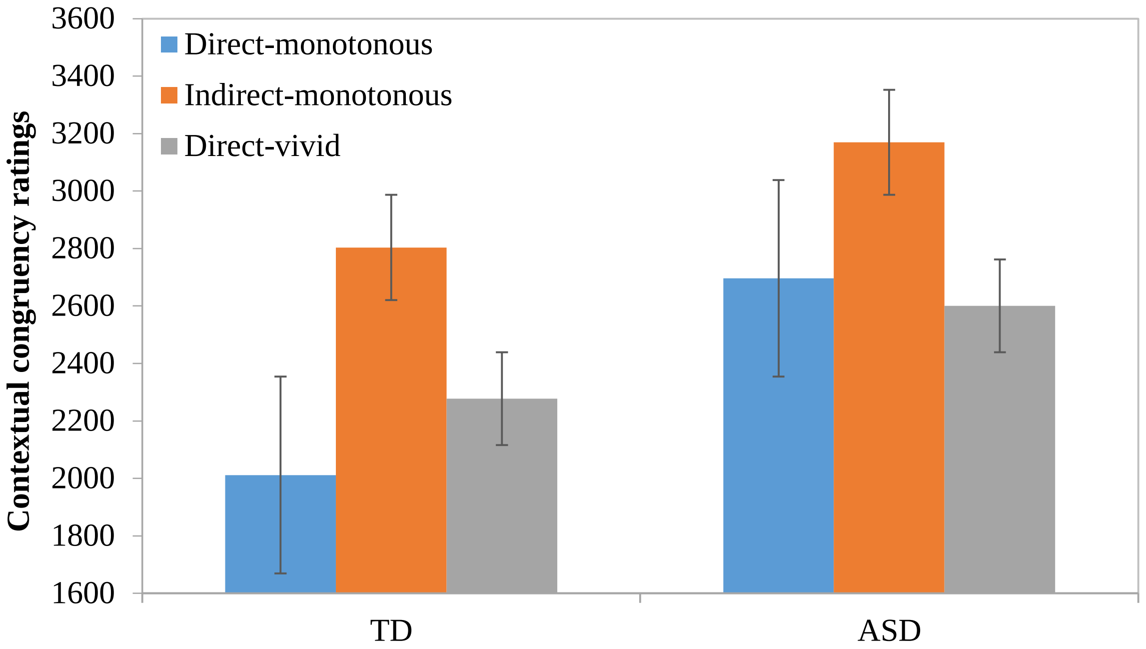


Figure 24. Mean response times for the direct-monotonous, indirect-monotonous and direct-vivid speech types. Error bars show standard errors.

EEG Power Analysis

The EEG power changes between context and speech in the three speech type conditions (direct-monotonous, direct-vivid and indirect-monotonous), over the predefined ROIs are presented in Figure 25 for the TD group and Figure 26 for the ASD group. Change in power in each of the three power bands (upper theta (6 – 8 Hz), lower alpha (8 – 10 Hz) and upper alpha (10 – 12 Hz), was analysed using a mixed ANOVA, with hemisphere (left vs. right), ROI (frontal vs. central vs. parietal vs. occipital) and speech condition (direct-monotonous vs. direct-vivid vs. indirect-monotonous) as within subjects variables, and group (ASD vs. TD) as the between subjects variable. Significant interactions were followed up post-hoc using paired t tests.

Upper theta (6 – 8 Hz). Analysis of power change in upper theta showed no effect of group (*p* = .14) or hemisphere (*p* = .53). However, there was a main effect of ROI [F(3, 132)

= 3.86, $p < .05$, ηp2 = .08] with decrease in theta power greater over frontal regions than posterior/occipital sites. Importantly, a main effect of speech was observed [F(2, 88) = 5.32, $p < .01$, $\eta_p^2 = .11$]. Paired t tests revealed that direct-monotonous speech (M = -.211µV2) elicited a significantly greater reduction in upper theta power compared to both direct-vivid speech [*M* = -.099µV2; t(45) = -2.99, $p < .01$], and indirect speech [*M* = -.144µV2; t(45) = -2.45, $p < .05$].There was no difference in theta decrease between direct-vivid and indirect-monotonous speech ($p = .23$). None of the interactions involving speech and group reached significance (all *p*'s > .2).

Lower alpha (8 – 10 Hz). Analysis of power change from context to speech processing in the lower alpha band revealed no main effect of group ($p = .26$), hemisphere ($p = .63$), or ROI ($p = .31$). A main effect of speech was observed [F(2, 88) = 4.8, $p < .01$, $\eta_p^2 = .1$], but this did not interact with group ($p = .38$). Paired t tests revealed that direct-monotonous speech (*M* = -.518µV2) elicited a significantly greater decrease in lower alpha compared to direct-vivid speech [*M* = -.217µV2; t(45) = -2.84, $p < .01$], and marginally greater compared to indirect speech [*M* = -.299µV2; t(45) = -1.8, $p = .070$]. As in the upper theta band, there was no difference in lower alpha decrease between direct-vivid and indirect-monotonous speech ($p = .21$). None of the interactions involving speech and group reached significance (all *p*'s > .26).

Upper alpha (10 – 12 Hz). Analyses revealed no main effect of group ($p = .91$), or hemisphere ($p = .063$), but there was a main effect of ROI [F(3, 132) = 3.26, $p < .05$, $\eta_p^2 = .07$], with decrease in upper alpha greatest over than frontal, central and posterior sites. The main effect of speech was marginally significant [F(2, 88) = 2.82, $p = .065$, $\eta_p^2 = .06$], reflecting a significantly larger decrease in upper alpha for direct-monotonous speech (*M* = -.442µV2) compared to both direct-vivid speech [*M* = -.343µV2; t(45) = -2.12, $p < .05$] and indirect speech [*M* = -.442µV2; t(45) = -2.67, $p < .01$]. Upper alpha power did not differ between direct-vivid and indirect speech (p = .88). None of the interactions involving speech and group reached significance (all p's > .42).

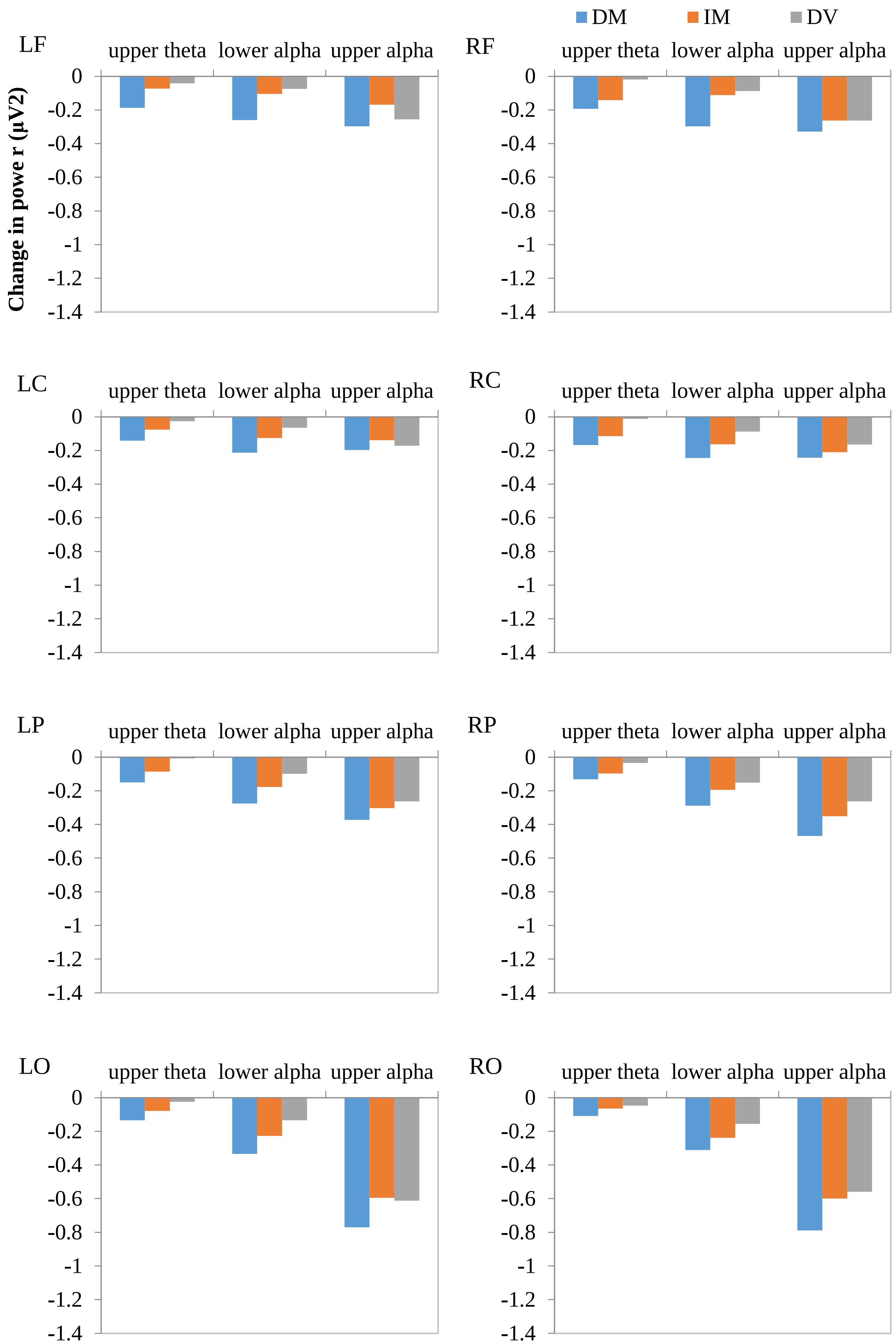


Figure 25. Change in power from context to speech in the TD group for the three speech type conditions; direct-monotonous (DM), direct-vivid (DV) and indirect-monotonous (IM), over ROIs (left/right frontal, central, parietal and occipital regions).

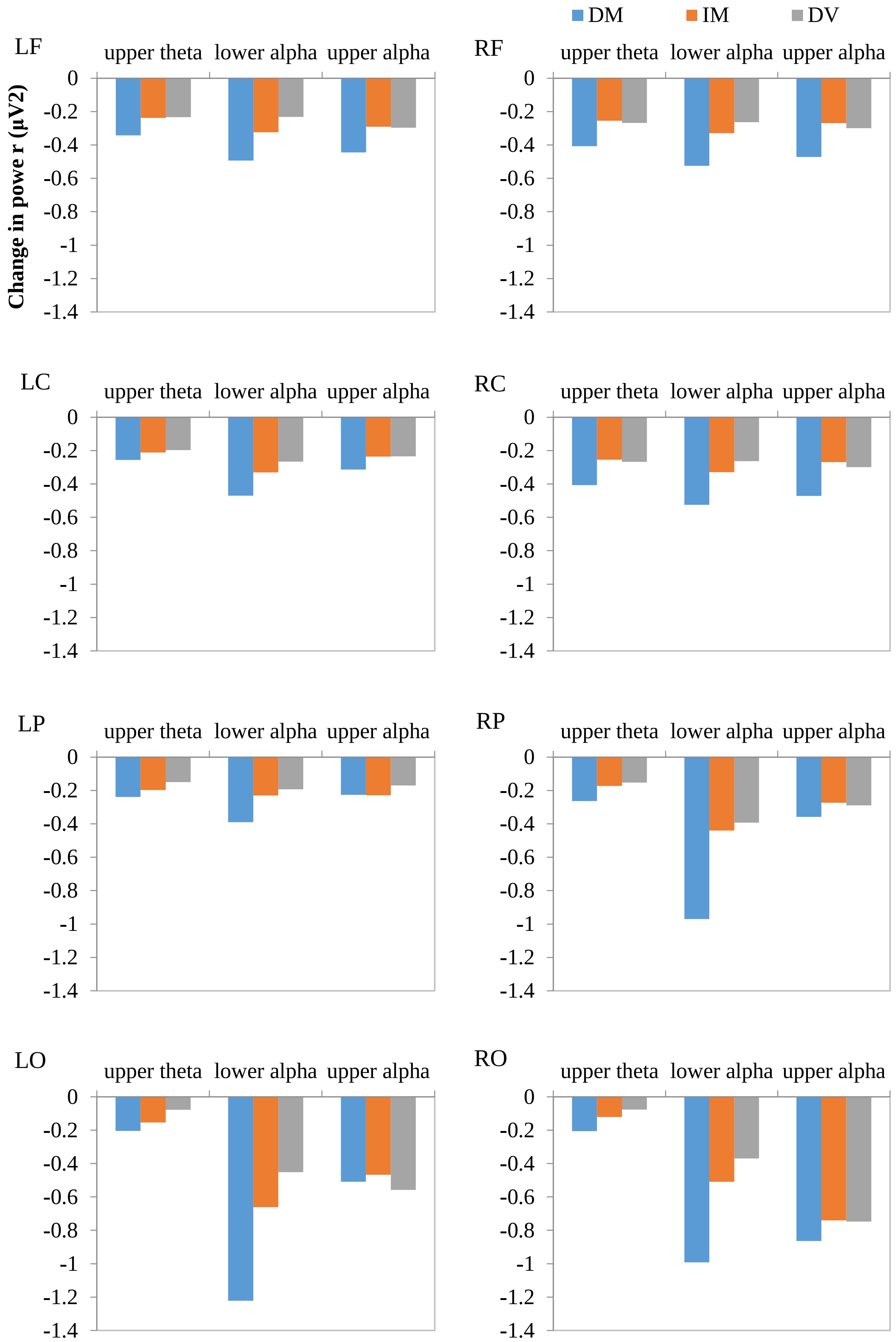


Figure 26. Change in power from context to speech in the ASD group for the three speech type conditions; direct-monotonous (DM), direct-vivid (DV) and indirect-monotonous (IM), over ROIs (left/right frontal, central, parietal and occipital regions).

Discussion

The aim of Experiment 4 was to investigate behavioural and neural evidence for simulations of spoken language in individuals with and without ASD. More specifically, I aimed to explore whether individuals with ASD represent the speaker's emotions and intentions, expressed through tone of voice, in the same way that TD individuals do. The current study replicated Yao and Scheepers (2012) paradigm that involved listening to short stories that included a final direct (e.g. *He said "God, that movie was terrible! I've never been so bored in my life."*) or indirect (e.g. *He said that the movie was terrible and that he had never been so bored in his life*) speech sentence. Critically, direct speech was either spoken in a monotonous tone (thus lacked supra-segmental information), or in a vivid tone. Indirect speech was spoken in monotone. Participants' task was to rate how well they thought the speech sentence fitted the wider story context, based on how vivid and engaging it sounded. Behavioural responses were supplemented with continuous EEG recordings to investigate the local oscillatory dynamics that underlie the processing of direct and indirect speech in individuals with and without ASD.

In their behavioural findings, Yao and Scheepers (2012) showed that TD adults detected the inappropriate prosody in direct-monotonous speech and therefore rated it as a significantly worse fit with the context (i.e. more incongruent) than either direct-vivid speech or indirect-monotonous speech (which were rated as equally congruent). We expected to replicate this pattern of effects in the TD sample here. Indeed, results supported this hypothesis in showing that the TD group rated the direct-monotonous speech as significantly less fitting the wider context than either direct-vivid or indirect-monotonous speech.

Our expectations for the ASD group were less clear. On the one hand, findings in the previous experiments presented in this thesis have demonstrated that individuals with ASD are able to construct spatial simulations of written events that are comparable to those created by TD adults, taking advantage of contextual information within the same time course and utilising the same neurological mechanisms. This would suggest that ASD participants could also replicate Yao and Scheepers (2012) behavioural findings in simulating the context-appropriate prosodic properties of speech. On the other hand, a vast amount of empirical evidence suggests that both adults and children with ASD demonstrate specific impairments in processing prosodic elements of speech. This includes deficits in attributing mental states and emotions to voices (Rutherford, Baron-Cohen & Wheelwright, 2002) and difficulty interpreting communicative intent (Wang, et al, 2006). This existing literature would suggest that individuals with ASD would show difficulty recognising the appropriate prosodic properties of speech in the current study (i.e. would fail to distinguish direct-monotonous and direct-vivid speech).

In fact, behavioural results showed a general bias for higher ratings of fit between the speech portion of the short stories and the wider context in the ASD group compared to the TD across all three speech types. Nevertheless, Yao and Scheepers's (2012) congruency effect was replicated in the ASD group, with significantly lower congruency ratings given to the direct-monotonous speech compared to either direct-vivid or indirect-monotonous speech. However, this effect was subsumed under a significant interaction between speech type and group, which revealed that the ASD group gave direct-monotonous and indirect-monotonous speech higher congruency ratings than the TD group; there was no between-group differences in ratings for direct-vivid speech. This may suggest that although ASD participants were correctly able to judge the appropriateness of the speaker's tone of voice (i.e. they distinguished the incongruent direct-monotonous speech from direct-vivid and indirect-monotonous speech), they may have weaker expectations regarding prosody in speech and were less confident in judging the prosody in this condition. Furthermore, individuals with ASD are more likely to converse with other individuals (with ASD) who have difficulty producing appropriate prosody. Consequently, they are less disrupted than TD individuals when processing direct-monotonous speech where the prosody is inappropriate. However, the fact that direct-vivid speech was rated as equally fitting between TD and ASD individuals shows that people with ASD are sensitive to prosody in narrative speech, and thus have similar expectations of context-appropriate speech acts.

These behavioural effects are further supported by the reaction time (RT) findings. Responses were slower in both groups when judging the fit of indirect compared to direct speech, however the two groups showed some differences in the timing of responses across conditions. ASD participants took considerably longer than TD participants to respond to direct-monotonous speech, and although there was no significant difference in reaction times for ASD and TD participants to process and judge direct-vivid and indirect-monotonous speech, an interesting pattern occurred. While the two groups were equally as fast to process direct-vivid and indirect-monotonous speech, visual inspection of the reaction time plot shows a trend for ASD participants to respond slower overall across all speech types compared to TD participants. Furthermore, considerably more data points were removed from the ASD group prior to analysis of response time. This high variability in response times across conditions in comparison to the TD group would suggest heterogeneous abilities in the ASD group. These subtle pattern mirrors the effect found in the previous experiment on the behavioural signatures and ERPs of written language, where there was a trend in the reaction time findings for the ASD group to respond slower than the TD group.

The group differences in response times to direct-monotonous speech in the current experiment may be analogous to the findings reported in Chapter 3, reflecting subtle processing differences in how individuals with and without ASD simulate both written and spoken language. Processing incongruent intonation in spoken language in the current experiment might require additional stages of processing in individuals with compared to without ASD, in the same way that processing contextual uncertainty in written language is subtly more demanding. Moreover, this slow-down in reaction time could reflect the lack of confidence in judging speech in the direct-monotonous condition, as suggested by the contextual congruency ratings, which show a similar pattern. Even so, this slowdown in processing supports the assertion that ASD participants, like TD participants, were considering and simulating the prosodic elements of the spoken utterances, and that this simulation of speech may have led to the slow-down in responses for direct speech (which should activate a re-enactment of the speech act) versus indirect speech.

Behavioural measures were supplemented with EEG power analysis in order to investigate the oscillatory dynamics underlying spoken language simulation as it happens. Analyses focused on activity in theta and alpha wave bands, which in the TD population are thought to reflect the encoding of new information into a memory trace in episodic memory, attentional and general task demands and semantic processing and retrieval respectively (see for example Klimesch,1999; Bastiaansen, van Berkum & Hagoort, 2002; Röhm, Klimesch, Haider & Doppelmayr, 200; Batinaansen & Hagoort, 2006). The change in power from processing the context sentence (which was identical across all three speech condition) to processing the speech sentence was calculated in three power windows (upper theta, 6 – 8Hz; lower alpha, 8 – 10Hz; upper alpha, 10 – 12Hz). This allowed me to control for differences in baseline power between individuals (particularly the ASD group for whom resting state brain activity is known to differ from TD people, see Caterino, et al, 2011; Tierney, et al, 2012; Mathewson, et al, 2012).

Electrophysiological results revealed that upper theta and lower and upper alpha desynchronization occurred from the processing of the story context to processing the speech sentence and this oscillatory pattern was comparable for the two groups. However, while there was no significant difference in upper theta, lower alpha or upper alpha power change from context to speech processing between the TD and ASD group, visual inspect of the power plots does suggest slightly greater desynchronization in the ASD group. It seems that processing the speech content and representing the prosodic content was subtly more demanding for the ASD, which would explain the slowdown in response time in the behavioural data. Nevertheless, both groups showed significantly greater upper theta and alpha desynchronization during the processing of direct- monotonous speech compared to both direct- vivid speech and indirect- monotonous speech. Moreover, power change in upper theta, lower alpha and upper alpha from processing context to speech did not differ between the direct-vivid and indirect-monotonous speech conditions for either group. This would suggest that ASD participants are utilising the same oscillatory neural dynamics as TD individuals in order to represent prosodic elements and activate an appropriate simulations of spoken language events.

These findings fit well within the literature on theta and alpha oscillations in language comprehension and on perceptual simulations of direct speech. Recall, direct speech provides a demonstration of the reported speech event and is therefore differentially represented in a simulation to indirect speech during language comprehension (Clark & Gerrig, 1990). Readers and listeners incorporate the speaker's tone of voice into a perceptual simulation of the event (Yao, Belin, & Scheepers, 2011) and what constitutes this simulation of the speaker's tone of voice are the supra-segmental acoustic information (Yao, Belin & Scheepers, 2011). When the supra-segmental acoustic information is not available for encoding – as in the case of the direct- monotonous speech condition – listeners must mentally represent it. This is in contrast to simulating an event described by direct- vivid speech where the supra-segmental information is provided for encoding and indirect- monotonous speech which is merely a description of the event so is not represented by a vivid perceptual simulation of the voice.

Recall, theta oscillations reflect demands on working memory and the construction of a mental trace of an event into episodic memory (i.e. the setting up of a mental simulation of the language input). Consequently, one could explain the current findings of greater theta oscillations for direct- monotonous speech compared to direct- vivid and indirect-monotonous speech for both TD and ASD groups as reflecting the effortful perceptual representation of the incongruent speaker's tone of voice during simulation of the event. Theta oscillations reflect the encoding of information as a trace, but in the direct-monotonous condition this information is not available for encoding. Thus, theta desynchronization may be associated with the process of representing this absent supra-segmental information by both TD and ASD participants; a process which is cognitively demanding.

Lower alpha power changes reflect attentional processes and general task demands (Gevins, et al, 1997). Consequently, the larger change in lower alpha for direct-monotonous speech in the current study may be interpreted as a reflection of increased attention and greater task demand in having to represent the absent supra-segmental information, in comparison to perceptually simulating direct-vivid or indirect-monotonous speech. Since supra-segmental information is not available to participants in the monotonous-direct condition, and effort is required to simulate this information, changes in upper alpha may reflect reliance on semantic content. If participants are unable to rely on prosodic elements (i.e. an appropriate tone of voice by the speaker), they may rely more on the semantic content in order to simulate the event in the monotonous-direct speech condition. This is in contrast to the vivid-direct or monotonous-direct speech conditions where rich prosodic information is available or not necessary in order to effectively simulate the event. This would explain the change in upper alpha between direct-monotonous and direct- vivid speech and between direct- monotonous and indirect- monotonous speech.

Taken together, the current electrophysiological findings of theta and alpha desynchronization in the direct-monotonous condition compared to the direct-vivid and indirect-monotonous conditions may reflect the activation of a simulation of the spoken event and effortful representation of the absent supra-segmental acoustic information. This would further support evidence that ASD participants are simulating spoken language in the same way as TD participants, utilising the same oscillatory neural dynamics of the brain's language network.

Analyses in the current study focused on power change, a technique associated with local oscillatory synchronization. That is, oscillatory synchronization that occurs within a given brain network. Research has emphasised baseline differences in power between TD and ASD individuals, though as stated, this was controlled for in the current study by analysing the change in power from processing context to processing speech. However, alternative neuro analysis methods are available that could have been applied to the current data in order to enhance understanding of the effects found. Such analysis techniques include Time-Frequency Analysis (TFA) and Coherence Analysis.

Time-frequency analysis involves decomposing the EEG into the sum of a set of oscillations, and the power in each frequency band is phase-locked, or estimated at each moment in time (Kappenman & Luck, 2012). The aim is to observe changes in oscillatory power as a function of time and frequency, phase-locked to an event. TFA analysis has revealed increases in power in the theta frequency range during processing of semantic violations such as *"The Dutch trains are sour"* at the onset of the final-sentence noun (sour) (Hagoort, Hald, Bastiaansen & Petersson, 2004). Likewise, Davidson and Indefrey (2007) examined time-frequency power changes in response to semantic and grammatical violations during sentence processing. Semantic violations such as *"The girl speaks three tress"* (vs. a control, *"The wind swept through the trees"*) were associated with power increases in the theta frequency. In the current study, time-frequency could be synced to the onset of the speech sentence, which could inform how quickly changes in theta and alpha oscillations emerge during the processing of direct and indirect speech in individuals with and without ASD. However, one issue with TFA is it has relatively poor time resolution (Bastiaansen, Mazaheri & Jensen, 2012). Local synchronous activations of a large number of neurons, which by spatial summation of postsynaptic potentials result in increased amplitudes of EEG oscillations, are to a large extent not picked up by the same electrode, but by different electrodes. Applying TFA to the current data would capture the timing of effects in the oscillatory activity of individuals with and without ASD, which would be of interest considering effects seem to be emerging later in the ASD group in the behavioural findings of the current experiment and in the previous ERP experiment. However, TFA does not capture this spatial component, preventing adequate identification of multiple regions with defined topography (Koenig, Marti-Lopez & Valdes-Sosa, 2001).

One method of examining covariance among EEG signals is through coherence analysis. Coherence refers to long-range synchronization between neural networks, with increased coherence between signals from multiple brain regions reflecting the networks' involvement in the cognitive effort (Tucker, Roth & Bair, 1986). Research has noted differences in EEG coherence between ASD and TD individuals. Elevated coherence has been observed in the theta frequency range for ASD individuals compared to controls, along with reduced alpha coherence (Murias, Webb, Greenson & Dawson, 2007). Likewise, analysis of intrahemispheric and interhemispheric coherence in children with ASD and matched TD children during an eye-closed resting state revealed a pattern of under-connectivity in ASD, including decreased intrahemispheric delta and theta coherence across short to medium and long inter-electrode distances, as well as low coherence of delta, theta and alpha across frontal, temporal and posterior regions (Coben, Clarke, Hudspeth & Barry, 2008). Differences in coherence patterns between those with ASD and TD individuals are thought to be stable and perhaps constitute an EEG coherence-based phenotype of ASD (Duffy & Als, 2012). Such patterns are thought to reflect over and under-connectivity at spatial and temporal scales in ASD (Murias, Webb, Greenson & Dawson, 2007).

Examining EEG coherence over the speech segment in the current study could identify differences in coherence between the ASD and TD group, which would fit with this theory of under-connectivity. While in the current study it was found that individuals with ASD utilise the same oscillatory dynamics as TD individuals when simulating prosodic elements of speech, the coherence between active networks in individuals with and without ASD could not be assessed. Though it is outside the scope of this thesis, of interest in future research is to reanalyse the current data using coherence analysis to investigate EEG coherence during simulations of spoken language in ASD.

Chapter Summary

Taken together, the findings from the current study suggest that ASD individuals are able to simulate the prosodic properties of spoken language. More specifically, and in contrast to previous research on prosodic processing in ASD, such individuals are able to effectively simulate the speaker's tone of voice, and respond appropriately when this expectation is violated (as in the direct monotonous speech condition). In addition, the current study suggests that these distinct simulations of spoken language are comparable to those activated by TD individuals. Both groups demonstrated the same oscillatory dynamics patterns, at least within the theta and alpha power bands. The current study supplemented traditional behavioural measures with EEG power measures as an indicator of the neurological patterns of speech simulation over time. As well as providing evidence that ASD individuals do in fact show comparable oscillatory dynamics during simulation as TD individuals, the study also further demonstrated EEG as an effective means for exploring the covert processes that underlie simulations of written and spoken language. Future research could explore this further using the new tools and analyses that are becoming commonplace in neuroscientific research, such coherence analysis discussed above.

Chapter 5

The two studies presented in this Chapter further develop the findings on mental representations of spoken language from Chapter 4 to investigate simulations of conceptual spoken language and to explore how these language simulations are updated in time. This Chapter introduction will be presented as follows; I will begin by defining simulations of conceptual language in the TD population, focusing on how language and real-world knowledge mediate visual attention, and how this has been studied by tracking eye movements. Next, I will discuss what is currently known about language-mediated eye movement in ASD and how such individuals process spoken language in context. Following this, I will present the methodology of the current study and justify the use of eye-tracking as a means of measuring the online processing of language, before introducing the paradigm and hypotheses.

Language mediates visual attention

Sentence comprehension is an active process that results in behaviours directed towards the contents of the concurrent world (Altmann & Kamide, 2007). These behaviours may be action based (as shown in Chapters 2 and 3) and are also observable at the neurological level (Chapters 3 and 4). However, these behaviours may also be attention-based; as participants move their attention around a visual scene in response to language they hear (Altmann & Kamide, 2007). Cooper (1974) claims that the association between the meaning of spoken language and a concurrent visual scene provides a sensitive measure of spoken language comprehension without the need to interrupt the continuity of the linguistic input. An increase in eye movements towards an object in a visual scene is thought to reflect increased activation of mental representations of that given object during comprehension (Altmann & Kamide, 2007).

As words in a sentence unfold the point at which the eyes move to the corresponding objects reflects the time at which listeners are able to disambiguate the potential referents, which is thought to be at the theoretically earliest opportunity (Altmann & Kamide, 2004). This has been demonstrated extensively in the eye tracking literature in comprehension visual world experiments. In these experiments participants listen to an utterance while simultaneously viewing an experimental visual display (Huettig, Rommers & Meyer, 2011). The visual input generally consists of a semi-realistic scene that includes objects mentioned in the utterance along with un-mentioned distractor objects, while the sentence describes or comments on the scene (Huettig, et al, 2011). The aim is to study how the unfolding linguistic input makes contact with the visual world and at what point this happens (Altmann & Kamide, 2004), indicated by fixations on and saccades across the visual scene. Generally, researchers are interested in fixations and saccades towards predetermined regions of interest in the visual display, as these are indicative of the direction of listeners' visual attention towards an object in the visual scene, and are driven by a continuous and anticipative interpretation of the unfolding language. This reflects linguistic processing as the ongoing spoken language is interpreted word-by-word in real time in the context of the visual display, explaining language with the domain of visual processing (Cooper, 1974).

In a visual world paradigm task, Altmann and Kamide (1999) presented participants with sentences such as *"The boy will eat the cake"*, with an accompanying visual display including a boy, a cake, a toy train, a toy car and a ball. Theoretically, the verb *'eat'* should constrain the comprehender's anticipation of how the rest of the input will unfold, limiting the mental representations activated to edible objects. Analysis of eye movements around the scene showed that the probability of launching saccades towards the cake was greater than when the same visual scene was presented along with the sentence *"The boy will move the cake"*. This difference emerged before the onset of the final noun (*cake*). The authors argued that in the first condition (*eat*), the cake is the only object in the visual display to satisfy the selection restriction of the verb (i.e. requiring an edible object), therefore the mental representation of the cake can be activated as early as the verb. However, in the move condition, the cake is not the only object in the scene to satisfy the verb move, meaning that participants cannot restrict reference at the verb and thus cannot anticipate reference to the cake over the other objects in the scene.

Similarly, Kamide, Altmann and Haywood (2003) found that anticipatory eye movements could also be directed by world knowledge on the appropriateness of potential goal objects. They presented sentences such as *"The woman will spread the butter on the bread"* or *"The woman will slide the butter to the man"* along with a visual scene depicting a woman, a man, butter, bread and a coffee cup. Anticipatory eye movements to the appropriate objects were found to occur in the post-verbal expression (during *'the butter'*), demonstrating the incremental nature with which comprehenders can anticipate upcoming referents. Furthermore, in a second experiment Kamide and colleagues demonstrated that information about the agent combines with information about the verb's selection restriction to direct predictions about the unfolding language. Presenting sentences like *"The man will ride the motorbike"* versus *"The girl will ride the carousel"*, the authors observed more eye movements towards the motorbike after *'The man will ride'*, and the carousel after *'The girl will ride'*. This was argued to be the result of a combinatory effect of the verb's selection restriction and world knowledge about the agent, which manifest at the verb onset. While both the motorbike and the carousel satisfy the restriction selection of the verb *'ride'*, knowledge of the agent and real world plausibility suggests the man is more likely to ride the motorbike and the girl more likely to ride the carousel. This demonstrates the incremental processing of sentences, word-by-word, with the listener applying constraints during online analysis of the linguistic input as it unfolds. That is, comprehenders are continuously updating the mental representation of the linguistic input as it unfolds, assigning appropriate thematic roles and disambiguating referents.

Crucially, whilst the sentences used in these tasks are dynamically unfolding representations of events (with the tense of a sentence depicting the beginning or end of an event), the accompanying visual scenes merely depict the static states of the objects (Altmann & Kamide, 2007). Altmann and Kamide (2007) examined the representational basis of anticipatory eye movements in sentences like, *"The man will drink all of the beer"* versus *"The man has drunk all of the wine"*. They observed anticipatory eye movements to appropriate objects as a function of the tense of the verb (i.e. future vs. past tense). That is, at the onset of sentence-final referring expression, there were more fixations on the empty wine glass following *'has drunk'* than *'will drink'*, and more fixations on the full beer glass following *'will drink'* than *'has drunk'*. This demonstrates that anticipatory eye movements can be directed by object affordances, even when that object is not being explicitly named.

Taken together, these results suggest that anticipatory eye movements are doing more than reflecting what the comprehender expects to be referenced next. Rather, they reflect the mapping of the unfolding sentence onto affordances of the objects in the visual scene. That is, comprehenders are not mapping the unfolding linguistic input onto the visual display itself, but rather mapping it onto a mental representation of the visual display that is dynamically interpreted in relation to the event structure; a mental representation of the described event (Altmann & Kamide, 2007). This mental representation is both dynamic and changeable in relation to how the input unfolds. It is this observation of eye movements mediated by language that permit the investigation of the interplay between the mental world and the external visual world.

Mapping language onto the mental world

Altmann and Kamide (2009) explored this mapping between language and dynamically updateable mental representations of visual scenes. They presented sentences such as *"The woman will put the glass onto the table. Then, she will pick up the bottle, and pour the wine carefully into the glass"* versus *"The woman is too lazy to put the glass onto the table. Instead, she will pick up the bottle, and pour the wine carefully into the glass"*. The accompanying visual scene included a woman, a table, a full bottle of wine and an empty wine glass (with the latter two objects depicted on the floor). In the first experiment, the sentence and visual scenes were presented concurrently, however in the second experiment the visual scene was only shown before the sentence began and was replaced by a blank screen at sentence onset. Both experiments revealed increased anticipatory eye movements to the table in the 'moved' condition, and to the glass in the 'unmoved', suggesting they were driven by the mentally updated location of the described objects, rather than their actual locations in the scene. This implies that eye movements are driven by language; comprehenders map the sentence onto a mental representation of the visual scene, independently of the objects' actual locations in the scene (Altmann, 2004).

The dynamic mental representations of events have been explored further by manipulating event-related information about an object's location. Kukona, Altmann and Kamide (2014) presented participants with spoken sentences such as *"The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug. [But first/And then], he will taste the sweetcorn"*. This sentence was accompanied by a visual array containing four container objects (namely, a bowl, jar, pan and jug). Kukona and colleagues observed more eye movements towards the event-appropriate target container following the discourse-final noun sweetcorn. That is, there were more eye movements towards the jar (the goal location) following *'And then…'* and more towards the bowl (the source location) following *'But first…'*. This data clearly shows that listeners continuously track event-related changes and are able to adapt their mental representations of the input accordingly. That is, they are able to update these simulations (future thinking; *'And then'*) as well as backdate them (past thinking; *'But first'*), based on new linguistic information.

Hence, sentence comprehension requires listeners to simulate the unfolding linguistic input in real time. These mental representations are constrained during online analysis by the sentence's event-structure, the selection restrictions of the verb, event-related information and the listener's real world knowledge. That is, listeners incrementally integrate the conceptual properties of language and real world knowledge into a simulation of the event. This continuous process of analysing the linguistic input and simultaneously updating a mental representation of the event is cognitively demanding, as comprehenders must retain a vast amount of information in working memory. Thus far I have shown how TD individuals comprehend spoken events by incrementally mapping the unfolding linguistic input onto a mental simulation of the event in real-time. I now move to discuss online event simulation in individuals with ASD, focusing on the integration of information into a mental simulation of the described event.

Integration deficits in ASD

It has been suggested that the ability to integrate information within a context in order to build a mental simulation of the event is deficient in ASD. This is evident in research that shows ASD children with pragmatic deficits are more likely to be impaired in specific inference making compared to TD children, children with specific language impairments (SLI) and those with pragmatic language impairments (PLI) (Norbury & Bishop, 2002). In order to make inferences one must integrate linguistic information with general knowledge, suggesting an integration deficit in ASD.

Saldaña and Frith (2007) tested whether individuals with ASD are deficient in inference making and in accessing relevant real-world knowledge for in-context language comprehension. They measured the time taken for ASD and TD adolescents to read a question that was either related to physical world knowledge (e.g. *"Can rocks be large?"*) or social world knowledge (e.g. *"Can people cry because they are happy?"*). Critically, the question was preceded by a short vignette, such as (1) or (2) that necessitated an inference.

(1a) The Indians pushed the rocks off the cliff onto the cowboys. The cowboys were badly injured.

(1b) The Indians pushed the cowboys off the cliffs onto the rocks. The cowboys were badly injured.

(2a) Maria had never won a race before. The tears streamed down Maria's face.

(2b) Maria had never lost a race before. The tears streamed down Maria's face.

In vignettes 1a and 2a, the inference that the rocks hurt the cowboys and that Maria was happy primes the question, while in vignettes 1b and 2b the cowboys were injured due to the fall so the size of the rocks is not primed by the inference (similarly Maria is not described being happy, thus the question is not primed). Consequently, TD individuals should read and respond to the question slower following vignettes 1b and 2b than vignettes 1a and 2a as they are not primed. However, this should not be the case for ASD participants if indeed they are impaired in inference making. Interestingly however, both TD and ASD participants read and answered the questions faster when it was primed by the preceding inference and more slowly when it was not primed. That is, both groups were able to make a physical inference that the rocks were large because they cowboys had been hurt by them (1b) and a social inference that Maria was crying with happiness because this was the first time she had one a race (2a). This would suggest that individuals with ASD do activate relevant physical and social world knowledge necessary for bridging inferences and for forming simulations of an event, and do so in a similar time-course as TD individuals.

Nonetheless, eye-tracking measures during bridging inferences reveal that children with ASD show text processing difficulties. In a replication of Saldaña and Frith (2007), Sansosti, Was, Rawson and Remaklus (2013) found that at a behavioural level children with ASD were just as able as TD children at constructing bridging inferences necessary for comprehension of the text. However, the eye movement data suggested that ASD participants had greater difficulty processing the passages compared to TD children. More specifically, the mean total fixation duration on utterances during reading were higher for ASD participants than TD participants, implying that text processing was more demanding for the former group. Thus, while individuals with ASD are clearly able to construct implicit inferences, Sansosti et al. (2013) argue that they have difficulty integrating them into a higher-text simulation. Whilst behavioural data shows that such individuals can activate relevant real world knowledge, there may be a delay integrating this background knowledge into the construction of the mental simulation of the linguistic input online.

To further investigate deficits in processing ambiguous information in context Brock, Norbury, Einav and Nation (2008) recorded eye movements of ASD and TD language-matched adolescents as they listened to constraining sentences similar to those used in Altmann and Kamide (1999) (e.g. *"Joe stroked the hamster quietly"*) and neutral sentences (e.g. *"Sam chose the hamster reluctantly"*). While listening to these sentences participants simultaneously viewed a visual scene depicting four objects. In target present conditions the display included the target (i.e. a hamster), a phonological competitor (e.g. a hammer) and two unrelated distractors. In target absent conditions the display included a phonological competitor of the target word and three unrelated distractors. Participants' task was to press a button if any word in the sentence matched any of the images in the display. Interestingly, Brock et al. observed language-mediated eye movements in the ASD group. That is, like TD individuals, eye movements of ASD participants were affected by the semantic association between the sentence verb (*'stroke'* vs. *'chose'*) and the target object, as well as the phonological overlap between the target word and the competitor object. Both TD and ASD participants exhibited an increase in fixations towards the target object well before the onset of the target word (hamster) when a constraining verb (*'stroke'*) was provided. Furthermore, a phonological effect was observed during the processing of neutral sentences (with a neutral verb such as chose) as both TD and ASD participants showed increased fixations towards the phonological competitor (hammer), which was enhanced in the constraining verb condition. This suggests that ASD individuals, like TD individuals, are able to anticipate an upcoming referent and do so in a comparable time-course to TD individuals. However, it was also found that, irrespective of ASD diagnosis, individuals with poorer language ability showed less sensitivity to sentence context. This suggests a relationship between general language impairment and context-processing difficulties.

In the remainder of this chapter I will present two visual-world eye tracking experiments that examine how individuals with and without ASD integrate the conceptual properties of language with real-world experience in a mental simulation of a spoken event.

The current experiments

The aim of the experiments presented in this chapter is to explore the flexibility of simulations of conceptual spoken language. More specifically, the experiments make use of the visual world paradigm to investigate how individuals with ASD update simulations in real-time and whether they are able to undo these simulations based on new information.

Experiment 5

The aim of Experiment 5 is to establish the degree to which individuals with and without ASD update mental simulations of an event in time based on the unfolding linguistic input. To do so, the same visual world paradigm and stimuli used by Altmann and Kamide (2007) were employed. Participants listened to sentences such as (1) and (2), where the tense of the main verb was manipulated to imply either a future or past event.

(1) *The man will drink all of the beer.*

(2) *The man has drunk all of the wine.*

Each sentence was accompanied by a visual scene, which depicted a man, a full beer glass, an empty wine glass and distractor items (cheese and crackers).

It is predicted that results from TD participants will replicate previous findings, with anticipatory eye movements being restricted to appropriate objects by the associated verb, such that individuals will look towards the full beer glass following *'will drink'* and to the empty wine glass following *'has drunk'*. In contrast, eye-tracking data may reveal processing difficulties for participants with ASD since research suggests such individuals demonstrate greater processing difficulty and a delay in integrating information online (Sansosti, Was, Rawson, Remaklus, 2013). Consequently, impairments in integrating conceptual properties of the linguistic input (i.e. the verb restrictions) with real world knowledge about the agents may be revealed in the eye-tracking of ASD participants. Such individuals may therefore show no or delayed anticipatory eye movements towards the appropriate referent in the visual scene given the unfolding linguistic input.

On the other hand, as I have discussed above, research on sentence processing in context by individuals with ASD is mixed, with some showing comparable processing to TD and some showing impairments. Moreover, the results presented thus far in this thesis suggest that individuals with ASD appear to not only simulate language in the same way as TD individuals, but also utilise the same neurological systems to process contextual information during comprehension (see Chapters 3 and 4). Given this, ASD participants may also show no incremental processing deficits compared to their TD peers in the current study. Such individuals may show real-time mapping of the linguistic input onto a simulation of the described event that is comparable to TD individuals, constructing a simulation constrained by the event structure (i.e. restriction of the verb, *'will drink'* vs. *'has drunk'*) and real world knowledge of the referents. In terms of eye movement findings, we would then expect both groups to elicit more looks to the empty wine glass following *'has drunk'* compared to *'will drink'* and more looks to the full beer glass following *'will drink'* than *'has drunk'*, which would replicate Altmann and Kamide's (2007) findings.

Method

Participants

Participants were 17 adults with ASD (13 males, 4 females, ratio 13:4; *M* Age = 19.76, *SD* Age = 2.22, Age range 18 – 27) and 17 typically developing participants (5 males, 12 females, ratio 5:12; *M* Age = 19.53, *SD* Age = 1.94, Age range 18 – 26), all students at the University of Kent. All participants were native English speakers and none reported any other language or neurological/neurodevelopmental disorder.

ASD students were recruited through the University's Disability and Dyslexia Support Service (DDSS), who forwarded our study information onto eligible students. Individuals in the ASD group were paid for their participation. The TD participants were students of the University of Kent recruited through the School of Psychology's online Research Participant Scheme (RPS) and were awarded course credits or cash for taking part.

All participants completed the same series of assessment measures outlined in Chapter 1. ASD participants scored significantly higher on the number of self-reported autistic traits of the AQ, but there was no difference in full IQ score between the ASD group and TD group. Means for IQ, AQ and the remaining assessments as well as comparison statistics between the two groups, are reported in Table 10.

Table 10. *Assessment test result results, with means and t values for the TD and ASD groups. Standard deviations are noted in parenthesis.*

	TD	ASD	Difference
WAIS			
Full IQ	102.35 (9.29)	108.59 (9.86)	t(16) = -1.71
Verbal IQ	101.94 (8.38)	109.12 (9.71)	t(16) = -2.26*
Performance IQ	102.24 (11.26)	106.47 (12.24)	t(16) = -0.94
TROG	98.65 (7.18)	101.00 (7.69)	t(16) = -0.91
BPVS	109.77 (11.06)	116.77 (10.92)	t(16) = -2.37*
AQ	13.77 (6.53)	29.65 (12.35)	t(16) = -4.1***

*Significant at ***.001 **.01 *.05*

Materials

Thirty-two sentences taken from Altmann and Kamide (2007) were paired with 16 colour images. The tense of each sentence was manipulated such that half depicted an event in the future tense, and half depicted the same event in the past tense, as in examples (1) and (2). The final set of experimental sentences is presented in Appendix E.

(1) "The man will drink the beer."

(2) "The man has drunk the wine."

Each sentence pair was accompanied by a visual scene, thus the sixteen experimental items were made up of two sentence-picture pairs. Visual scenes contained an agent (e.g. a man), the two objects described in the sentence (e.g. the full glass of beer and the empty wine glass) and two distractor items (see Figure 27). All scenes were 900x700 pixels in size, and were presented on a 17 inch colour monitor in 1024 x 768 pixels resolution. The objects were taken from a ClipArt package and a Google Images search and the visual scenes were constructed using Paint Software. Regions of interested corresponded to the two critical objects in the scene (i.e. the empty wine glass and the full beer glass). The different sizes of the different display items means that extending the region of interest beyond the pixels of the object would change the absolute number of fixations recorded, which would impact the data (i.e. more fixations to larger objects). However, as in Altmann and Kamide (2007), predictions are more concerned with changes in bias to look towards one region over another (i.e. to look to one critical object over the other), as opposed to absolute number of fixations.

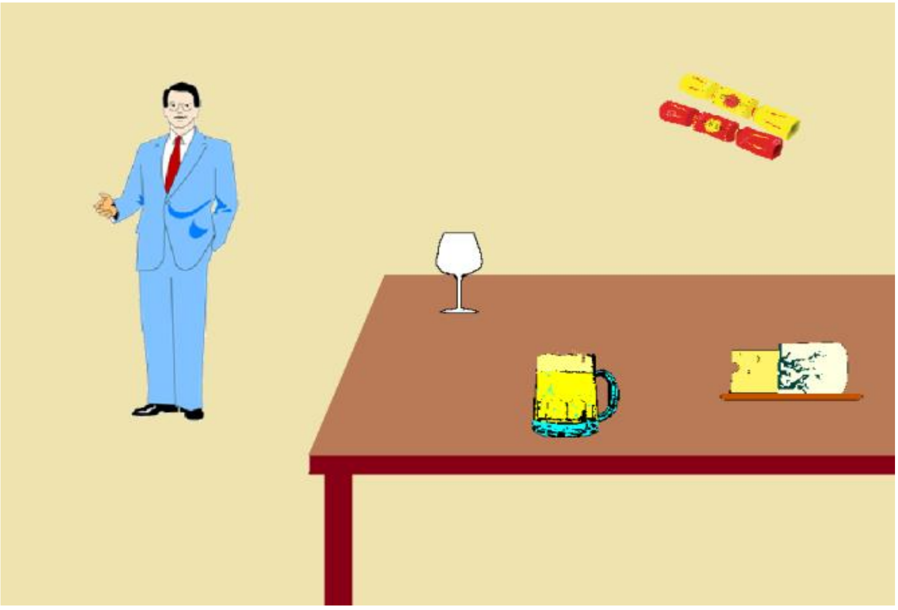


Figure 27. Example visual display.

The experimental items were divided into two lists, with each list containing 16 unique experimental items, eight in each of the two conditions. Participants were randomly assigned to one of these two lists, which ensured that across these lists (and therefore across participants) each item was seen in both conditions. Items were presented in a fixed random order, alongside filler items to distract from the study's purpose.

Filler items were of the same sentence-picture format as experimental items. Sixteen of the filler items included similar pictures to the experimental items but with two potential protagonists, and were described in future tense active sentences (e.g. *"The teenager will ride the rollercoaster."*; pictures included a boy, a young girl, a rollercoaster and a carousel). Eight filler items were accompanied by a passive sentence (e.g. *"The pizza will be eaten by the lady"*; pictures include a woman, a cat, a pizza slice and a bird) and another eight filler items were past tense active sentences (e.g. *"The hiker has climbed the mountain"*; pictures included a hiker, a koala, a mountain and a tree).

All sentences were recorded in a single session by a female native English speaker and were spoken with a normal prosody with an average utterance duration of 1976ms. The auditory files were presented as 44.1 KHz stereo sound clips via speakers connected to the eye-tracker PC. The temporal onsets and offset of critical words '*will/has [verb]*', *'the'* and [*object*] were all hand-coded for every trial, with millisecond resolution using Wavepad sound editing software for later analysis. The mean duration of these words were: *'will/has [verb]'* = 970ms, '*the*' = 122ms, and *[object]* = 337ms. None of these differed between conditions, all t's < 1.

Design

The experiment employed a 2(Group: TD vs. ASD) x 2(Tense: past vs. future) mixed design. The two tense conditions were manipulated within participants, such that participants saw both past and future tense sentence-picture items. The proportion of trials on which participants fixated the critical objects (i.e. the full beer glass or the empty wine glass) was the DV and was measured at three key points (the onset of '*will/has'*, *'the'* and *[object]*) to provide an indication of participants' anticipation of reference to these objects.

Procedure

Participants sat in front of a colour monitor while eye movements were recorded from the right eye using an SR Research EyeLink 1000 eye-tracker (viewing was binocular), running at 1000 Hz sampling rate. Distance from the screen was kept constant at 60cm for all participants using a fixed chin rest. Eye-tracking was recorded from the participants' dominant eye. Participants were told they would be shown images on a screen, accompanied by a spoken sentence, presented through the loudspeaker. Their task was to listen to these sentences whilst simultaneously viewing the accompanying visual scene.

The experiment was controlled using Experiment Builder software. Each trial began with a black fixation point in the centre of the screen to control for ocular drift. Following successful fixation on this point, images were presented on screen for 1000ms before the related auditory sentence was initiated. Images remained on screen for a total of 5000ms, with the corresponding sentence ending approximately two seconds before the end of the trial. The experiment was divided into two blocks with 24 trials in each block. The eye- tracker was calibrated and validated according to standard EyeLink nine-point calibration procedure at the start of the experiment and was recalibrated midway through the study to correct for any drift in eye movements. This procedure took about half a minute and the entire experiment took approximately 15 minutes to complete.

Results

Eye movements that were initiated during the sentence were processed according to the relevant sound onsets on a trial-by-trial basis. The spatial coordinates of fixations were mapped onto appropriate interest areas, corresponding to the two critical objects in the visual scene (e.g. the full beer glass and the empty wine glass). If a fixation was located within 20 pixels around an object's perimeter, it was coded as belonging to that object, otherwise, it was coded as background. Eye movements that landed beyond the boundaries of the screen were eliminated from analysis.

To visualise the data, the proportion of trials on which participants made at least one fixation on the past tense object (e.g. the empty wine glass) and the future tense object (e.g. the full beer glass) were plotted for each group as a function of time (i.e. the number of trials with at least one fixation on an area of interest divided by the total number of trials). The resulting plots are shown separately for the past tense object (the empty wine glass, Figure 28) and the future tense object (the full beer glass, Figure 29), and illustrate the onset of critical words as the auditory sentence progressed. For ease of exposition, I will refer to the example sentence, *"The man will drink/has drunk all of the beer/wine"* when describing results.

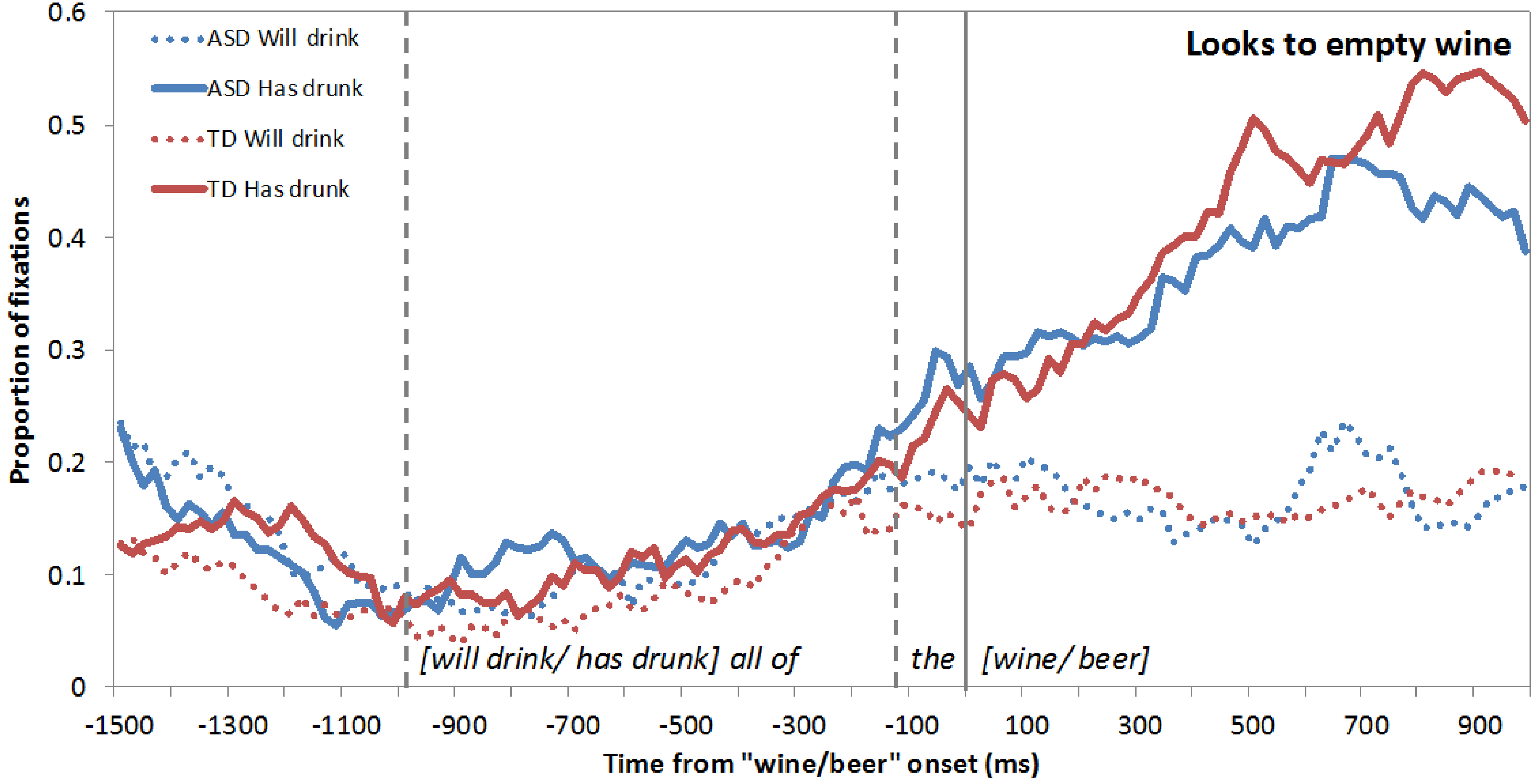


Figure 28. Time course of the mean proportion of fixations to the empty wine glass for each tense condition (past, 'has drunk' and future 'will drink') for TD and ASD groups. Note that the vertical lines indicate the average onset of words in the target sentence, as labelled.

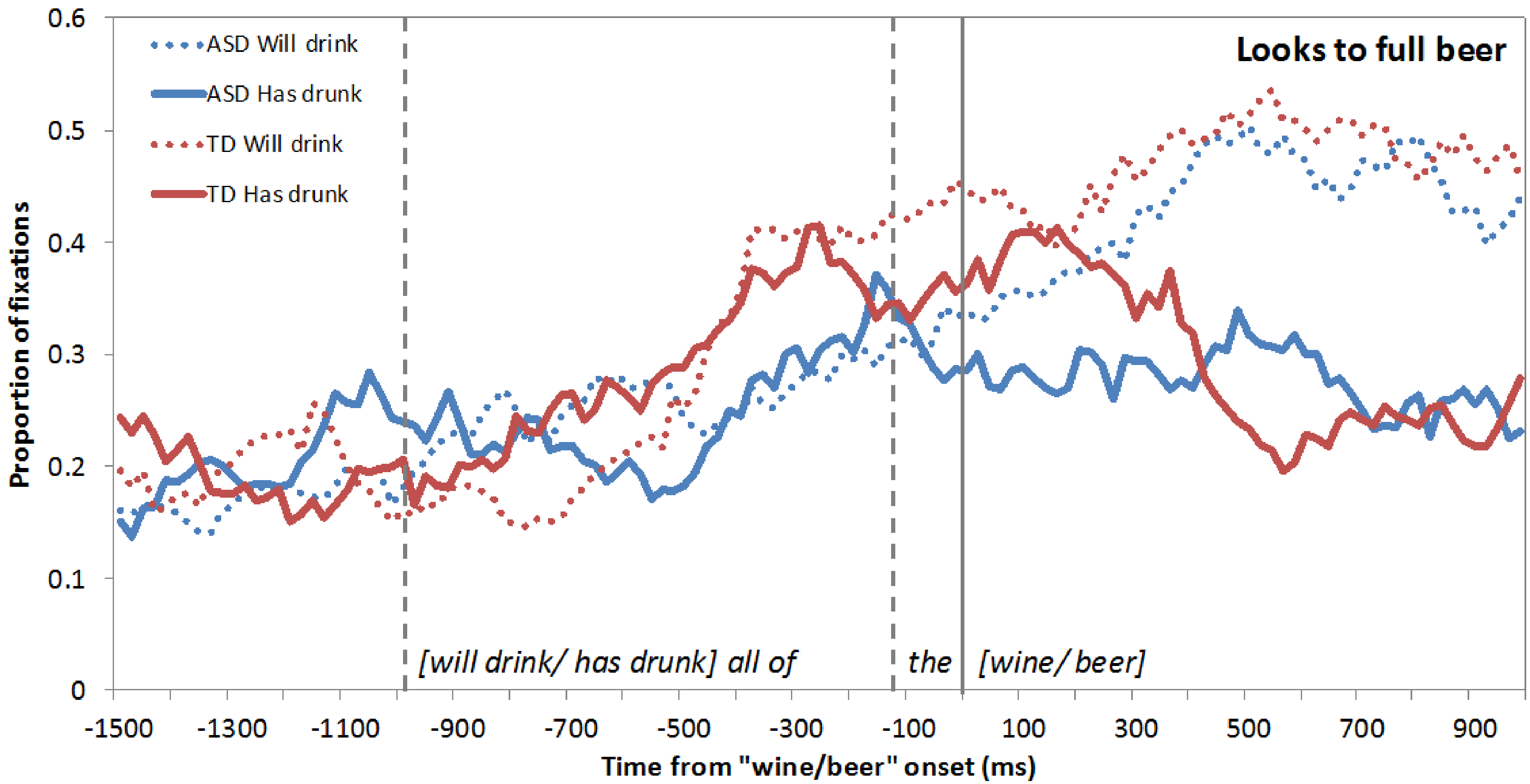


Figure 29. Time course of the mean proportion of fixations to the full beer glass for each tense condition (past, 'has drunk' and future 'will drink') for TD and ASD groups. Note that the vertical lines indicate the average onset of words in the target sentence, as labelled.

For statistical analysis, we examined the proportion of trials on which participants made a fixation on either the empty wine glass or the full beer glass at three points within the spoken sentence: at the onset of *'will/has'*, at the onset of *'the'* and at the onset of *'wine/beer'*. These three time-points were defined on a trial-by-trial basis. The proportion score for each time-point was calculated for each participant by dividing the number of trials on which participants made at least one fixation on each area of interest (i.e. the empty wine glass or the full beer glass) by the total number of trials in that condition. For example, if a participant was fixating the wine glass at the onset of *'will'* on five out of the eight trials in that condition, their proportion score would be 0.625. The resulting mean proportions at each time-point, for each condition and group, are shown in Figures 30 and 31.

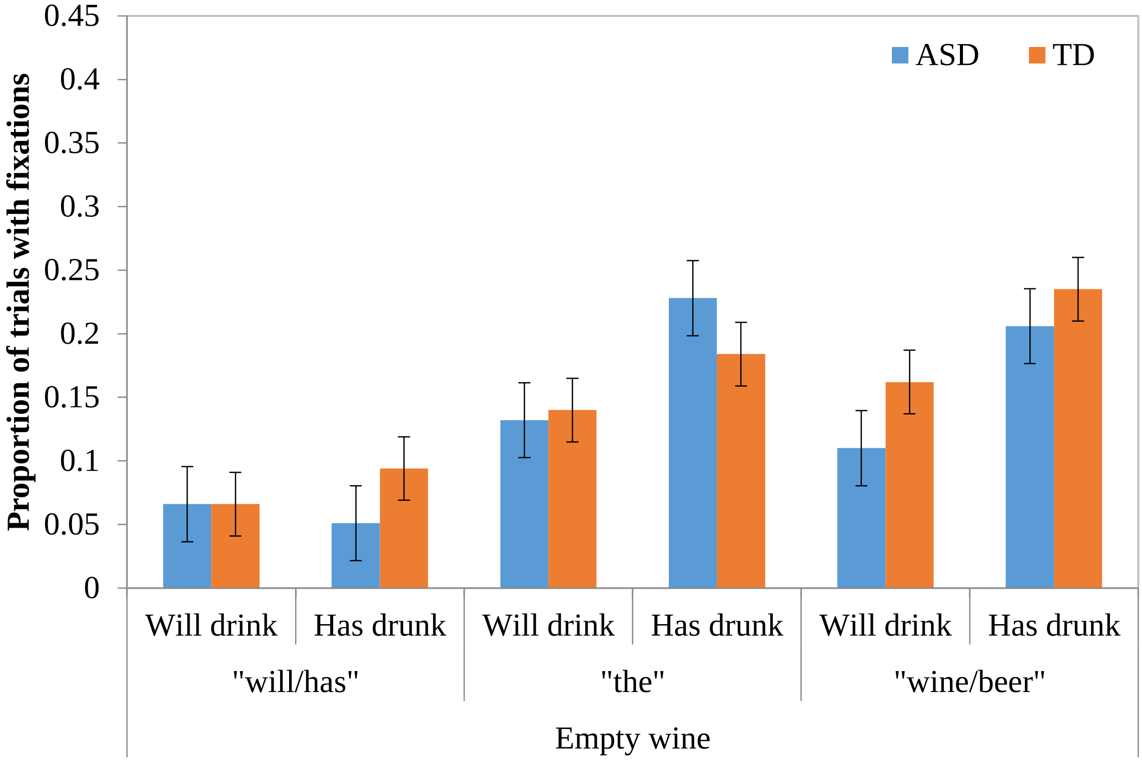


Figure 30. Mean proportion of trials with fixations on the empty wine glass at the onset of 'will/has', the onset of 'the' and the onset of 'wine/beer'. Error bars show standard errors.

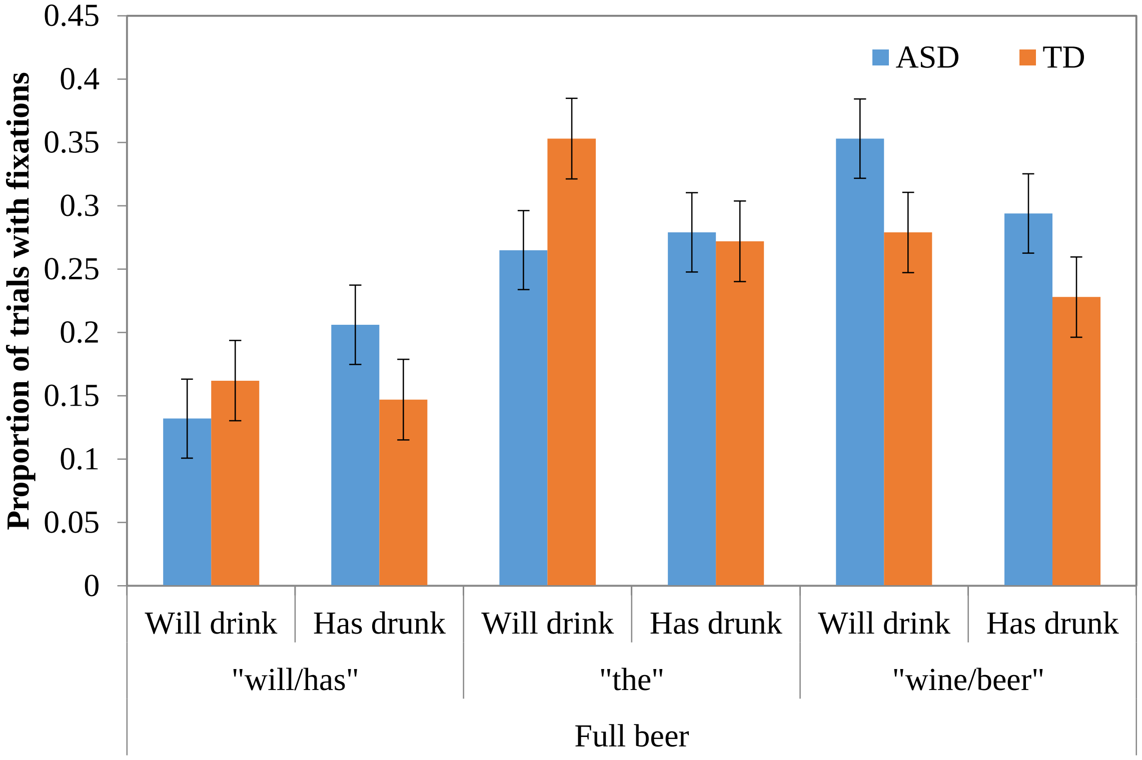


Figure 31. Mean proportion of trials with fixations on the full beer glass at the onset of 'will/has', the onset of 'the' and the onset of 'wine/beer'. Error bars show standard errors.

Eye movements were analysed separately at each time-point for each of the two target objects using linear mixed effect logit models. This method was chosen over ANOVA, which has been used in the previous Chapters of this thesis, because linear models are better suited to eye movement data which involves predicting categorical outcomes, whereas ANOVA is better suited to predicting continuous data (e.g. predicting reaction times) (Altmann & Kamide, 2007). Participants are treated as a random effect in traditional analysis methods such as ANOVA, because psycholinguistic researchers are not interested in the experimental effects in those individuals completing the experiment only, but on all language users. A similar logic applies to the linguistic materials used; the stimuli does not exhaust all examples of language. Consequently, factors of human speech should also be modelled as a random factor (Baayen, Davidson & Bates, 2008). It is for this reason that linear models have established themselves as the optimal means of analysing visual world data, and are therefore the most suitable analyses for the current study.

Analyses were conducted using the lmer function in the lme4 package (Bates & Maechler, 2010) using R (version 3.2.0, R Development Core Team, 2015). Participants and items were entered into a single model as random effects and condition (will vs. has) and group (TD vs. ASD) as fixed effects. Trials were binary coded for each time-point (i.e. at the onset of *'will/has'*, at the onset of *'the'* and at the onset of *'wine/beer'*) as either having a fixation (fixation = 1), or not having a fixation (fixation = 0) on the region of interest. This value was used as the dependent variable. The two levels of each fixed factor were coded using ANOVA-style contrasts (-.5 vs. .5, respectively). Models using the fixed effects as "maximal" random slopes on the by-subject and by-item random effects were run (Barr, Levy, Scheepers & Tily, 2013), as justified by the experimental design (DV ~ Condition:Group + (1 + Condition:Group | Item) + (1 + Condition:Group | Participant). However, because the full maximal model did not converge in any of our models, the model was re-fitted until the model converged by removing the random slopes from the by-subject and by-item random effects that contributed the least variance. For all tests a significance level of 5% was used. Results are reported in Table 11.

Table 11. *Parameter estimates for each target object at each time point. (For analysis of fixations to the empty wine glass, random slopes included were verb on participants at the onset of 'will/has' and 'the' and verb on items and participants at the onset of 'wine/beer'. For analysis of fixations to the full beer glass, random slopes included were verb on participants at the onset of 'will/has' and 'the' and verb on items and participants at the onset of 'wine/beer'.)*

		Empty wine		Full beer	
		Est	Z	Est	Z
At onset of 'will/has'	Intercept	2.8	10.65	2.00	7.00
	Verb	0.15	0.34	0.28	1.01
	Group	0.34	0.91	0.1	0.31
	Verb x Group	0.68	0.92	0.7	1.41
At onset of 'the'	Intercept	1.76	7.87	1.01	4.78
	Verb	0.52	2.21*	0.2	0.97
	Group	0.11	0.47	0.21	0.92
	Verb x Group	0.36	0.75	0.47	1.14
At onset of 'wine/beer'	Intercept	1.72	8.27	1.00	5.27
	Verb	0.69	2.23*	0.24	1.13
	Group	0.32	1.37	0.37	1.81•
	Verb x Group	0.29	0.54	0.04	0.1

•p < .1; *p < .05; **p < .01; ***p < .001.

Analyses at the onset of *'will/has'* showed no significant differences in fixation proportions on either object as a function of verb condition. However, at the onset of *'the'*, participants were significantly more likely to fixate the empty wine glass following *'has drunk'* than *'will drink'*. In contrast, there was no difference in the proportion of fixations to the full beer glass at the onset of *'the'* following *'will drink'* than *'has drunk'*, and did not reach significance either as an effect of group or verb or as a group:verb interaction. To rule out performance of the ASD group masking the effect in the TD group at the onset of *'the'*, a post hoc analysis was conducted, but revealed only a numerical preference for TD participants to fixate the full beer glass, which did not reach statistical significance. At the onset of *'wine/beer'*, participants continued to make more fixations on the empty wine glass following *'has drunk'* than *'will drink'*, and showed an overall trend towards a greater probability of fixating the full beer glass following *'will drink'* than *'has drunk'*, however this bias did not reach significance. There was also a marginal group effect at the onset of *'wine/beer'*, such that participants in the ASD group showed a higher proportion of fixations on the full beer glass than participants in the TD group. Importantly, the verb by group interaction was not significant at any time window or on either object, suggesting that both TD and ASD groups predicted reference according to past and future verbs in comparable ways.

Discussion

The aim of Experiment 5 was to investigate whether and how individuals with and without ASD update mental simulations in real-time. During a visual world task, participants heard sentences such as *"The man will drink all of the beer"* versus *"The man has drunk all of the wine"* while viewing a concurrent visual scene depicting a man, a full beer glass, an empty wine glass and two distractor items. Previously, it has been found that TD individuals are able to anticipate upcoming referents using world knowledge about object affordances, with more saccades towards the empty wine glass in the past tense *'has drunk'* condition and more saccades towards the full beer glass in the future tense *'will drink'* condition before the onset of the final noun (i.e. *'wine/beer'*) (Altmann & Kamide, 2007). Of interest in Experiment 5 was whether individuals with ASD are also able to anticipate upcoming referents and whether they integrate the unfolding linguistic input and real world knowledge into a simulation of the event online within the same time-course as TD individuals.

Results revealed no differences in anticipatory eye movements between TD and ASD participants at three locations in the sentence: at the onset of *'will drink/has drunk'*, at the onset of *'the'* and at the onset of *'wine/beer'* in both the past (*'has drunk'*) and future (*'will drink'*) tense conditions. More specifically, Altmann and Kamide's (2007) findings that comprehenders anticipate the upcoming referent were partially replicated by both the TD and ASD groups. At the onset of the verb phrase (*'will drink/has drunk'*) there was no bias to look towards one object over the other (i.e. to look towards the empty wine glass or the full beer glass) in either condition, since verbal information about the upcoming events has not yet been uttered. However, from the onset of *'the'*, participants showed more eye movements to the empty wine glass following *'has drunk'* than *'will drink'*. Thus, by the onset of *'the'* both TD and ASD participants had inferred that the object to be referred to next in the unfolding event was drinkable, but had already been drunk (i.e. the empty wine glass). Moreover, this anticipation was constrained by the tense restriction of the preceding verb and by real world knowledge of the items depicted in the concurrently presented visual scene. In the *'will drink'* condition however, a trend to preferentially fixate the full beer glass following *'will drink'* compared to *'has drunk'* did not reach significance in either group, either at the onset of *'the'* or at the onset of *'wine/beer'*.

The findings suggest that like TD individuals, ASD individuals demonstrated anticipatory eye movements directed towards the empty wine glass or full beer glass as a function of the verb tense. That is, ASD individuals are just as able to predict references according to the conceptual properties of spoken language. Moreover, individuals with ASD are equally sensitive to object affordances as TD individuals when comprehending an event. Anticipatory eye movements are thought to reflect more than just what will be referred to next, but instead reflect a system that appreciates the selection restrictions of the verb as well as real world knowledge regarding objects described in the event (Altmann & Kamide, 2007).

In the current study both TD and ASD participants showed a bias to fixate the empty wine glass at the onset of *'the'* following *'has drunk'* because both groups had an understanding that according to the verb the object to be referred to next is both drinkable (satisfying the verb restriction) and was no longer depicted in the visual world (real world knowledge). The results therefore suggest that ASD individuals build a mental simulation of an event online, as the linguistic input unfolds, that is comparable to that constructed by TD individuals. Likewise, they update these simulations incrementally according to the context by integrating the conceptual properties of the utterances with their real world knowledge, suggesting individuals with ASD do not experience a deficit with inferencing as previously reported (Norbury & Bishop, 2002; Sansosti, Was, Rawson & Remaklus, 2013).

Furthermore, Experiment 5 provides further support for Brock et al.'s (2008) observation of language-mediated eye movements in ASD. Recall that Brock et al. found that eye movements are sensitive to the semantic association between the sentence verb and target object. When hearing sentences such as *"Joe stroked the hamster quietly"* versus *"Sam chose the hamster quietly"* eye movements towards the target object (hamster) were greater for both TD and ASD participants well before the onset of the target word when a constraining verb (stroke) was provided. Interestingly, they also found that irrespective of ASD diagnosis, individuals with lower language scores showed reduced sensitivity to sentence context. The ASD participants in the current study showed no language deficits in comparison to TD participants (as confirmed by their demographics in Table 11).

Consequently, it could be argued that insensitivity to linguistic context is directly associated with language impairment rather than the general social communication deficits seen in ASD (see Brock et al, 2008 for discussion), thus ASD participants in the current study were able to successfully process the event in context and online as a result of intact language ability. Of interest in future research would be to assess individuals with poor language who do and do not have a diagnosis of ASD to attempt to tease apart the finer processes required to simulate events in real-time.

Having established that individuals with ASD are able to incrementally simulate events during language comprehension, the aim of Experiment 6 is to investigate the flexibility of these simulations. In Experiment 6 I explore the flexibility of mental simulations of spoken events and examine for the first time whether individuals with ASD can effectively undo simulations based on new information in the same way as TD individuals.

Experiment 6

The aim of Experiment 6 is to explore how individuals with and without ASD track event-related location changes. More specifically, I am investigating whether individuals with ASD are able to update and keep track of mental simulations of multiple episodic events in real-time and how they undo these simulations based on incoming information. This study utilised the same visual world paradigm and stimuli developed by Kukona, Altmann and Kamide (2014). Participants listened to discourses such as (1) and (2) while concurrently viewing a visual display depicting the four container objects mentioned in the discourse (i.e. a bowl, a jar, a pan and a jug).

(1) *The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug.*

(2a) *But first he will taste the [sweetcorn/gravy]*.

(2b) *And then he will taste the [sweetcorn/gravy]*.

In (1) the movement of two critical referents (i.e. *sweetcorn/gravy*) was described. In (2), *'But first'* refers to the source location of the discourse-final noun before the event occurred (i.e. before the sweetcorn/gravy was moved) and *'And then'* refers to the goal location after the event.

It is predicted that results from TD participants will replicate Kukona, Altmann and Kamide's (2014) findings. That is, it is expected that TD participants will preferentially fixate the context-relevant target container at the onset of the discourse-final noun (*sweetcorn/gravy*). It is also predicted that TD participants will show the two forms of competition effects observed by Kukona, Altmann and Kamide (2014). That is, TD participants will be more likely to fixate the container not directly referred to but associated with the discourse-final noun (the object-competitor) than the other distractors, and will be more likely to fixate the container that played the same role as the target container (the role-competitor) than the unrelated-distractor container at the onset of the discourse-final noun.

In relation to predictions regarding the ASD group, given the findings of Experiment 5 that individuals with ASD are able to simulate the conceptual properties of language online in the same way as TD individuals (and previous chapters), it could be that the two groups do not differ in terms of anticipatory eye movements in the current study. That is, individuals with ASD may also show the ability to track event-related location changes across multiple episodic events in real-time. If this is the case, ASD participants should also show a bias to fixate the context-relevant target container. They should also experience relevant interference from the role-competitor (i.e. the container that plays the same role as the target container, but is not associated with the discourse-final noun) and the object-competitor (i.e. the container associated with the target but not directly referred to).

More specifically, I predict that ASD participants will be able to track event-related location changes in the *'And then'* condition, as Experiment 5 showed that ASD individuals were able to simulate a spoken event in context in the same way as TD individuals. Of particular interest is whether ASD individuals are able to undo their mental simulation of the event described in the discourse following *'But first'*. In this instance, comprehenders must not only track event-related changes, but appreciate that the event has not yet occurred. The studies presented in this thesis thus far have shown that individuals with ASD are able to process written and spoken language in context and utilise the same neurological systems as TD individuals. Given this, it may be that in the current study the ASD group show no impairment in undoing a mental simulation in comparison to the TD group.

Method

Participants

Participants were 17 adults with ASD (13 males, 4 females, ratio 13:4; *M* Age = 19.76, *SD* Age = 2.22, Age range 18 – 27) and 24 typically developing participants (4 males, 13 females, ratio 4:13; *M* Age = 19.53, *SD* Age = 1.94, Age range 18 – 26), all students at the University of Kent. All participants were native English speakers and none reported any other language or neurological/neurodevelopmental disorder.

ASD students were recruited through the University's Disability and Dyslexia Support Service (DDSS), who forwarded our study information onto eligible students. Individuals in the ASD group were paid for their participation. The TD participants were students of the University of Kent recruited through the School of Psychology's online Research Participant Scheme (RPS) and were awarded course credits.

All participants completed the same series of assessment measures outlined in Chapter 1. ASD participants scored significantly higher on the number of self-reported autistic traits of the AQ, but there was no difference in full IQ score between the ASD group and TD group. Means for IQ, AQ and the remaining assessments as well as comparison statistics between the two groups, are reported in Table 12.

Table 12. *Assessment test results, with means and t values for TD and ASD groups. Standard deviations are noted in parenthesis.*

	TD	ASD	Difference
WAIS			
Full IQ	102.35 (9.29)	108.59 (9.86)	t(16) = -1.71
Verbal IQ	101.94 (8.38)	109.12 (9.71)	t(16) = -2.26*
Performance IQ	102.24 (11.26)	106.47 (12.24)	t(16) = -0.94
TROG	98.65 (7.18)	101.00 (7.69)	t(16) = -0.91
BPVS	109.78 (11.06)	116.77 (10.92)	t(16) = -2.37*
AQ	15.06 (5.96)	29.65 (12.35)	t(16) = -4.95***

*Significant at ***.001 **.01 *.05*

Materials

Forty-eight experimental discourses taken from Kukona, Altmann and Kamide (2014) were paired with 48 colour visual arrays. Discourses were made up of two sentences. The first sentence described the movement of two critical objects (sweetcorn/gravy) between containers. The second sentence either continued the temporal trajectory of described events (*'And then'*) thus referring to the goal location, or prompted participants to mentally undo described events (*'But first'*) thus referring to the source location. The discourse-final object in each item was one of the two critical objects mentioned in the first sentence (i.e. *sweetcorn/gravy*) meaning participants could not anticipate which item would be referenced. To further control for anticipatory eye movements, the crossing of movement was balanced such that items were described as moving from a source location to a goal location (1a) or into the goal location from the source location (1b). This resulted in each sentence having eight forms. Note that for analysis we averaged across the two discourse-final objects and two directions of movement (these manipulations were solely included to eliminate predictive patterns in the items).

(1a) *The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug.*

(1b) *The boy will pour the sweetcorn into the jar from the bowl, and he will pour the gravy into the jug from the pan.*

(2a) *And then he will taste the [sweetcorn/gravy].*

(2b) *But first he will taste the [sweetcorn/gravy].*

Each discourse was accompanied by a visual display. Visual displays depicted four opaque containers (e.g. a bowl, a jar, a jug and a pan), with each container positioned in one quadrant of the display (see Figure 32). The four containers represented the target location, the object-based competitor location, the role-based competitor, and the unrelated distractor location. The target location was the context-relevant container, based on the discourse-final object (i.e. the jar following 1a and 2a). The object-based competitor location referred to the container that was associated with the discourse-final object, but was the competing location (i.e. the bowl following 1a and 2a). The role-based competitor location referred to the container than was unrelated to the discourse-final object, but played the same role in the described transfer as the target location (i.e. the jug following 1a and 2a). Finally, the unrelated distractor location was the container that was both unrelated to the discourse-final object and did not play the same role in the described transfer as the target container (i.e. the pan following 1a and 2a). Note that the objects referred to in the discourses (e.g. sweetcorn/gravy) was never depicted in the visual arrays. The container objects were taken from a ClipArt package and Google Image search and the visual arrays were constructed using Paint Software. The arrays were 900x900 pixels in size, and were presented on a 17 inch colour monitor in 1024 x 768 pixels resolution.

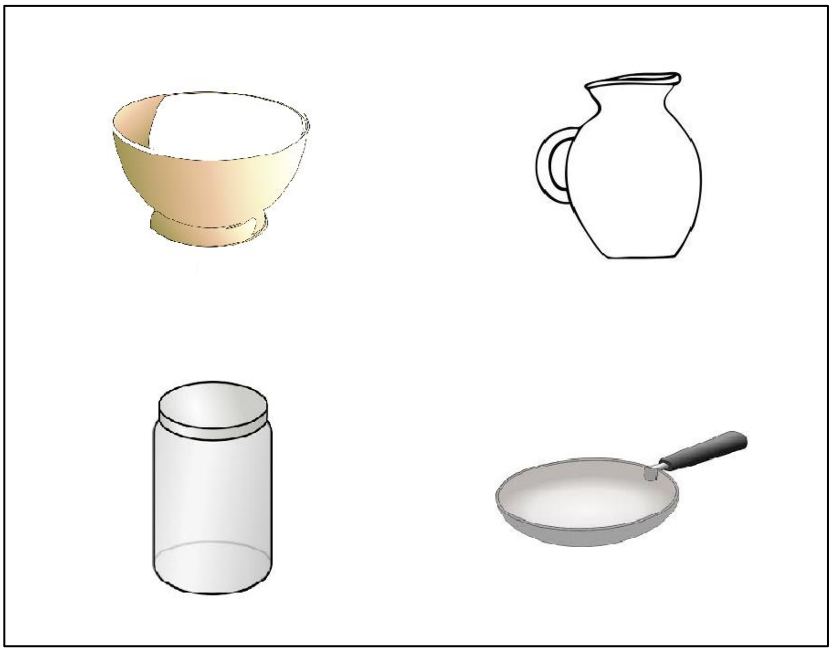


Figure 32. Example visual display.

The experimental items were divided into eight lists, with each list containing 48 unique experimental items, six in each of the eight discourse forms. Participants were randomly allocated to one of these eight lists, to ensure that across the lists (and therefore across participants) each item appeared in all eight conditions. Items were presented to participants in a fixed random order.

All sentences were recorded in a single session by a female native English speaker and were spoken with a normal prosody with an average total duration of 10,374ms. The auditory files were presented as 44.1Hz stereo sound clips via speakers connected to the eye-tracker PC. The temporal onset and offset of the discourse-final noun (e.g. *'sweetcorn'*) was handed-coded for every trial, with millisecond resolution using Wavepad sound editing software for later analysis. The mean duration of this word was 521ms.

Design

The experiment employed a 2(Group: TD vs. ASD) x 2(Conjunction: And then vs. But first) mixed design. The conjunction was manipulated within participants. The proportion of trials on which participants fixated each of the four locations was the DV and was measured at four key points in the critical second sentence: (1) during the final-discourse object (e.g. *'sweetcorn'*) (2) at the offset of the discourse-final object (e.g. '*sweetcorn^*') (3) the 500ms following the discourse-final object offset, and (4) the 500ms between 500ms and 1000ms after discourse-final object offset.

Procedure

As in Experiment 5, participants sat in front of a colour monitor while eye movements were recorded from the right eye using an SR EyeLink 1000 eye-tracker (viewing was binocular), running at 1000 Hz sampling rate. Distance from the screen was kept constant at 60cm for all participants using a fixed chin rest. Eye-tracking was recorded from the participants' dominant eye. Participants were told they would be shown images on a screen, accompanied by a spoken discourse, presented through the loudspeaker. Their task was to listen to these sentences whilst simultaneously viewing the accompanying visual scene.

The experiment was controlled using Experiment Builder software. Each trial began with a black fixation point in the centre of the screen to control for ocular drift. Following successful fixation on this point, images were presented on screen for 1000ms before the related auditory discourse was initiated. The trial automatically terminated after 15000ms, meaning that corresponding sentences ended approximately two seconds before the end of the trial. The experiment was divided into four blocks, with 12 trials in each. The eye-tracker was calibrated and validated according to standard EyeLink nine-point calibration procedure at the start of the experiment and was recalibrated midway through the study to correct for any drift in eye movements. This procedure took about half a minute and the entire experiment took approximately 30 minutes to complete.

Results

Eye movements that were initiated during the sentence were processed according to the relevant sound onsets, defined on a trial-by-trial basis. The spatial coordinates of fixations were mapped onto the appropriate interest areas, corresponding to the four container objects in the visual array (e.g. bowl, jar, jug and pan). If a fixation was located 20 pixels around an object's perimeter, it was coded as belonging to that object; otherwise, it was coded as background. Eye movements that landed beyond the boundaries of the screen were eliminated from analysis.

To visualise the data, the proportion of trials on which participants made at least one fixation on each container object were plotted for each group as a function of time (i.e. the number of trials with at least one fixation on an area of interest divided by the total number of trials). The resulting plots are shown separately for *'And then'* (Figure 33) and *'But first'* (Figure 34) separately for the TD group and the ASD group. The plots illustrate the onset of critical *'And then/But first…'* sentence, with the solid line marking the onset of the discourse-final object. For ease of exposition, I will refer to the example sentence, *"The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug. And then/But first he will taste the sweetcorn."* when describing results.

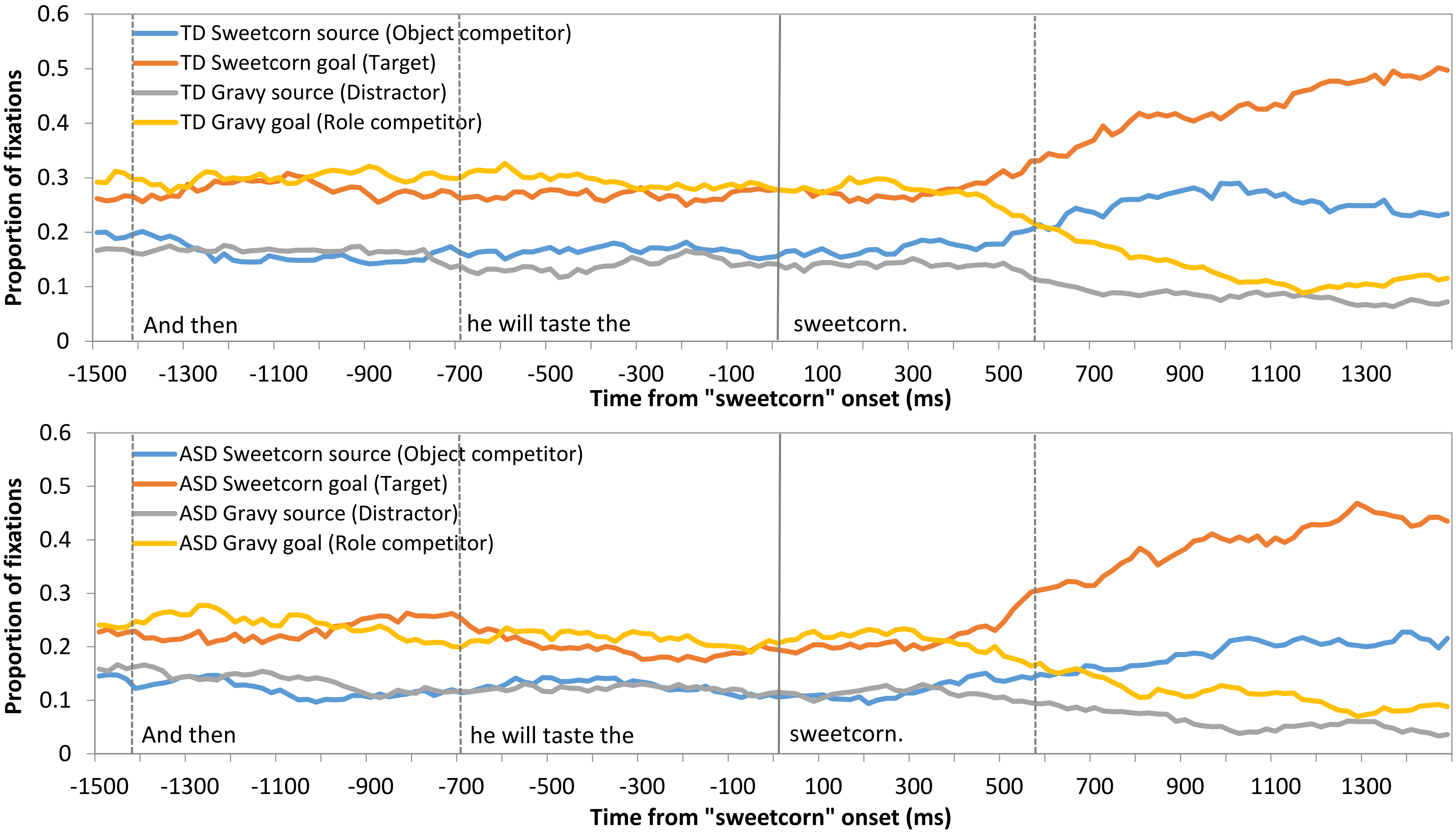


Figure 33. Time course of the mean proportion of fixations to each container object as the critical 'And then...' sentence unfolds for the TD group (top) and the ASD group (bottom). Note that the vertical lines indicate the average onset of words in the critical sentence, as labelled and the solid vertical line indicates the onset of ‘sweetcorn’.

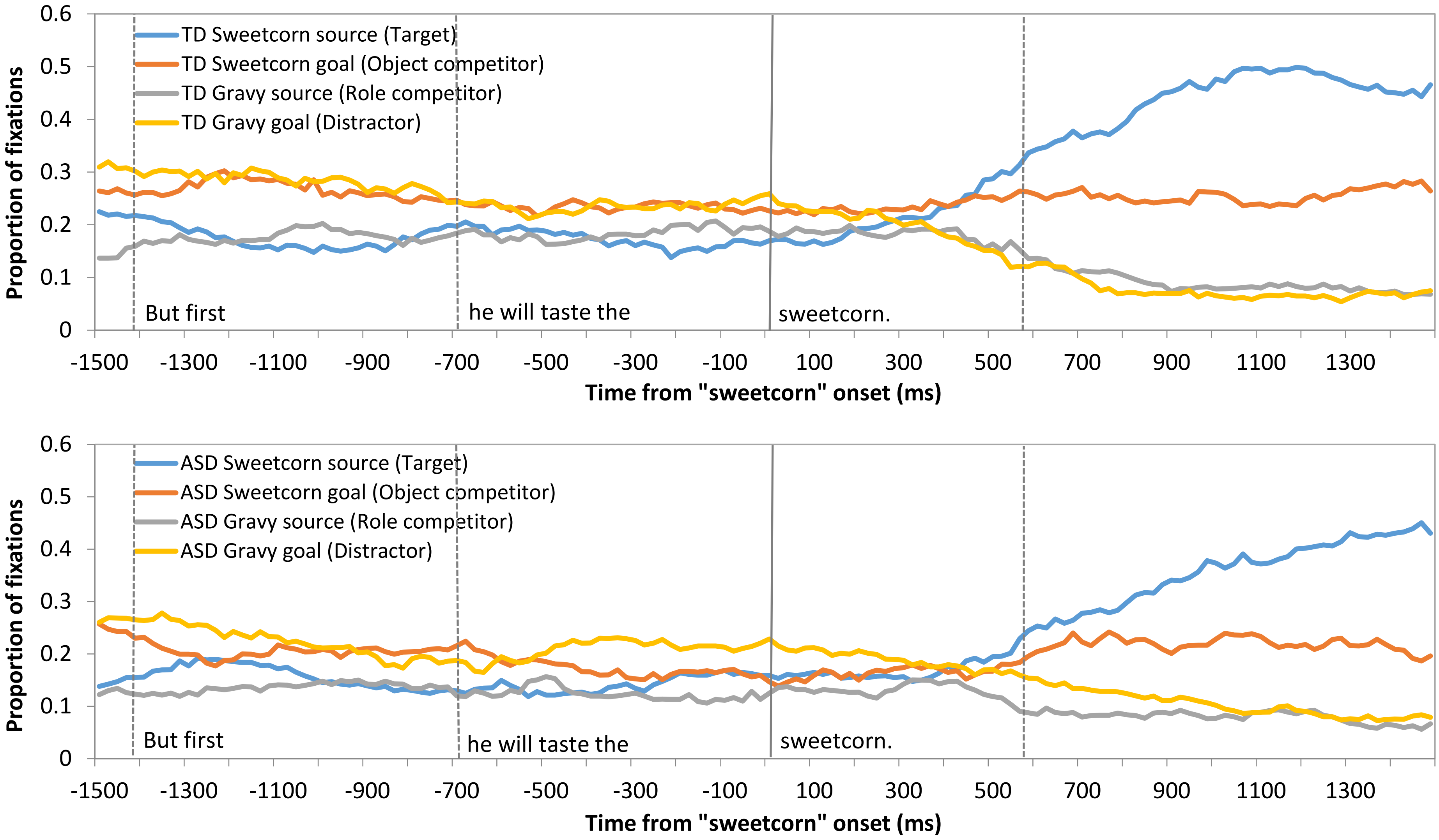


Figure 34. Time course of the mean proportion of fixations to each container object as the critical But first...' sentence unfolds for the TD group (top) and the ASD group (bottom). Note that the vertical lines indicate the average onset of words in the critical sentence, as labelled and the solid vertical line indicates the onset of 'sweetcorn'.

For statistical analysis, we examined the proportion of trials on which participants made a fixation on each container object at four positions in the second critical sentence (beginning *'And then…'* or *'But first…'*): (1) during the final-discourse object (e.g. '*sweetcorn'*) (2) at the offset of the discourse-final object (e.g. *'sweetcorn^'*) (3) the 500ms following the discourse-final object offset, and (4) the 500ms between 500ms and 1000ms after discourse-final object offset. As in Experiment 5, the proportion value for each time-point was calculated for each participant by dividing the number of trials on which participants made at least one fixation on each area of interest (i.e. the four containers) by the total number of trials in that condition. The resulting mean proportions at each time-point, for each condition and group, are show in Figures 35 & 36.

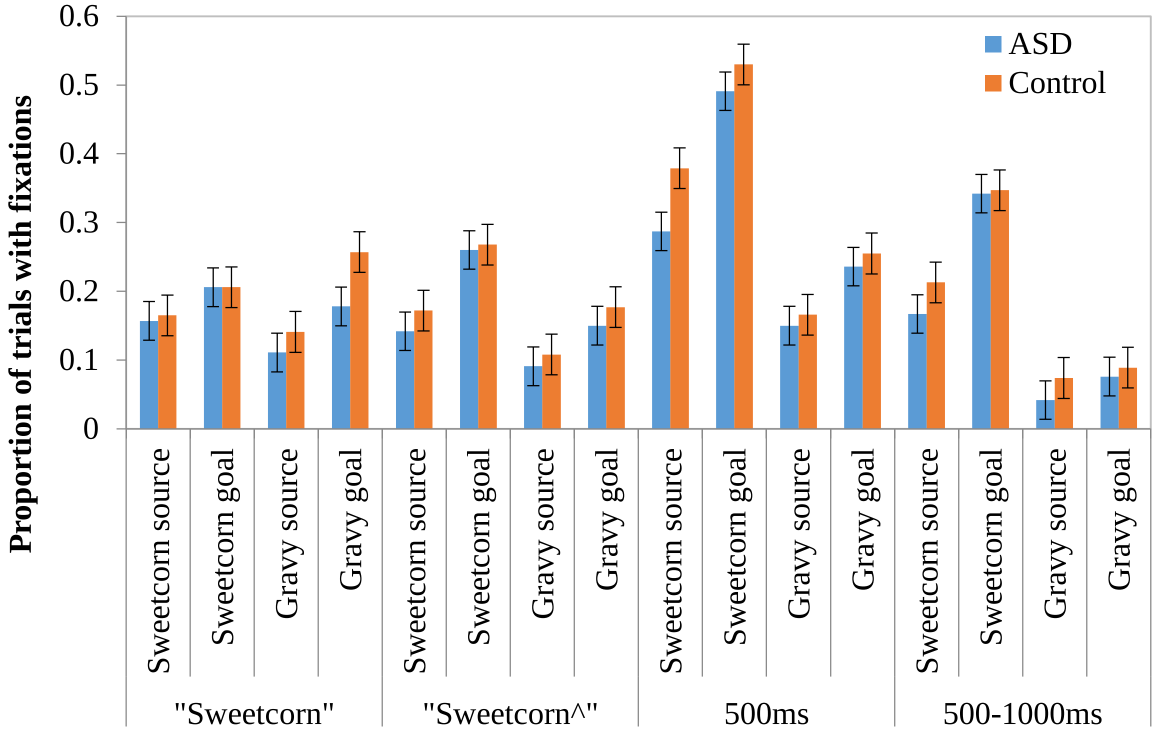


Figure 35. Mean proportion of fixations for 'And then' on each of the four container objects during sentence-final 'sweetcorn', at the offset of 'sweetcorn', 500ms following the offset of the discourse final noun, and the time between 500ms and 1000ms after discourse final noun offset. Error bars show standard errors.

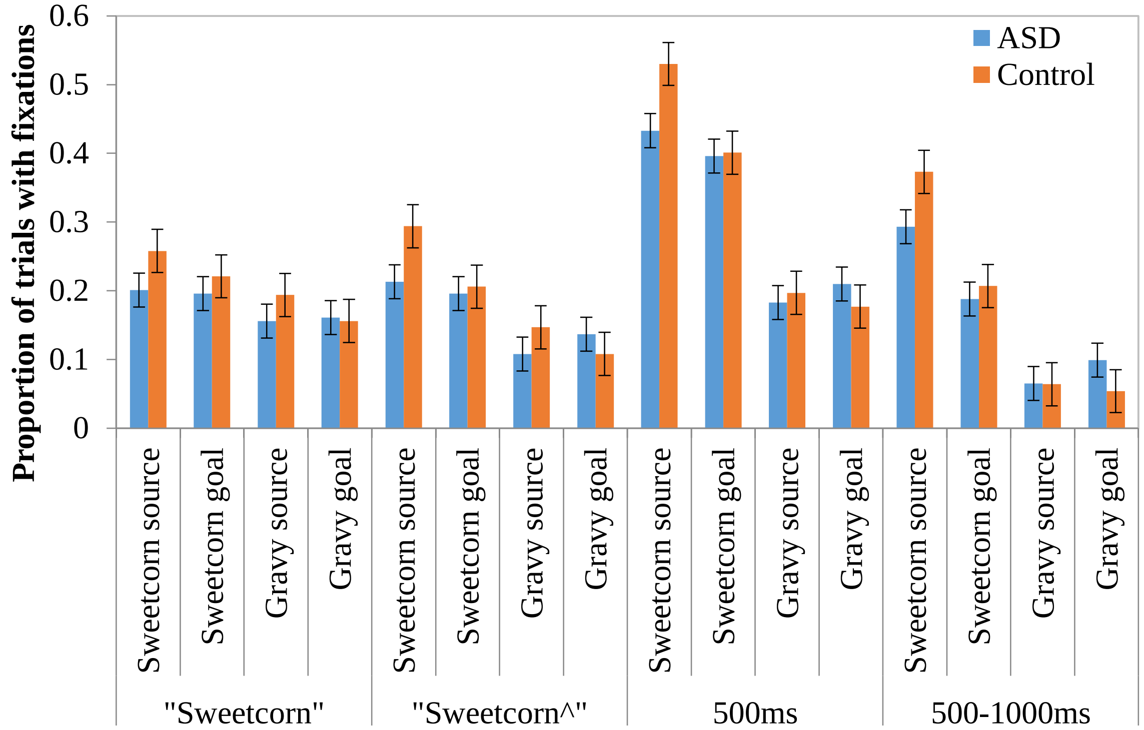


Figure 36. Mean proportion of fixations for 'But first' on each of the four container objects during sentence-final 'sweetcorn', at the offset of 'sweetcorn', 500ms following the offset of the discourse final noun, and the time between 500ms and 1000ms after discourse final noun. Error bars show standard errors.

Eye movements were analysed separately at each time-point for each of the four containers using mixed effect logit models, justification for which is discussed in Experiment 5 above. Analyses were conducted using the lmer function in the lme4 packages (Bates & Maechler, 2010) using R (version 3.2.0, R Development Core Team, 2015). As in Kukona et al., six pairwise comparisons were performed for each time-region, between the sweetcorn source, sweetcorn goal, gravy source, and gravy goal, for both *'But first'* and *'And then'* sentence contexts. Trials were binary coded for each of the four time-points as either having a fixation (fixation = 1), or not having a fixation (fixation = 0) on the region of interest. This was used as the dependent variable. Thus, we submitted eye movements (i.e., for two containers at a time) to 1-factor analyses with container type and group (TD vs. ASD) as fixed effects, and random intercepts and slopes by participants and items. The two levels of each fixed factor were coded using ANOVA style deviation contrasts (-0.5 vs. 0.5, respectively). Models using the fixed effects as maximal random slopes on the by-subject and by-item random effects were run, as justified by the experimental design (DV ~ Container:Group + (1 + Container:Group | Item) + (1 + Container:Group | Participant). However, because the full maximal model did not converge in any of our models, the model was re-fitted until it converged by removing random slopes from the by-subject and by-item random effects that contributed the least variance. For all tests a significance level of 5% was used. Results are reported in Tables 13 & 14 for *'And then'* and *'But first'* separately.

Table 13. *Pairwise comparisons for container, group and the container by group interaction for 'And then...'*

		And then							
		"sweetcorn."		"sweetcorn.^"		+500ms		+500 – 1000ms	
		Est.	*Z*	*Est.*	*Z*	*Est.*	*z*	*Est.*	*z*
sweetcorn goal									
vs. sweetcorn source	Container	0.39	2.4*	0.63	4.16***	0.76	4.57***	0.78	3.96***
	Group	0.12	0.9	0.13	0.97	0.3	1.71•	0.16	1.15
	Container x Group	0.13	0.45	0.18	0.62	0.24	0.74	0.29	0.73
vs. gravy source	Container	0.76	4.56***	1.22	6.56***	1.79	8.24***	2.24	12.8***
	Group	0.23	1.46	0.12	0.62	0.15	0.9	0.33	1.46
	Container x Group	0.09	0.29	0.16	0.45	0.04	0.1	0.61	1.76•
vs. gravy goal	Container	0.1	0.64	0.64	3.44**	1.2	5.69***	1.8	7.09***
	Group	0.33	2.19*	0.12	0.88	0.14	0.94	0.11	0.69
	Container x Group	0.28	0.94	0.16	0.44	0.07	0.19	0.17	0.34
sweetcorn source									
vs. gravy goal	Container	0.32	2.1*	0.05	0.34	0.43	3.41***	0.98	5.21***
	Group	0.27	1.52	0.21	1.58	0.26	2.14	0.24	1.36
	Container x Group	-0.43	1.5	0.02	0.09	0.31	1.27	0.13	0.38
vs. gravy source	Container	0.3	2.11*	0.53	3.46***	1.07	6.9***	1.39	7.68***
	Group	0.17	0.89	0.21	1.2	0.28	1.63	0.46	2.11*
	Container x Group	0.23	0.79	0.03	0.1	0.28	1.07	0.13	0.86
gravy goal									
vs. gravy source	Container	0.66	4.28***	0.58	3.04**	0.61	4.0***	0.55	2.01*
	Group	0.38	1.77•	0.2	1.04	0.12	0.76	0.43	1.65•
	Container x Group	0.2	0.71	0.001	0.002	0.03	0.11	0.5	1.04

•p < .1; *p < .05; **p < .01; ***p < .001.

Table 14. *Pairwise comparisons for container, group and the container by group interaction for 'But first...'*

		But first							
		"sweetcorn."		"sweetcorn.^"		+500ms		+500 – 1000ms	
		Est.	*Z*	*Est.*	*Z*	*Est.*	*z*	*Est.*	*z*
sweetcorn goal									
vs. sweetcorn source	Container	011	0.66	0.28	1.73•	0.51	3.63*	0.66	4.25***
	Group	0.25	0.58	0.25	1.85•	0.22	1.35	0.26	1.83•
	Container x Group	0.2	0.64	0.39	1.24	0.46	1.65•	0.26	0.84
vs. gravy source	Container	0.16	0.75	0.53	3.49***	1.00	7.16***	1.28	7.6***
	Group	0.21	1.42	0.21	1.44	0.03	0.24	0.06	0.35
	Container x Group	0.11	0.36	0.3	0.99	0.04	0.15	0.12	0.35
vs. gravy goal	Container	0.37	2.27*	0.63	4.22***	1.13	7.51***	1.42	4.54***
	Group	0.05	0.29	0.11	0.61	0.14	0.93	0.39	1.58
	Container x Group	0.2	0.62	0.34	1.23	0.26	0.9	0.92	1.63
sweetcorn source									
vs. gravy goal	Container	0.47	3.01**	0.9	4.97***	1.63	9.07***	1.93	7.55***
	Group	0.15	0.79	0.08	0.54	0.09	0.58	0.14	0.8
	Container x Group	0.39	1.29	0.72	2.07*	0.73	2.04*	1.04	2.15*
vs. gravy source	Container	0.32	2.08*	0.85	6.33***	1.52	8.74***	1.96	9.66***
	Group	0.3	1.92•	0.39	2.84**	0.2	1.47	0.19	1.11
	Container x Group	0.08	0.28	0.08	0.29	0.51	1.48	0.39	0.97
gravy goal									
vs. gravy source	Container	0.16	1.08	0.04	0.27	0.14	0.92	0.03	0.12
	Group	0.1	0.55	0.04	0.26	0.17	0.97	0.33	0.26
	Container x Group	0.32	1.13	0.63	2.09*	0.23	1.81	0.66	1.58

•p < .1; *p < .05; **p < .01; ***p < .001.

The results revealed that when the temporal sequence of the events was uninterrupted (i.e. following *'And then'*), participants fixated the context-relevant container (i.e. the sweetcorn goal) reliably more than all other containers by the offset of *'sweetcorn'*. Participants also fixated object competitor containers, which were not directly referred to but were containers associated with the object (i.e. the sweetcorn source location), reliably more than the distractors immediately from *'sweetcorn'* until 1000ms after offset. Finally, participants fixated role competitor containers, which were unrelated to the object but played the same role as the target location (i.e. the gravy goal), reliably more than distractor containers across all time-regions. Importantly, as in Experiment 5, none of the interactions with group reached significance, suggesting that both TD and ASD groups mentally represented and updated the object's episodic trace in comparable ways.

When listeners needed to mentally undo the described event (i.e. following *'But first'*), both the TD and ASD group successfully distinguished the target object (i.e. the sweetcorn source) from the offset of *'sweetcorn'*, favouring it above other objects in the display. Despite this favourability for the target object, both groups also showed appropriate interference from the object-competitor container (i.e. sweetcorn goal), and no role-competitor (i.e. gravy source) interference.

However, this bias to favour the target container was found to be weaker in the ASD group compared to the TD group. This is observed in analyses of the Container by group interaction at three time windows; *'sweetcorn'* offset, 500ms after *'sweetcorn'* offset and from 500ms to 1000ms after *'sweetcorn'* offset, comparing the role-competitor (i.e. gravy source) with the context-relevant container (i.e. sweetcorn source). Analysis revealed that while both groups were able to disambiguate the two containers by the offset of *'sweetcorn'*, this effect appeared later in ASD participants, with the TD group showing a bigger difference in fixation proportions between the two containers compared to the ASD group. That is, TD participants showed a higher proportion of fixations to the context-relevant container (sweetcorn source) than the role-competitor container (gravy source) ($z = 6.42$, $p < .001$), compared to ASD participants ($z = 2.11$, $p < .05$). This would suggest better target detection by TD individuals compared to individuals with ASD, with interference possibly impacting ASD participant's ability to completely disengage from the role-competitor 500ms after *'sweetcorn'* offset. However, ASD participants were eventually able to fully disengage and show a stronger bias to the context-relevant container.

This is confirmed by a marginal group effect at *'sweetcorn'* offset, where TD participants were better able to differentiate the context-relevant location (sweetcorn source) from the object-competitor (sweetcorn goal) ($z = 2.28$, $p < .05$), while ASD participants suffered interference from the object-competitor ($z = 0.23$, $p = .82$). Follow up of a partially significant Container by group interaction ($z = 1.65$, $p < .1$) revealed this interference persisted 500ms after *'sweetcorn'* offset for ASD participants ($z = 0.64$, $p = .53$) compared to TD participants ($z = 2.46$, $p < .05$). However, ASD participants were eventually able to disengage from the object competitor and fixate the context-relevant container from 500ms to 100ms after *'sweetcorn'* offset ($z = 3.49$, $p < .001$ vs. $z = 3.09$, $p < .01$). This later effect in the ASD group is analogous to the findings in the behavioural and electrophysiological data of the previous experiments. These small group differences are particularly interesting in that they could point to subtle processing differences between those with and without ASD during language simulation.

Discussion

Using the visual world paradigm and stimuli employed by Kukona, Altmann and Kamide (2014), the aim of Experiment 6 was to investigate whether individuals with ASD are able to update mental simulations of multiple episodic events in real-time and whether they are able to undo these simulations based on incoming linguistic information. Participants heard discourses such as *"The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug. And then/But first he will taste the sweetcorn"* while concurrently viewing a visual display depicting the four container objects mentioned in the discourse. Previous research found that from the onset of the discourse-final noun (*'sweetcorn'*) TD individuals are biased to fixate the context relevant container. That is, they fixate the goal location following *'And then'* and they fixate the source location following *'But first'*. In addition, TD individuals were more likely to fixate the container that was associated with the target, but was not directly referred to (object-competitor), and the container that played the same role as the target container (role-competitor) than the distractor container. Of interest in the current study was whether individuals with ASD are able to track event-related location changes in the same way as TD individuals by mapping multiple episodic events, particularly whether individuals with ASD would be able to undo their mental simulation of a described event that has been encoded in time following *'But first'*.

Results revealed that both TD and ASD participants fixated the context-relevant container (i.e. the sweetcorn goal) following *'And then'* from *'sweetcorn'* onwards, demonstrating that both groups were able to successfully track the target content across multiple episodic events. This suggests that individuals with ASD are unimpaired in simulating multiple episodic events when the temporal sequence of events is uninterrupted. In addition, results showed object- and role-based competition in the TD and ASD groups. That is, following *'And then'* both groups fixated the object-competitor container that was not referred to but was associated with the critical content, more than distractor items. Likewise, both groups fixated the role-competitor; the container object that played the same role as the target, reliably more than the distractor. Kukona and colleagues (2014) explain these interference effects in terms of the objects' episodic traces in a simulation across event time.

More specifically, object episodic traces encode the object's physical location, intrinsic state, affordances and role in the event at specific temporal locations along the event timeline. They further propose that these object episodic traces across time are bound to a single representation of the given object, which allows the comprehender to track the object across event time, while allowing for variations of the object to be retrieved as a function of event time. Recall that mentally simulating an event involves the activation and retrieval of traces from long term memory (Singh & Mishra, 2010; Zwaan, et al, 2004). In the current study, when comprehenders retrieve an object's location from memory, activation leads to activation of other object traces due to their conceptual overlap. This explains the competitor effects observed in the current study as traces of the target and the competitor are activated and compete for the comprehender's attention.

Thus, in the current study, individuals with ASD were just as able to track event-location changes following *'And then'* as they activate multiple object episodic traces when simulating events in time. What is more, not only are individuals with ASD able to activate and hold these multiple representations, they also find this no more demanding than TD individuals. Rather, they are able to track event changes continuously, activating appropriate episodic traces of objects from memory online as the event moves in time.

However, while ASD individuals do not show impairment in activating and retrieving appropriate episodic traces into a simulation of an event across time when the temporal sequence of events is uninterrupted, results from the *'But first'* condition in Experiment 6 suggest they may be impaired at undoing a described event. Following *'But first'*, both TD and ASD participants were able to distinguish the context-relevant container object from all other containers from the offset of the discourse-final noun. Moreover, both groups experienced appropriate interference from the object-competitor container. That is, based on the conceptual properties of the linguistic input; both groups were able to suppress object episodic traces that had been activated in a simulation of the event across time, effectively undoing the simulation. However, this bias to fixate the context-relevant target was found to be weaker in the ASD group, evident in the fact that TD participants showed a higher proportion of fixations to the target container over the role-competitor container, compared to the ASD group. That is, the difference in fixations between the target container and role-competitor containers was greater in the TD group compared to the ASD group.

This weaker bias for the container-relevant target in the ASD group was further confirmed by interference from the object-competitor container in this group, compared to the TD group. Participants with ASD experienced more interference from the object-competitor compared to TD participants, and thus showed a weaker bias to the target container. Recall that the object-competitor was the container object associated with the critical content, but was not directly referred to. Interestingly, individuals with ASD were able to activate the episodic trace of this object, but were unable to disengage from it at the offset of the discourse-final noun. Moreover, this interference from the activated trace of the object-competitor persisted even 500ms after the offset of the discourse-final noun. Nonetheless, ASD participants were eventually able to disengage from the object-competitor and move attention to the context-relevant container object. A similar pattern of disengagement was observed for the role-competitor too, with individuals with ASD unable to immediately move attention away from the competitor and onto the context-relevant object until later.

A delay in disengaging from the competitor objects in ASD is analogous with the late effects found in the group in the previous experiments reported in this thesis. Although ASD participants do eventually overcome the object- and role-competitor interference in Experiment 6 to fixate the context relevant container, the delay in doing so is yet more evidence of possible processing differences between those with and without ASD.

Experiment 6 supports Brock et al's (2008) findings, not only of language-mediated eye movements in ASD, but also of the role of competitors. Recall that Brock et al observed increased fixations towards the phonological competitor (*hammer*), which was enhanced in the constraining verb condition, in both the TD and ASD group. In the current experiment, ASD participants displayed not only a clear bias for the target container, but also appropriate interference from competitor containers. This suggests that ASD individuals, like TD individuals, are able to anticipate an upcoming referent and this process is comparable to TD individuals. Therefore, the findings of the current experiment suggest that impairments in simulating an event that does not follow an uninterrupted temporal sequence in ASD are not related to memory. Rather, the results of the current study would imply that individuals with ASD exhibit interference from alternative episodic memory traces and a delay in switching.

The focus of the current experiment was on simulations of event-related changes in object location. However, research is yet to explore how such individuals with ASD track and simulate other event-related changes in real-time. While in the current experiment it has been found that individuals with ASD are able to reliably track event-related object location changes, of interest would be to investigate whether such individuals can also track event-related object state changes. Hindy, Altmann, Kalenik and Thompson-Schill (2012) investigated whether competing states of an object described as changing state during an event interfere with one another. In two experiments they presented sentences in which the first-sentence action was varied to induce a change in an object's state that was either minimal (e.g. *"The squirrel will sniff the acorn. And then/But first, it will lick the acorn. "*) or a substantial change (e.g. *"The squirrel will crack the acorn. And then/But first, it will lick the acorn."*) (Experiment 1), or the action was held constant and the object was changed to induce a minimal (e.g. *"The girl will stomp on the penny. And then, she will look down at the* *penny"*) or substantial (e.g. *"The girl will stomp on the egg. And then, she will look down at the egg"*) change. Participants then completed a Stroop task.

Tracking objects across events requires the comprehender to maintain multiple representations of the same object in different states and this process elicits a neural response during fMRI recording that overlaps with increased activation during conflict trails in a Stroop task; evidence of a competition effect (Hindy, et al, 2012; Hindy, Solomon, Altmann, & Thompson-Schill, 2015). Moreover, this competition effect was observed when the implied state change was driven by described action (Experiment 1) and by the affordances of the described object (Experiment 2). Furthermore, the more an object changed in state (i.e. the egg's state changes substantially in *"The girl will stomp on the egg"* compared to the minimal change that occurs in *("The girl stomped on the penny"*), the more information must be inferred in order to activate a context-appropriate representation of the same object in the second sentence (i.e. *"And then she will look down at the egg/penny"*). The authors concluded that these multiple incompatible simulations of the event elicit competition and the greater the difference between the initial state and the end state, the greater the conflict. Recall that in the current experiment, the participants do not see the object that is moved, therefore they hold a single representation of the object that is constant across time. However, in Hindy et al's (2012) study, the state of the object is not constant, and whether individuals can track these changes is of interest in future research.

Chapter Summary

To summarise, in this Chapter I have presented two visual world eye-tracking experiments. The aim of this Chapter was to investigate the dynamic nature of mental simulation of spoken language in individuals with and without ASD. Taken together, the two studies suggest that individuals with ASD are able integrate conceptual properties of language and real world knowledge into a mental simulation of a described event in real-time and do so online.

Moreover, ASD individuals are able to build these simulations at the same rate as TD individuals, and incrementally update them according to the context. In this Chapter I have also shown that individuals with ASD, like TD individuals, are able to encode multiple episodic events into a coherent simulation, tracking multiple event-changes in location. However, individuals with ASD may be impaired in their ability to undo their mental simulations, since they experience acute interference from activated traces of episodic events that compete for attention.

Chapter 6: General discussion

6.1 Overview

This thesis explored the simulation model of language comprehension, which argues that comprehension is facilitated through the construction of mental simulations of described events, which are embodied in cognition; grounded in action and perception. In TD individuals, extensive research has been conducted and these simulations are known to be constructed online, as the linguistic event unfolds and are constrained by various characteristics of the input. As the linguistic input becomes more complex, the comprehender must activate multiple and more complex simulations that are continuously updated in real-time. Such high order cognitive processing is thought to be underpinned by the mirror neuron system and other neural networks in the TD population. This thesis examined for the first time whether comparable mental simulations of language are activated by people with ASD.

ASD is thought to be underpinned by a dysfunction of the mirror neuron system, a network responsible for cognitive processes such as action understanding and imitation. Evidence for this dysfunction has been well-documented in the literature, with individuals with ASD exhibiting abnormal oscillatory activity of mirror neurons in the motor cortex and even at the behavioural level, showing impairments in action understanding and imitation. Such individuals demonstrate impairments in overall imitation ability, including face, action on object imitations and motor imitation (Stone, Ousley, & Littleford 1997; Rogers, Hepburn, Stackhouse & Wehner, 2003). Alongside this, ASD is most notably characterised by a triad of social and communication impairments and repetitive and stereotyped behaviours, with marked deficits in language production and imitation, prominently within pragmatics and prosody, but also affecting lower levels of language. Indeed, research has suggested a relationship between imitation abilities and social communication skills in ASD (Ingersoll,

2008) as well as the possibility that communication impairments themselves may result from impairments in action understanding (Vivanti, et al, 2011).

Given this, I set out to explore simulations of language in ASD as a possible insight into the social communication and language impairments that mark the disorder. My overall goal was to investigate whether ASD is associated with a deficit in mentally simulating language, which in turn affects comprehension. More specifically, the research explored whether individuals with ASD simulate language at all, and if so, whether they simulate it in the same way as TD individuals.

To address this broader question, I have presented six experiments in this thesis that address specific questions regarding the nature of simulations of language in ASD. In Chapter 2, two paradigms, the action-sentence compatibility effect (ACE) (Glenberg & Kaschak, 2002) and the sentence-picture verification task (Stanfield & Zwaan, 2001), were used to investigate the behavioural signatures of motor and spatial simulations of language. These preliminary experiments allowed me to answer the basic question of whether individuals with ASD simulate the motor and spatial content of language at all, and if so, whether these simulations activated as quickly and for as long as they are in TD individuals? Using advanced experimental methods, Chapter 3 extended the use of the sentence verification paradigm with EEG/ERP measures to examine spatial simulations of written language, and identified the neurological correlates of spatial simulations in individuals with and without ASD, and how these simulations are affected by contextual uncertainty.

Following this, the focus of thesis moved from investigating simulations of written language to explore simulations of spoken language. The aim of Chapter 4 was to investigate how individuals with and without ASD simulate and integrate the prosodic elements of spoken language, addressing the question; do individuals with ASD simulate the speaker's tone of voice, to infer emotions and intentions? To answer this, EEG event-related power change measures were used in conjunction with a listening paradigm in which participants listened to short stories and judged how well the speech content fit the wider context (see Yao, Belin & Scheepers, 2012). Finally, using a different experimental approach, Chapter 5 investigated the time-course and flexibility of simulations of conceptual spoken language. Using the visual world paradigm (Altmann & Kamide, 2007; Kukona, Altmann & Kamide, 2014) in conjunction with eye-tracking measures in two studies, I investigated whether individuals with ASD are able to update simulations of an event in real-time, as the linguistic event unfolds, and whether they can undo these simulations based on new linguistic information?

There are currently four prominent cognitive theories of ASD that might be used to interpret the results in this thesis; these have been discussed more extensively in Chapter 1. To review, the Theory of Mind account of ASD posits that the disorder is primarily underlined by a deficit in social cognition. The cognitive mechanistic ability to attribute mental states to oneself and others in order to explain and predict others' actions, and to produce appropriate emotional reactions is thought to be impaired in individuals with ASD (Frith & Happé, 1994; Baron-Cohen, 2004). Evidence for this account has come from observed impairments on false belief understanding and perspective taking. In order to understand that another's beliefs may be true or false, one must suppress their own beliefs in favour of the other's, implying the presence of a theory of mind. Children with ASD show deficits in their ability to attribute false beliefs to others and use this to predict behaviour (Baron-Cohen, Leslie & Frith, 1985). Interestingly, whilst people with ASD are impaired in their ability to attribute mental states, they are unimpaired on perceptual perspective-taking tasks (Piaget, Inhelder & Mayer, 1967).

The Weak Central Coherence (WCC) theory of ASD on the other hand, suggests that people with the disorder lack the capacity for Gestalt processing styles preferred by TD individuals. Instead, individuals with ASD show a bias for local and featural processing, which impairs their ability to understand the wider situation. This theory can explain the pattern of superior and poor performance within a single postulate, with the former occurring when local attention is advantageous and the latter when global attention is required; consequently the WWC account characterises ASD as a differential cognitive style as opposed to a cognitive deficit (Happé & Frith, 2006). This featural processing bias in ASD has been observed at the perceptual, visuospatial and auditory level (Happé, 1996; Jarrold, & Russell, 1997; Mottron, Peretez & Ménard, 2000). Moreover, research on face processing further supports this account, with individuals with ASD showing a preference for configural processing of local information and impaired global face processing (Behrnmann, et al, 2006).

Thirdly, the Executive Dysfunction theory suggests that individuals with ASD have impairments in functions that allow TD individuals to quickly adapt to diverse situations and simultaneously inhibit inappropriate behaviour (Hill, 2004), and it is these deficits (rather than social deficits per se) which underlie impaired social function in ASD. Executive function deficits in ASD have been documented in specific domains such as planning, which involves the constant monitoring, evaluation and updating of actions, mental flexibility defined as the ability to shift between different thoughts or actions according to situational factors (Hill, 2004), and inhibition, the ability to suppress irrelevant or interfering information and impulses (Robinson, et al, 2009).

The final cognitive theory of ASD, the disordered complex information processing theory, proposes that the disorder reflects reduced capabilities to process complex information across a number of cognitive domains (Minshew & Goldstein, 1998). Evidence suggests that individuals with ASD have intact or even superior performance levels compared to TD individuals in tasks that assess basic or mechanical abilities; it is only when tasks require higher order cognitive processing that individuals with ASD begin to display impairments (see Au-Yeung, Benson, Castelhano & Rayner, 2011; Benson, Castelhano, Au-Yeung & Rayner, 2012; Au-Yeung, Kaakinen & Benson, 2014). Complex information processing deficits occur due to the demand associated with integrating information, the speed of processing required and the need to processes large amounts of often novel information (Minshew, Williams & McFadden, 2008).

These four cognitive theories have provided a framework to interpret evidence of language comprehension deficits in the experiments presented in this thesis. That is, I have explored how the experimental findings in this thesis can be explained by any of these theories.

6.2 Summary of results

In Experiment 1A participants made sensibility judgements on concrete and abstract sentences that described an action away from the body (e.g. *"You threw the Frisbee to Dave."/"You pitched the idea to Larry."*) or towards the body (e.g. *"Dave threw the Frisbee to you"/"Larry pitched the idea to you."*). Response direction was manipulated such that participants pressed a key on a keyboard placed at 90º that was either near or far from the body. Results of Experiment 1A did not reveal the expected interaction between implied sentence direction and response direction (i.e. the ACE interaction), which would signal activation of a motor simulation of the language input, in either the TD or ASD group. Therefore, the task was re-run in a second experiment (Experiment 1B) on a larger control sample of only TD individuals in order to validate the paradigm; however the effect again failed to emerge. A detailed discussion of possible explanation as to why the effect failed to emerge in this paradigm has been presented in Chapter 2, so will not be discussed further here.

Experiment 2 explored the behavioural signatures of spatial simulations of language, using the sentence-picture verification task. Participants were presented with sentences such as *"The eagle is in the sky/nest"* and were instructed to make a mentioned/not mentioned judgement on a subsequently presented image. On experimental trials the image depicted the object mentioned in the preceding sentence, but critically, it either matched or mismatched the implied shape (i.e. an eagle with its wings outstretched vs. with its wings folded). The time between sentence offset and picture onset (i.e. the ISI) was manipulated to be either 250ms or 1500ms. The expected facilitation effect (i.e. shorter reaction times and fewer errors) for matching sentence-picture pairs, and an interference effect (i.e. longer reaction times and more errors) for mismatching sentence-picture pairs was observed in both the TD and ASD groups. Moreover, no effect of ISI was observed and this did not significantly interact with group. That is, within 250ms of reading the sentence, both TD and ASD participants had constructed a simulation of the described event that was readily available for comparison against the subsequently presented image. Furthermore, the mismatch effect was also present in both groups at 1500ms after sentence offset, suggesting that these spatial simulations remained active for a prolonged period of time. Thus, the results demonstrate that not only do individuals with ASD simulate the spatial properties of language, but they do so as quickly, and maintain them for as long as TD individuals.

In Experiment 3, the sentence-picture verification was again used, but in conjunction with EEG/ERP measures. The stimuli were also altered to manipulate the level of contextual uncertainty (e.g. *"The old lady [knows/thinks] that the picnic basket is open/closed"*). Again, participants were asked to make a mentioned/not mentioned judgement on a subsequently presented image that either matched or mismatched the shape implied in the preceding sentence (i.e. an open picnic basket vs. a closed picnic basket). Behavioural findings showed that the mismatch effect observed in Experiment 2 was replicated, with both TD and ASD participants showing a facilitation effect for matching sentence-picture pairs and an interference effect for mismatching sentence-picture pairs. Moreover, the certainty of the action (afforded by the verb, knows/thinks) did not modulate these effects, nor did it interact with group. That is, both the TD and ASD groups were just as fast to respond to the image when the preceding sentence was certain (*'knows'*) compared to when it was uncertain (*'thinks'*). This was taken as behavioural evidence that individuals with ASD are able to activate simulations of certain and uncertain events as quickly as TD individuals and are equally sensitive to mismatches between the mental simulation and subsequent image.

ERPs during sentence reading and picture verification were analysed to further understand the neurological correlates that underlie these spatial simulations of certain and uncertain events in individuals with and without ASD. During sentence reading, contextual uncertainty had no effect on the N400 ERP evoked at final word onset (i.e. *'open/closed'*), and the lack of interaction between verb and group meant that this effect was not observed in either the TD or ASD group. This suggests that neither group had difficulty processing and interpreting the event relative to the level of contextual uncertainty. However, a group effect was observed, with the ASD group showing a smaller N400 compared to the TD group. Analysis of ERPs during picture verification revealed no overall mismatch effect on N400 amplitude in either the TD or ASD group, however, there was a significant interaction between contextual uncertain and mismatch. The N400 was significantly larger for mismatching images than matching images when the preceding sentence was certain, but no difference in N400 amplitude between matching and mismatching images when the preceding sentence was uncertain. This effect did not further interact with group, implying that both TD and ASD participants can rapidly activate comparable spatial simulations and utilise the same underlying neural mechanisms. When processing a certain event (*'knows'*), a single simulation of the described event is activated and checked against the subsequently presented image. When the image mismatches the single simulation of the described certain event, a larger N400 is elicited. In contrast, when processing an uncertain event (*'thinks'*), multiple simulations are activated (i.e. the open picnic basket and the closed picnic basket). Both the matching and mismatching image can map onto these active simulations, thus neither elicit a mismatch detection response. Taken together, these findings suggest that individuals with and without ASD activate comparable simulations of spatial properties of certain and uncertain events in the same time course. Moreover, individuals with ASD make use of the same underlying neural mechanisms as TD individuals.

Experiment 4 examined simulations of spoken language. Participants heard short stories, where the final sentence was either a direct (e.g. *He said "God, that movie was terrible! I've never been so bored in my life."*) or indirect (e.g. *He said that the movie was terrible and that he had never been so bored in his life*) speech sentence. Critically, the direct speech sentences were either spoken in a vivid or monotonous tone. Participants' task was to rate how well this final speech sentence fit the wider sentence context, based on how vivid and engaging it sounded. These behavioural responses were supplemented with continuous EEG recording to investigate the oscillatory neural dynamics that underpin simulations of direct and indirect speech in those with and without ASD. Behavioural findings showed that participants with ASD had a general bias for higher ratings of fit between the final speech sentence and wider story context, compared to TD participants. However, the congruency effect was observed in both groups, with TD and ASD participants rating the direct-monotonous speech as being the least contextually congruent, the direct-vivid speech as most congruous and the indirect-monotonous speech as between the two. Interestingly, ASD participants rated direct-monotonous and indirect-monotonous speech as significantly more congruous compared to TD participants, but the two groups showed no difference in ratings of direct-vivid speech. This effect was further supported by the reaction time results. Thus, individuals with ASD were able to judge the appropriateness of the speaker's tone of voice, although their expectation regarding prosody in speech may be weaker.

EEG power analysis revealed that upper theta, lower alpha and upper alpha desynchronization occurred during the speech sentence (relative to the context), and these changes was comparable for the TD and ASD groups. Both groups showed greater theta and alpha desynchronization during the processing of direct-monotonous speech compared to both direct-vivid and indirect-monotonous speech. Moreover, the changes in theta and alpha power did not differ between direct-vivid or indirect-monotonous conditions for either group. This suggests that ASD participants utilised the same underlying neurological dynamics as TD individuals to represent the prosodic elements of spoken language and activate a relevant simulation. Taken together, the behavioural and electrophysiological findings reflect the activation of simulations of spoken language by individuals with ASD that are comparable to TD individuals, and that simulations by both groups rely on the same underlying oscillatory neural dynamics.

In Experiments 5 and 6 participants completed a visual world task during continuous eye-tracking to investigate how individuals update simulations in real-time as the linguistic input unfolds. More specifically, in Experiment 5, the aim was to explore how individuals with and without ASD simulate past and future events online by manipulating the verb tense. Participants heard sentences such as *"The man will drink all of the beer"* vs. *"The man has drunk all of the wine"* while concurrently viewing a visual scene depicting objects mentioned in the utterance (i.e. a man, a full beer glass, and an empty wine glass) alongside other distractor items. Results replicated Altmann and Kamide's (2007) findings by showing that comprehenders anticipated the upcoming referent, with no difference in eye movements found between the ASD and TD group. That is, from the onset of *"the"* both groups showed increased eye movements to the empty wine glass following *"has drunk"* compared to *"will* *drink"*, suggesting that individuals with ASD are just as effective at anticipating the relevant object and are able to simulate the linguistic event online, constrained by the verb, in the same way as TD individuals. A non-significant trend to preferentially fixate the full beer glass following *"will drink"* compared to *"has drunk"* from the onset of *"the"* was also found.

Finally, Experiment 6 explored how individuals with and without ASD update simulations of multiple episodic events and undo them as the linguistic event unfolds. Participants heard sentences that described the location change of objects between containers (e.g. *"The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug. And then/But first, he will taste the sweetcorn/gravy"*), whilst concurrently viewing a visual display depicting the four containers. Analysis of eye movements revealed that in the *"And then"* condition, both TD and ASD participants fixated the context-relevant container object significantly more than any other container in the visual display, by the offset of "*sweetcorn*", and fixated the object- and role-competitor objects reliably more than distractor containers from *"sweetcorn"* onset to 1000 msec after offset. This suggests that like TD individuals, individuals with ASD are able to continuously track event changes and activate objects' episodic traces online where the temporal sequence of events is uninterrupted.

Interestingly, results revealed that individuals with ASD may be impaired at undoing mental simulations, when the temporal sequence of described events is interrupted. In the *"But first"* condition, both TD and ASD participants distinguished the context-relevant container and experienced appropriate object-competitor interference, from the offset of the discourse final noun (i.e. *sweetcorn/gravy*). Yet, this bias to fixate the context-relevant container was weaker in the ASD group, evident in significantly more interference from the object-competitor container compared to the TD group. This interference remained even

500ms after discourse final noun offset, though ASD participants were eventually able to disengage from the object-competitor and preferentially fixate the context relevant container. This pattern of disengagement was also true of the role-competitor container, with ASD participants unable to immediately disengage from the role-competitor. Nevertheless, the bias towards the target container and relevant interference from competitor containers suggests that like TD individuals, individuals with ASD are able to anticipate upcoming referents using comparable to processes. Consequently, the results from Experiment 6 suggest that individuals with ASD are able to in real-time, track and simulate multiple episodic events in a way comparable to TD individuals. However, impairments occur when the temporal sequence of the event being simulated is interrupted, which results in interference from alternative episodic memory traces and a delay in switching.

6.3 Interpretation of findings

Overall, the findings of the six experiments presented in this thesis suggest that in most areas of language processing, individuals with ASD comprehend language in the same way as TD individuals. That is, individuals with ASD activate simulations of a linguistic event that are comparable to those activated by TD individuals. It is well-established in the TD literature that mental simulations of language facilitate understanding, so this finding that individuals with ASD mentally simulate described events in a way comparable to TD individuals has implications for how such individuals use and comprehend language.

At a general level, this would suggest that mental simulations of language do not seem to tap into social skills. Whilst ASD is foremost characterised as a social impairment, research has begun to make further distinctions between different phenotypes within the autism spectrum, particularly in terms of language abilities. For example, researchers have identified ASD children with or without language impairment (see Norbury & Nation, 2011; Lucas, & Norbury, 2014). Given that the ASD group in this thesis did not show any language deficit, the participants can be considered to have a social deficit, but no language impairment. Thus, the results suggest that although individuals with ASD have a social deficit, when language skills is equated they are as capable as TD individuals at mentally simulating described events. This indicates that social skills do not impact the ability to simulate language information, and thus mental simulations and social skills would appear to tap different cognitive processes.

The findings are perhaps surprising given the extensive amount of research on impairments in ASD that would indicate a deficit in the ability to simulate language. The literature on action understanding and imitation in ASD would suggest that such individuals should have difficulty mentally simulating described events. The process of simulating a linguistic event entails the representation of the objects and actions described by the input, followed by the mapping of semantic representations of the incoming language onto a mental model of the world.

Research has shown children with ASD are impaired at motor imitation (Stone, Ousley & Littleford, 1997) and this extends into adulthood (Rogers, Bennetto, McEvoy & Pennington, 1996; Avikainen, et al, 2003). The observation and internalisation of actions is supported by the MNS, and in the TD population, underpins social communication and language abilities (Ingersoll, 2008). During typical language development, phonetic gestures of the speaker, including movements of the mouth, lips and tongue are internally represented by the comprehender as invariant motor actions and mimicked to drive speech production (Liberman & Mattingly, 1985). As a result, internalisation and imitation of the actions of others involve identical cognitive mechanisms, namely the MNS, and provide the foundation for the development of dialogue. Furthermore, research suggests that individuals with ASD have difficulty integrating linguistic information with real-world knowledge (Norbury & Bishop, 2002), and therefore may have difficulty mapping semantic representations of the linguistic event onto a mental model of the world during language simulation. Consequently, potential differences in the ability to understand and imitate peoples' actions, alongside differences in mapping representations may explain the social communication deficits in ASD.

Given the deficits in processes believed to underpin simulations of language in the TD population, the findings in the current thesis that individuals with ASD do not show evidence of impaired simulation are particularly interesting. It may be then, that the findings can be explained in terms of the processes tapped by the experiments. The simulations participants activate in the current experiments tap into language ability, as opposed to action understanding or imitation. Since the ASD participants show no language impairment, this would explain why they show no impairment in simulating linguistic information.

Previous research that shows no difference between TD and ASD individuals is similar to the current experiments, in that it taps into language more specifically. For example, research has shown that children and adolescents with ASD are able to make bridging inferences by integrating relevant physical and social world knowledge, and activate simulations of events in a similar time-course as TD individuals (Saldaña & Frith, 2007; Sansosti, Was, Rawson & Remaklus, 2013). Moreover, individuals with ASD show language-mediated eye movements, affected by semantic associates, suggesting that like TD individuals they are able to anticipate upcoming referents within the same time course (Brock, et al, 2008). Thus, when individuals with ASD show no language impairment they seem to perform as well as TD individuals, and only when such individuals have a language impairment or when the language itself reaches a high level of complexity do differences occur. This further suggests that mental simulations are underpinned by language ability, and not the social abilities that characterise ASD. Moreover, the tasks used in the current thesis were not particularly cognitively demanding. It is only when the tasks became more complex that participants with ASD show difficulty, suggesting an impairment in processing complex information as opposed to a general simulation deficit.

If the findings from the studies presented in this thesis demonstrate that individuals with ASD are broadly equivalent to TD individuals in the ability to simulate the properties of written and spoken language online during comprehension, then there must be a more subtle phenomena that can account for the well-documented deficits in the communication domain in ASD. One particularly interesting observation is the subtle processing differences observed in the different experiments, which can be taken together to say something about impairments in everyday communication in ASD.

In Experiment 2, although there was no significant group effect, visual inspection of the response time graph showed that the ASD group were marginally slower to respond across all conditions compared to TD participants. While as a single observation this may not be of immediate interest, a similar pattern was revealed in the behavioural findings in Experiment 3. That is, across all conditions, ASD participants were slightly slower to respond in comparison to TD participants. More interestingly, these small differences in response time were also detectable in the ERP findings in Experiment 3, and thus could point to subtle processing differences between individuals with and without ASD.

In Experiment 3, analysis of the ERPs evoked by the critical word revealed that although contextual uncertainty had no impact on the N400 amplitude for either group, ASD participants showed a smaller N400 in comparison to TD participants. This reduced N400 amplitude in the ASD group may reflect neural underconnectivity, which is associated with the disorder. The link between abnormalities in ERP amplitude and the functional connectivity of the underlying brain mechanism has been documented in ASD. For example, Gomot et al (2006) examined auditory event-related fMRI to determine the regional brain activity associated with detection of frequency-deviant and complex novel sounds in children and adolescents with and without ASD. The ASD group showed reduced activation of the left anterior cingulate cortex for both deviant and novel sound detection. Interestingly, this confirmed previous ERP evidence from Gomot et al (2002) who found that the electrophysiological pattern of the mismatch negativity (MMN) ERP – the component that reflects the automatic detection of frequency changes – emphasised a left frontal dysfunction in ASD. Accordingly, the reduced N400 evoked by the critical word in the ASD group in Experiment 3 may reflect underconnectivity, which would explain the later effect found in the behavioural data. Evidence of a delayed effect is emphasised by further visual inspection of the ERP plots, which highlights a possible group effect in a later time window (600 – 700ms). This later effect could have been driven by, and therefore confounded by, the earlier group difference at the 300 – 450ms time window.

Furthermore, subtle group differences in the ERP data were also found at picture verification. Analysis of the N1 time window revealed subtle group differences in the ERP's topography, with ASD participants exhibiting greater negativity at anterior versus posterior sites in comparison to TD participants. This topographic difference is believed to reflect visual hypersensitivity and increased arousal in individuals with ASD, which can disrupt stimulus processing (Baruth, et al, 2010). The occurrence of group differences in the ERPs evoked by critical word and at picture verification are analogous to the later effects observed in the behavioural findings in Experiment 3 and serve as electrophysiological evidence of possible processing differences between those with and without ASD.

The possibility of subtle group differences in processing are also evident in Experiment 4. While the congruency effect was replicated in both groups, participants with ASD had a general bias for higher ratings across speech types compared to TD participants. These effects in the congruency ratings were subsumed by the reaction time findings which showed a trend for ASD participants to respond slower overall across all speech types. This pattern again mirrors that found in Experiments 2 and 3, and provides additional support for a difference in processing, as opposed to a processing impairment in ASD. That is, the bias and later effect would suggest individuals with ASD have a weaker or different expectation regarding prosody in speech, implying a different processing strategy to TD individuals.

This processing difference is pronounced in the EEG power data, which although not statistically significant, shows a trend across upper theta and lower and upper alpha for greater desynchronization in the ASD group. It would seem then, that representing the prosodic content during speech processing is subtly more demanding for individuals with, in comparison to without, ASD. Moreover, these behavioural and electrophysiological group differences are not only analogous to those observed in Experiment 3, but suggest subtle processing differences in how those with and without ASD processes spoken as well as written language.

Finally, noteworthy evidence of different processing strategies was found in Experiment 6. Recall that the bias to fixate the target container following *'But first'* sentences was found to be weaker in the ASD group from the offset of *'sweetcorn'*. The ability to disambiguate the context-relevant container from the role-competitor container by the offset of *'sweetcorn'* appeared later in the ASD group, with TD participants showing a bigger difference in the proportion of fixations between the two containers compared to ASD participants. Moreover, TD participants were better able to differentiate the context-relevant container from the object-competitor container, with ASD participants suffering interference and consequently a delay in switching to the appropriate container. ASD participants were eventually able to overcome the interference, disengage from the competitor containers and fixate the context-relevant container, but this effect occurred later in comparison to the TD group. Again, this observation adds to the other subtle differences found across the experiments presented in this thesis, and are particularly interesting with regards to what they mean in terms of impairments in everyday communication in ASD.

Collectively, the small group differences are the real significance of the findings in this thesis. I set out to investigate the social communication and language comprehension impairments of ASD, proposing that deficits in this domain may be linked to an inability to mentally simulate language. This hypothesis was based on evidence that the cognitive processes and mechanisms underlying simulations in the TD population are thought to be impaired in ASD, so could account for the communication deficits associated with the disorder. However, the findings I have presented would suggest that when language abilities are intact, individuals with ASD are broadly equivalent to TD individuals in their ability to activate simulations of written and spoken language. I have shown that such individuals are effectively able to simulate the spatial and prosodic content of written and spoken language online, and are capable of tracking multiple linguistic events in real-time. Given this, there must be another, more subtle phenomena to explain why individuals with ASD, despite intact language ability and fluency, struggle with social communication. I believe it is the subtle group differences in processing observed across the experiments in the current thesis that can account for impaired everyday communication.

The nature of social communication in everyday life is under no circumstances as controlled as the language used in the current experiments. During daily interactions, individuals are required to process vast amount of information in order to successfully engage in dialogue. Therefore, the ability to simulate language for the purpose of comprehension and communication is far more rapid and multisensory than demonstrated in this thesis. Individuals must integrate the many properties of the linguistic input with general world knowledge and continually update these simulations online as new information becomes available. If individuals with ASD already demonstrate subtle processing differences in the controlled experiments presented in this thesis, no doubt those differences will be more pronounced in everyday communication. Given this, the social communication deficits observed in individuals with ASD who have intact language abilities are not associated with an inability to mentally simulate and experience language, but rather with a subtle delay that significantly impacts everyday communication and interactions.

In sum, these findings would first suggest that mental simulations of language do not tap into social skills, instead the two are served by different cognitive mechanisms. Second, it seems that performance on the different tasks employed here is linked. Despite covering a broad range of paradigms, techniques and language structures to assess mental representations, the different tasks rely on the same underlying processes related to language ability. Finally, the consistent observation of subtle processing differences between those with and without ASD across the experiments are a significant finding of this thesis. This finding can account for the social communication impairments found in individuals with ASD who have intact language abilities and are able to simulate language. In the next section I will go through each of the four theories of ASD I have reviewed above and consider how the findings, and the specific results from each study, fits with the predictions made by each theory.

6.3.1 Interpretation of findings in relation to the cognitive theories of ASD

The theory of mind literature points to an inability to impute mental states as a predictor of socialization, imagination and communication deficits (Frith & Happé, 1994). Language impairments are believed to be associated with theory of mind deficits, as the ability to make social inferences and recognising intentions is fundamental to communicating with others (Oberman & Ramachandra, 2007). However, none of the experiments presented in this thesis tapped into a theory of mind component of language simulations or the ability to mentalise during comprehension. Nevertheless, while it is difficult to comment in depth on how this thesis fits within the theory of mind literature, the current findings do show that impairments in social skills do not seem to affect performance on language tasks.

There seems to be no evidence that the ASD participants were unable to process information globally during the experiments, which would conflict with the WCC account of ASD. Individuals with ASD are thought to prefer local level processing, as opposed to the Gestalt processing style preferred by TD individuals, and the WCC theory attributes any differences between the groups to distinct cognitive biases. However, findings in this thesis do not support this notion of different processing styles in relation to global versus local processing, as more often than not no group effects emerged. All the tasks used in this thesis involved a combination of both local and contextual (global) information and success required the participants to appropriately integrate the two types of information. That is, to interpret the local information the participants had to be aware of the broader context.

Interestingly, participants with ASD did not seem to be delayed or impaired in global processing. Experiment 2 demonstrated behaviourally that individuals with ASD must be engaging in global processing when comprehending sentences such as *"The eagle is in the sky"* as they generate a global simulation of the event. ASD participants were able to integrate the properties of the linguistic input into a global representation of the event very rapidly (within 250ms) and in the same way as TD individuals. Furthermore, Experiment 3 showed that the sentence context influenced processing of the image within 400ms of the image onset. The electrophysiological findings showed how rapidly participants with ASD were responding as quickly and in the same way as TD participants, suggesting both groups have equal access to the context and are rapidly able to incorporate this into a simulation.

Experiment 4 further demonstrated the effect of context, with online measures of power showing individuals with ASD integrate the context with the prosodic elements of speech immediately, while listening to the discourse. This was evident in activation patterns in the ASD group that was comparable to those of the TD group. The electrophysiological evidence shows that individuals with ASD construct a perceptual simulation of the spoken event by representing the absent supra-segmental acoustic information (i.e. they represent the speaker's tone of voice when the speech is said in a direct-monotonous tone) and integrating this with contextual information in a way that is comparable to TD individuals; underpinned by the same neurological oscillatory patterns. So it seems that there is no delay in individuals with ASD, or a bias towards contextual (global) processing in the TD group that is not present in the ASD group. Thus, there is no evidence for weak central coherence during language simulation, at least for the ASD participants recruited.

Furthermore, the findings of Experiments 5 and 6 suggest that individuals with ASD do not have an integration deficit or a delay attending to the wider context, at least in terms of language simulation, as proposed by the WCC account. Recall that simulations are constructed online; as the sentence unfolds comprehenders integrate information from the linguistic input, such as the agent and information about the verb's restriction, with real-world knowledge to anticipate upcoming referents (see Altmann & Kamide, 1999; Kamide, Altmann & Haywood, 2003). So, in Experiment 5, when participants heard *"The man will drink all of the wine"*, they integrated information from the input, including the agent (the man) and the verb, into a simulation of the event. The WCC theory would predict that individuals with ASD would be impaired in integrating information into a simulation of this event; however no such effect was found. Like TD participants, ASD participants were able to integrate information online, as the sentence unfolded, into a cohesive simulation of the input. Moreover, Experiment 6 shows that individuals with ASD are not only able to integrate information for a single episodic event, but for multiple episodic events, despite being more difficult for the ASD group when they were required to undo these simulations.

Taken together, the current findings do not support a WCC account of ASD, at least in terms of language simulations.

The findings presented in this thesis however, do reveal some indications of difficulties with executive functioning in the ASD participants. It should first be noted that I deliberately set out to match participants groups on a number of IQ and language skills, and while the ASD group in fact showed superior performance to the TD group on a number of cognitive measures (particularly vocabulary and digit span), not all aspects of executive functioning were tapped. Most notably, the battery of assessments did not measure inhibitory control, planning or cognitively flexibility; executive functions that are important for effective social communication. Recall, the Executive Function account posits that pragmatic language impairments in ASD are associated with impairments in executive functions, including a lack of flexibility of thought and weak generativity (Bishop, 2005).

Most of the tasks employed in the experiments presented in this thesis are relatively simple at the sentence comprehension level, so may not allude to executive dysfunction in the ASD group. However, one exception to this is the *'But first'* sentences in Experiment 6. The inability for ASD participants to process *'But first'* sentences as effectively as TD participants would suggest that these sentences in fact burden certain aspects of executive functioning. Processing such sentences requires the comprehender to mentally undo their simulation of the event, which necessitates inhibitory control of competing episodic traces, and cognitively flexibility to move attention to the appropriate episodic trace. As a result, the difficulty for ASD participants to immediately disengage from competing episodic traces during *'But first'* sentence processing would suggest the process places demand on executive functions in this group. To investigate this explanation further, it would be of interest to have participants complete assessments of executive functioning and correlate scores with performance on the visual world paradigm used in Experiment 6. Those individuals with

ASD who are impaired in processing *'But first'* sentences, which demands the ability to disengage from and inhibit one episodic trace in favour of another, should may show marked impairments in measures of executive functioning.

The current findings also fit well within the literature on complex information processing deficits in ASD. Previous research, particularly in the eye-tracking literature, has repeatedly found no group differences between TD and AD participants on simple-processing cognitive tasks (see Au-Yeung, Benson, Castelhano & Rayner, 2011; Benson, Castelhano, Au-Yeung & Rayner, 2012; Au-Yeung, Kaakinen & Benson, 2014). This is the overarching observation in this thesis; ASD participants consistently performed at the same level as TD participants. More interestingly, there was no significant group effect not only at the behavioural level, but also at the electrophysiological level and in the eye movement data. Any significant differences between the groups only emerged in the final experiment (Experiment 6). As stated in my discussion of the findings in relation to the Executive Dysfunction approach, while the tasks used in this research were relatively simple at the sentence comprehension level, the sentences used in Experiment 6 were less so, and required more complex information processing.

Recall, that the disorder complex information processing theory states that the pragmatic language impairments characteristic of ASD are the result of a generalised dissociation between basic and complex tasks in terms of linguistic information processing demands. That is, a dissociation between tasks that simply require basic procedural linguistic abilities, and those that require complex, interpretative linguistic skills (Minshew, Goldstein & Siegel, 1995). Relating this to the current thesis and simulations of language more broadly, it could be argued that the tasks used relied on more basic skills, as they required the comprehender to activate static representations of the linguistic event. In contrast, Experiment 6 required more complex language abilities as comprehenders had to activate multiple dynamic representations and keep track of them in real-time. Verbal abilities are not a prerequisite for disordered complex information processing in ASD (Minshew, Goldstein & Siegel, 1995) and in fact, such abilities were intact in the current sample of ASD participants. Consequently, it was the complexity of rapidly tracking and integrating multiple representations and the amount of information to be processed that ultimately impacted ASD.

In Experiment 2, processing a sentence such as, *"The ranger saw an eagle in the sky"* required the reader to activate a single simulation (i.e. of a bird with its wings outstretched). A single, static representation of the eagle with its wings outstretched can be considered simple in that it does not implicate any other information about the state of the referent other than its shape. That is, it is not a dynamic representation in the sense that it is manipulated based on new information from the linguistic input. Rather, by the sentence offset, the static representation of the physical state of the object is integrated with real world knowledge about the object and this single simulation is then mapped onto the subsequently presented image. Indeed, if the sentence had continued and provided more information, this additional information would have been represented and integrated into the simulation.

In fact, when additional information was given in the form of a context of uncertainty (Experiment 3), individuals with ASD still do not find this cognitively demanding and perform at a level comparable to TD individuals. This process of integrating representations of referents with the given context could also be considered simple, at least for the current ASD participants. When processing a sentence such as, *"The old lady thinks that the picnic basket is open"*, readers activate two static representations of the object (i.e. an open picnic basket and a closed picnic basket). Given the context of uncertainty requires the integration of multiple representations of the referent, two simulations are readily available and do not compete with one another. Instead they are each mapped onto the subsequently presented image and the representation that mismatches is dropped in favour of the other. In reality, language is seldom presented without a context, hence integrating the context could be considered a mechanical linguistic ability and would explain why the ASD group performed comparably to TD individuals. Similarly, in Experiment 4 ASD participants were again as sensitive to prosodic violations as TD individuals and activated appropriate perceptual simulations of the spoken event. This would suggest that representation of the speakers tone of voice is a procedural ability, at least for the current ASD participants, thus no deficit in processing emerged.

Support for a complex information processing deficit of ASD is emphasised in Chapter 5. Recall, that no significant group differences emerged when participants were required to construct a simulation of an event online. ASD participants were just as able as TD participants at integrating information into a simulation of the event in real-time (as in Experiment 5), and interestingly, were able to activate and maintain multiple episodic traces of event-related object location changes when the temporal sequence of events was uninterrupted (following *"And then"*) (Experiment 6). It was only when participants were required to undo these mental simulations of the events (following *"But first"*) that group differences emerged. ASD participants experienced a weaker bias to the context-relevant container in Experiment 6, and greater interference from competitor containers. In the preceding tasks used in this thesis, participants activated and even tracked multiple representation in real-time, and this could be considered a simple, procedural ability, at least for the current ASD group. However, for *'But first'* sentences, the dynamic nature of the simulations required could be considered more complex for ASD participants to activate and maintain, as they had to disengage from one episodic trace and inhibit it in favour of another. This more cognitively demanding complex ability to rapidly undo mental simulations by disengaging from competing traces and switching to the appropriate trace could be dissociated from the previous basic tasks and so fits with Minshew and Goldstein's (1998) complex information processing model of ASD.

Taken together, the finding that individuals with ASD who show no language impairment are able to mentally simulate described events has implications for how such individuals use and comprehend language. It seems that individuals with ASD are able to follow and comprehend described events in simple situations, such as in one-to-one conversations. However, when events or situations become more complicated, such as when there is more than one interlocutor or the conversation switches in time (i.e. the tense changes), difficulties begin to emerge. That is, differences in mentally simulating language in individuals with and without ASD start when information processing becomes complex.

6.4 Limitations and Future Research

The experiments presented in this thesis have employed a broad range of paradigms and experimental techniques to provide valuable new insights into simulations of language and comprehension capabilities in ASD. However, they also highlight some limitations and interesting avenues of future research. Many of these issues and future research questions have been discussed in depth in the relevant chapters. One overarching limitation of this research has been the sample of ASD participants recruited. As stated in the previous empirical chapters, all ASD participants were recruited from the University of Kent, with a diagnosis of High Functioning Autism or Asperger's Syndrome. However, the decision to focus on this high functioning diagnosis, as opposed to recruiting across the Autism Spectrum is advantageous. Due to the nature of the cognitive tasks used in the experiments conducted, intact verbal abilities were required. As this research assessed simulations of language, a high-order cognitive ability, ASD participants had to have language skills comparable to TD individuals. Moreover, matching the two groups across IQ and language skills means their effects on performance are controlled for. The advantage of controlling for IQ and language abilities is that they can be ruled out as a possible explanation of any group differences. Consequently, interpretation of the findings focuses on processing differences between the groups, as opposed to cognitive impairments in the ASD group.

Research has emphasised a strong relationship between language competence and comprehension skills. Children with different language phenotypes within the ASD population demonstrate differential reading comprehension profiles. Examination of IQ, language and reading skills has revealed that children with ASD and language impairments (ALI) and children with Specific Language Impairments (SLI) perform comparably, while children with ASD and no language impairments (ALN) show markedly higher scores (Lindgren, Folstein, Tomblin & Tager-Flusberg, 2009). These children with ASD who also display structural language impairments show generally lower performance on reading accuracy and comprehension compared to those with ASD and no structural language impairments, despite word-level reading being intact in both groups. However, word-level reading is believed to be associated with oral language abilities, higher in ALN than ALI individuals (Norbury & Nation, 2011). Likewise, children with ASD and age-appropriate language skills demonstrate sentence and passage level comprehension abilities comparable to TD children, whilst children with ASD and language impairments (ALI) showed difficulties in reading even at word level (Lucas & Norbury, 2014). Consequently, the decision to recruit HFA and AS participants for the current research and match them on a number of language and IQ measures is justified to examine the specific effects of impaired social understanding on language simulations and comprehension.

In fact, the ASD group had comparable, if not more advanced, language abilities and IQ levels compared to the TD group, performing significantly higher on a number of the language and IQ assessments across the experiments. This could reflect motivation levels of the two participant groups. The ASD group may have been considerably more motivated to perform well on the tasks, perhaps driven by a greater invested interest in the research. This is in comparison to the TD group, who may have been less motivated to perform optimally. It would be interesting to test the current experiments on a wide range of individuals with ASD and investigate whether individuals who are lower on the spectrum are able to simulate the spatial properties of language (as in Experiment 2) and again, whether the same neurological mechanisms are activated (as in Experiment 3).

In addition, it would be interesting to investigate the developmental trajectory of language comprehension, by investigating simulations of language in children with and without ASD. The current research has established that adults with ASD are appropriately able to exploit the linguistic input and integrate relevant information in order to make inferences about the linguistic event. However, as discussed in Chapter 5, there is debate within the literature about whether children with ASD are impaired in information integration necessary for inference making. Some evidence suggests that children with ASD are just as able as TD children to integrate real-world knowledge and constraints of the linguistic input into a simulation necessary for inference making (Saldaña & Frith, 2007), whilst others suggest that although no group differences exist at a behavioural level, implicit measures (i.e. eye-tracking) reveal that ASD children show text processing difficulties while making inferences (Sansosti, Was, Rawson & Remaklus, 2013). Future studies could further investigate inference making in children with ASD, using the visual world paradigm and examining anticipatory eye movements (as in Chapter 5) as well as exploring at what point in development difficulties emerge. Research on false belief understanding has shown that this ability develops around three to four years old in TD children, and continues to develop into adolescence. Of interest in future research would be to investigate whether there is a similar typically developing trajectory for mental simulations and could it be that in ASD, although as adults such individuals are able to mentally simulate language, does this skill develop later or at a slower rate to TD individuals?

Another possible shortcoming that should be considered is how the two groups interpret the instructions. This is particularly relevant to Experiment 4, where participants were asked to rate how well the final speech sentence fit the wider context, based on how vivid and engaging it sounded. It is well-established that individuals with ASD demonstrate a preference for logic, and consequently may have interpreted the "ratings" with regards to the content of the speech sentence (i.e. how well does the speech content fit with the wider context) as opposed to the prosodic content. Overall, the ASD group rated the speech content higher than the TD group. However, it could be that the participants with ASD were rating based on the semantic rather than prosodic content, particularly in the direct-monotonous condition, which should have been rated as least fitting the wider context. The ASD group did rate the direct-monotonous speech as more inappropriate than both direct-vivid and indirect-monotonous speech, so were judging the prosodic content appropriately, but were still rating them higher than the TD group. This pattern makes it difficult to distinguish between whether participants had genuine difficulty detecting the inappropriate prosody in the direct-monotonous condition, or perhaps had specific difficulty understanding the instructions. Nonetheless, the electrophysiological evidence showed no group difference, suggesting that at the neurological level ASD participants were as sensitive as TD participants to the prosodic properties of the speech.

Further insight may also be gained from new analysis of the current data using advanced analysis techniques. As discussed in Chapter 4 for example, other suitable neuro analysis techniques are available that could be applied to the data set to gain further understanding of the observed effects. In Experiment 4, changes in event-related power from processing the discourse context to speech were analysed using power analysis; an analysis method associated with local synchronization. Whilst this provided exciting results about the local oscillatory mechanisms underlying simulations of speech in individuals with ASD, it would be interesting to re-analyse the data to explore the long-range synchronization that occurs between neural networks during speech simulation. One such technique that would provide this insight is coherence analysis; a neuro analysis technique that looks for covariance among EEG signals of neural networks from multiple brain regions. Analysis of EEG coherence over the speech segment in Experiment 4 could be done to investigate whether there are differences in coherence between ASD and TD individuals, or whether both groups display not only the same local synchronization patterns, but also long-range synchronization during simulation of the speaker's tone of voice.

Likewise, the findings presented in Chapter 5 warrant future research to further enhance understanding of simulations in two ways. First, in relation to the eye movement measures and second, with regards to the experimental paradigm. In Experiments 5 and 6, analysis focused on the proportion of fixations to each of the regions of interest in given time windows as the linguistic event unfolded. Such global eye movement measures have been used previously in the literature, such as by Sansosti et al (2013), so using such measures in the current thesis was justified. However, the disadvantage of global eye movement measures is that the more subtle processing differences between groups are masked. Indeed, Sansosti and colleagues did find group differences. The authors analysed global eye movement measures, including the number of fixations, sum of fixation durations and number of regressions during a comprehension task that necessitated the reader to make bridging inference. However, the findings say little about the more subtle nature of the group differences. Instead, using local temporal eye movement measures might better capture group processing differences. Recall, Benson et al (2012) analysed global eye movement measure (namely, the mean time fixating the target region) in the "which is weird" task, but also analysed local temporal eye movement measures, including the time taken to begin fixating a given region of interest, the number of fixations it took to get there, and the duration of the first fixation when it landed on the target region. By analysing these local temporal eye movement measures the authors could better capture the group processing differences. Given this, it would be interesting to apply this local temporal eye movement analysis to the data in Chapter 5, to be understand the processing strategies of the two groups.

As shown in Chapter 5, the visual world paradigm is an effective task for investigating simulations of language in ASD. Experiment 6 explored how comprehenders track multiple event-related changes in object location, but it would be interesting to investigate whether individuals with ASD are also able to track other event-related changes, such as object state changes. As discussed in Chapter 5, in the current study participants did not see the object (i.e. the sweetcorn/gravy) that was moved, therefore their representation of the object is consistent across time. Of interest in future research would be to investigate how individuals with and without ASD simulate events in which the state of the object is not constant across time. Sentences where an object's state is either minimally (e.g. *"The squirrel will sniff the acorn. And then/But first, it will lick the acorn. "*) or substantially changed (e.g. *"The squirrel will crack the acorn. And then/But first, it will lick the acorn."*) require the comprehender to maintain multiple representations of the same object in different states (i.e. a whole acorn and a cracked acorn), which elicit a competition effect (Hindy, Altmann, Kalenik & Thompson-Schill, 2012). Whether individuals with ASD can track event-related changes in object state, especially when this requires mentally undoing a substantial change event (which seems to be considerably more cognitively demanding than tracking changes in object location), warrants future research.

Finally, as explained above, the findings suggest some possible disruption of executive functions. However, in the current thesis a full assessment of participants' executive functions was not conducted. To investigate the relationship between executive functions and language simulations future research could look to correlate the two. That is, ask participants to complete an assessments of all aspects executive functioning and correlate scores with performance on the visual world paradigm, such as that used in Experiment 6. Individuals with ASD who are impaired in processing sentences such as the *'But first'* sentences, which demands the ability to disengage from and inhibit one episodic trace in favour of another, should may show marked impairments in measures of executive functioning.

6.6 Conclusions

In this thesis I have used a number of psycholinguistic paradigms in conjunction with cognitive research techniques to explore for the first time, simulations of language in individuals with ASD. Using a range of paradigms has allowed me to tap into different aspects of mental simulations, while cognitive research methods such as EEG and eye-tracking have provided measures from the behavioural level to the neurological level. This approach has given insight into mental simulations of language in ASD, an area that until now has been largely neglected. Moreover, this thesis contributes to previous research in terms of what it means to mentally simulate language. Mental representations are the basis of language comprehension and ability, and the current findings show that the ability to simulate language is grounded in language ability as opposed to social skills. In terms of ASD, this finding has implications for how such individuals communicate and understand language.

The research provides evidence that individuals with ASD do simulate language and they do so in the same way as TD individuals. Individuals with ASD are able to simulate the spatial properties of written language and appropriately exploit the sentence context, utilising the same neurological mechanisms as TD individuals. Such individuals also simulate prosodic elements of spoken language, activating representations of the speaker's tone of voice that are comparable to those of TD individuals and which rely on the same underlying oscillatory neural dynamics. But, despite appropriately recognising violations of expected prosody, evident in the fact that individuals with ASD give a lower rating to direct-monotonous speech in comparison to both indirect-monotonous and direct-vivid speech, they rate direct-monotonous speech significantly higher than the TD group. This would imply such individuals do display some explicit deficit or bias in interpreting this prosodic content, but it is unclear from the current findings whether this reflects a deficit in detecting inappropriate prosody or difficulty understanding the instructions (i.e. a semantic deficit).

Furthermore, like TD individuals, simulations by individuals with ASD are activated in real-time as the linguistic event unfolds, and are constrained by the input (i.e. by the verb restrictions). The ability to track object-location changes and activate and maintain multiple episodic traces of these events is also intact in ASD when the temporal sequence of events is uninterrupted. However, when comprehension requires the undoing of simulations, individuals with ASD demonstrate significantly more interference, and an inability to disengage and switch from competing episodic traces. Most notably, individuals with ASD demonstrate subtle differences in processing while simulating language during comprehension, evident in slightly delayed response effects that are subsumed by electrophysiological and eye movement differences. Such processing differences have a significant impact on language comprehension and it is this difference, as opposed to an impairment, that accounts for impairments in the social communication domain in ASD.

Taken together, the experimental findings presented in this thesis provide evidence in favour of a complex information processing dysfunction in ASD as opposed to general language comprehension impairments. The high functioning ASD individuals tested here showed comparable performance to TD individuals on a range of language comprehension tasks, and only when these tasks become significantly more complex (as in Experiment 6) did group differences emerge and ASD participants show notable difficulties in language processing. This thesis therefore provides new insights into simulations of language in ASD and potential advances in understanding the social communication deficits associated with the disorder. It also opens other possible avenues for research to further understand language simulations in ASD.

References

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinion in Neurobiology, 12*, 169 – 177. doi: 10.1016/S0959-4388(02)00301-X

Ahirwal, M. K., & Londhe, N. D. (2012). Power Spectrum Analysis of EEG Signals for Estimating Visual Attention. *International Journal of Computer Applications, 42(15)*, 22 – 25

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the Time Course of Spoken Word Recognition Using Eye Movements: Evidence for Continuous Mapping Models. *Journal of Memory and Language, 38*, 419-439

Altmann, G. T. M. (2004). Language-mediated eye movements in the absence of a visual world: the 'blank screen paradgim'. *Cognition, 93*, 79-87. doi: 10.1016/j.cognition.2004.02.005

Altmann, G. T. M., & Kamide, Y, (1999). Incremental interpretation at verbs: restricting the domain of subsequent reference. *Cognition, 73*, 247-264

Altamm, G. T. M., & Kamide, Y. (2004). Now You See It, Now You Don't: Mediating the Mapping between Language and the Visual World. In J. M. Henderson, & F. Ferreira (Eds.), *The interface of language, vision and action: What we can learn from free-viewing eye tracking* (pp. 347-386). New York: Psychology Press

Altmann, G. T. M., & Kamide, Y. (2007). The real-world mediation of visual attention by language and world knowledge: Linking anticipatory (and other) eye movements to linguistic processing. *Journal of Memory and Language, 57*, 502-518. doi: 10.1016/j.jml.2006.12.004

Altmann, G. T. M., & Kamide, Y, (2009). Discourse-mediation of the mapping between language and the visual world: Eye movements and mental representations. *Cognition, 111*, 55-71. doi: 10.1016/j.cognition.2008.12.005

American Psychiatric Association. (1994). *DSM-IV: Diagnostic and statistical manual of mental disorders* (4th ed., pp. 493 – 518). Washington, DC: American Psychiatric Association

Apperly, I. A., Back, E., Samson, D., & France, L. (2008). The cost of thinking about false beliefs: Evidence from adults' performance on a non-inferential theory of mind task. *Cognition, 106*, 1093 – 1108. doi: 10.1016/j.cognition.2007.05.005

Aravena, P., Hurtado, E., Riveros, R., Cardona, J. F., Manes, F., & Ibánez, A. (2010). Applauding with Closed Hands: Neural Signature of Action-Sentence Compatibility Effects. *PLoS one, 5(7),* e11751

Attwood, A., Frith, U., & Hermelin, B. (1988). The Understanding and Use of Interpersonal Gestures by Autistic and Down's Syndrome Children. *Journal of Autism and Developmental Disorders, 18(2),* 241-257

Au-Yeung, S. K., Benson, V., Castelhano, M., & Rayner, K. (2011). Eye Movement Sequences during Simple versus Complex Information Processing of Scenes in Autism Spectrum Disorder. *Autism Research and Treatment, 2011(Article 657383),* 1 – 7

Au-Yeung, S. K., Kaakinen, J. K., & Benson, V. (2014). Cognitive Perspective-Taking During Scene Perception in Autism Spectrum Disorder: Evidence from Eye Movements. *Autism Research, 7,* 84 – 93

Au-Yeung, S. K., Kaakinen, J. K., Liversedge, S. P., & Benson, V. (2015). Processing of written irony in autism spectrum disorder: An eye-movements study. *Autism Research*. doi: 10.1002/aur.1490

Avikainen, S., Wohlschläger, A., Liuhanen, S., Hänninen, R., Hari, R. (2003). Impaired Mirror Image Imitation in Asperger and High-Functioning Autistic Subjects. *Current Biology, 13(4)*, 339 – 341

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modelling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*, 390 – 412

Bargh, J. C., Chen, M., & Burrows, L. (1996). Automaticity of Social Behaviour: Direct Effects of Trait Construction and Stereotype Activation on Action. *Journal of Personality and Social Psychology, 71(2)*, 230 – 244. doi: 10.1037/0022-3514.71.2.230

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition, 21*, 37-46

Baron-Cohen, S. (1989). The Autistic Child's Theory of Mind: a Case of Specific Developmental Delay. *Journal of Child Psychology and Psychiatry, 30(2)*, 285 – 297

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. *Journal of Developmental and Learning Disorders, 5*, 47-78

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning Autism, Males and Females, Scientisits and Mathematicians. *Journal of Autism and Developmental Disorders*, *31(1)*, 5 – 17

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., & Wheelwright, S. (2003). The systemizing quotient: an investigation of adults with Asperger syndrome or high-functioning autism, and normal sex differences. *Phil. Trans. Royal Society London, 358,* 361-374. doi: 10.1098/rstb.2002.1206

Baron-Cohen, S. (2004). Autism: Research into causes and intervention. *Paediatric Rehabilitation, 7*, 73-78

Baron-Cohen, S. (2009). Autism: The Empathizing-Systemizing (E-S) Theory. *The Year in Cognitive Neuroscience 2009, 1156,* 68-80. doi: 10.1111/j.1749-6632.2009.04467

Baron-Cohen, S., Ashwin. E., Ashwin, C., Tavasolli, T., & Chakrabarti, B. (2009). Talent in autism: hyper-systemizing, hyper-attention to detail and sensory hypersensitivity. *Philosophical Transactions of The Royal Society, 364*, 1377-1383. doi: 10.1098/rstb.2008.0337

Baron-Cohen, S., Scott, F. J., Allison, C., Williams, J., Bolton, P., Matthews, F. E., & Brayne C. (2009). Prevalence of autism-spectrum disorder conditions: UK school-based population study. *The British Journal of Psychiatry, 194*, 500-509. doi: 10.1192/bjp.bp.108.059345

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24- month-old infants. *Infant Behaviour and Development, 19(2),* 159 – 170

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

Barsalou, L. W. (2008). Grounded Cognition. *Annual Review of Psychology, 59*, 617 – 645. doi: 10.1146/annurev.psych.59.103006.093639

Bartlett, F. C. (1932). *Remembering: An experimental and social study.* Cambridge, UK: Cambridge University Press

Baruth, J. M., Casanova, M. F., Sears, L., & Sokhadze, E. (2010). Early-Stage Visual Processing Abnormalities in High-Functioning Autism Spectrum Disorder (ASD). *Translational Neuroscience, 1(2),* 177 – 187

Bastiaansen. M. C. M., van Berkum, J. J. A, & Hagoort, P. (2002a). Event-related theta power increases in the human EEG during online sentence processing. *Neuroscience Letters, 323*, 13 – 16.

Bastiaansen. M. C. M., van Berkum, J. J. A, & Hagoort, P. (2002b). Syntactical Processing Modulates the θ Rhythm of the Human EEG. *NeuroImage, 17*, 1479 – 1492. doi: 10.1016/nimg.2002.1275

Bastiaansen, M. C. M., van der Linden, M. ter Keurs, M., Dijkstra, T., & Hagoort, P. (2005). Theta Responses Are Involved in Lexical-Semantic Retrieval during Language Processing. *Journal of Cognitive Neuroscience, 17(3),* 530 – 541. doi:

Bastiaansen, M. C. M., & Hagoort, P. (2006). Oscillatory neural dynamics during language comprehension. *Progress in Brain Research, 159*, 179 – 196. doi:

Bastiaansen, M. C. M., Oostenveld, R., Jensen, O., & Hagoort, P. (2008). I see what you mean: Theta power increases are involved in the retrieval of lexical semantic information. *Brain and Language, 106*, 15 – 28. doi: 10.1016/j.bandl.2007.10.006

Bastiaansen, M., Mazaheri, A., & Jensen, O. (2012). Beyond ERP's: oscillatory neuronal dynamics. In E. S. Kappenman, & S. J. Luck (Eds.), *The Oxford Handbook of Event-Related Potential Components*. Oxford University Press, Oxford: UK

Bates, D., and Maechler, M. (2010). Package "lme4". Reference manual for the 556 package. Available at http://cran.r-project.org/web/packages/lme4/lme4.pdf 557 (Assessed 22.06.2012)

Beckman, M. (1996). The parsing of prosody. *Language and Cognitive Processes, 11,* 17 – 67

Behrmann, M., Avidan, G., Leonard, G. L., Kimchi, R., Luna, B., Humphreys, K., & Minshew, N. (2006). Configural processing in autism and its relationship to face processing. *Neuropsychologia, 44*, 110 – 129. doi: 10.1016/j.neuropsychologia.2005.04.002

Belkadi, A. (2006). Language impairments in autism: evidence against mind-blindness. *SOAS Working Papers in Linguistics, 14*, 3-13

Benson, V., Castelhano, M. S., Au-Yeung, S. K., & Rayner, K. (2012). Eye movements reveal no immediate "WOW" ("which one's weird") effect in autism spectrum disorder. *The Quarterly Journal of Experimental Psychology, 65(6)*, 1139 – 1150

Bishop, D. V. M., Maybery, M., Wong, D., Maley, A., Hill, W., & Hallmayer, J. (2004). Are Phonological Processing Deficits Part of the Broad Autism Phenotype? *American Journal of Medical Genetics Part B (Neuropsychiatric Genetics), 128(B)*, 54-60

Bishop, D. V. M. (2005). Executive functions in children with communication impairments, in relation to autistic symptomatology. *Autism, 9(1)*, 7 – 27

Bölte, S., Holtmann, M., Poustka, F., Scheurich, A., & Schmidt, L. (2006). Gestalt Perception and Local-Global Processing in High-Functioning Autism. *Journal of Autism and Developmental Disorders*, pages. doi: 10.1007/s10803-006-0231-x

Borreggine, K. L., & Kaschak, M. P. (2006). The Action-Sentence Compatibility Effect: It's All in the Timing. *Cognitive Science*, *30*, 1097 – 1112

Boucher, J., Lewis, V., & Collis, G. M. (2000). Voice Processing Abilities in Children with Autism, Children with Specific Language Impairments, and Young Typically Developing Children. *Journal of child Psychology and Psychiatry, 41(7)*, 847 – 857. doi:

Brock, J., Brown, C. C., Boucher, J., & Rippon, G. (2002). The temporal binding deficit hypothesis of autism. *Development and Psychopathology*, *14*, 209 – 224. doi:

Brock, J., Norbury, C., Einav, S., & Nation, K. (2008). Do individuals with autism process words in context? Evidence from language-mediated eye-movements. *Cognition, 108*, 896 – 904

Brunyé, T. T., Ditman, T., Mahoney, C. R., Walters, E. K., & Taylor, H. A. (2010). You heard it here first: Readers mentally simulate described sounds. *Acta Psycgologica, 135*, 209 – 215. doi: 10.1016/j.actpsy/2010.06.008

Catarino, A., Churches, O., Baron-Cohen, S., Andrade, A., & Ring, H. (2011). Atypical EEG complexity in autism spectrum disorders: A multiscale entropy analysis. *Clinical Neurophysiology, 122*, 2375 – 2383. doi:

Chevallier, C., Noveck, I., Happé, F., & Wilson, D. (2009). From acoustics to grammar: Perceiving and interpreting grammatical prosody in adolescents with Asperger Syndrome. *Research in Autism Spectrum Disorder, 3*, 502 – 516

Clark, H. H., & Gerrig, R. J. (1990). Quotations as Demonstrations. *Language, 66(4),* 764 – 805. doi:

Coben, R., Clarke, A. R., Hudspeth, W., & Barry, R.J. (2008). EEG power and coherence in autism spectrum disorder. *Clinical Neurophysiology, 119*, 1002 – 1009. doi:

Colle, L., Baron-Cohen. S., & Wheelwright, S. (2008). Narrative Discourse in Adults with High-Functioning Autism or Asperger Syndrome. *Journal of Autism and Developmental Disorders, 38*, 28-40. doi: 10.1007/s10803-007-0357-5

Cooper, R. M. (1974). The Control of Eye Fixation by the Meaning of Spoken Language: A New Methodology for the Real-Time Investigation of Speech Perception, Memory and Language Processing. *Cognitive Psychology, 6*, 84-107

Corbett, B. A., Constantine, L. J., Hendren, R., Rocke, D., & Ozonoff, S. (2009). Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development. *Psychiatric Research, 166(2-3),* 210 – 222

Dale, P. S., & Crain-Thoreson, C. (1993). Pronoun reversals: who, when, and why? *Journal of Child Lanugage, 20,* 573-589

David, N., Aumann, C., Bewernick, B. H., Santos, N. S., Lehnhardt, F., & Vogeley, K. (2010). Investigation of Mentalizing and Visuospatial Perspective Taking for Self and Other in Asperger Syndrome. *Journal of Autism and Developmental Disorders, 40,* 290-299. doi: 10.1007/s10803-0867-4

Diefenbach, C., Rieger, M., Massen, C., & Prinz, W. (2013). Action-sentence compatibility: the role of action effects and timing. *Frontiers in Psychology, 4(272),* 1 – 20

Diehl, J. D., Friedberg, C., Paul, R., & Snedeker, J. (2015). The use of prosody during syntactic processing in children and adolscents with autism spectrum disorders. *Developmental Psychopathology, 27,* 867 – 884

Duffy, F. H., & Als, H. (2012). A stable pattern of EEG spectral coherence distinguishes children with autism from neuro-typical controls – a large case control study. *BMC Med Central, 10(64)*

Dunn, M., Vaughan, H., Kreuzer, J., & Kurtzberg, D. (1999). Electrophysiologic Correlates of Semantic Classification in Autistic and Normal Children. *Developmental Neuropsychology, 16(1),* 79 – 99. doi:

Dunn, M., & Bates, J. C. (2005). Developmental changes in neutral processing of words by children with autism. *Journal of Autism and Developmental Disorders, 35(3),* 361 – 376

Ethofer T., Kreifelts, B., Wiethoff, S., Wolf, J., Grodd, W., Vuilleumier, P., & Wildgruber, D. (2009). Differential Influences of Emotion, Task and Novelty on Brain Regions

Underlying the Processing of Speech Melody. *Journal of Cognitive Neuroscience, 21(7)*, 1255 – 1268. doi: 10.1162/jocn.2009.21099

Ferguson, H. J., Tresh, M., & Leblond, J. (2013). Examining mental simulations of uncertain events. *Psychonomic Bulletin and Review, 20*, 391 – 399.

Ferstl, E. C., & von Cramon, D. Y. (2002). What Does the Frontomedian Cortex Contribute to Language Processing: Coherence of Theory of Mind? *Neuroimage*, *17*, 1599-1612. doi: 10.1016/nimg.2002.1247

Flavell, J. H., Everett, B. A., Croft, K., & Flavell, E. R. (1981). Young Children's Knowledge About Visual Perception: Further Evidence for the Level 1-Level 2 Distinction. *Developmental Psychology, 17(1)*, 99-103

Frith, U. (1989). *Autism: Explaining the Enigma.* Oxford, UK: Basil Blackwell

Frith, U., & Happé, F. (1994). Autism: Beyond "theory of mind". *Cognition, 50*, 115-132

Foroni, F., & Semin, G. R. (2013). Comprehension of action negation involves inhibitory simulation. *Frontiers in Human Neuroscience, 7(209)*, 1 – 7. doi: 10.3389/fnhum.2013.00209

Gabard-Durnman, L., Tierney, A. L., Vogel-Farley, V., Tager-Flusberg, H., & Nelson, C. A. (2013). Alpha Asymmetry in Infants at Risk for Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders,…* doi: 10.1007/s10803-013-1926-4

Geurts, H. M., Verté, S., Oosterlaan, J., Roeyers, H., & Sergeant, J. A. (2004). How specific are executive functioning deficits in attention deficit hyperactivity disorder and autism? *Journal of Child Psychology and Psychiatry*, *45(4)*, 836 – 854. doi:

Gevins, A., Smith, M. E., McEvoy, L., & Yu, D. (1997). High-resolution EEG mapping of cortical activation related to working memory: effects of task difficulty, type of processing, and practice. *Cerebral Cortex, 7*, 374 – 385. doi:

Glenberg, A. M., Meyer, M., & Lindem, K. (1987). Mental models contribute to foregrounding during text comprehension. *Journal of Memory and Language, 26(1),* 69 – 83

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin and Review, 9(3)*, 558-565

Glenberg, A., Sato, M., Cattaneo, L., Riggio, L., Palumbo, D., & Buccino, G. (2008). Processing Abstract Language Modulates Motor Ststem Activity. *Quarterly Journal of Experimental Psychology, 61(6),* 905 – 919

Gomot, M., Giard, M., Adrien, J., Barthelemy, C., & Bruneau, N. (2002). Hypersensitivity to acoustic changes in children with autism: Electrophysiological evidence of left frontal cortex dysfunctioning. *Psychophysiology, 39,* 577 – 584

Gomot, M., Bernard, F. A., Davis, M. H., Belmonte, M. K., Ashwin, C., Bullmore, E. T., & Baron-Cohen, S. (2006). *NeuroImage, 29,* 475 – 484

Griffiths, 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:

Groan, W. B., Ziers, M. P., van der Gaag, R., & Buitelaar, J. K. (2008). The phenotype and neural correlates of language in autism: A integrative review. *Neuroscience and Biobehavioural Reviews, 32*, 1416-1425. doi: 10.1016/j.neurobiorev.2008.05.008

Grossman, R. B., Bemis, R. H., Skwerer, D. P., & Tager-Flusberg, H. (2010). Lexical and Affective Prosody in Children with High Functioning Autism. *Journal of Speech, Language, and Hearing Research, 53,* 778 – 793

Hadjikhani, N., Joseph, R. M., Snyder, J., & Tager-Flusberg, H. (2006). Anatomical Differences in Mirror Neuron System and Social Cognitive Network in Autism. *Cerebral Cortex, 16*, 1276 – 1282

Hagoort, P., Hald, L., Bastiaansen, M., & Petersson, K. M. (2004). Integration of Word Meaning and World Knowledge in Language Comprehension. *Science, 304*, 438 – 441. doi:

Hald, L. A., Steenbeek-Planting, E. G., & Hagoort (2007). The interaction of discourse context and world knowledge in online sentence comprehension. Evidence from the N400. *Brain Research, 1146,* 210 – 218

Hald, L. A., Marshall, J., Janssen, D. P., & Garnham, A. (2011). Switching modalities in a sentence verification task: ERP evidence for embodied language processing. *Frontiers in Psychology, 2(45),* 1- 15. doi:

Halgren, E., Dhond, R. P., Christensen, N., Van Petten, C., Marinkovic, K., Lewine, J. D., & Dale, A. M. (2002). N400-like Magnetoencephalography Responses Modulated by Semantic Context, Word Frequency, and Lexical Class in Sentences. *NeuroImage, 17*, 1101 – 1116

Háppe, F. G. E. (1993). Communicative competence and theory of mind in autism: A test of relevance theory. *Cognition, 48*, 101 – 119

Háppe, F. G. E. (1994). An Advanced Trst of Theory of Mind: Understanding of Story Characters' Thoughts and Feelings by Able, Autistic, Mentally Handicapped and Normal Children and Adults. *Journal of Autism and Developmental Disorders, 24,* 129 – 154

Happé, F. (1996). Studying weak central coherence at low levels: children with autism do not succumb to visual illusions: a research not. *Journal Child Psychology and Psychiatry, 37*, 873-877

Háppe, F. G. E. (1997). Central coherence and theory of mind in autism: Reading homographs in context. *British Journal of Developmental Psychology, 15(1)*, 1 – 12. doi:

Happé, F. (1999). Autism: cognitive deficit or cognitive style? *Trends in Cognitive Sciences, 3(6)*, 216-222

Happé, F., Ronald, A., & Plomin, R. (2003). Time to give up on a single explanation for autism. *Nature Neuroscience, 9(10)*, 1218-1220. doi: 10.1038/nn1770

Happé, F., & Frith, U. (2006). The Weak Coherence Account: Detail-focused Cognitive Style in Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders,* , pages. doi: 10.1007/s10803-005-0039-0

Hill, E. L. (2004). Executive dysfunction in autism. *TRENDS in Cognitive Neurosciences, 8(1)*, 26 – 32

Hill, E. L., & Bird, C. M. (2006). Executive processes in Asperger Syndrome: Patterns of performance in a multiple case series. *Neuropsychologia, 44*, 2822 – 2835

Hindy, N. C., Altmann, G. T. M., Kalenik E., & Thompson-Schill, S. L. (2012). The Effect of Object State-Change on Event Processing: Do Objects Compete with Themselves? *Journal of Neuroscience, 32(17)*, 5795 – 5803

Hindy, N. C., Solomon, S. H., Altmann, G. T. M., & Thompson-Schill, S. L. (2015). A Cortical Network for the Encoding of Object Change. *Cerebral Cortex, 25*, 884 – 894

Hirschfeld, G., Zwitswerlood, P., & Dobel, C. (2011). Effects of language comprehension on visual processing – MEG dissociates early perceptual and late N400 effects. *Brain and Language, 116(2),* 91 – 96. doi: 10.1016/j.bandl.2010.07.002

Hirschfeld, G., Feldker, K., & Zwitserlood, P. (2012). Listening to “flying ducks”: Individual differences in sentence-picture verification investigated with ERPs. *Psychophysiology, 49*, 312 – 321. doi: 10.1111/j.1469-8986.2011.01315.x

Hommel, B., Musseler, J., Aschersleben, G., & Prinz, W. (2001). The Theory of Event Coding (TEC): A framework for perception and action planning. *Behavioural and Brain Science, 24*, 849 – 937

Howlin, P., Goode, S., Hutton, J., & Rutter, M. (2009). Savant skills in autism: psychometric approaches and parental reports. *Philosophical Transactions of The Royal Society, 364*, 1359-1367. doi: 10.1098/rstb.2008.0328

Huettig, F., Rommers, J., & Meyer, A. S. (2011). Using the visual world paradigm to study language processing: A review and critical evaluation. *Acta Psychologia, 3,* (21 pages). doi: 10.1016/j.actpsy.2010.11.003

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

Hughes, C. Russell, J., & Robbins, T. W. (1994). Evidence of executive dysfunction in autism. *Neuropsychologia, 32(4),* 477 – 492

Ingersoll, B. (2008). The Social Role of Imitation in Autism: Implications for the Treatment of Imitation Deficits. *Infants and Young Children, 21(2),* 107 – 119

Jaegher, H. (2013). Embodiment and sense-making in autism. *Frontiers in Integrative Neuroscience, 7(15)*, 1-19.doi: 10.3389/fnint.2013.00015

Jarrold, C., & Russell, J. (1997). Counting Abilities in Autism: Possible Implications for Central Coherence Theory. *Journal of Autism and Developmental Disorders, 27(1),* 25-38. doi:

Jolliffe, T., & Baron-Cohen, S. (1999). A test of central coherence theory: linguistic processing in high-functioning adults with autism or Asperger syndrome: is local coherence impaired? *Cognition, 71*, 149 – 185.

Jurado, M. B., & Rosselli, M. (2007). The Elusive Nature of Executive Functions: A Review of our Current Understanding. *Neuropsychological Review, 17*, 2013 – 233

Just, M. A., Cherkassky, V. L., Keller, T. A., & Minshew, N. J. (20040. Cortical activation and synchronisation during sentence comprehension in high-functioning autism: evidence of underconnectivity. *Brain, 127*, 1811-1821. doi: 10.1093/brain/awh199

Kaland, N., Smith, L., & Mortensen, E. L. (2008). Brief Report: Cognitive Flexibility and Focused Attention in Children and Adolescents with Asperger Syndrome or High-Functioning Autism as Measured on the Computerised Version of the Wisconsin Card Sorting Test. *Journal of Autism and Developmental Disorders, 36*, 1161 – 1165

Kamide, Y., Altmann, G. T. M., & Haywood, S. L. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language, 49,* 133-156. doi: 10.1016/S0749-596X(03)00023-8

Kamide, Y., Lindsay, S., Scheepers, C., & Kukona, A. (2015). Event processing the visual world: Projected motion paths during spoken sentence comprehension. *Journal of Experimental Psychology, Learning, memory and cognition.*

Kaschak, M. P., & Borreggine, K. L. (2008). Temporal dynamics of the action-sentence compatibility effect. *Quarterly Journal of Experimental Psychology, 61(6),* 883 – 895

Kaup, B., Lüdtke, J., & Zwaan, R. A. (2006). Processing negated sentences with contradictory predicates: Is a door that is not open mentally closed? *Journal of Pragmatics, 38*, 1033 – 1050. doi: 10.1016/j.pragma.2005.09.012

Kaup, B., Yaxley, R. H., Madden, C. J., Zwaan, R. A., & Lüdtke, J. (2007). Experiential simulation of negated text information. *The Quarterly Journal of Experimental Psychology, 60(7)*, 976 – 990. doi: 10.1080/17470210600823512

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

Klimesch, W., Schmike,H., & Schwaiger, J. (1994). Episodic and semantic memory: an analysis in the EEG theta and alpha band. *Electroencephalography and Clinical Neurophysiology, 91(6)*, 428 – 441. doi: 10.1016/13-4694(94)90164-3

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain Research Reviews, 29*, 169 – 195

Klimesch, W., Doppelmayr, M., & Hanslmayr, S. (2006). Upper alpha ERD and absolute power: their meaning for memory performance. *Progress in Brain Research*, *159*, 151 – 164. doi: 10.1016/S0079-61213(06)59010-7

Koenig, T., Marti-Lopez, F., & Valdes-Sosa, P. (2001). Topographic Time-Frequency Decomposition of the EEG. *NeuroImage, 14*, 383 – 390

Krahmer, E., & Swerts, M. (2005). How Children and Adults Produce and Perceive Uncertainty in Audiovisual Speech. *Language and Speech, 48(1)*, 29 – 53. doi: 10.1177/00238309050480010201

Kukona, A., Altmann, G. T. M., & Kamide, Y. (2014). Knowing *what, where and when*: Event comprehension in language processing. *Cognition*, *133(1)*, 25 – 31

Kurby, C. A., Magliano, J. P., & Rapp, D. N. (2009). Those Voices in your Head: Activation of Auditory Images During Reading. *Cognition, 112(3)*, 457 – 461. doi: 10.1016/j.cognition.2009.05.007

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 4(12)*, 463 – 470. doi: 10.1016/S1364-6613(00)01560-6

Kutas, M., & Hillyard, S. A. (1980). Reading Senseless Sentences: Brain Potentials Reflect Semantic Incongruity. *Science, 207(4427)*, 203 – 205. doi:

Lahaie, A., Mottron, L., Arguin, M., Berthiaume, C., Jemel, B., & Saumier, D. (2006). Face Perception in High-Functioning Autistic Adults: Evidence for Superior Processing of Face Parts, Not for a Configural Face-Processing Deficit. *Neuropsychology, 20(1)*, 30 – 41. doi: 10.1037/0894-4105.20.1.30

Lawson, J., Baron-Cohen, S., & Wheelwright, S. (2004). Empathising and Systemising in Adults with and without Asperger Syndrome. *Journal of Autism and Developmental Disorders, 34(3)*, 301 – 310

Liberman, A. M., & Mattingly, I. G. (1985). The motor theory of speech perception revised. *Cognition, 21*, 1 – 36

Lindgren, K. A., Folstein, S. E., Tomblin, J. B., & Tager-Flusberg, H. (2009). Language and Reading Abilities of Children with Autism Spectrum Disorders and Specific Language Impairment and Their First-Degree Relatives. *Autism Research, 29(1)*, 22 – 38

Lindsay, S., Scheepers, C., & Kamide, Y. (2013). To Dash or to Dawdle: Verb-Associated Speed of Motion Influences Eye Movements during Spoken Sentence Comprehension. *PLOS one, 8(6)*, 1 – 11

Liss, M., Fein, D., Allen, D., Dunn., M., Feinstein, C., Morris, R., Waterhouse, L., & Rapin, I. (2001). Executive Functioning in High-function Children with Autism. *Journal of Child Psychology and Psychiatry, 42(2),* 261 – 270

Litman, D., Rotaru, M., & Nicholas, G. (2003). Classifying Turn-Level Uncertainty Using Word-Level Prosody. In *Proceedings of Interspeech 2009*

López,B., Donnelly, N., Hadwin,J. A., & Leekam, S. R. (2004). Face processing in high-functioning adolescents with autism: Evidence for a weak central coherence. *Visual Cognition, 11,* 673 – 688. doi: 10.1080/13506280344000437

Lucas, R., & Norbury, C. F. (2014). Levels of Text Comprehension in Children with Autism Spectrum Disorders (ASD): The Influence of Language Phenotype. *Journal of Autism and Developmental Disorders, 44(11),* 2756 – 27568

Luck, S. J., & Kappenman, E. S. (2013). *The Oxford Handbook of Event-Related Potential Components*. Oxford University Press, Oxford: UK

MacKay, G., & Shaw, A. (2004). A comparative study of figurative language in children with autistic spectrum disorders. *Child language Teaching and Therapy, 20,* 13 – 32

Martin, I., & McDonald, S. (2003). Weak central coherence, no theory of mind, or executive dysfunction? Solving the puzzle of pragmatic language disorders. *Brain and Language, 85*, 451 – 466

Martin, I., & McDonald, S. (2004). An Exploration of Causes of Non-Literal Language Processing in Individuals with Asperger Syndrome. *Journal of Autism and Developmental Disorders, 34(3),* 311 – 328

Martineau, J., Cochin, S., Magne, R., & Barthelemy, C. (2008). Impaired cortical activation in autistic children: Is the mirror neuron system involved? *International Journal of Psychophysiology, 68*, 35 – 40

Masangkay, Z. S., McCluskey, K. A., McIntyre, C. W., Sims-Knight, J., Vaughn, B. E., & Flavell, J. H, (1974). The Early Development of Inferences about the Visual Percepts of Others. *Child Development, ,* 357-366. doi:

Mathewson, K. J, Jetha, M. K., Drmic, I. E., Bryson, S. E., Goldberg, J. O., & Schmidt, L. A. (2012). Regional EEG alpha power, coherence, and behavioural symptomatology in autism spectrum disorder. *Clinical Neurophysiology, 123,* 1798 – 1809. doi:

Matson, J. L., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorder. *Research in Autism Spectrum Disoders, 5(1),* 418-425. doi: 10.1016/j.rasd.2010.06.004

McAlonan, G. M., Cheung, V., Cheung, C., Suckling, J., Lam, G. Y., Tai, K. S., Yip, L., Murphy, D. G. M., & Chua, S. E. (2005). Mapping the brain in autism. A voxel-based MRI study of volumetric differences and intercorrelations in autism. *Brain, 128,* 268 – 276

McPartland, J. C., Reichow, B., & Volkmare, F. R. (2012). Sensitivity and Specificity of Proposed *DSM-5* Diagnostic Criteria for Autism Spectrum Disorder. *Journal of American Academy of Child & Adolescent Psychiatry, 51(4),* 368-383

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of Facial and Manual Gestures by Human Neonates. *American Association for the Advancement of Science, 198 (4312),* 75 – 78

Mesulam, M. M. (1998). From sensation to cognition. *Brain, 121,* 1013 – 1052

Minshew, N. J., Goldstein, G., & Siegel, D. J. (1995). Speech and Language in High-Functioning Autistic Individuals. *Neuropsychology, 9(2),* 255 – 261

Minshew, N. J. ,& Goldstein, G. (1998). Autism as a Disorder of Complex Information Processing. *Mental Retardation and Developmental Disorders Research Reviews, 4,* 129 – 136

Minshew, N. J., Williams, D. L., & McFadden, K. (2008). Information processing, Neural Connectivity, & Neuronal Organization. In A. W. Zimmermann (Ed.), *Autism: Current theories and evidence* (pp. 381 - 405). Totowa, NJ: Humana Press

Mizuno, A., Liu, Y., Williams, D. L., Keller, T. A., Minshew, N. J., & Just, M. A. (2011). The neural basis of deictic shifting in linguistic perspective-taking in high-functioning autism. *Brain, 134*, 2422-2435. doi: 10.1093/brain/awr151

Moll, H., & Tomasello, M. (2006). Level 1 perspective-taking at 24 months of age. *British Journal of Developmental Psychology, 24*, 603-613. doi: 10.1348/026151005X55370

Mottron, L., Peretz, I., & Ménard, E. (2000). Local and Global Processing of Music in High-functioning Persons with Autism: Beyond Central Coherence? *Journal of Child Psychology and Psychiatry, 41(8),* 10575-1065

Murias, M., Webb, S. J., Greenson, J., & Dawson, G. (2007). Resting state cortical connectivity reflected in EEG coherence in individuals with autism. *Biological Psychiatry, 62(3),* 270 – 273. doi:

Muthukumaraswamy, S. D., Johnson, B. J., & McNair, N. A. (2004). Mu rhythm modulation during observation of an object-directed grasp. *Cognitive Brain Research, 19*, 195 – 201

Nieuwland, M. S., & Kuperberg, G. R. (2008) When the Truth is Not Too Hard to Handle: An Event-Related Potential Study on Pragmatics of Negation. *Psychological Science, 19(12),* 1213 - 1218

Nigam, A., Hoffman, J. E., & Simons, R. F. (1992). N400 to Semantically Anomalous Pictures and Words. *Journal of Cognitive Neuroscience, 4(1),* 15 – 22. doi: 10.1162/jocn.1992.4.1.15

Norbury,C. F., & Bishop, D. V. M. (2002). Inferential processing and story recall in children with communication problems: a comparison of specific language impairment, pragmatic language impairment and high-functioning autism. *International Journal of Language and Communication Disorders, 37(3)*, 227 – 251

Norbury, C. F., & Nation, K. (2011). Understanding Variability in Reading Comprehension in Adolescents With Autism Spectrum Disorders: Interactions With language Status and Decoding Skills. *Scientific Studies of Reading, 15(3)*, 191 – 210

Noveck, I. A., Guelminger, R., Georgieff, N., & Labruyere, N. (2007). What Autism Can Reveal About *Every…not* Sentences. *Journal of Semantics, 24*, 73 – 90

Oberman, L. M., Hubbard, E. M., McCleery, J. P., Altschuler, E. L., Ramachandran, V. S., & Pineda, J. A. (2005) EEG evidence for mirror neuron dysfunction in autism spectrum disorder. *Cognitive Brain Researh, 24*, 190 – 198

Oberman, L. M., & Ramachandran, V. S. (2007). The Simulating Social Mind: The Role of the Mirror Neuron System and Simulation in the Social and Communicative Deficits of Autism Spectrum Disorder. *Psychological Bulletin, 133(2)*, 310 – 327

Oberman, L. M., Ramachandran, V. S., & Pineda, J. A. (2008). Modulation of mu suppression in children with autism spectrum disorders in response to familiar or unfamiliar stimuli: The mirror neuron hypothesis. *Neuropsychologia, 46*, 1558 – 1565

Ozonoff, S., & McEvoy, R. E. (1994). A longitudinal student of executive function and theory of mind development in autism. *Development and Psychopathology, 6*, 415 – 431

Ozonoff, S., & Jensen, J. (1999). Brief Report: Specific Executive Function Profiles in Three Neurodevelopmental Disorders. *Journal of Autism and Developmental Disorders, 29(2)*, 171 – 177

Pecher, D., van Dantzig, S., Zwaan, R. A., & Zeelenberg, R. (2009). Language comprehenders retain implied shape and orientation of objects. *The Quarterly Journal of Experimental Psychology, 6296),* 1108 – 1114

Pijnacker, J., Geurts, B., van Lambalgen, M., Buitelaar, J., & Hagoort, P. (2010). Exceptions and anomalies: An ERP study on context sensitivity in autism. *Neuropsychologia, 48,* 2940 – 2951. doi:

Pon-Barry, H., & Shieber, S. M. (2011). Recognizing Uncertainty in Speech. *EURASIP Journal on Advances in Signal Processing, 2011(251753),* 1- 11. doi: 10.1155/2011/251753

Paul, R., Augustyn, A., Klin, A., & Volkmar, F. R. (2005). Perception and Production of Prosody by Speakers with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 35(2),* 205-220. doi: 10.1007/s10803-004-1999-1

Peppé, S., McCann, J., Gibbon, F. E., O'Hare, A., & Rutherford, M. (2006). Receptive and Expressive Prosodic Ability in Children with High-Functioning Autism. *QMU Speech Science Research Centre Working Papers, WP-5*

Perkins, T., Stoke, M., McGillivray, J. & Bittar, R. (2010). Mirror neuron dysfunction in autism spectrum disorders. *Journal of Clinical Neuroscience, 17,* 1239 – 1243

Piaget, J., Inhelder, B., & Mayer, E. (1967). The Co-ordination of Perspectives. In J. Piaget & B. Inhelder (Eds.), *The Child's Conception of Space* (pp. 209-246). London, UK: Routledge & Kegan Paul

Prioir, M. (2003). Is there an increase in the prevalence of autism spectrum disorders? *Journal of Paediatric Child Heath, 39,* 81-82

Pulvermüller, F., Lutzenberger, W., & Preissl, H. (1999). Nouns and Verbs in the Intact Brain: Evidence from Event-related Potentials and High-frequency Cortical Responses. *Cerebral Cortex, 9,* 497 – 506. doi:

Pulvermüller, F. (2001). Brain reflections of words and their meaning. *TRENDS in Cognitive Sciences, 5(12),* 517 – 524. doi:

Pulvermüller, F., Härle, M., & Hummel, F. (2001). Walking or Talking?: Behavioural and Neurophysiological Correlates of Action Verb Processing. *Brain and Language, 78*, 143 – 168. doi: 10.1006/brln.2000.2390

Pulvermüller, F. Hauk, O., Nikulin, V. V., & Ilmoniemi, R. J. (2005). Functional links between motor and language systems. *European Journal of Neuroscience, 21*, 793 – 797. doi: 10.1111/j.1460-9568.2005.03900.x

Pulvermüller, F., Shtyrov, Y., & Ilmoniemi, R. (2005). Brain Signatures of Meaning Access in Action Word Recognition. *Journal of Cognitive Neuroscience, 17(6),* 884 – 892

Ramachandran, V. S. (2000). Mirror neurons and imitation learning as the driving force behind “the great leap forward” in human evolution. Retrieved from http://www.edge.org/3rd_culture/ ramachandran/ramachandran_p1.html.

Ramachandran, V. S., & Oberman, L. M. (2006). Broken mirrors: A theory of autism. *Scientific American, 295*, 62 – 69

Rapin, I., & Dunn, M. (2003). Update on the language disorders of individuals on the autism spectrum. *Brain and Development, 25*, 166-172. doi: 10.1016/S0387-7604(02)00191-2

Rizzolatti, G., Arbib, M. A. (1998). Language within our grasp. *Trends in Neuroscience, 21*, 188 – 194

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience, 2*, 661 – 670

Rizzolatti, G., Fogassi, L., & Gallese, V. (2006). Mirrors in the mind. *Scientific American, 295(5),* 54 – 61

Robinson, S., Goddard, L., Dritschel, B., Wisely, M., & Howlin, P. (2009). Executive functions in children with Autism Spectrum Disorders. *Brain and Cognition, 71(3),* 362 – 368

Röhm, D., Klimesch, W., Haider, H., & Doppelmayr, M. (2001). The role of theta and alpha oscillations for language comprehension in the human electroencephalogram. *Neuroscience Letters, 310(2-3),* 137 – 140. doi: 10.1016/S0304-3940(01)02106-1

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

Ronald, A., Happé, F., Bolton, P., Butcher, L. M., Price, T. S., Wheelwright, S., Baron-Cohen, S., & Plomin, R. (2006). Genetic Heterogeneity Between the Three Components of the Autism Spectrum: A Twin Study. *Journal of the American Academy of Child & Adolescent Psychiatry, 45(6),* 691-699. doi: 10.1097/01.chi.0000215325.13058.9d

Rogers, S. J., Bennetto, L., McEvoy, R., & Pennington, B. F. (1996). Imitation and Pantomime in High-Functioning Adolescents with Autism Spectrum Disorder. *Child Development, 67*, 2060 – 2073

Rogers, S. J., Hepburn, S. L., Stackhouse, T., & Wehner, E. (2003). Imitation performance in toddlers with autism and those with other developmental disorders. *Child Psychology and Psychiatry, 44,* 763 – 781

Rundblad, G., & Annaz, D. (2009). The atypical development of metaphor and metonymy comprehension in children with autism. *Autism*, 1-18

Russo, N. M., Shoe, E., Trommer, B., Nicol, T., Zecker, S., Bradlow, A., & Kraus, N. (2008). Deficient Brainstem Encoding of Pitch in Children with Autism Spectrum Disorders. *Clinical Neuropsychology, 119(8),* 1720 – 1731

Rutherford, M. D., Baron-Cohen, S., & Wheelwright, S. (2002). Reading the Mind in the Voice: A Study with Normal Adults and Adults with Asperger Syndrome and High Functioning Autism. *Journal of Autism and Developmental Disorders, 32(3),* 189-194

Saldaña, D., & Frith, U. (2007). Do readers with autism make bridging inferences from world knowledge? *Journal of Experimental Child Psychology, 96*, 310 – 319

Salmond, C. H., Vargha-Khadem, F., Gadian, D. G., de Haan, M., & Baldeweg, T. (2007). Heterogeneity in the Patterns of Neural Abnormality in Autistic Spectrum Disorders: Evidence from ERP and MRI. *Cortex, 43,* 686-699

Sanford, A. J., & Garrod, S. C. (1981). *Understanding written language: Explorations of comprehension beyond the sentence*. Chichester, UK: Wiley

Sanford, A. J., & Emmott, C. (2012). *Mind, Brain and Narrative.* Cambridge, UK: Cambridge University Press

Sansosti, F. J., Was, C., Rawson, K. A., & Remaklus, B. L. (2013). Eye movements during processing of text requiring bridging inferences in adolescents with higher functioning autism spectrum disorders: A preliminary investigation. *Research in Autism Spectrum Disorders, 7,* 1535 – 1542

Schaffer, H. R. (2004). *Introducing Child Psychology.* Blackwell Publishing

Schank, R., & Abelson, R. (1977). *Scripts, plans, goals, and understanding.* Hillsdale, N.J: Erlbaum

Scorolli, C., & Borghi, A. M. (2007). Sentence comprehension and action: Effector specific modulation of the motor system. *Brain Research, 1130,* 119 – 124

Singer, W. (1999). Neuronal Synchorny: A Versatile Code for the Definition of Relations? *Neuron, 24*, 49 – 65

Singh, N., & Mishra, K. (2010). Simulating Motion in Figurative Language Comprehension. *The Open Neuroimaging Journal, 4*, 46 – 52. doi: 10.2174/1874440001004010046

South, M., Ozonoff, S., McMahon, W. M. (2007). The relationship between executive functioning, central coherence, and repetitive behaviours in the high-functioning autism spectrum. *Autism, 11*, 437 – 451

Sperber, D., & Wilson, D. (1987). Précis of Relevance: Communication and Cognition. *Behavioural and Brain Science, 10*, 697 – 754

Stanfield, R. A., & Zwaan, R. A. (2001). The Effect of Implied Orientation Derived from Verbal Context on Picture Recognition. *Psychological Science, 12(2),* 153 – 156. doi: 10.1111/1467-9280.00326

Stone, W. L., Ousley, O. Y., & Littleford, C. D. (1997). Motor imitation in young children with autism: What's the object? *Abnormal Child Psychology, 25,* 475 – 485

Stone, W. L., & Yoder, P. J. (2001). Predicting Spoken Language Level in Children with Autism Spectrum Disorders. *Autism, 5(4),* 341 – 361. doi: 10.1177/1362361301005004002

Stroop, J. R. (1935). Studies of inference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643 – 662

Tian, Y., Breheny, R., & Ferguson, H. J. (2010). Why we simulate negated information: A dynamic pragmatic account. *The Quarterly Journal of Experimental Psychology, 63(12),* 2305 – 2312. doi: 10.1080/17470218.2010.525712

Tager-Flusberg, H. (1999). A Psychological Approach to Understanding Social and Language Impairments in Autism. *Int Rev Psychiatry, 11(4),* 325-334

Tager-Flusberg, H., Paul, R., & Lord, C. (2005). Language and Communication in Autism. In F. R. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.), *Handbook of autism and* *pervasive developmental disorders* (3rd ed.) (pp. 335 – 364). Hoboken, NJ: Wiley and Sons

Tanenhaus, M. K., & Trueswell, J. C. (2006). Eye Movements and Spoken Language Comprehension. *I*n M. J. Traxler, & M. A. Gernsbacher. (Eds.), *Handbook of Psycholinguistics* (pp. 863-900). (Second Edition). Amsterdam: Elsevier

Tettamanti, M., Manenti, R., Della Rosa, P. A., Falini, A., Perani, D., Cappa, S. F., & Moro, A. (2008). Negation in the brain: Modulating action representations. *NeuroImage, 43,* 358 – 367. doi: 10.1016/j.neuroimage.2008.08.004

Tian, Y., Breheny, R., & Ferguson, H. J. (2010). Why We Simulate Negated Information: A Dynamic Pragmatic Account. *The Quarterly Journal of Experimental Psychology, 63*, 2305 - 2312

Tierney, A. L., Gabard-Durnam, L., Vogel-Farley, V., Tager-Flusberg, H., & Nelson, C. A. (2012). Developmental Trajectories of Resting Power: An Endophenotype of Autism Spectrum Disorder. *PLoS ONE, 7(6),* e39127

Théoret, H., Halligan, E., Kobayashi, M., Fregni, F., Tager-Flusberg, H., & Pascual-Leone, A. (2005). Impaired motor facilitation during action observation in individuals with autism spectrum disorder. *Current Biology, 15(3),* 84 – 85

Toal, F., Daly, E. M., Page, L., Deeley, Q., Bloemen, O., Cutter, W. J., Brammer, M. J., Curran, S., Robertson, D., Murphy, C., Murphy, K. C., & Murphy, D. G. M. (2009). Clinical and anatomical heterogeneity in autistic spectrum disorder: a structural MRI study. *Psychological Medicine,* , pages. doi: 10.1017/S0033291709991541

Tomasello, M. (1999). The Human Adaptation for Culture. *Annual Review of Anthropology, 28,* 509 – 529

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Henrike, M. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioural and Brain Sciences, 28*, 675 – 735

Towgood, K. J., Meuwese, J. D. I., Gilbert, S. J., Turner, M. S., & Burgess, P. W. (2009). Advantages of the multiple case series approach to the study of cognitive deficits in autism spectrum disorder. *Neuropsychologia, 47*, 2981 – 2988. doi: 10.1016/j.neuropsychologia.2009.06.028

Tucker, D. M., Roth, D. L., & Bair, T. B. (1986). Functional Connections Among Cortical Regions: Topography of EEG Coherence. *Electroencephaolography and clinical Neurophysiology*, *63*, 242 – 250

Van Berkum, J. J. A., Hagoort, P., & Brown, C. M. (1999). Semantic Integration in Sentences and Discourse: Evidence from the N400. *Journal of Cognitive Neuroscience*, *11(6)*, 657 – 671

Van Berkum, J. J. A., Zwitserlood, P., Hagoort, P., & Brown, C. M. (2003). When and how do listeners relate a sentence to the wider discourse? Evidence from the N400 effect. *Cognitive Brain Research, 17,* 701 – 718

Van Droof, L., Ledoux, K., Pickett, E. J., Buz, E., Billings, N., & Gordon, B. (2010, May). *Advancing the Measurement of Receptive Language in Nonverbal Individuals with Autism.* Poster presented at The International Meeting for Autism Research (IMFAR), Philadelphia, PA.

Van Herten, M., Kolk, H. H. J., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Cognitive Brain Research*, *22*, 241 – 255

Vivanti, G., McCormick, C., Young, S., nadig, A., Ozonoff, S., & Rogers, S. J. (2011). Intact and Impaired Mechanisms of Action Understanding in Autism. *Developmental Psychology, 47(3),* 841 – 856

Von Kriegstein, K., Eger, E., Kleinschmidt, A., & Giraud, A. L. (2003). Modulation of neural responses to speech by directing attention to voices or verbal content. *Cognitive Brain Research, 17,* 48 – 55. doi:

Wagner, M., & Watson, D. G. (2010). Experimental and theoretical advances in prosody: A review. *Language and Cognitive Processes, 25(7-9),* 905 – 945

Wang, A. T., Lee, S. S., Sigman, M., & Dapretto, M. (2006). Neural basis of irony comprehension in children with autism: the role of prosody and context. *Brain, 129,* 932-943. doi: 10.1093/brain/aw1032

Warreyn, P., Roeyers, H., Oelbrandt, T., & De Groote, I. (2005). What Are You Looking at? Joint Attention and Visual Perception Taking in Young Children With Autism Spectrum Disorder. *Journal of Developmental and Physical Disabilities, 17(1),* 55-73. doi: 10.1007/s10882-005-2201-1

West, W. C., & Holcomb, P. J. (2002). Event-related potentials during discourse-level semantic integration of complex pictures. *Cognitive Brain Research, 13,* 363 – 375

Williams, J. H. G., Whiten, A., Sudendorf, T., & Perrett, D. I. (2001). Imitation, mirror neurons, and autism. *Neuroscience and Biobehavioural Review, 25,* 287 – 295

Williams, J. H. G., Waiter, G. D., Gilchrist, A., Perrett, D. I., Murray, A. D., & Whiten, A. (2006). Neural mechanisms of imitation and 'mirror neuron' functioning in autistic spectrum disorder. *Neuropsychologia, 44,* 610 – 621

Wimmer, H., & Perner, J. (1983). Beliefs and beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition, 13*, 103-128

Yao, B., & Scheepers, C. (2011). Contextual modulation of reading rate for direct versus indirect speech quotations. *Cognition, 121*, 447-453. doi: 10.1016/j.cognition.2011.08.007

Yao, B., & Scheepers, C. (2011). Silent reading of direct versus indirect speech activates voice-selective areas in auditory cortex. *Journal of Cognitive Neuroscience, 23(10),* 3146-3152

Yao, B., Belin, P., & Scheepers, C. (2012). Brain 'talks over' boring quotes: Top-down activation of voice-selective areas while listening to monotonous direct speech quotations. *NeuroImage, 60(3),* 1832 – 1842. doi: 10.1016/j.neuroimage.2012.01.111

Yao, B., & Scheepers, C. (2015). "Inner Voice Experiences during Processing of Direct and Indirect Speech." Explicit and Implicit Prosody in Sentence Processing. *Springer International Publishing*, 287 – 307

Yaxley, R. H., & Zwaan, R. A. (2007). Simulating visibility during language comprehension. *Cognition, 105(1)*, 229 – 236. doi: 10.1016/j.cognition.2006.09.003

Zhou, P., & Christianson, K. (2015). I "hear" what you're "saying": Auditory perceptual simulation, reading speed, and reading comprehension *The Quarterly Journal of Experimental Psychology, ...* doi: 10.1080.17470218.2015.1018282

Zwaan, R. A., Langston, M. C., & Graesser, A. C. (1995). The Construction of Situation Models in Narrative Comprehension: An Event-Indexing Model. *Psychological Science, 6(5)*, 292 – 297

Zwaan, R. A., Magliano, J. P., & Graesser, A. C. (1995). Dimensions of Situation Model Construction in Narrative Comprehension. *Journal of Experimental Psychology, 21(2)*, 386 – 397

Zwaan, R. A., & Radvansky, G. A. (1998). Situation Models in Language Comprehension and Memory. *Psychological Bulletin, 123(2),* 162 – 185

Zwaan, R. A., Stanfield, R. A., & Yaxley, R. H. (2002). Language Comprehenders Mentally Represent the Shapes of Objects. *Psychological Science, 13(2)*, 168 – 171. doi: 10.1111/1467-9280.00430

Zwaan, R. A. (2004). The Immersed Experiencer: Toward and Embodied Theory of Language Comprehension. In B. H. Ross (ed.). *The Psychology of Learning and Motivation* (Vol. 44, pp. 35-62). New York: Academic Press

Zwaan, R. A., Madden, C. J., Yaxley, R. H., & Aveyard, M. E. (2004). Moving words: dynamic representations in language comprehension. *Cognitive Sciences*, *28*, 611 – 619. doi: 10.1016/j.cogsci.2004.03.004

Zwaan, R. A., & Madden, C. J. (2005). Embodied Sentence Comprehension. In Pecher, D., & Zwaan, R. A. (Eds*.), Grounding Cognition: The Role of Perception and Action in Memory, Language and Thinking* (pp. 224 – 245). New York: Cambridge Press

Zwaan, R. A., & Taylor, L. J. (2006). Seeing, Acting, Understanding: Motor Resonance in Language Comprehension. *Journal of Experimental Psychology, 135(1)*, 1 – 11. doi: 10.1037/0096-3445.135.1.1

Zwaan, R. A. (2009). Mental simulation in language comprehension and social cognition. *European Journal of Social Psychology, 39*, 1142 – 1150. doi: 10.1002/ejsp.661

Zwickel, J., White, S. J., Coniston, D., Senju, A., & Frith, U. (2011). Exploring the building blocks of social cognition: spontaneous agency perception and visual perceptive talking in autism. *SCAN, 6*, 564-571. doi: 10.1093/scan/nsq088

Appendix A

Experiment 1 materials

1.

You handed Courtney the notebook.

Courtney handed you the notebook.

2.

You passed John the cup.

John passed you the cup.

3.

You handed Craig the letter.

Craig handed you the letter.

4.

You gave Kelly the present.

Kelly gave you the present.

5.

You handed Claire the bottle.

Claire handed you the bottle.

6.

You sent Steph an invitation.

Steph sent you an invitation.

7.

You gave Harry the eraser.

Harry gave you the eraser.

8.

You handed Dom the scissors.

Dom handed you the scissors.

9.

You made Wendy a cup of tea.

Wendy made you a cup of tea.

10.

You lent Milly the umbrella.

Milly lent you the umbrella.

11.

You gave Alex the card.

Alex gave you the card.

12.

You gave Emma the box of chocolates.

Emma gave you the box of chocolates.

13.

You sent Leah a gift.

Leah sent you a gift.

14.

You handed Bob the spanner.

Bob handed you the spanner.

15.

You gave Rachel a piece of chewing gum.

Rachel gave you a piece of chewing gum.

16.

You delivered the pizza to Andy.

Andy delivered the pizza to you.

17.

You delivered the parcel to Julie.

Julie delivered the parcel to you.

18.

You kicked the football to Trevor.

Trevor kicked the football to you.

19.

You threw the Frisbee to Dave.

Dave threw the Frisbee to you.

20.

You gave the flowers to Sarah.

Sarah gave the flowers to you.

21.

You passed the note to Dave.

Dave passed the note to you.

22.

You passed the plate to George.

George passed the plate to you.

23.

You delivered the take away food to Sam.

Sam delivered the take away food to you.

24.

You passed the salt to Lilly.

Lilly passed the salt to Lilly.

25.

You hit the tennis ball to Will.

Will hit the tennis ball to you.

26.

You delivered the newspaper to Tim.

Tim delivered the newspaper to you.

27.

You baked a cake for Neil.

Neil baked a cake for you.

28.

You passed the coat hanger to Helen.

Helen passed the coat hanger to you.

29.

You gave the folder to the Manager.

The Manager gave the folder to you.

30.

You passed the makeup bag to Vicky.

Vicky passed the makeup bag to you.

31.

You told Liz the story.

Liz told you the story.

32.

You invited Aaron to lunch.

Aaron invited you to lunch.

33.

You told Kim the gossip.

Kim told you the gossip.

34.

You taught Joanne the song.

Joanne taught you the song.

35.

You told Jess how you felt.

Jess told you how she felt.

36.

You taught Jill how to cook.

Jill taught you how to cook.

37.

You told Laura the truth.

Laura told you the truth.

38.

You text Phoebe with the news.

Phoebe text you with the news.

39.

You told Kerry the plan.

Kerry told you the plan.

40.

You phoned the company about the problem.

The company phoned you about the problem.

41.

You taught Josh how to drive.

Josh taught you how to drive.

42.

You instructed Chloe on how to play the piano.

Chloe instructed you on how to play the piano.

43.

You telephoned Jane for a chat.

Jane telephoned you for a chat.

44.

You told Bill the bad news.

Bill told you the bad news.

45.

You ordered Janet to pay the bill.

Janet ordered you to pay the bill.

46.

You told Carl to go ahead.

Carl told you to go ahead.

47.

You forwarded the email to Jacky.

Jacky forwarded the email to you.

48.

You radioed the message to the policeman.

The policeman radioed the message to you.

49.

You transferred the money to Ben's bank account.

Ben transferred the money to your bank account.

50.

You explained the project proposal to the Boss.

The Boss explained the project proposal to you.

51.

You left a voice message for Chris.

Chris left a voice message for you.

52.

You pitched the idea to Larry.

Larry pitched the idea to you.

53.

You showed the new gadget to Paul.

Paul showed the new gadget to you.

54.

You radioed the warning to the pilot.

The pilot radioed the warning to you.

55.

You expressed your opinion to Tim.

Tim expressed his opinion to you.

56.

You radioed the coordinates to the boat.

The boat radioed the coordinates to you.

57.

You explained the map to the passer-by.

The passer-by explained the map to you.

58.

You showed the house to the family.

The family showed the house to you.

59.

You sang a song for Zara.

Zara sang a song for you.

60.

You told the story to the reporter.

The reporter told the story to you.

Appendix B

Experiment 2 materials

1.

The egg is in the frying pan.

The egg is in the carton.

2.

The eagle is in the nest.

The eagle is in the sky.

3.

The spectacles are on the man's face.

The spectacles are in the case.

4.

The onion is in the basket.

The onion is in the frying pan.

5.

The penguin is in the water.

The penguin is on the land.

6.

The pineapple is in the tin.

The pineapple is on the tree.

7.

The porcupine is relaxed.

The porcupine is defensive.

8.

The duck is in the water.

The duck is in the sky.

9.

The pram is in the car.

The pram is in the park.

10.

The sailboat is docked.

The sailboat is out at sea.

11.

The hen is in the nest.

The hen is in the yard.

12.

The chilli is on the plant.

The chilli is on the pizza.

13.

The owl is in the tree.

The owl is in the sky.

14.

The ladder is in the van.

The ladder is against the wall.

15.

The frog is in the pond.

The frog is on the lily pad.

16.

The lime is in the basket.

The lime is in the bottle.

17.

The butterfly is in the sky.

The butterfly is on a flower.

18.

The lettuce is in the salad.

The lettuce is in the allotment.

19.

The spring onions are in the supermarket.

The spring onions are in the saucepan.

20.

The lion is sleeping.

The lion is hunting.

21.

The cake is in the oven.

The cake is in the display.

22.

The cow is sleeping.

The cow is grazing.

23.

The helium balloon is on the floor.

The helium balloon is in the air.

24.

The camel is drinking.

The camel is walking.

25.

The book is in the bag.

The book is being read.

25.

The towel is on the hook.

The towel is in the cupboard.

26.

The carrot is in the saucepan.

The carrot is in the basket.

27.

The hummingbird is on the branch.

The hummingbird is feeding.

28.

The chicken fillet is in the fridge.

The chicken fillet is in the stir fry.

29.

The shirt is in the suitcase.

The shirt is in the wardrobe.

30.

The dog is sleeping.

The dog is walking.

31.

The tie is being worn.

The tie is hung up.

32.

The deckchair is by the pool.

The deckchair is in the shed.

33.

The Christmas card is on the mantelpiece.

The Christmas card is in the envelope.

34.

The tissue is in the packet.

The tissue is in the bin.

35.

The pumpkin is in the field.

The pumpkin is in the saucepan.

36.

The conker is on the tree.

The conker is on the string.

37.

The ribbon is on the roll.

The ribbon is on the gift.

38.

The van is being driven.

The van is being loaded.

39.

The ironing board is in the cupboard.

The ironing board is being used.

40.

The cat is frightened.

The cat is resting.

41.

The cheese is on the cocktail stick.

The cheese is on the board.

42.

The tortoise is walking.

The tortoise is hibernating.

43.

The stapler is being loaded.

The stapler is being used.

44.

The snail is hiding.

The snail is moving.

45.

The poster is on the wall.

The poster is in the tube.

46.

The sheep is sleeping.

The sheep is grazing.

47.

The noodles are in the packet.

The noodles are in the wok.

Appendix C

Experiment 3 materials

1.

The student thinks that the textbook is closed.

The student thinks that the textbook is open.

The student knows that the textbook is closed.

The student knows that the textbook is open.

2.

The park ranger thinks that the eagle is airborne.

The park ranger thinks that the eagle is grounded.

The park ranger knows that the eagle is airborne.

The park ranger knows that the eagle is grounded.

3.

The chef thinks that the egg is in its shell.

The chef thinks that the egg has been fried.

The chef knows that the egg is in its shell.

The chef knows that the egg has been fried.

4.

The farmer's wife thinks that the wellies are dirty.

The farmer's wife thinks that the wellies are clean.

The farmer's wife knows that the wellies are dirty.

The farmer's wife knows that the wellies are clean.

5.

The coach thinks that the hockey star is playing.

The coach thinks that the hockey star is sat down.

The coach knows that the hockey star is playing.

The coach knows that the hockey star is sat down.

6.

The clown thinks that the balloon is burst.

The clown thinks that the balloon is inflated.

The clown knows that the balloon is burst.

The clown knows that the balloon is inflated.

7.

The biologist thinks that the bat is flying.

The biologist thinks that the bat is resting.

The biologist knows that the bat is flying.

The biologist knows that the bat is resting.

8.

Mrs Smith thinks that the umbrella is closed.

Mrs Smith thinks that the umbrella is open.

Mrs Smith knows that the umbrella is closed.

Mrs Smith knows that the umbrella is open.

9.

The zoologist thinks that the pufferfish is frightened.

The zoologist thinks that the pufferfish is relaxed.

The zoologist knows that the pufferfish is frightened.

The zoologist knows that the pufferfish is relaxed.

10.

The jockey thinks that the horse is lying down.

The jockey thinks that the horse is standing up.

The jockey knows that the horse is lying down.

The jockey knows that the horse is standing up.

11.

The shopkeeper thinks that the wrapping paper is screwed up.

The shopkeeper thinks that the wrapping paper is rolled up.

The shopkeeper knows that the wrapping paper is screwed up.

The shopkeeper knows that the wrapping paper is rolled up.

12.

The designer thinks that the shirt is hung up.

The designer thinks that the shirt is crumpled.

The designer knows that the shirt is hung up.

The designer knows that the shirt is crumpled.

13.

The businessman thinks that his phone is closed.

The businessman thinks that his phone is open.

The businessman knows that his phone is closed.

The businessman knows that his phone is open.

14.

The zookeeper thinks that the snake is coiled up.

The zookeeper thinks that the snake is stretched out.

The zookeeper knows that the snake is coiled up.

The zookeeper knows that the snake is stretched out.

15.

The gardener thinks that the tomato is sliced.

The gardener thinks that the tomato is whole.

The gardener knows that the tomato is sliced.

The gardener knows that the tomato is whole.

16.

Mum thinks that the loaf of bread is sliced.

Mum thinks that the loaf of bread is whole.

Mum knows that the loaf of bread is sliced.

Mum knows that the loaf of bread is whole.

17.

The politician thinks that the flag is fluttering.

The politician thinks that the flag is motionless.

The politician knows that the flag is fluttering.

The politician knows that the flag is motionless.

18.

The hiker thinks that his map is folded up.

The hiker thinks that his map is open.

The hiker knows that his map is folded up.

The hiker knows that his map is open.

19.

The bird watcher thinks that the duck is on the ground.

The bird watcher thinks that the duck is in flight.

The bird watcher knows that the duck is on the ground.

The bird watcher knows that the duck is in flight.

20.

The man thinks that the shrimp is raw.

The man thinks that the shrimp is cooked.

The man knows that the shrimp is raw.

The man knows that the shrimp is cooked.

21.

The nanny thinks that the pushchair is folded up.

The nanny thinks that the pushchair is opened out.

The nanny knows that the pushchair is folded up.

The nanny knows that the pushchair is opened out.

22.

The cook thinks that the spaghetti is cooked.

The cook thinks that the spaghetti is raw.

The cook knows that the spaghetti is cooked.

The cook knows that the spaghetti is raw.

23.

The camper thinks that his sleeping mat is laid out.

The camper thinks that his sleeping mat is rolled up.

The camper knows that his sleeping mat is laid out.

The camper knows that his sleeping mat is rolled up.

24.

Andrew thinks that the drawer is closed.

Andrew thinks that the drawer is open.

Andrew knows that the drawer is closed.

Andrew knows that the drawer is open.

25.

The mechanic thinks that the tyre is inflated.

The mechanic thinks that the tyre is punctured.

The mechanic knows that the tyre is inflated.

The mechanic knows that the tyre is punctured.

26.

The security guard thinks that the gate is locked.

The security guard thinks that the gate is unlocked.

The security guard knows that the gate is locked.

The security guard knows that the gate is unlocked.

27.

The housekeeper thinks that the door is open.

The housekeeper thinks that the door is closed.

The housekeeper knows that the door is open.

The housekeeper knows that the door is closed.

28.

The athlete thinks that his water bottle is full.

The athlete thinks that his water bottle is empty.

The athlete knows that his water bottle is full.

The athlete knows that his water bottle is empty.

29.

Mrs Green thinks that the chocolate is melted.

Mrs Green thinks that the chocolate is solid.

Mrs Green knows that the chocolate is melted.

Mrs Green knows that the chocolate is solid.

30.

Mary thinks that the ice lolly is frozen.

Mary thinks that the ice lolly is thawed.

Mary knows that the ice lolly is frozen.

Mary knows that the ice lolly is thawed.

31.

John thinks that the tomato is dried.

John thinks that the tomato is juicy.

John knows that the tomato is dried.

John knows that the tomato is juicy.

32.

The old lady thinks that the picnic basket is closed.

The old lady thinks that the picnic basket is open.

The old lady knows that the picnic basket is closed.

The old lady knows that the picnic basket is open.

33.

Granny thinks that the wool is messed up.

Granny thinks that the wool is rolled up.

Granny knows that the wool is messed up.

Granny knows that the wool is rolled up.

34.

The holiday maker thinks that the deckchair is folded up.

The holiday maker thinks that the deckchair is opened out.

The holiday maker knows that the deckchair is folded up.

The holiday maker knows that the deckchair is opened out.

35.

The schoolboy thinks that the snail is out of its shell.

The schoolboy thinks that the snail is inside its shell.

The schoolboy knows that the snail is out of its shell.

The schoolboy knows that the snail is inside its shell.

36.

The lady thinks that her scarf is scrunched up.

The lady thinks that her scarf is folded up.

The lady knows that her scarf is scrunched up.

The lady knows that her scarf is folded up.

37.

Mark thinks that the tube of tooth paste is empty.

Mark thinks that the tube of tooth paste is full.

Mark knows that the tube of tooth paste is empty.

Mark knows that the tube of tooth paste is full.

38.

Amy thinks that the Christmas cracker is pulled.

Amy thinks that the Christmas cracker is whole.

Amy knows that the Christmas cracker is pulled.

Amy knows that the Christmas cracker is whole.

39.

Sarah thinks that the hot air balloon is deflated.

Sarah thinks that the hot air balloon is inflated.

Sarah knows that the hot air balloon is deflated.

Sarah knows that the hot air balloon is inflated.

40.

Alison thinks that the envelope is open.

Alison thinks that the envelope is sealed.

Alison knows that the envelope is open.

Alison knows that the envelope is sealed.

41.

The girl thinks that the pencil is blunt.

The girl thinks that the pencil is sharp.

The girl knows that the pencil is blunt.

The girl knows that the pencil is sharp.

42.

Mum thinks that the cake is whole.

Mum thinks that the cake is sliced.

Mum knows that the cake is whole.

Mum knows that the cake is sliced.

43.

The boy thinks that the Lego model is broken.

The boy thinks that the Lego model is complete.

The boy knows that the Lego model is broken.

The boy knows that the Lego model is complete.

44.

The hairdresser thinks that the girl's hair is straight.

The hairdresser thinks that the girl's hair is curly.

The hairdresser knows that the girl's hair is straight.

The hairdresser knows that the girl's hair is curly.

45.

The housekeeper thinks that the T Shirt is dirty.

The housekeeper thinks that the T Shirt is clean.

The housekeeper knows that the T Shirt is dirty.

The housekeeper knows that the T Shirt is clean.

46.

The child thinks that the cat is asleep.

The child thinks that the cat is awake.

The child knows that the cat is asleep.

The child knows that the cat is awake.

47.

The air traffic controller thinks that the aeroplane is grounded.

The air traffic controller thinks that the aeroplane is taking off.

The air traffic controller knows that the aeroplane is grounded.

The air traffic controller knows that the aeroplane is taking off.

48.

The footballer thinks that the ball is inflated.

The footballer thinks that the ball is deflated.

The footballer knows that the ball is inflated.

The footballer knows that the ball is deflated.

49.

Karen thinks that the candle is lit.

Karen thinks that the candle is out.

Karen knows that the candle is lit.

Karen knows that the candle is out.

50.

John thinks that the chair is broken.

John thinks that the chair is fixed.

John knows that the chair is broken.

John knows that the chair is fixed.

51.

The camper thinks that the fire is out.

The camper thinks that the fire is lit.

The camper knows that the fire is out.

The camper knows that the fire is lit.

52.

The auctioneer thinks that the desk is modern.

The auctioneer thinks that the desk is antique.

The auctioneer knows that the desk is modern.

The auctioneer knows that the desk is antique.

53.

Mum thinks that the little boy is crying.

Mum thinks that the little boy is laughing.

Mum knows that the little boy is crying.

Mum knows that the little boy is laughing.

54.

Jack thinks that the ice cream has melted.

Jack thinks that the ice cream is frozen.

Jack knows that the ice cream has melted.

Jack knows that the ice cream is frozen.

55.

Julie thinks that the lipstick is rolled up.

Julie thinks that the lipstick is rolled down.

Julie knows that the lipstick is rolled up.

Julie knows that the lipstick is rolled down.

56.

The dinner lady thinks that the child's lunchbox is empty.

The dinner lady thinks that the child's lunchbox is full.

The dinner lady knows that the child's lunchbox is empty.

The dinner lady knows that the child's lunchbox is full.

57.

The sales assistant thinks that the cash register is open.

The sales assistant thinks that the cash register is closed.

The sales assistant knows that the cash register is open.

The sales assistant knows that the cash register is closed.

58.

The bar worker thinks that the beer glass is empty.

The bar worker thinks that the beer glass is full.

The bar worker knows that the beer glass is empty.

The bar worker knows that the beer glass is full.

59.

Tom thinks that the folder is closed.

Tom thinks that the folder is open.

Tom knows that the folder is closed.

Tom knows that the folder is open.

60.

The waitress thinks that the plate is full.

The waitress thinks that the plate is clear.

The waitress knows that the plate is full.

The waitress knows that the plate is clear.

61.

The garage owner thinks that the car is new.

The garage owner thinks that the car is old.

The garage owner knows that the car is new.

The garage owner knows that the car is old.

62.

The vet thinks that the dog is fat.

The vet thinks that the dog is thin.

The vet knows that the dog is fat.

The vet knows that the dog is thin.

63.

Mrs Brown thinks that her glasses are in the case.

Mrs Brown thinks that her glasses are out of the case.

Mrs Brown knows that her glasses are in the case.

Mrs Brown knows that her glasses are out of the case.

64.

The student thinks that the pencil case is open.

The student thinks that the pencil case is closed.

The student knows that the pencil case is open.

The student knows that the pencil case is closed.

65.

The secretary thinks that the filing cabinet is closed.

The secretary thinks that the filing cabinet is open.

The secretary knows that the filing cabinet is closed.

The secretary knows that the filing cabinet is open.

66.

The nanny thinks that the pushchair is folded up.

The nanny thinks that the pushchair is opened out.

The nanny knows that the pushchair is folded up.

The nanny knows that the pushchair is opened out.

67.

Mrs Smith thinks that the bowl is whole.

Mrs Smith thinks that the bowl is cracked.

Mrs Smith knows that the bowl is whole.

Mrs Smith knows that the bowl is cracked.

68.

The boy thinks that the yo-yo is unwound.

The boy thinks that the yo-yo is rolled up.

The boy knows that the yo-yo is unwound.

The boy knows that the yo-yo is rolled up.

69.

The hair dresser thinks that the comb is broken.

The hair dresser thinks that the comb is fixed.

The hair dresser knows that the comb is broken.

The hair dresser knows that the comb is fixed.

70.

The child thinks that the scissors are open.

The child thinks that the scissors are closed.

The child knows that the scissors are open.

The child knows that the scissors are closed.

71.

The jeweller thinks that the gold necklace is undone.

The jeweller thinks that the gold necklace is done up.

The jeweller knows that the gold necklace is undone.

The jeweller knows that the gold necklace is done up.

72.

The child thinks that the rucksack is open.

The child thinks that the rucksack is closed.

The child knows that the rucksack is open.

The child knows that the rucksack is closed.

73.

The computer technician thinks that the computer is on.

The computer technician thinks that the computer is off.

The computer technician knows that the computer is on.

The computer technician knows that the computer is off.

74.

The cyclist thinks that the bike chain is locked.

The cyclist thinks that the bike chain is unlocked.

The cyclist knows that the bike chain is locked.

The cyclist knows that the bike chain is unlocked.

75.

Gary thinks that the shirt has short sleeves.

Gary thinks that the shirt has long sleeves.

Gary knows that the shirt has short sleeves.

Gary knows that the shirt has long sleeves.

76.

Sally thinks that the wardrobe is closed.

Sally thinks that the wardrobe is open.

Sally knows that the wardrobe is closed.

Sally knows that the wardrobe is open.

77.

The lady thinks that the carrot is chopped.

The lady thinks that the carrot is whole.

The lady knows that the carrot is chopped.

The lady knows that the carrot is whole.

78.

The florist thinks that the flowers are alive.

The florist thinks that the flowers are dead.

The florist knows that the flowers are alive.

The florist knows that the flowers are dead.

79.

The man thinks that the car is dirty.

The man thinks that the car is clean.

The man knows that the car is dirty.

The man knows that the car is clean.

80.

The lady thinks that the box of chocolates is open.

The lady thinks that the box of chocolates is closed.

The lady knows that the box of chocolates is open.

The lady knows that the box of chocolates is closed.

81.

The businessman thinks that the phone is open.

The businessman thinks that the phone is closed.

The businessman knows that the phone is open.

The businessman knows that the phone is closed.

82.

Jill thinks that the snowman is standing.

Jill thinks that the snowman has melted.

Jill knows that the snowman is standing.

Jill knows that the snowman has melted.

83.

The scientist thinks that the Bunsen burner is off.

The scientist thinks that the Bunsen burner is on.

The scientist knows that the Bunsen burner is off.

The scientist knows that the Bunsen burner is on.

84.

The builder thinks that the house is complete.

The builder thinks that the house is unfinished.

The builder knows that the house is complete.

The builder knows that the house is unfinished.

85.

The man thinks that the van door is open.

The man thinks that the van door is closed.

The man knows that the van door is open.

The man knows that the van door is closed.

86.

The zoologist thinks that the penguin is walking.

The zoologist thinks that the penguin is sliding.

The zoologist knows that the penguin is walking.

The zoologist knows that the penguin is sliding.

87.

The boy thinks that the DVD case is open.

The boy thinks that the DVD case is closed.

The boy knows that the DVD case is open.

The boy knows that the DVD case is closed.

88.

The chambermaid thinks that the towels are folded.

The chambermaid thinks that the towels are laid out flat.

The chambermaid knows that the towels are folded.

The chambermaid knows that the towels are laid out flat.

89.

The artist thinks that the canvas is painted.

The art is thinks that the canvas is bare.

The artist knows that the canvas is painted.

The art is knows that the canvas is bare.

90.

The librarian thinks that the shelf is full.

The librarian thinks that the shelf is empty.

The librarian knows that the shelf is full.

The librarian knows that the shelf is empty.

91.

The man thinks that the cigarette is out.

The man thinks that the cigarette is lit.

The man knows that the cigarette is out.

The man knows that the cigarette is lit.

92.

The chef thinks that the steak is raw.

The chef thinks that the steak is cooked.

The chef knows that the steak is raw.

The chef knows that the steak is cooked.

93.

The monkey thinks that the banana is peeled.

The monkey thinks that the banana is sealed.

The monkey knows that the banana is peeled.

The monkey knows that the banana is sealed.

94.

Claire thinks that the tap is on.

Claire thinks that the tap is off.

Claire knows that the tap is on.

Claire knows that the tap is off.

95.

The window cleaner thinks that the curtains are closed.

The window cleaner thinks that the curtains are open.

The window cleaner knows that the curtains are closed.

The window cleaner knows that the curtains are open.

96.

Mum thinks that the fridge is full.

Mum thinks that the fridge is empty.

Mum knows that the fridge is full.

Mum knows that the fridge is empty.

97.

The vet thinks that the dog is wet.

The vet thinks that the dog is dry.

The vet knows that the dog is wet.

The vet knows that the dog is dry.

98.

Sam thinks that the window is shut.

Sam thinks that the window is open.

Sam knows that the window is shut.

Sam knows that the window is open.

99.

The electrician thinks that the plug is off.

The electrician thinks that the plug is on.

The electrician knows that the plug is off.

The electrician knows that the plug is on.

100.

Tara thinks that the socks are separate.

Tara thinks that the socks are together.

Tara knows that the socks are separate.

Tara knows that the socks are together.

101.

Steve thinks that the pen has a lid.

Steve thinks that the pen has not got a lid.

Steve knows that the pen has a lid.

Steve knows that the pen has not got a lid.

102.

The boy thinks that the biscuit tin lid is off.

The boy thinks that the biscuit tin lid is on.

The boy knows that the biscuit tin lid is off.

The boy knows that the biscuit tin lid is on.

103.

The nursery worker thinks that the apple is sliced.

The nursery worker thinks that the apple is whole.

The nursery worker knows that the apple is sliced.

The nursery worker knows that the apple is whole.

104.

The waiter thinks that the coffee cup is full.

The waiter thinks that the coffee cup is empty.

The waiter knows that the coffee cup is full.

The waiter knows that the coffee cup is empty.

105.

The lady thinks that the shoes are heeled.

The lady thinks that the shoes are flat.

The lady knows that the shoes are heeled.

The lady knows that the shoes are flat.

106.

The baker thinks that the baguette is whole.

The baker thinks that the baguette is cut.

The baker knows that the baguette is whole.

The baker knows that the baguette is cut.

107.

The greengrocer thinks that the bananas are unripe.

The greengrocer thinks that the bananas are ripe.

The greengrocer knows that the bananas are unripe.

The greengrocer knows that the bananas are ripe.

108.

The child thinks that the cookie is in half.

The child thinks that the cookie is whole.

The child knows that the cookie is in half.

The child knows that the cookie is whole.

109.

The traffic warden thinks that the carpark barrier is up.

The traffic warden thinks that the carpark barrier is down.

The traffic warden knows that the carpark barrier is up.

The traffic warden knows that the carpark barrier is down.

110.

The tourist thinks that the pebble is smooth.

The tourist thinks that the pebble is rough.

The tourist knows that the pebble is smooth.

The tourist knows that the pebble is rough.

111.

The postman thinks that the box is open.

The postman thinks that the box is sealed.

The postman knows that the box is open.

The postman knows that the box is sealed.

112.

The carpenter thinks that the nail is straight.

The carpenter thinks that the nail is bent.

The carpenter knows that the nail is straight.

The carpenter knows that the nail is bent.

113.

The surveyor thinks that the building is derelict.

The surveyor thinks that the building is sound.

The surveyor knows that the building is derelict.

The surveyor knows that the building is sound.

114.

Grace thinks that the pineapple is whole.

Grace thinks that the pineapple is sliced.

Grace knows that the pineapple is whole.

Grace knows that the pineapple is sliced.

115.

The trainer thinks that the horse is lying down.

The trainer thinks that the horse is galloping.

The trainer knows that the horse is lying down.

The trainer knows that the horse is galloping.

116.

The gardener thinks that the flower is closed.

The gardener thinks that the flower is open.

The gardener knows that the flower is closed.

The gardener knows that the flower is open.

117.

The musician thinks that the guitar is in the box.

The musician thinks that the guitar is out of the box.

The musician knows that the guitar is in the box.

The musician knows that the guitar is out of the box.

118.

The passer-by thinks that the postman is walking.

The passer-by thinks that the postman is riding a bike.

The passer-by knows that the postman is walking.

The passer-by knows that the postman is riding a bike.

119.

The interior designer thinks that the paint tray is full.

The interior designer thinks that the paint tray is empty.

The interior designer knows that the paint tray is full.

The interior designer knows that the paint tray is empty.

120.

The conservationist thinks that the rhino is charging.

The conservationist thinks that the rhino is grazing.

The conservationist knows that the rhino is charging.

The conservationist knows that the rhino is grazing.

121.

The cook thinks that the garlic is whole.

The cook thinks that the garlic is in cloves.

The cook knows that the garlic is whole.

The cook knows that the garlic is in cloves.

122.

The party -goer thinks that the wine glass is full.

The party-goer thinks that the wine glass is empty.

The party -goer knows that the wine glass is full.

The party-goer knows that the wine glass is empty.

123.

The writer thinks that the paper is scrunched up.

The writer thinks that the paper is flat.

The writer knows that the paper is scrunched up.

The writer knows that the paper is flat.

124.

The astronomer thinks that the moon is a crescent.

The astronomer thinks that the moon is full.

The astronomer knows that the moon is a crescent.

The astronomer knows that the moon is full.

125.

The lawyer thinks that the briefcase is open.

The lawyer thinks that the briefcase is closed.

The lawyer knows that the briefcase is open.

The lawyer knows that the briefcase is closed.

126.

The child thinks that the hedgehog is walking.

The child thinks that the hedgehog is curled up.

The child knows that the hedgehog is walking.

The child knows that the hedgehog is curled up.

127.

The student thinks that the laptop is open.

The student thinks that the laptop is closed.

The student knows that the laptop is open.

The student knows that the laptop is closed.

128.

Grandma thinks that the jam jar is full.

Grandma thinks that the jam jar is empty.

Grandma knows that the jam jar is full.

Grandma knows that the jam jar is empty.

129.

The employee thinks that the fish bowl is full.

The employee thinks that the fish bowl is empty.

The employee knows that the fish bowl is full.

The employee knows that the fish bowl is empty.

130.

The plumber thinks that the toolbox is closed.

The plumber thinks that the toolbox is open.

The plumber knows that the toolbox is closed.

The plumber knows that the toolbox is open.

131.

The rubbish man thinks that the rubbish bin is closed.

The rubbish man thinks that the rubbish bin is open.

The rubbish man knows that the rubbish bin is closed.

The rubbish man knows that the rubbish bin is open.

132.

The customer thinks that the plastic bag is empty.

The customer thinks that the plastic bag is full.

The customer knows that the plastic bag is empty.

The customer knows that the plastic bag is full.

133.

Sarah thinks that the blinds are open.

Sarah thinks that the blinds are closed.

Sarah knows that the blinds are open.

Sarah knows that the blinds are closed.

134.

The old man thinks that the puzzle is complete.

The old man thinks that the puzzle is unfinished.

The old man knows that the puzzle is complete.

The old man knows that the puzzle is unfinished.

135.

The driver thinks that the traffic lights are red.

The driver thinks that the traffic lights are green.

The driver knows that the traffic lights are red.

The driver knows that the traffic lights are green.

136.

Laura thinks that the orange is segmented.

Laura thinks that the orange is whole.

Laura knows that the orange is segmented.

Laura knows that the orange is whole.

137.

The cook thinks that the tinfoil is rolled up.

The cook thinks that the tinfoil is screwed up.

The cook knows that the tinfoil is rolled up.

The cook knows that the tinfoil is screwed up.

138.

Mum thinks that the baby's bottle is empty.

Mum thinks that the baby's bottle is full.

Mum knows that the baby's bottle is empty.

Mum knows that the baby's bottle is full.

139.

Joy thinks that the lamp is off.

Joy thinks that the lamp is on.

Joy knows that the lamp is off.

Joy knows that the lamp is on.

140.

The fisherman thinks that the fish is swimming.

The fisherman thinks that the fish is on the hook.

The fisherman knows that the fish is swimming.

The fisherman knows that the fish is on the hook.

141.

The scout thinks that the rope is wound up.

The scout thinks that the rope is tangled.

The scout knows that the rope is wound up.

The scout knows that the rope is tangled.

142.

Granny thinks that the needle is thread.

Granny thinks that the needle is not thread.

Granny knows that the needle is thread.

Granny knows that the needle is not thread.

143.

The lady thinks that the mascara is open.

The lady thinks that the mascara is sealed.

The lady knows that the mascara is open.

The lady knows that the mascara is sealed.

144.

The zoologist thinks that the bat is hanging.

The zoologist thinks that the bat is flying.

The zoologist knows that the bat is hanging.

The zoologist knows that the bat is flying.

145.

The chef thinks that the knife is sharp.

The chef thinks that the knife is blunt.

The chef knows that the knife is sharp.

The chef knows that the knife is blunt.

146.

The old lady thinks that the pigeon is flying.

The old lady thinks that the pigeon is grounded.

The old lady knows that the pigeon is flying.

The old lady knows that the pigeon is grounded.

147.

Meg thinks that the purse is closed.

Meg thinks that the purse is open.

Meg knows that the purse is closed.

Meg knows that the purse is open.

148.

The cook thinks that the cheese is grated.

The cook thinks that the cheese is sliced.

The cook knows that the cheese is grated.

The cook knows that the cheese is sliced.

149.

The mathematician thinks that the compass is open.

The mathematician thinks that the compass is closed.

The mathematician knows that the compass is open.

The mathematician knows that the compass is closed.

150.

The child thinks that the crayon is snapped.

The child thinks that the crayon is whole.

The child knows that the crayon is snapped.

The child knows that the crayon is whole.

151.

The caddie thinks that the golfer is swinging his club.

The caddie thinks that the golfer is waiting.

The caddie knows that the golfer is swinging his club.

The caddie knows that the golfer is waiting.

152.

The chauffer thinks that the car door is open.

The chauffer thinks that the car door is shut.

The chauffer knows that the car door is open.

The chauffer knows that the car door is shut.

153.

The child thinks that the Christmas tree is decorated.

The child thinks that the Christmas tree is bare.

The child knows that the Christmas tree is decorated.

The child knows that the Christmas tree is bare.

154.

Leah thinks that the bouncy castle is inflated.

Leah thinks that the bouncy castle is deflated.

Leah knows that the bouncy castle is inflated.

Leah knows that the bouncy castle is deflated.

155.

Mum thinks that the milk bottle is full.

Mum thinks that the milk bottle is empty.

Mum knows that the milk bottle is full.

Mum knows that the milk bottle is empty.

156.

The student thinks that the CD player is closed.

The student thinks that the CD player is open.

The student knows that the CD player is closed.

The student knows that the CD player is open.

157.

The baker thinks that the cake is iced.

The baker thinks that the cake is plain.

The baker knows that the cake is iced.

The baker knows that the cake is plain.

158.

The policeman thinks that the handcuffs are locked.

The policeman thinks that the handcuffs are unlocked.

The policeman knows that the handcuffs are locked.

The policeman knows that the handcuffs are unlocked.

159.

Milly thinks that the chocolate is in the wrapper.

Milly thinks that the chocolate is unwrapped.

Milly knows that the chocolate is in the wrapper.

Milly knows that the chocolate is unwrapped.

160.

The designer thinks that the coat is done up.

The designer thinks that the coat is undone.

The designer knows that the coat is done up.

The designer knows that the coat is undone.

Appendix D

Experiment 4 materials

[D] = direct speech; [I] = indirect speech

1.

Julie and Mark had been classmates and have not seen each other for years. Today, they met in the local supermarket and Julie started a conversation about career paths.

[D] She said: “My life has been amazing! After merely three years, I’m now a solicitor.”

[I] She said that her life had been amazing, and that after merely three years, she now was a solicitor.

2.

One of Melanie’s students, Jason, came into her office and said he could not reach her this morning. Melanie was confused because she had been in her office the whole time.

[D] She said: “Well, in that case, there must be something wrong with my telephone.”

[I] She said that in that case, there must be something wrong with her telephone.

3.

A Blackwell book store has recently opened in Edinburgh. Today, Alexia, a young mother living nearby, came in and asked for advice.

[D] She said: “It’s my son’s birthday tomorrow and I would like to purchase some storybooks on adventure.”

[I] She said that it was her son’s birthday soon and she would like to purchase some storybooks on adventure.

4.

It was 5.30 pm and everybody was ready to leave the office. At one desk, Elaine was having a brief chat with Steven about her work.

[D] She said: “Gosh, the amount of admin is killing me at the moment. I feel completely exhausted.”

[I] She said that the amount of admin was killing her at the moment, and that she felt completely exhausted.

5.

It was February 14. Carolyn and Tony were on a date at the newly opened Chinese restaurant. The past couple of weeks, Carolyn was desperately trying to lose some weight.

[D] So she said to Tony: “Oh, I hope you don’t mind if I’m just having a starter.”
[I] So she said to Tony that hopefully he wouldn’t mind if she were just having a starter.
6.
Ramona and Keith were postgraduate students in Linguistics. Today, they met in the local café and Ramona started chatting about her favourite subjects.
[D] She said: “Latin is boring! I’m much more interested in Eastern languages.”
[I] She said that she found Latin boring and that she was much more interested in Eastern languages.
7.
Derek’s birthday was just a couple of days away and his girlfriend Ruby had arranged something special. Tonight Ruby decided to unveil the plan that she kept hidden from him for so long.
[D] Over dinner, she said to Derek: “Well, your birthday is coming up soon, so I booked us tickets to London to visit the opera.”
[I] Over dinner, she revealed to Derek that since his birthday was coming up soon, she booked them tickets to London to visit the opera.
8.
At the party on Friday night, some new faces were to be seen. Clare immediately caught Justin’s eye, which went over to her and offered her a drink.
[D] Clare replied: “Thanks very much, but I actually don’t drink any alcohol.”
[I] Clare thanked him and mentioned that she actually doesn’t drink any alcohol.
9.
Alison and Nick travelled to Beijing during the Olympics. Alison was amazed by the fine fabric on offer when they entered a big silk market.
[D] She said to Nick: “I could buy the whole lot of it! The silk feels so incredibly smooth.”
[I] She said to Nick that she could buy the whole lot of it, and that the silk felt so incredibly smooth.
10.
In the office, Ned told Daniela that his car had been damaged during an accident the other day. Daniela was sorry to hear that and tried to comfort him.
[D] She said: “Well, at least you should get some money back from the insurance.”
[I] She said that at least he should get some money back from the insurance.
11.

At the department store, Colleen was busy working. She was serving a customer who wanted to know where he could buy some cosmetics for his wife.

[D] She replied: “Ah, cosmetics are actually on the second floor. Some of them are at a discount.”

[I] She replied that cosmetics were actually on the second floor, adding that some of them were at a discount.

12.

Jenny and Irvin were about to start a holiday trip to Barcelona. When they arrived at the airport to check in, Jenny noticed that a heavy thunderstorm was brewing outside.

[D] She complained: “That’s so unfair! I’m sure the plane will be delayed.”

[I] She complained that this was so unfair because she was sure that the plane would be delayed.

13.

Britney is a student at the University of Glasgow. After a heavy snow in the afternoon, she was complaining to her boyfriend James about the weather.

[D] She said: “I really hate the winter! It’s always dark and the roads are too slippery.”

[I] She said that she really hated the winter because it’s always dark and the roads are too slippery.

14.

Jasmine had been ill for a week so her brother Colin took her to the doctor. After an hour, Jasmine came back to the waiting room looking rather disgruntled.

[D] She complained: “The treatment was absolutely useless! Next time, I’d rather go to a specialist."

[I] She complained that the treatment was absolutely useless and that, next time, she’d rather go to a specialist.

15.

A famous symphony was going to be played for free at the university concert hall. Kate and Andrew were reading the advert, and Kate looked particularly interested.

[D] She said: “It sounds really good and it’s for free! I’m definitely going to that concert.”

[I] She said that it sounded really good and that it was for free, adding that she would definitely go to that concert.

16.

On Valentine’s Day, Simon at long last worked up the courage to propose to Emma. Emma wasn't sure, but at the same time, she didn't want to upset him.

[D] So she explained: "You are a really nice bloke, Simon, but I'm simply not ready for such a commitment."
[I] So she explained that although she thought he was a really nice bloke, she was simply not ready for such a commitment.
17.
Two college students were talking about on-line shopping. Fraser thought it was pointless and boring, but Brenda couldn't disagree more.
[D] She said: "What!? On-line shopping is absolutely amazing! I just snapped up some really cheap DVDs on Amazon."
[I] She said she found on-line shopping absolutely amazing, and that she had just snapped up some really cheap DVDs on Amazon.
18.
It was quarter past seven and the Aberdeen Stock House was serving dinner. Debbie and Mike were very pleased with the meal and Debbie in particular was totally smitten.
[D] She said: "We have to come here more often. The fish was really tasty and the soup was absolutely delicious."
[I] She said that they should go there more often because the fish was really fresh and the soup was absolutely delicious.
19.
It was 6-year-old Herbert's first day at school. His mother Laura, who had never let him play with other children before, was very anxious.
[D] She said to her husband: "I'm really not sure whether Herbert is ready for this. I'd rather wait for another year."
[I] She said to her husband that she was really not sure whether Herbert was ready for this, and that she'd rather wait for another year.
20.
In order to finish the project in time, Audrey had been working in the office from 7am to 8pm without taking a break. Her colleague Sean just came back from dinner with a big smile on his face, which obviously upset her a bit.
[D] She complained: "It's so unfair! My stomach has been rumbling all day. I could eat a whole elephant."
[I] She complained that it was so unfair because her stomach had been rumbling all day, and that she could eat a whole elephant.
21.

Cheryl and Barry were in the waiting lounge for their honeymoon flight to Paris. Shortly before boarding time, Cheryl noticed that her handbag was damaged.
[D] She shouted: “Oh no! There's a hole in my bag! Don't tell me I've lost my passport!...”
[I] She shouted that there was a hole in her bag. She was worried that she had lost her passport.
22.
It was eight o’ clock in the evening when the Britain’s Got Talent live recording session had finished. On their way out of the theatre, Sarah and Ross were having a giggle over some of the auditions.
[D] Sarah said: “The jugglers at the end were funny, weren’t they? Quite pathetic, actually, but very entertaining.”
[I] Sarah found that the jugglers at the end were very funny – quite pathetic, actually, but very entertaining.
23.
Jessica and John were enjoying a hot and sunny day at the holiday resort in Spain. When they were heading towards their usual spot on the beach, Jessica was slightly overwhelmed by the heat.
[D] She said: “Phew, this is almost a bit too hot for me! Perhaps we should first go back for a drink under the sunshade.”
[I] She said that it was almost a bit too hot for her, and suggested to first go back for a drink under the sunshade.
24.
In the small town of Oban lies this charming little pub. One day, famous writer Aileen burst in with a big smile on her face.
[D] She said: “Guess what – my new novel has been accepted for publication! I'll buy everyone a round.”
[I] She said that her new novel had been accepted for publication and that she wanted to buy everyone a round.
25.
Theatrical agent Peter was visited by one of his clients. Shauna, a talented but struggling actress and singer, was desperate for a part in the new musical.
[D] She said: “It’s embarrassing to say, but without this job, I won't even be able to pay for electricity.”

[I] She was embarrassed to say that without this job, she wouldn't even be able to pay for electricity.

26.

It was Sunday afternoon when housewife Heather was tidying up the bedroom. After just two minutes, she came out of the bedroom and confronted her husband Ben.

[D] She said: “I can’t believe how messy you are! The first thing I found on the floor was your dirty pyjamas!”

[I] She said that she could not believe how messy he was, and that the first thing she found on the floor was his dirty pyjamas.

27.

Morton needed to speak to his project supervisor Marianne at her office. When he asked whether she could spare a minute, she seemed rather busy.

[D] She replied: “I’m really sorry, but I have to finish marking some essays first.”

[I] She replied that she was really sorry and that she had to finish marking some essays first.

28.

It was Christmas Eve and everyone was drinking and dancing at the local pub. Judith was already quite tipsy when she noticed that George was with a girl she had not seen before.

[D] She went over and complained to George: “You’ve actually never told me that you had such a beautiful sister.”

[I] She went over and complained to George that he actually never told her that he had such a beautiful sister.

29.

Maureen had helped David a lot with his coursework, so David wanted to invite her for dinner. Asked what kind of food she would fancy, Maureen first thought for a second.

[D] Then she replied: “I’m normally not that adventurous, but perhaps I should try some sushi.”

[I] Then she replied that although she would normally not be that adventurous, perhaps she should try some sushi.

30.

Jane was a new post-graduate at the department. When she signed up at the Sports Club, she was having a conversation with Gregg about her favourite sports.

[D] She said: “Oh, I haven’t practised a lot recently, but I used to be quite good at tennis.”

[I] She said that although she had not practised a lot recently, she used to be quite good at tennis.

31.

Leon and Betty were trying to get a mortgage for a new flat. While Betty was studying the relevant newspaper adverts, Leon was browsing some web-sites.

[D] After a while, he said to Betty: “Hmm, these days, it looks as if nobody would give us an instant cashback.”

[I] After a while, he said to Betty that it looked as if nobody would give them an instant cashback.

32.

Marcus and Helen were planning a trip to Europe for their wedding anniversary. Marcus was leaning more towards Prague while Helen preferred Rome.

[D] Marcus explained: “Okay, Rome is nice, but the Czechs actually have much better beer.”

[I] Marcus explained that Rome would be nice, but that the Czechs would actually have much better beer.

33.

Bill and Dianne went out bowling together. When Dianne wanted to pick a ball of her favourite colour, Bill looked a bit worried.

[D] He said: “That one looks quite heavy. I’d rather pick the green one which I think is much smaller.”

[I] He said that the ball looked quite heavy and that he’d rather pick the green one which he thought was much smaller.

34.

Rob and Becky were buying duvet covers at the store. When Becky chose a bright red one, Rob was completely against the colour.

[D] He said: “No way! Just imagine that every morning you'd be waking up in a sea of blood!”

[I] He asked Becky just to imagine that every morning she would be waking up in a sea of blood.

35.

Harry and Leona were enjoying an afternoon walk in the park. When they were approaching the pond, Harry was impressed by this peaceful place.

[D] He said: “This is so relaxing after a busy week! It is almost magical.”

[I] He found that it was so relaxing after a busy week, and that it was almost magical.

36.

Schoolteacher Edward recently caused a stir by marrying Lynda, one of his ex-pupils. Annoyed by all the gossip, Edward told Lynda to simply not listen to what people say.
[D] He said: “I think there’s nothing wrong about a teacher marrying a former student.”
[I] He said that he thought there was nothing wrong about a teacher marrying a former student.
37.
After making a small fortune in the lottery, Pamela bought quite an expensive car. Today in the car park, her colleague Ralph was extremely impressed by her new possession.
[D] He said: “Wow! Is that your new car? It looks really stylish.”
[I] He asked her whether that was her new car, adding that it looked really stylish.
38.
Brian invited some of his mates home and started making a mess in the kitchen. His mum was obviously not happy about this, and Brian was quick to offer an excuse.
[D] He told her: “Well, we just had a couple of drinks because the pubs are already closed.”
[I] He told her that they just had a couple of drinks because the pubs were already closed.
39.
Daniel was injured in a car crash last week. At the hospital, he was quickly recovering. Today, he was surprised that some distant relatives came to visit him.
[D] Not without sarcasm, Daniel said: “Oh, looks as if one has to get hurt to get some flowers.”
[I] Not without sarcasm, Daniel said that it looked as if one had to get hurt to get some flowers.
40.
Jacob had promised Cindy to buy a bonsai tree to decorate their living room. When Cindy wanted to place the plant by the television, he tried to persuade her of an alternative option.
[D] He said: “Look, if you do that, there will be no sunlight for the bonsai, so it's better to place it by the window.”
[I] He said that if she did that, there would be no sunlight for the bonsai, so it was better to place it by the window.
41.
PhD student Ella was summoned to her supervisor Jim’s office to give a report on her current progress. When Ella asked for an extension, Jim looked concerned.
[D] He said: “Hmm, we really need those data in by next month for that conference.”
[I] He said that they really needed those data in by next month for that conference.

42.
Albert was taking Joanne to the new Schwarzenegger movie. Albert was very excited, but since Joanne seemed not very keen, he tried to persuade her to go with him.
[D] He said: “Come on! I’m sure you will love it! The movie has some really cool special effects.”
[I] He said he was sure she would love it, and that the movie had some really cool special effects.
43.
Neil and Stephanie were visiting the local distillery. Neil was amazed by the range of different Whiskeys produced, and he tried a very expensive Single Malt.
[D] He said: “Gee, that’s a strong one! I’m glad I won’t have to drive us home.”
[I] He said it was really strong and that he was glad he didn’t have to drive them home.
44.
Clive and his wife Molly visited the new seafood restaurant for the first time. Clive was extremely anxious about food poisoning and did not want to have anything raw.
[D] So he said to Molly: “I don’t care what other people might think, but I will order properly cooked oysters.”
[I] So he said to Molly that, regardless of what other people might think, he would order properly cooked oysters.
45.
Luke and his friends were watching a movie at the cinema. Luke wasn’t particularly keen on romantic comedies, and he was complaining a lot after the film.
[D] He said: “God, that movie was terrible! I’ve never been so bored in my life.”
[I] He said that the movie was terrible and that he had never been so bored in his life.
46.
On the train to London, Thomas was very nervous about his upcoming job interview. When he reached for a cigarette to calm himself down, the middle-aged man next to him complained instantly.
[D] The man called out: “Oi! Smoking on public transport is illegal!”
[I] He called out that smoking on public transport was illegal.
47.
During a coffee break, university teachers Robert and Isabel met in the common room. Robert was slightly irritated with the mess in the kitchen.
[D] He said to Isabel: “Look at this! Certain people must always leave their dirty mugs on the

table.”
[I] He said to Isabel that, obviously, certain people must always leave their dirty mugs on the table.
48.
School teachers Duncan and Liana were arguing about the curriculum. Apparently, Duncan was not a big fan of Liana’s modern style of teaching.
[D] He said: “If my own children were at this school, I’d make sure they would never have to attend your lessons.”
[I] He said that if his own children were at this school, he’d make sure they would never have to attend her lessons.
49.
It was getting quite late and most of Andrea’s friends were about to leave her party. Scott in particular seemed to have had a great time when he was leaving.
[D] He said: “Sorry about the crack in that glass. The party was absolutely fantastic.”
[I] He apologised for the crack in that glass, adding that the party was absolutely fantastic.
50.
Doug always enjoyed a bit of gardening in his spare time. He recently bought a new lawnmower, but he was quite frustrated because it simply refused to work.
[D] He complained: “Sod it! Things used to be much better in the past. All one can buy these days is rubbish!”
[I] He complained that things used to be much better in the past, and that all one can buy these days was rubbish.
51.
After class, Roy had a serious conversation with one of his pupils. The boy had been accused of bullying and Roy was giving him a caution.
[D] Roy said: “If the accusations are true, you will be in serious trouble. One cannot tolerate such kind of behaviour.”
[I] Roy said that if the accusations were true, the boy would be in serious trouble, and that one cannot tolerate such kind of behaviour.
52.
In the board room, assistant manager Craig was giving a presentation on how to improve the company’s sales figures. When he noticed that his boss was anything but impressed, Craig used his lack of experience as an excuse.
[D] He said: “Sorry, this is actually my first ever presentation and I’m probably not very

persuasive."
[I] He said that this was actually his first ever presentation, and that he was probably not very persuasive.
53.
Alice was working in a small antiques shop down the local high street. Today, a weird-looking man with greasy hair and thick glasses came into the shop.
[D] He looked around and said: "You may be surprised to learn that I'm a world-renowned collector of rare pheasant paintings."
[I] He looked around and said that she might be surprised to learn that he was a world-renowned collector of rare pheasant paintings.
54.
Ray and Sandra were on a trip to the countryside for the weekend. Ray quite liked the outdoors and particularly that rural smell.
[D] He said: "Aah, this is so much better than crowded cities and pollution."
[I] He said that it was so much better than crowded cities and pollution.
55.
Earlier in the afternoon, Max and Janis were having a cigarette in front of the main entrance. Not knowing what to say, Max started his typical conversation about the weather.
[D] He said: "Gosh, it's quite windy today – but at least it's not raining."
[I] He said that although it was quite windy today, at least it was not raining.
56.
A journalist was interviewing Eric, the older brother of a famous pop diva. Eric did not really enjoy the attention he was given and wasn't sure what to say.
[D] He proclaimed: "I actually don't see my sister very often these days. She is completely devoted to her career."
[I] He proclaimed that he actually did not see his sister very often in those days, and that she was completely devoted to her career.
57.
Thomas went to the local McDonalds and incidentally met Sheena, who he knew from former Weight Watchers meetings. Naturally, they were both quite embarrassed, but Thomas finally broke the silence.
[D] He said: "Weight Watchers is rubbish, isn't it. I've tried so many diets but I'm still overweight."

[I] He said that Weight Watchers was rubbish, and that he had tried so many diets but was still overweight.

58.

A car-boot sale was taking place in the neighbourhood and Kenny was trying to get rid of some of the old records he owned since the 1970s. A trendy young woman appeared to be very interested, so Kenny started advertising.

[D] He said: “I can give you three albums for a fiver. You won’t find any of that stuff on the internet.”

[I] He said that he could give her three albums for a fiver, adding that she wouldn’t find any of that stuff on the internet.

59.

A trendy night club had been recently opened near Marvin’s flat and it proved instantly popular. However, Marvin often felt disturbed by the noise, and this morning he was complaining to the neighbours about it.

[D] He said: “This is unbelievable! Every time I have to work early hours, they are having a bash!”

[I] He said that every time he has to work early hours, they are having a bash.

60.

Carl, a taxi driver, was about to drive home when suddenly he saw a man by the road frantically waving his arms. Carl stopped and the man offered him double the fare if they make it to the airport within ten minutes.

[D] Carl replied: “I’ll try my best, mate, but cannot work any miracles.”

[I] Carl replied that he would try his best, but that he could not work any miracles.

61.

It was 11am in the morning when the fire alarm went off. Hearing people running down the corridors, Mary grabbed her jacket and burst into Peter’s office next door.

[D] She shouted: “Peter, quick, we have to leave immediately because the building is on fire!”

[I] She urged Peter to leave immediately because the building was on fire.

62.

It was early Tuesday morning when Claire was looking for the train tickets she left in one of her handbags the other day. After searching for a couple of minutes she became worried and confused.

[D] She said to partner Gareth: “Erm, that’s weird... I am pretty sure they were in that black

leather bag, but now they're gone."
[I] She said to her partner Gareth that it was weird because she was pretty sure that they were in that black leather bag, but now they were gone.
63.
Twenty-five year old Connie was going to sing in the quarter-final of a local talent competition. She was extremely nervous before her performance, even though her mother had tried to calm her down.
[D] She said: "No! I can't do it! This is the end of the journey. I can't face the audience this time!"
[I] She said that she could not do it and that was the end of the journey because she couldn't face the audience this time.
64.
At the beach, William and Phillip were enjoying the sunshine and a fresh sea breeze. Suddenly, William noticed a piece of wood floating in the sea, with something lying on it that looked like a lifeless human body.
[D] Without hesitation, William exclaimed: "Phil, look! There's someone in trouble! We have to get some help quickly!"
[I] Without hesitation, William exclaimed that there was someone in trouble and that they had to get some help quickly.
65.
At Mr. Harris's house, Police constables Paul and Ken had some sad news to impart. Mrs. Harris's husband, a well-known businessman, was killed in a car crash earlier this morning.
[D] When Paul spoke with her, he said: "Mrs. Harris, I am afraid that your husband was involved in a road accident. He was announced dead at the scene."
[I] When Paul spoke with her, he said that her husband was involved in a road accident and that he was announced dead at the scene.
66.
On the train to London, young mother Olivia was taking her 5 year old daughter for a holiday. The little girl could not understand why the youth who lit a cigarette at the station was scolded by other passengers.
[D] She asked: "If people don't like smoking, why don't they just hold their breath?"
[I] She suggested that if people don't like smoking, they could just hold their breath.
67.

It was quarter past seven at the French restaurant, and head chef Pascal was extremely distressed. During a routine check, the restaurant manager went berserk about the messy state of the kitchen.
[D] He said: “Is this how you want to make yourself a reputation?! It's a miracle that the health inspectors haven't closed us down yet!”
[I] He asked whether this would be the way he wanted to make himself a reputation, adding that it's a miracle that the health inspectors haven't closed them down yet.
68.
Teenagers Helen and Laura were shopping around at the summer sale. Helen was very fond of a black skirt and shrieked when she found that it was heavily discounted.
[D] She called out: “Laura, look! This is exactly what I always wanted, and it's merely fifty quid!”
[I] She called out to Laura that this is exactly what she always wanted, and that it was merely fifty quid.
69.
On Sunday afternoon, the Riley’s were going to the train station to pick up granddad who lived in the neighbouring town. Twelve year-old Karen did not understand why they went so early if the train was arriving at 6 pm.
[D] Mr Riley replied: “Well, just in case.. Remember last time when granddad forgot to set his watch properly?"
[I] Mr Riley replied that this was just in case, reminding her of the last time when granddad forgot to set his watch properly.
70.
A medical emergency tutorial was taking place in the operating theatre. The tutor was demonstrating the steps to treat a heavy injury to the students.
[D] He explained: “When the patient comes in, first set up the life-support machine and then stop the bleeding.”
[I] He explained that when the patient comes in, they first should set up the life-support machine and then stop the bleeding.
71.
At Omaha Beach, allied soldiers braved artillery fire, mortar attacks and all-round danger. In response to the enemy’s gunfire, the captain of the 1st Division rallied the soldiers.
[D] He shouted: “Be brave, lads! Toss your grenades and open fire with your rifles! We must silence that machine gun.”

[I] He told the soldiers to toss their grenades and open fire with their rifles, for they must silence that machine gun.

72.

The West End festival was coming soon and the organisers were discussing details of the live television broadcast. The current issue was where to set the television cameras and John was offering his plans.

[D] He said: “We might need television cameras along the High Street, and possibly even a helicopter to cover the whole area.”

[I] He suggested that they might need television cameras along the High Street and possibly even a helicopter to cover the whole area.

73.

Today in Northern Afghanistan, the United Nations Peacekeeping Force was ambushed by Taliban forces. Although they returned fire immediately, the UN troops suffered heavy losses.

[D] The officer hastily called for reinforcements: “We are facing rocket and mortar fire in the region! We urgently need armoured support!”

[I] The officer hastily called for reinforcements, confirming that they were facing rocket and mortar fire in the region and that they urgently needed armoured support.

74.

It was midnight already and moonlight dripped through the leaves on the pavements. Robert and Chloe just came back from a party, and Chloe was still full of energy.

[D] She patted Robert’s cheek and said: “Stop yawning, my darling! The day is far from over yet.”

[I] She patted Robert’s cheek and said that he should stop yawning because the day was far from over yet.

75.

Joseph, an extremely wealthy entrepreneur, was known to be addicted to horse racing. Tipped-off by an insider, he placed a huge bet on one horse today, which failed to win the race, however.

[D] Joseph was now shouting furiously on the phone: “Where did your bloody information come from!? I've lost nearly one million pounds!”

[I] Joseph was now shouting furiously on the phone, asking where the information had come from, and claiming that he had lost nearly one million pounds.

76.

Due to the economic recession, Ron's company has lost a great quantity of international trades. His wife noticed that every day he just slumped on the couch, with a tired and dull look on his face.

[D] She tried to comfort him by saying: "Why don't you stop your business for a while? We could spend more time together, and there is certainly a positive side to that!"

[I] She tried to comfort him by suggesting that if he stops his business for a while, they could have more time together, and there was certainly a positive side to that.

77.

At the airport, Carol and Fraser were boarding the flight to Barcelona for a conference. There were only 5 minutes left before the plane was taking off, and Carol started panicking because she couldn't find her boarding card.

[D] She turned to Fraser and said: "Oh no! I can't find my stupid boarding pass! I must have left it at the duty-free shop!"

[I] She turned to Fraser and said that she couldn't find her boarding pass and that she must have left it at the duty-free shop.

78.

At Glasgow Royal Infirmary, family members were sitting around a bed, feeling sad. A very old man was dying, and too weak to sit up. He wanted to say something, so his daughter placed a cushion under his head.

[D] He looked around slowly, thanked them for their coming, and said: "I am so happy to have the whole family around me in my final hour."

[I] He looked around slowly, thanked them for their coming, and added that he was so happy to have the whole family around him in his final hour.

79.

Gerry and Herbert were attending a first aid tutorial where they were practising resuscitation procedures using a plastic dummy. Gerry was busy remembering all the steps, but Herbert wouldn't bother and instead explained his own strategy.

[D] He said: "Look, it's not necessary to go through all the steps. The important thing is to ensure that air passages are not obstructed."

[I] He said that it's not necessary to go through all the steps, and that the important thing was to ensure that air passages were not obstructed.

80.

At House of Fraser, the manager was demonstrating her employees how to describe, in one sentence, the special features of a product. She did it by performing a mock sales pitch in front of them.

[D] Holding up a jacket, she said: "This leather jacket is made of the finest materials and represents the latest Italian couture."

[I] Holding up a jacket, she said that it was made of the finest materials and represented the latest Italian couture.

81.

A heavily armed robbery took place at the jewelleries' early this morning. The criminals escaped in a blue van. Within five minutes, three police cars, an armed response unit, and an ambulance showed up at the scene.

[D] The officer-in-charge ordered: "Every main road must be blocked immediately! And, for Christ's sake, call the helicopter in!"

[I] The officer-in-charge ordered that every main road must be blocked immediately, and that the helicopter should be called in.

82.

David was producing a TV documentary about the Vietnam War, and today, he was interviewing a 75 year-old Vietnam veteran. When David asked about the situation at the battle of Hue, the old soldier paused for a while.

[D] Then, slowly, he said: "This battle was one of the longest and most brutal of the entire war. It's haunting me in my dreams for the rest of my life."

[I] Then, slowly, he said that this battle was one of the longest and most brutal of the entire war, and that it would be haunting him in his dreams for the rest of his life.

83.

It was a Sunday in June, and a young couple were waiting for their relatives to arrive. Zoe was busy making cucumber sandwiches and scones, when her husband noticed that her hands were actually shaking a bit.

[D] She explained: "Don't worry, I'm OK! I'm just a little nervous because I really want everything to be perfect."

[I] She explained that she was OK, and that she was just a little nervous because she really wanted everything to be perfect.

84.

University lecturer Bridget was responsible for admission to the English Literature classes. This morning, she had to deal with yet another request from a student who wanted to change her course.

[D] The student said: "I'm not sure whether Contemporary Women's Poetry is right for me.

Is it possible to switch to Sexual Identity in the Works of Oscar Wilde instead?”
[I] The student said that she was not sure whether Contemporary Women’s Poetry was right for her and asked if it was possible to switch to Sexual Identity in the Works of Oscar Wilde instead.

85.

In the computer shop, a customer wanted to get his laptop fixed because the Windows upgrade hadn’t installed correctly. The shop assistant had a quick look and noticed that the customer was using the Home Edition.
[D] He said: "Well, I presume you've tried the wrong update. You can't really apply updates for XP Professional to the Home Edition."
[I] He presumed that the customer had tried the wrong update, adding that one cannot really apply updates for XP Professional to the Home Edition.

86.

At Saint Jacob’s hospital in Falmouth, Henry was waiting to have an X-ray taken. He fell off the bus this morning and feared he broke his leg, but worst of all, he was also very anxious about X-rays.
[D] The doctor said: "No need to worry! We will give you a lead board to protect you from radiation."
[I] The doctor told him not to worry because they would give him a lead board to protect him from radiation.

87.

The heat of the morning was intense but Charles and Lucy had managed to climb up a hill. From the top, Charles could see right down to the beach on the other side.
[D] Excited, he said to Lucy: "Brilliant! Let's run down to the beach and take a plunge into the sea!"
[I] Excited, he suggested to Lucy that they should run down to the beach and take a plunge into the sea.

88.

Mrs. Jones felt awkward to ask her son for help because she ran out of cash for the babysitter. She pretended to enter her son’s room 'by accident', trying to borrow £20.
[D] The boy replied: "You see, I'd love to help you out, but your credit history isn't what I would call spotless."
[I] The boy replied that he would love to help her out, but that her credit history wasn't what he would call spotless.

89.

Eleanor's son had always been a bit of a couch potato. Over dinner, Eleanor was passing a cutting from a London newspaper to her husband.

[D] She said: “There, just read this article about child education! It exactly confirms my concerns about watching too much TV.”

[I] She asked him to read that article about child education, for it exactly confirmed her concerns about watching too much TV.

90.

The Smiths had recently suffered from some financial problems, so Mr. Smith was looking for a better job. Today, he was going to have an interview with the manager of a big insurance company.

[D] Before he left, his wife said: "Best of luck, darling. Always remember that you are the best man for the job!"

[I] Before he left, his wife wished him best of luck, and advised him to remember that he is the best man for the job.

Appendix E

Experiment 5 materials

1.

The man will drink all of the beer.

The man has drunk all of the wine.

2.

The postman will deliver all of the letters.

The postman has delivered all of the parcels.

3.

The boy will destroy all of the blocks.

The boy has destroyed all of the sandcastles.

4.

The policeman will discharge all of the men.

The policeman has discharged all of the women.

5.

The woman will eat all of the cake.

The woman has eaten all of the scones.

6.

The boys will enjoy all of the pizza.

The boys have enjoyed all of the Chinese take-away.

7.

The scientist will evaporate all of the chemicals.

The scientist has evaporated all of the water.

8.

The woman will finish all of the pie.

The woman has finished all of the soup.

9.

The woman will give away all of the toys.

The woman has given away all of the clothes.

10.

The dog will hide all of the bones.

The dog has hidden all of the shoes.

11.

The cat will kill all of the mice.

The cat has killed all of the birds.

12.

The woman will pour all of the coke.

The woman has poured all of the wine.

13.

The fireman will douse all of the flames.

The fireman has doused all of the logs.

14.

The boy will release all of the birds.

The boy has released all of the dogs.

15.

The grocer will sell all of the apples.

The grocer has sold all of the oranges.

16.

The waitress will serve all of the coffees.

The waitress has served all of the dinners.

Appendix F

Experiment 6 materials

1.

The man will move the engagement ring from the wardrobe into the wallet, and he will move the pearl necklace from the filing cabinet into the jewellery box. And then, he will examine the engagement ring.

The man will move the engagement ring from the wardrobe into the wallet, and he will move the pearl necklace from the filing cabinet into the jewellery box. And then, he will examine the pearl necklace.

The man will move the engagement ring into the wallet from the wardrobe, and he will move the pearl necklace into the jewellery box from the filing cabinet. And then, he will examine the engagement ring.

The man will move the engagement ring into the wallet from the wardrobe, and he will move the pearl necklace into the jewellery box from the filing cabinet. And then, he will examine the pearl necklace.

The man will move the engagement ring from the wardrobe into the wallet, and he will move the pearl necklace from the filing cabinet into the jewellery box. But first, he will examine the engagement ring.

The man will move the engagement ring from the wardrobe into the wallet, and he will move the pearl necklace from the filing cabinet into the jewellery box. But first, he will examine the pearl necklace.

The man will move the engagement ring into the wallet from the wardrobe, and he will move the pearl necklace into the jewellery box from the filing cabinet. But first, he will examine the engagement ring.

The man will move the engagement ring into the wallet from the wardrobe, and he will move the pearl necklace into the jewellery box from the filing cabinet. But first, he will examine the pearl necklace.

2.

The boy will transfer the tomato from the sack into the pot, and he will transfer the carrot from the paper bag into the colander. And then, he will taske the tomato.

The boy will transfer the tomato from the sack into the pot, and he will transfer the carrot from the paper bag into the colander. And then, he will taste the carrot.

The boy will transfer the tomato into the pot from the sack, and he will transfer the carrot into the colander from the paper bag. And then, he will taste the tomato.
The boy will transfer the tomato into the pot from the sack, and he will transfer the carrot into the colander from the paper bag. And then, he will taste the carrot.
The boy will transfer the tomato from the sack into the pot, and he will transfer the carrot from the paper bag into the colander. But first, he will taske the tomato.
The boy will transfer the tomato from the sack into the pot, and he will transfer the carrot from the paper bag into the colander. But first, he will taske the carrot.
The boy will transfer the tomato into the pot from the sack, and he will transfer the carrot into the colander from the paper bag. But first, he will taste the tomato.
The boy will transfer the tomato into the pot from the sack, and he will transfer the carrot into the colander from the paper bag. But first, he will taste the carrot.

3.

The girl will transfer the folder from the briefcase into the building, and she will transfer the key from the TV stand into the handbag. And then, she will check the folder.
The girl will transfer the folder from the briefcase into the building, and she will transfer the key from the TV stand into the handbag. And then, she will check the key.
The girl will transfer the folder into the building from the briefcase, and she will transfer the key into the handbag from the TV stand. And the, she will check the folder.
The girl will transfer the folder into the building from the briefcase, and she will transfer the key into the handbag from the TV stand. And the, she will check the key.
The girl will transfer the folder from the briefcase into the building, and she will transfer the key from the TV stand into the handbag. But first, she will check the folder.
The girl will transfer the folder from the briefcase into the building, and she will transfer the key from the TV stand into the handbag. But first, she will check the key.
The girl will transfer the folder into the building from the briefcase, and she will transfer the key into the handbag from the TV stand. But first, she will check the folder.
The girl will transfer the folder into the building from the briefcase, and she will transfer the key into the handbag from the TV stand. But first, she will check the key.

4.

The man will move the chilli from the measuring jug into the pan, and he will move the garlic from the colander into the rubbish bin. And then, he will sniff the chilli.
The man will move the chilli from the measuring jug into the pan, and he will move the garlic

from the colander into the rubbish bin. And then, he will sniff the garlic.
The man will move the chilli into the pan from the measuring jug, and he will move the garlic into the rubbish bin from the colander. And then, he will sniff the chilli.
The man will move the chilli into the pan from the measuring jug, and he will move the garlic into the rubbish bin from the colander. And then, he will sniff the garlic.
The man will move the chilli from the measuring jug into the pan, and he will move the garlic from the colander into the rubbish bin. But first, he will sniff the chilli.
The man will move the chilli from the measuring jug into the pan, and he will move the garlic from the colander into the rubbish bin. But first, he will sniff the garlic.
The man will move the chilli into the pan from the measuring jug, and he will move the garlic into the rubbish bin from the colander. But first, he will sniff the chilli.
The man will move the chilli into the pan from the measuring jug, and he will move the garlic into the rubbish bin from the colander. But first, he will sniff the garlic.
5.
The boy will move the soap from the paper bag into the bathtub, and he will move the detergent from the cabinet into the dishwasher. And then, he will smell the soap.
The boy will move the soap from the paper bag into the bathtub, and he will move the detergent from the cabinet into the dishwasher. And then, he will smell the detergent.
The boy will move the soap into the bathtub from the paper bag, and he will move the detergent into the dishwasher from the cabinet. And then, he will smell the soap.
The boy will move the soap into the bathtub from the paper bag, and he will move the detergent into the dishwasher from the cabinet. And then, he will smell the detergent.
The boy will move the soap from the paper bag into the bathtub, and he will move the detergent from the cabinet into the dishwasher. But first, he will smell the soap.
The boy will move the soap from the paper bag into the bathtub, and he will move the detergent from the cabinet into the dishwasher. But first, he will smell the detergent.
The boy will move the soap into the bathtub from the paper bag, and he will move the detergent into the dishwasher from the cabinet. But first, he will smell the soap.
The boy will move the soap into the bathtub from the paper bag, and he will move the detergent into the dishwasher from the cabinet. But first, he will smell the detergent.
6.
The woman will transfer the earrings from the jewellery box into the handbag, and she will transfer the gold watch from the wardrobe into the car. And then, she will inspect the

earrings.
The woman will transfer the earrings from the jewellery box into the handbag, and she will transfer the gold watch from the wardrobe into the car. And then, she will inspect the gold watch.
The woman will transfer the earrings into the handbag from the jewellery box, and she will transfer the gold watch into the car from the wardrobe. And then, she will inspect the earrings.
The woman will transfer the earrings into the handbag from the jewellery box, and she will transfer the gold watch into the car from the wardrobe. And then, she will inspect the gold watch.
The woman will transfer the earrings from the jewellery box into the handbag, and she will transfer the gold watch from the wardrobe into the car. But first, she will inspect the earrings.
The woman will transfer the earrings from the jewellery box into the handbag, and she will transfer the gold watch from the wardrobe into the car. But first, she will inspect the gold watch.
The woman will transfer the earrings into the handbag from the jewellery box, and she will transfer the gold watch into the car from the wardrobe. But first, she will inspect the earrings.
The woman will transfer the earrings into the handbag from the jewellery box, and she will transfer the gold watch into the car from the wardrobe. But first, she will inspect the gold watch.
7.
The girl will move the noodles from the cabinet into the microwave, and she will move the tray from the oven into the shed. And then, she will sniff the noodles.
The girl will move the noodles from the cabinet into the microwave, and she will move the tray from the oven into the shed. And then, she will sniff the tray.
The girl will move the noodles into the microwave from the cabinet, and she will move the tray into the shed from the oven. And then, she will sniff the noodles.
The girl will move the noodles into the microwave from the cabinet, and she will move the tray into the shed from the oven. And then, she will sniff the tray.
The girl will move the noodles from the cabinet into the microwave, and she will move the tray from the oven into the shed. But first, she will sniff the noodles.
The girl will move the noodles from the cabinet into the microwave, and she will move the tray from the oven into the shed. But first, she will sniff the tray.

The girl will move the noodles into the microwave from the cabinet, and she will move the tray into the shed from the oven. But first, she will sniff the noodles.
The girl will move the noodles into the microwave from the cabinet, and she will move the tray into the shed from the oven. But first, she will sniff the tray.
8.
The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug. And then, he will taste the sweetcorn.
The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug. And then, he will taste the gravy.
The boy will pour the sweetcorn into the jar from the bowl, and he will pour the gravy into the jug from the pan. And then, he will taste the sweetcorn.
The boy will pour the sweetcorn into the jar from the bowl, and he will pour the gravy into the jug from the pan. And then, he will taste the gravy.
The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug. But first, he will taste the sweetcorn.
The boy will pour the sweetcorn from the bowl into the jar, and he will pour the gravy from the pan into the jug. But first, he will taste the gravy.
The boy will pour the sweetcorn into the jar from the bowl, and he will pour the gravy into the jug from the pan. But first, he will taste the sweetcorn.
The boy will pour the sweetcorn into the jar from the bowl, and he will pour the gravy into the jug from the pan. But first, he will taste the gravy.
9.
The man will transfer the pendant from the wallet into the basket, and he will transfer the ring from the jewellery box into the briefcase. And then, he will check the pendant.
The man will transfer the pendant from the wallet into the basket, and he will transfer the ring from the jewellery box into the briefcase. And then, he will check the ring.
The man will transfer the pendant into the basket from the wallet, and he will transfer the ring into the briefcase from the jewellery box. And then, he will check the pendant.
The man will transfer the pendant into the basket from the wallet, and he will transfer the ring into the briefcase from the jewellery box. And then, he will check the ring.
The man will transfer the pendant from the wallet into the basket, and he will transfer the ring from the jewellery box into the briefcase. But first, he will check the pendant.
The man will transfer the pendant from the wallet into the basket, and he will transfer the ring

from the jewellery box into the briefcase. But first, he will check the ring.
The man will transfer the pendant into the basket from the wallet, and he will transfer the ring into the briefcase from the jewellery box. But first, he will check the pendant.
The man will transfer the pendant into the basket from the wallet, and he will transfer the ring into the briefcase from the jewellery box. But first, he will check the ring.
10.
The girl will transfer the tank top from the rucksack into the clothesbasket, and she will transfer the swimsuit from the bathtub into the tumble dryer. And then, she will inspect the tank top.
The girl will transfer the tank top from the rucksack into the clothesbasket, and she will transfer the swimsuit from the bathtub into the tumble dryer. And then, she will inspect the swimsuit.
The girl will transfer the tank top into the clothesbasket from the rucksack, and she will transfer the swimsuit into the tumble dryer from the bathtub. And then, she will inspect the tank top.
The girl will transfer the tank top into the clothesbasket from the rucksack, and she will transfer the swimsuit into the tumble dryer from the bathtub. And then, she will inspect the swimsuit.
The girl will transfer the tank top from the rucksack into the clothesbasket, and she will transfer the swimsuit from the bathtub into the tumble dryer. But first, she will inspect the tank top.
The girl will transfer the tank top from the rucksack into the clothesbasket, and she will transfer the swimsuit from the bathtub into the tumble dryer. But first, she will inspect the swimsuit.
The girl will transfer the tank top into the clothesbasket from the rucksack, and she will transfer the swimsuit into the tumble dryer from the bathtub. But first, she will inspect the tank top.
The girl will transfer the tank top into the clothesbasket from the rucksack, and she will transfer the swimsuit into the tumble dryer from the bathtub. But first, she will inspect the swimsuit.
11.
The boy will transfer the log from the wheelbarrow into the crate, and he will transfer the axe from the shed into the rucksack. And then, he will examine the log.

The boy will transfer the log from the wheelbarrow into the crate, and he will transfer the axe from the shed into the rucksack. And then, he will examine the axe.
The boy will transfer the log into the crate from the wheelbarrow, and he will transfer the axe into the rucksack from the shed. And then, he will examine the log.
The boy will transfer the log into the crate from the wheelbarrow, and he will transfer the axe into the rucksack from the shed. And then, he will examine the axe.
The boy will transfer the log from the wheelbarrow into the crate, and he will transfer the axe from the shed into the rucksack. But first, he will examine the log.
The boy will transfer the log from the wheelbarrow into the crate, and he will transfer the axe from the shed into the rucksack. But first, he will examine the axe.
The boy will transfer the log into the crate from the wheelbarrow, and he will transfer the axe into the rucksack from the shed. But first, he will examine the log.
The boy will transfer the log into the crate from the wheelbarrow, and he will transfer the axe into the rucksack from the shed. But first, he will examine the axe.
12.
The girl will move the crème brûlée from the oven into the fridge, and she will move the steak from the measuring scale into the paper bag. And then, she will smell the crème brûlée.
The girl will move the crème brûlée from the oven into the fridge, and she will move the steak from the measuring scale into the paper bag. And then, she will smell the steak.
The girl will move the crème brûlée into the fridge from the oven, and she will move the steak into the paper bag from the measuring scale. And then, she will smell the crème brûlée.
The girl will move the crème brûlée into the fridge from the oven, and she will move the steak into the paper bag from the measuring scale. And then, she will smell the steak.
The girl will move the crème brûlée from the oven into the fridge, and she will move the steak from the measuring scale into the paper bag. But first, she will smell the crème brûlée.
The girl will move the crème brûlée from the oven into the fridge, and she will move the steak from the measuring scale into the paper bag. But first, she will smell the steak.
The girl will move the crème brûlée into the fridge from the oven, and she will move the steak into the paper bag from the measuring scale. But first, she will smell the crème brûlée.
The girl will move the crème brûlée into the fridge from the oven, and she will move the steak into the paper bag from the measuring scale. But first, she will smell the steak.
13.
The woman will transfer the jewels from the building into the car, and she will transfer the

cheque from the airplane into the safe. And then, she will inspect the jewels.
The woman will transfer the jewels from the building into the car, and she will transfer the cheque from the airplane into the safe. And then, she will inspect the cheque.
The woman will transfer the jewels into the car from the building, and she will transfer the cheque into the safe from the airplane. And then, she will inspect the jewels.
The woman will transfer the jewels into the car from the building, and she will transfer the cheque into the safe from the airplane. And then, she will inspect the cheque.
The woman will transfer the jewels from the building into the car, and she will transfer the cheque from the airplane into the safe. But first, she will inspect the jewels.
The woman will transfer the jewels from the building into the car, and she will transfer the cheque from the airplane into the safe. But first, she will inspect the cheque.
The woman will transfer the jewels into the car from the building, and she will transfer the cheque into the safe from the airplane. But first, she will inspect the jewels.
The woman will transfer the jewels into the car from the building, and she will transfer the cheque into the safe from the airplane. But first, she will inspect the cheque.
14.
The man will guide the horse from the ferry into the barn, and he will guide the panda from the lorry onto the airplane. And then, he will check the horse.
The man will guide the horse from the ferry into the barn, and he will guide the panda from the lorry onto the airplane. And then, he will check the panda.
The man will guide the horse into the barn from the ferry, and he will guide the panda onto the airplane from the lorry. And then, he will check the horse.
The man will guide the horse into the barn from the ferry, and he will guide the panda onto the airplane from the lorry. And then, he will check the panda.
The man will guide the horse from the ferry into the barn, and he will guide the panda from the lorry onto the airplane. But first, he will check the horse.
The man will guide the horse from the ferry into the barn, and he will guide the panda from the lorry onto the airplane. But first, he will check the panda.
The man will guide the horse into the barn from the ferry, and he will guide the panda onto the airplane from the lorry. But first, he will check the horse.
The man will guide the horse into the barn from the ferry, and he will guide the panda onto the airplane from the lorry. But first, he will check the panda.
15.

The girl will move the Tupperware from the dishwasher into the cabinet, and she will move the plate from the microwave into the sink. And then, she will examine the Tupperware.
The girl will move the Tupperware from the dishwasher into the cabinet, and she will move the plate from the microwave into the sink. And then, she will examine the plate.
The girl will move the Tupperware into the cabinet from the dishwasher, and she will move the plate into the sink from the microwave. And then, she will examine the Tupperware.
The girl will move the Tupperware into the cabinet from the dishwasher, and she will move the plate into the sink from the microwave. And then, she will examine the plate.
The girl will move the Tupperware from the dishwasher into the cabinet, and she will move the plate from the microwave into the sink. But first, she will examine the Tupperware.
The girl will move the Tupperware from the dishwasher into the cabinet, and she will move the plate from the microwave into the sink. But first, she will examine the plate.
The girl will move the Tupperware into the cabinet from the dishwasher, and she will move the plate into the sink from the microwave. But first, she will examine the Tupperware.
The girl will move the Tupperware into the cabinet from the dishwasher, and she will move the plate into the sink from the microwave. But first she will examine the plate.
16.
The woman will move the ice cube from the jug into the sink, and she will move the lemonade from the fridge into the lunchbox. And then, she will examine the ice cube.
The woman will move the ice cube from the jug into the sink, and she will move the lemonade from the fridge into the lunchbox. And then, she will examine the lemonade.
The woman will move the ice cube into the sink from the jug, and she will move the lemonade into the lunchbox from the fridge. And then, she will examine the ice cube.
The woman will move the ice cube into the sink from the jug, and she will move the lemonade into the lunchbox from the fridge. And then, she will examine the lemonade.
The woman will move the ice cube from the jug into the sink, and she will move the lemonade from the fridge into the lunchbox. But first, she will examine the ice cube.
The woman will move the ice cube from the jug into the sink, and she will move the lemonade from the fridge into the lunchbox. But first, she will examine the lemonade.
The woman will move the ice cube into the sink from the jug, and she will move the lemonade into the lunchbox from the fridge. But first, she will examine the ice cube.
The woman will move the ice cube into the sink from the jug, and she will move the lemonade into the lunchbox from the fridge. But first, she will examine the lemonade.

17.

The man will move the tablecloth from the trunk into the sideboard, and he will move the CDs from the desk drawer into the TV stand. And then, he will inspect the tablecloth.

The man will move the tablecloth from the trunk into the sideboard, and he will move the CDs from the desk drawer into the TV stand. And then, he will inspect the CDs.

The man will move the tablecloth into the sideboard from the trunk, and he will move the CDs into the TV stand from the desk drawer. And then, he will inspect the tablecloth.

The man will move the tablecloth into the sideboard from the trunk, and he will move the CDs into the TV stand from the desk drawer. And then, he will inspect the CDs.

The man will move the tablecloth from the trunk into the sideboard, and he will move the CDs from the desk drawer into the TV stand. But first, he will inspect the tablecloth.

The man will move the tablecloth from the trunk into the sideboard, and he will move the CDs from the desk drawer into the TV stand. But first, he will inspect the CDs.

The man will move the tablecloth into the sideboard from the trunk, and he will move the CDs into the TV stand from the desk drawer. But first, he will inspect the tablecloth.

The man will move the tablecloth into the sideboard from the trunk, and he will move the CDs into the TV stand from the desk drawer. But first, he will inspect the CDs.

18.

The girl will transfer the potato from the microwave into the bowl, and she will transfer the beans from the pot into the jar. And then, she will smell the potato.

The girl will transfer the potato from the microwave into the bowl, and she will transfer the beans from the pot into the jar. And then, she will smell the beans.

The girl will transfer the potato into the bowl from the microwave, and she will transfer the beans into the jar from the pot. And then, she will smell the potato.

The girl will transfer the potato into the bowl from the microwave, and she will transfer the beans into the jar from the pot. And then, she will smell the beans.

The girl will transfer the potato from the microwave into the bowl, and she will transfer the beans from the pot into the jar. But first, she will smell the potato.

The girl will transfer the potato from the microwave into the bowl, and she will transfer the beans from the pot into the jar. But first, she will smell the beans.

The girl will transfer the potato into the bowl from the microwave, and she will transfer the beans into the jar from the pot. But first, she will smell the potato.

The girl will transfer the potato into the bowl from the microwave, and she will transfer the beans into the jar from the pot. But first, she will smell the beans.

19.

The boy will transfer the grapefruit from the colander into the sack, and he will transfer the apple from the basket into the crate. And then, he will sniff the grapefruit.

The boy will transfer the grapefruit from the colander into the sack, and he will transfer the apple from the basket into the crate. And then, he will sniff the apple.

The boy will transfer the grapefruit into the sack from the colander, and he will transfer the apple into the crate from the basket. And then, he will sniff the grapefruit.

The boy will transfer the grapefruit into the sack from the colander, and he will transfer the apple into the crate from the basket. And then, he will sniff the apple.

The boy will transfer the grapefruit from the colander into the sack, and he will transfer the apple from the basket into the crate. But first, he will sniff the grapefruit.

The boy will transfer the grapefruit from the colander into the sack, and he will transfer the apple from the basket into the crate. But first, he will sniff the apple.

The boy will transfer the grapefruit into the sack from the colander, and he will transfer the apple into the crate from the basket. But first, he will sniff the grapefruit.

The boy will transfer the grapefruit into the sack from the colander, and he will transfer the apple into the crate from the basket. But first, he will sniff the apple.

20.

The man will direct the politician from the car onto the airplane, and he will direct the general from the building onto the ferry. And then, he will check on the politician.

The man will direct the politician from the car onto the airplane, and he will direct the general from the building onto the ferry. And then, he will check on the general.

The man will direct the politician onto the airplane from the car, and he will direct the general onto the ferry from the building. And then, he will check on the politician.

The man will direct the politician onto the airplane from the car, and he will direct the general onto the ferry from the building. And then, he will check on the general.

The man will direct the politician from the car onto the airplane, and he will direct the general from the building onto the ferry. But first, he will check on the politician.

The man will direct the politician from the car onto the airplane, and he will direct the general from the building onto the ferry. But first, he will check on the general.

The man will direct the politician onto the airplane from the car, and he will direct the general onto the ferry from the building. But first, he will check on the politician.

The man will direct the politician onto the airplane from the car, and he will direct the general onto the ferry from the building. But first, he will check on the general.

21.

The man will move the courgette from the measuring scale into the oven, and he will move the asparagus from the box into the pan. And then, he will taste the courgette.

The man will move the courgette from the measuring scale into the oven, and he will move the asparagus from the box into the pan. And then, he will taste the asparagus.

The man will move the courgette into the oven from the measuring scale, and he will move the asparagus into the pan from the box. And then, he will taste the courgette.

The man will move the courgette into the oven from the measuring scale, and he will move the asparagus into the pan from the box. And then, he will taste the asparagus.

The man will move the courgette from the measuring scale into the oven, and he will move the asparagus from the box into the pan. But first, he will taste the courgette.

The man will move the courgette from the measuring scale into the oven, and he will move the asparagus from the box into the pan. But first, he will taste the asparagus.

The man will move the courgette into the oven from the measuring scale, and he will move the asparagus into the pan from the box. But first, he will taste the courgette.

The man will move the courgette into the oven from the measuring scale, and he will move the asparagus into the pan from the box. But first, he will taste the asparagus.

22.

The woman will transfer the plum from the lunchbox into the measuring scale, and she will transfer the watermelon from the car into the fridge. And then, she will smell the plum.

The woman will transfer the plum from the lunchbox into the measuring scale, and she will transfer the watermelon from the car into the fridge. And then, she will smell the watermelon.

The woman will transfer the plum into the measuring scale from the lunchbox, and she will transfer the watermelon into the fridge from the car. And then, she will smell the plum.

The woman will transfer the plum into the measuring scale from the lunchbox, and she will transfer the watermelon into the fridge from the car. And then, she will smell the watermelon.

The woman will transfer the plum from the lunchbox into the measuring scale, and she will transfer the watermelon from the car into the fridge. But first, she will smell the plum.

The woman will transfer the plum from the lunchbox into the measuring scale, and she will

transfer the watermelon from the car into the fridge. But first, she will smell the watermelon.
The woman will transfer the plum into the measuring scale from the lunchbox, and she will transfer the watermelon into the fridge from the car. But first, she will smell the plum.
The woman will transfer the plum into the measuring scale from the lunchbox, and she will transfer the watermelon into the fridge from the car. But first, she will smell the watermelon.
23.
The woman will move the hay from the barn into the wheelbarrow, and she will move the stones from the rubbish bin onto the lorry. And then, she will examine the hay.
The woman will move the hay from the barn into the wheelbarrow, and she will move the stones from the rubbish bin onto the lorry. And then, she will examine the stones.
The woman will move the hay into the wheelbarrow from the barn, and she will move the stones onto the lorry from the rubbish bin. And then, she will examine the hay.
The woman will move the hay into the wheelbarrow from the barn, and she will move the stones onto the lorry from the rubbish bin. And then, she will examine the stones.
The woman will move the hay from the barn into the wheelbarrow, and she will move the stones from the rubbish bin onto the lorry. But first, she will examine the hay.
The woman will move the hay from the barn into the wheelbarrow, and she will move the stones from the rubbish bin onto the lorry. But first, she will examine the stones.
The woman will move the hay into the wheelbarrow from the barn, and she will move the stones onto the lorry from the rubbish bin. But first, she will examine the hay.
The woman will move the hay into the wheelbarrow from the barn, and she will move the stones onto the lorry from the rubbish bin. But first, she will examine the stones.
24.
The girl will guide the cow from the lorry onto the ferry, and she will guide the tiger from the cage into the building. And then, she will check the cow.
The girl will guide the cow from the lorry onto the ferry, and she will guide the tiger from the cage into the building. And then, she will check the tiger.
The girl will guide the cow onto the ferry from the lorry, and she will guide the tiger into the building from the cage. And then, she will check the cow.
The girl will guide the cow onto the ferry from the lorry, and she will guide the tiger into the building from the cage. And then, she will check the tiger.
The girl will guide the cow from the lorry onto the ferry, and she will guide the tiger from the cage into the building. But first, she will check the cow.

The girl will guide the cow from the lorry onto the ferry, and she will guide the tiger from the cage into the building. But first, she will check the tiger.
The girl will guide the cow onto the ferry from the lorry, and she will guide the tiger into the building from the cage. But first, she will check the cow.
The girl will guide the cow onto the ferry from the lorry, and she will guide the tiger into the building from the cage. But first, she will check the tiger.
25.
The man will transfer the cabbage from the fridge into the measuring jug, and he will transfer the chicken from the sink into the box. And then, he will sniff the cabbage.
The man will transfer the cabbage from the fridge into the measuring jug, and he will transfer the chicken from the sink into the box. And then, he will sniff the chicken.
The man will transfer the cabbage into the measuring jug from the fridge, and he will transfer the chicken into the box from the sink. And then, he will sniff the cabbage.
The man will transfer the cabbage into the measuring jug from the fridge, and he will transfer the chicken into the box from the sink. And then, he will sniff the chicken.
The man will transfer the cabbage from the fridge into the measuring jug, and he will transfer the chicken from the sink into the box. But first, he will sniff the cabbage.
The man will transfer the cabbage from the fridge into the measuring jug, and he will transfer the chicken from the sink into the box. But first, he will sniff the chicken.
The man will transfer the cabbage into the measuring jug from the fridge, and he will transfer the chicken into the box from the sink. But first, he will sniff the cabbage.
The man will transfer the cabbage into the measuring jug from the fridge, and he will transfer the chicken into the box from the sink. But first, he will sniff the chicken.
26.
The girl will move the dress from the clothesbasket into the chest of drawers, and she will move the gym shorts from the rucksack into the washing machine. And then, she will inspect the dress.
The girl will move the dress from the clothesbasket into the chest of drawers, and she will move the gym shorts from the rucksack into the washing machine. And then, she will inspect the gym shorts.
The girl will move the dress into the chest of drawers from the clothesbasket, and she will move the gym shorts into the washing machine from the rucksack. And then, she will inspect the dress.

The girl will move the dress into the chest of drawers from the clothesbasket, and she will move the gym shorts into the washing machine from the rucksack. And then, she will inspect the gym shorts.
The girl will move the dress from the clothesbasket into the chest of drawers, and she will move the gym shorts from the rucksack into the washing machine. But first, she will inspect the dress.
The girl will move the dress from the clothesbasket into the chest of drawers, and she will move the gym shorts from the rucksack into the washing machine. But first, she will inspect the gym shorts.
The girl will move the dress into the chest of drawers from the clothesbasket, and she will move the gym shorts into the washing machine from the rucksack. But first, she will inspect the dress.
The girl will move the dress into the chest of drawers from the clothesbasket, and she will move the gym shorts into the washing machine from the rucksack. But first, she will inspect the gym shorts.
27.
The man will move the jumper from the tumble dryer into the wardrobe, and he will move the mittens from the handbag into the trunk. And then, he will examine the jumper.
The man will move the jumper from the tumble dryer into the wardrobe, and he will move the mittens from the handbag into the trunk. And then, he will examine the mittens.
The man will move the jumper into the wardrobe from the tumble dryer, and he will move the mittens into the trunk from the handbag. And then, he will examine the jumper.
The man will move the jumper into the wardrobe from the tumble dryer, and he will move the mittens into the trunk from the handbag. And then, he will examine the mittens.
The man will move the jumper from the tumble dryer into the wardrobe, and he will move the mittens from the handbag into the trunk. But first, he will examine the jumper.
The man will move the jumper from the tumble dryer into the wardrobe, and he will move the mittens from the handbag into the trunk. But first, he will examine the mittens.
The man will move the jumper into the wardrobe from the tumble dryer, and he will move the mittens into the trunk from the handbag. But first, he will examine the jumper.
The man will move the jumper into the wardrobe from the tumble dryer, and he will move the mittens into the trunk from the handbag. But first, he will examine the mittens.
28.

The man will move the water bowl from the cage into the dishwasher, and he will move the teacup from the sideboard into the microwave. And then, he will inspect the water bowl.
The man will move the water bowl from the cage into the dishwasher, and he will move the teacup from the sideboard into the microwave. And then, he will inspect the teacup.
The man will move the water bowl into the dishwasher from the cage, and he will move the teacup into the microwave from the sideboard. And then, he will inspect the water bowl.
The man will move the water bowl into the dishwasher from the cage, and he will move the teacup into the microwave from the sideboard. And then, he will inspect the teacup.
The man will move the water bowl from the cage into the dishwasher, and he will move the teacup from the sideboard into the microwave. But first, he will inspect the water bowl.
The man will move the water bowl from the cage into the dishwasher, and he will move the teacup from the sideboard into the microwave. But first, he will inspect the teacup.
The man will move the water bowl into the dishwasher from the cage, and he will move the teacup into the microwave from the sideboard. But first, he will inspect the water bowl.
The man will move the water bowl into the dishwasher from the cage, and he will move the teacup into the microwave from the sideboard. But first, he will inspect the teacup.
29.
The woman will transfer the silver spoon from the sideboard into the jewellery box, and she will transfer the license from the chest of drawers into the wallet. And then, she will check the silver spoon.
The woman will transfer the silver spoon from the sideboard into the jewellery box, and she will transfer the license from the chest of drawers into the wallet. And then, she will check the license.
The woman will transfer the silver spoon into the jewellery box from the sideboard, and she will transfer the license into the wallet from the chest of drawers. And then, she will check the silver spoon.
The woman will transfer the silver spoon into the jewellery box from the sideboard, and she will transfer the license into the wallet from the chest of drawers. And then, she will check the license.
The woman will transfer the silver spoon from the sideboard into the jewellery box, and she will transfer the license from the chest of drawers into the wallet. But first, she will check the silver spoon.
The woman will transfer the silver spoon from the sideboard into the jewellery box, and she

will transfer the license from the chest of drawers into the wallet. But first, she will check the license.

The woman will transfer the silver spoon into the jewellery box from the sideboard, and she will transfer the license into the wallet from the chest of drawers. But first, she will check the silver spoon.

The woman will transfer the silver spoon into the jewellery box from the sideboard, and she will transfer the license into the wallet from the chest of drawers. But first, she will check the license.

30.

The woman will move the socks from the washing machine into the tumble dryer, and she will move the jacket from the trunk into the wardrobe. And then, she will examine the socks.

The woman will move the socks from the washing machine into the tumble dryer, and she will move the jacket from the trunk into the wardrobe. And then, she will examine the jacket.

The woman will move the socks into the tumble dryer from the washing machine, and she will move the jacket into the wardrobe from the trunk. And then, she will examine the socks.

The woman will move the socks into the tumble dryer from the washing machine, and she will move the jacket into the wardrobe from the trunk. And then, she will examine the jacket.

The woman will move the socks from the washing machine into the tumble dryer, and she will move the jacket from the trunk into the wardrobe. But first, she will examine the socks.

The woman will move the socks from the washing machine into the tumble dryer, and she will move the jacket from the trunk into the wardrobe. But first, she will examine the jacket.

The woman will move the socks into the tumble dryer from the washing machine, and she will move the jacket into the wardrobe from the trunk. But first, she will examine the socks.

The woman will move the socks into the tumble dryer from the washing machine, and she will move the jacket into the wardrobe from the trunk. But first, she will examine the jacket.

31.

The woman will transfer the bones from the rubbish bin into the shed, and she will transfer the leaves from the crate into the wheelbarrow. And then, she will check the bones.

The woman will transfer the bones from the rubbish bin into the shed, and she will transfer the leaves from the crate into the wheelbarrow. And then, she will check the leaves.

The woman will transfer the bones into the shed from the rubbish bin, and she will transfer the leaves into the wheelbarrow from the crate. And then, she will check the bones.

The woman will transfer the bones into the shed from the rubbish bin, and she will transfer

the leaves into the wheelbarrow from the crate. And then, she will check the leaves.
The woman will transfer the bones from the rubbish bin into the shed, and she will transfer the leaves from the crate into the wheelbarrow. But first, she will check the bones.
The woman will transfer the bones from the rubbish bin into the shed, and she will transfer the leaves from the crate into the wheelbarrow. But first, she will check the leaves.
The woman will transfer the bones into the shed from the rubbish bin, and she will transfer the leaves into the wheelbarrow from the crate. But first, she will check the bones.
The woman will transfer the bones into the shed from the rubbish bin, and she will transfer the leaves into the wheelbarrow from the crate. But first, she will check the leaves.
32.
The woman will move the cheese from the box into the paper bag, and she will move the avocado from the measuring jug into the sack. And then, she will sniff the cheese.
The woman will move the cheese from the box into the paper bag, and she will move the avocado from the measuring jug into the sack. And then, she will sniff the avocado.
The woman will move the cheese into the paper bag from the box, and she will move the avocado into the sack from the measuring jug. And then, she will sniff the cheese.
The woman will move the cheese into the paper bag from the box, and she will move the avocado into the sack from the measuring jug. And then, she will sniff the avocado.
The woman will move the cheese from the box into the paper bag, and she will move the avocado from the measuring jug into the sack. But first, she will sniff the cheese.
The woman will move the cheese from the box into the paper bag, and she will move the avocado from the measuring jug into the sack. But first, she will sniff the avocado.
The woman will move the cheese into the paper bag from the box, and she will move the avocado into the sack from the measuring jug. But first, she will sniff the cheese.
The woman will move the cheese into the paper bag from the box, and she will move the avocado into the sack from the measuring jug. But first, she will sniff the avocado.
33.
The girl will move the kitten from the bathtub into the cage, and she will move the puppy from the wheelbarrow into the barn. And then, she will inspect the kitten.
The girl will move the kitten from the bathtub into the cage, and she will move the puppy from the wheelbarrow into the barn. And then, she will inspect the puppy.
The girl will move the kitten into the cage from the bathtub, and she will move the puppy into the barn from the wheelbarrow. And then, she will inspect the kitten.

The girl will move the kitten into the cage from the bathtub, and she will move the puppy into the barn from the wheelbarrow. And then, she will inspect the puppy.
The girl will move the kitten from the bathtub into the cage, and she will move the puppy from the wheelbarrow into the barn. But first, she will inspect the kitten.
The girl will move the kitten from the bathtub into the cage, and she will move the puppy from the wheelbarrow into the barn. But first, she will inspect the puppy.
The girl will move the kitten into the cage from the bathtub, and she will move the puppy into the barn from the wheelbarrow. But first, she will inspect the kitten.
The girl will move the kitten into the cage from the bathtub, and she will move the puppy into the barn from the wheelbarrow. But first, she will inspect the puppy.
The girl will move the aubergine from the sink into the bowl, and she will move the pizza from the lunchbox into the oven. And then, she will taste the aubergine.
34.
The girl will move the aubergine from the sink into the bowl, and she will move the pizza from the lunchbox into the oven. And then, she will taste the pizza.
The girl will move the aubergine into the bowl from the sink, and she will move the pizza into the oven from the lunchbox. And then, she will taste the aubergine.
The girl will move the aubergine into the bowl from the sink, and she will move the pizza into the oven from the lunchbox. And then, she will taste the pizza.
The girl will move the aubergine from the sink into the bowl, and she will move the pizza from the lunchbox into the oven. But first, she will taste the aubergine.
The girl will move the aubergine from the sink into the bowl, and she will move the pizza from the lunchbox into the oven. But first, she will taste the pizza.
The girl will move the aubergine into the bowl from the sink, and she will move the pizza into the oven from the lunchbox. But first, she will taste the aubergine.
The girl will move the aubergine into the bowl from the sink, and she will move the pizza into the oven from the lunchbox. But first, she will taste the pizza.
35.
The woman will move the trousers from the suitcase into the washing machine, and she will move the sweatshirt from the tumble dryer into the chest of drawers. And then, she will smell the trousers.
The woman will move the trousers from the suitcase into the washing machine, and she will move the sweatshirt from the tumble dryer into the chest of drawers. And then, she will

smell the sweatshirt.
The woman will move the trousers into the washing machine from the suitcase, and she will move the sweatshirt into the chest of drawers from the tumble dryer. And then, she will smell the trousers.
The woman will move the trousers into the washing machine from the suitcase, and she will move the sweatshirt into the chest of drawers from the tumble dryer. And then, she will smell the sweatshirt.
The woman will move the trousers from the suitcase into the washing machine, and she will move the sweatshirt from the tumble dryer into the chest of drawers. But first, she will smell the trousers.
The woman will move the trousers from the suitcase into the washing machine, and she will move the sweatshirt from the tumble dryer into the chest of drawers. But first, she will smell the sweatshirt.
The woman will move the trousers into the washing machine from the suitcase, and she will move the sweatshirt into the chest of drawers from the tumble dryer. But first, she will smell the trousers.
The woman will move the trousers into the washing machine from the suitcase, and she will move the sweatshirt into the chest of drawers from the tumble dryer. But first, she will smell the sweatshirt.
36.
The woman will pour the oil from the pan into the rubbish bin, and she will pour the cream from the jug into the bowl. And then, she will sniff the oil.
The woman will pour the oil from the pan into the rubbish bin, and she will pour the cream from the jug into the bowl. And then, she will sniff the cream.
The woman will pour the oil into the rubbish bin from the pan, and she will pour the cream into the bowl from the jug. And then, she will sniff the oil.
The woman will pour the oil into the rubbish bin from the pan, and she will pour the cream into the bowl from the jug. And then, she will sniff the cream.
The woman will pour the oil from the pan into the rubbish bin, and she will pour the cream from the jug into the bowl. But first, she will sniff the oil.
The woman will pour the oil from the pan into the rubbish bin, and she will pour the cream from the jug into the bowl. But first, she will sniff the cream.
The woman will pour the oil into the rubbish bin from the pan, and she will pour the cream

into the bowl from the jug. But first, she will sniff the oil.
The woman will pour the oil into the rubbish bin from the pan, and she will pour the cream into the bowl from the jug. But first, she will sniff the cream.
37.
The boy will move the bracelet from the handbag into the desk drawer, and he will move the credit card from the safe into the suitcase. And then, he will examine the bracelet.
The boy will move the bracelet from the handbag into the desk drawer, and he will move the credit card from the safe into the suitcase. And then, he will examine the credit card.
The boy will move the bracelet into the desk drawer from the handbag, and he will move the credit card into the suitcase from the safe. And then, he will examine the bracelet.
The boy will move the bracelet into the desk drawer from the handbag, and he will move the credit card into the suitcase from the safe. And then, he will examine the credit card.
The boy will move the bracelet from the handbag into the desk drawer, and he will move the credit card from the safe into the suitcase. But first, he will examine the bracelet.
The boy will move the bracelet from the handbag into the desk drawer, and he will move the credit card from the safe into the suitcase. But first, he will examine the credit card.
The boy will move the bracelet into the desk drawer from the handbag, and he will move the credit card into the suitcase from the safe. But first, he will examine the bracelet.
The boy will move the bracelet into the desk drawer from the handbag, and he will move the credit card into the suitcase from the safe. But first, he will examine the credit card.
38.
The boy will move the baguette from the basket into the rucksack, and he will move the clementine from the jar into the measuring scale. And then, he will inspect the baguette.
The boy will move the baguette from the basket into the rucksack, and he will move the clementine from the jar into the measuring scale. And then, he will inspect the clementine.
The boy will move the baguette into the rucksack form the basket, and he will move the clementine into the measuring scale form the jar. And then, he will inspect the baguette.
The boy will move the baguette into the rucksack form the basket, and he will move the clementine into the measuring scale form the jar. And then, he will inspect the clementine.
The boy will move the baguette from the basket into the rucksack, and he will move the clementine from the jar into the measuring scale. But first, he will inspect the baguette.
The boy will move the baguette from the basket into the rucksack, and he will move the clementine from the jar into the measuring scale. But first, he will inspect the clementine.

The boy will move the baguette into the rucksack form the basket, and he will move the clementine into the measuring scale form the jar. But first, he will inspect the baguette.
The boy will move the baguette into the rucksack form the basket, and he will move the clementine into the measuring scale form the jar. But first, he will inspect the clementine.
39.
The boy will move the milk from the crate into the lunchbox, and he will move the egg from the barn into the basket. And then, he will smell the milk.
The boy will move the milk from the crate into the lunchbox, and he will move the egg from the barn into the basket. And then, he will smell the egg.
The boy will move the milk into the lunchbox from the crate, and he will move the egg into the basket from the barn. And then, he will smell the milk.
The boy will move the milk into the lunchbox from the crate, and he will move the egg into the basket from the barn. And then, he will smell the egg.
The boy will move the milk from the crate into the lunchbox, and he will move the egg from the barn into the basket. But first, he will smell the milk.
The boy will move the milk from the crate into the lunchbox, and he will move the egg from the barn into the basket. But first, he will smell the egg.
The boy will move the milk into the lunchbox from the crate, and he will move the egg into the basket from the barn. But first, he will smell the milk.
The boy will move the milk into the lunchbox from the crate, and he will move the egg into the basket from the barn. But first, he will smell the egg.
40.
The boy will guide the goat from the shed onto the lorry, and he will guide the elephant from the ferry into the cage. And then, he will check the goat.
The boy will guide the goat from the shed onto the lorry, and he will guide the elephant from the ferry into the cage. And then, he will check the elephant.
The boy will guide the goat onto the lorry from the shed, and he will guide the elephant into the cage from the ferry. And then, he will check the goat.
The boy will guide the goat onto the lorry from the shed, and he will guide the elephant into the cage from the ferry. And then, he will check the elephant.
The boy will guide the goat from the shed onto the lorry, and he will guide the elephant from the ferry into the cage. But first, he will check the goat.
The boy will guide the goat from the shed onto the lorry, and he will guide the elephant from

the ferry into the cage. But first, he will check the elephant.
The boy will guide the goat onto the lorry from the shed, and he will guide the elephant into the cage from the ferry. But first, he will check the goat.
The boy will guide the goat onto the lorry from the shed, and he will guide the elephant into the cage from the ferry. But first, he will check the elephant.
The man will transfer the diplomatic documents from the airplane into the safe, and he will transfer the passport from the briefcase into the filing cabinet. And then, he will inspect the diplomatic documents.
41.
The man will transfer the diplomatic documents from the airplane into the safe, and he will transfer the passport from the briefcase into the filing cabinet. And then, he will inspect the passport.
The man will transfer the diplomatic documents into the safe from the airplane, and he will transfer the passport into the filing cabinet from the briefcase. And then, he will inspect the diplomatic documents.
The man will transfer the diplomatic documents into the safe from the airplane, and he will transfer the passport into the filing cabinet from the briefcase. And then, he will inspect the passport.
The man will transfer the diplomatic documents from the airplane into the safe, and he will transfer the passport from the briefcase into the filing cabinet. But first, he will inspect the diplomatic documents.
The man will transfer the diplomatic documents from the airplane into the safe, and he will transfer the passport from the briefcase into the filing cabinet. But first, he will inspect the passport.
The man will transfer the diplomatic documents into the safe from the airplane, and he will transfer the passport into the filing cabinet from the briefcase. But first, he will inspect the diplomatic documents.
The man will transfer the diplomatic documents into the safe from the airplane, and he will transfer the passport into the filing cabinet from the briefcase. But first, he will inspect the passport.
42.
The boy will transfer the rubber duck from the desk drawer into the trunk, and he will transfer the shampoo from the suitcase into the bathtub. And then, he will examine the rubber duck.

The boy will transfer the rubber duck from the desk drawer into the trunk, and he will transfer the shampoo from the suitcase into the bathtub. And then, he will examine the shampoo.
The boy will transfer the rubber duck into the trunk from the desk drawer, and he will transfer the shampoo into the bathtub from the suitcase. And then, he will examine the rubber duck.
The boy will transfer the rubber duck into the trunk from the desk drawer, and he will transfer the shampoo into the bathtub from the suitcase. And then, he will examine the shampoo.
The boy will transfer the rubber duck from the desk drawer into the trunk, and he will transfer the shampoo from the suitcase into the bathtub. But first, he will examine the rubber duck.
The boy will transfer the rubber duck from the desk drawer into the trunk, and he will transfer the shampoo from the suitcase into the bathtub. But first, he will examine the shampoo.
The boy will transfer the rubber duck into the trunk from the desk drawer, and he will transfer the shampoo into the bathtub from the suitcase. But first, he will examine the rubber duck.
The boy will transfer the rubber duck into the trunk from the desk drawer, and he will transfer the shampoo into the bathtub from the suitcase. But first, he will examine the shampoo.
43.
The woman will transfer the will from the safe into the briefcase, and she will transfer the money from the wallet into the desk drawer. And then, she will examine the will.
The woman will transfer the will from the safe into the briefcase, and she will transfer the money from the wallet into the desk drawer. And then, she will examine the money.
The woman will transfer the will into the briefcase from the safe, and she will transfer the money into the desk drawer from the wallet. And then, she will examine the will.
The woman will transfer the will into the briefcase from the safe, and she will transfer the money into the desk drawer from the wallet. And then, she will examine the money.
The woman will transfer the will from the safe into the briefcase, and she will transfer the money from the wallet into the desk drawer. But first, she will examine the will.
The woman will transfer the will from the safe into the briefcase, and she will transfer the money from the wallet into the desk drawer. But first, she will examine the money.
The woman will transfer the will into the briefcase from the safe, and she will transfer the money into the desk drawer from the wallet. But first she will examine the will.
The woman will transfer the will into the briefcase from the safe, and she will transfer the money into the desk drawer from the wallet. But first, she will examine the money.
44.
The girl will move the magazine from the TV stand into the filing cabinet, and she will move

the tea towel from the clothesbasket into the sideboard. And then, she will inspect the magazine.

The girl will move the magazine from the TV stand into the filing cabinet, and she will move the tea towel from the clothesbasket into the sideboard. And then, she will inspect the tea towel.

The girl will move the magazine into the filing cabinet from the TV stand, and she will move the tea towel into the sideboard from the clothesbasket. And then, she will inspect the magazine.

The girl will move the magazine into the filing cabinet from the TV stand, and she will move the tea towel into the sideboard from the clothesbasket. And then, she will inspect the tea towel.

The girl will move the magazine from the TV stand into the filing cabinet, and she will move the tea towel from the clothesbasket into the sideboard. But first, she will inspect the magazine.

The girl will move the magazine from the TV stand into the filing cabinet, and she will move the tea towel from the clothesbasket into the sideboard. But first, she will inspect the tea towel.

The girl will move the magazine into the filing cabinet from the TV stand, and she will move the tea towel into the sideboard from the clothesbasket. But first, she will inspect the magazine.

The girl will move the magazine into the filing cabinet from the TV stand, and she will move the tea towel into the sideboard from the clothesbasket. But first, she will inspect the tea towel.

45.

The boy will pour the pasta from the pot into the colander, and he will pour the mushrooms from the sack into the measuring jug. And then, he will taste the pasta.

The boy will pour the pasta from the pot into the colander, and he will pour the mushrooms from the sack into the measuring jug. And then, he will taste the mushrooms.

The boy will pour the pasta into the colander from the pot, and he will pour the mushrooms into the measuring jug from the sack. And then, he will taste the pasta.

The boy will pour the pasta into the colander from the pot, and he will pour the mushrooms into the measuring jug from the sack. And then, he will taste the mushrooms.

The boy will pour the pasta from the pot into the colander, and he will pour the mushrooms

from the sack into the measuring jug. But first, he will taste the pasta.
The boy will pour the pasta from the pot into the colander, and he will pour the mushrooms from the sack into the measuring jug. But first, he will taste the mushrooms.
The boy will pour the pasta into the colander from the pot, and he will pour the mushrooms into the measuring jug from the sack. But first, he will taste the pasta.
The boy will pour the pasta into the colander from the pot, and he will pour the mushrooms into the measuring jug from the sack. But first, he will taste the mushrooms.

46.

The man will move the instructions manual from the filing cabinet into the TV stand, and he will move the mug from the dish washer into the cabinet. And then, he will check the instructions manual.
The man will move the instructions manual from the filing cabinet into the TV stand, and he will move the mug from the dish washer into the cabinet. And then, he will check the mug.
The man will move the instructions manual into the TV stand from the filing cabinet, and he will move the mug into the cabinet from the dish washer. And then, he will check the instructions manual.
The man will move the instructions manual into the TV stand from the filing cabinet, and he will move the mug into the cabinet from the dish washer. And then, he will check the mug.
The man will move the instructions manual from the filing cabinet into the TV stand, and he will move the mug from the dish washer into the cabinet. But first, he will check the instructions manual.
The man will move the instructions manual from the filing cabinet into the TV stand, and he will move the mug from the dish washer into the cabinet. But first, he will check the mug.
The man will move the instructions manual into the TV stand from the filing cabinet, and he will move the mug into the cabinet from the dish washer. But first, he will check the instructions manual.
The man will move the instructions manual into the TV stand from the filing cabinet, and he will move the mug into the cabinet from the dish washer. But first, he will check the mug.

47.

The boy will pour the pineapple juice from the jar into the jug, and he will pour the egg whites from the bowl into the pot. And then, he will taste the pineapple juice.
The boy will pour the pineapple juice from the jar into the jug, and he will pour the egg whites from the bowl into the pot. And then, he will taste the egg whites.

The boy will pour the pineapple juice into the jug from the jar, and he will pour the egg whites into the pot from the bowl. And then, he will taste the pineapple juice.
The boy will pour the pineapple juice into the jug from the jar, and he will pour the egg whites into the pot from the bowl. And then, he will taste the egg whites.
The boy will pour the pineapple juice from the jar into the jug, and he will pour the egg whites from the bowl into the pot. But first, he will taste the pineapple juice.
The boy will pour the pineapple juice from the jar into the jug, and he will pour the egg whites from the bowl into the pot. But first, he will taste the egg whites.
The boy will pour the pineapple juice into the jug from the jar, and he will pour the egg whites into the pot from the bowl. But first, he will taste the pineapple juice.
The boy will pour the pineapple juice into the jug from the jar, and he will pour the egg whites into the pot from the bowl. But first, he will taste the egg whites.
48.
The girl will move the shirt from the chest of drawers into the suitcase, and she will move the pants from the washing machine into the clothesbasket. And then, she will check the shirt.
The girl will move the shirt from the chest of drawers into the suitcase, and she will move the pants from the washing machine into the clothesbasket. And then, she will check the pants.
The girl will move the shirt into the suitcase from the chest of drawers, and she will move the pants into the clothesbasket from the washing machine. And then, she will check the shirt.
The girl will move the shirt into the suitcase from the chest of drawers, and she will move the pants into the clothesbasket from the washing machine. And then, she will check the pants.
The girl will move the shirt from the chest of drawers into the suitcase, and she will move the pants from the washing machine into the clothesbasket. But first, she will check the shirt.
The girl will move the shirt from the chest of drawers into the suitcase, and she will move the pants from the washing machine into the clothesbasket. But first, she will check the pants.
The girl will move the shirt into the suitcase from the chest of drawers, and she will move the pants into the clothesbasket from the washing machine. But first, she will check the shirt.
The girl will move the shirt into the suitcase from the chest of drawers, and she will move the pants into the clothesbasket from the washing machine. But first, she will check the pants.