Exploring Memory Updating Ability in Individuals with Low and High Levels of Autistic-like Traits

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Abstract

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterised by impairments in social interaction and communication, and repetitive and stereotypic patterns of thoughts and behaviours. In addition, the symptoms associated with ASD are believed to occur along a continuum of severity, extending to typically-developing people with and without a family history of the disorder. These lesser symptoms have become more commonly known to encompass a broader autism phenotype. The widespread nature of the associated difficulties highlights the importance of investigating the underlying basis of the disorder.

One class of theory that has emerged from investigations of the cognitive underpinnings of ASD proposes that the difficulties associated with the disorder arise from impairments in executive functions. Executive functions encompass a wide range of higher-level cognitive abilities that enable an individual to flexibly change his/her thoughts and behaviours in accordance with environmental changes, in order to maintain appropriate goal-directed behaviour. However, studies in the realm of executive dysfunction theory have largely focused on a particular subset of executive functions, viz. inhibition, planning, and set-shifting (or cognitive flexibility). One additional executive function that has received much less attention within the ASD literature is memory updating.

Memory updating has been conceptualised as related to but separate from cognitive flexibility, and is implicated in various everyday activities such as keeping track of unfolding news events. For example, when reading a news report, the reader constructs a situation model based on the information presented in the report; if the report contains a retraction or correction of initially plausible but ultimately
incorrect information, the reader must update the situation model in order to keep an up-to-date version of the report in memory.

Previous studies have found impaired set-shifting ability in individuals with ASD, who have been observed to exhibit greater difficulties on various tasks requiring this ability compared to typically-developing counterparts (e.g., greater difficulty shifting to a new sorting rule in the Wisconsin Card Sorting Test). Given their impaired set-shifting ability, it is possible that individuals with ASD may also have limited memory updating ability. However, no studies have considered this.

The current thesis presents an exploration of memory updating in individuals with low and high levels of autistic-like traits. To this end, the Autism-Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) was used to select university students forming low- and high-AQ groups for each experiment. The AQ is commonly used to assess levels of autistic-like traits in the general population, and numerous studies have found that individuals with high levels of autistic-like traits exhibit similar cognitive profiles to individuals with ASD (e.g., Almeida, Dickinson, Maybery, Badcock, & Badcock, 2013; Grinter, Maybery, et al., 2009).

In the following chapters, I first present background literature on three main cognitive theories commonly used to explain the symptoms associated with ASD, followed by five experiments employing different methodologies to investigate memory updating ability in individuals with low and high levels of autistic-like traits. Experiments 1 to 3 employed complex narrative reports involving retracted information to emulate updating of situation models of an unfolding event. Experiments 4 and 5 employed the homograph-reading task (Frith & Snowling, 1983) and a basic memory updating task, respectively, to further delve into memory updating ability in individuals with low and high levels of autistic-like traits.
Overall, results do not provide conclusive evidence that individuals with high levels of autistic-like traits have limited memory updating ability compared to individuals with low levels of autistic-like traits. However, it is important for future research to investigate memory updating ability further in a more general population with high levels of autistic-like traits, as the current research program relied on samples of high-functioning university students. Investigating memory updating ability in individuals with an ASD diagnosis would also be valuable in establishing whether there is continuity or discontinuity along the autism spectrum in regard to memory updating ability.
Conference Proceedings Arising from this Thesis

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Statement of Candidate Contribution

Each experiment contained within this thesis was designed by the candidate in collaboration with her supervisors, Professor Murray Maybery and Senior Lecturer Ullrich Ecker. All data analyses were performed by the candidate, and all drafts of the thesis chapters were also prepared by her.

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Ullrich Ecker (Co-supervisor)   Date
CHAPTER 1

Exploring Memory Updating Ability in Individuals with Low and High Levels of Autistic-like Traits
The primary objective of this thesis was to investigate memory updating ability in individuals with low levels of autistic-like traits compared to individuals with high levels of autistic-like traits in order to approximate how memory updating may be implicated in individuals with Autism Spectrum Disorder (ASD). Specifically, I investigated whether or not individuals with high levels of autistic-like traits have limited memory updating ability. This thesis first presents background literature on ASD and the three main theories that have resulted from investigations of the underlying basis of the associated difficulties, and discusses how previous findings suggest there may be limited memory updating ability in individuals with ASD. I then present five experiments that employ different techniques to explore memory updating ability in individuals with low and high levels of autistic-like traits (Chapters 2 to 5). This is followed by a general discussion of the main findings, their relation to previous literature, and recommendations for future studies.

1.1. Autism Spectrum Disorder

Autism Spectrum Disorder is a pervasive developmental disorder that is characterised by persistent deficits in social interaction and communication, and restricted and repetitive patterns of behaviours and interests (American Psychiatric Association, 2013). It is typically recognisable within the first three years of childhood, and is four times more likely in males than females (APA, 2013; Australian Bureau of Statistics, 2014). The estimated prevalence of ASD has increased over the last two decades, with some recent studies showing estimates as high as 1.1% (Fombonne, 2004; Glasson et al., 2008; Kogan et al., 2009; K. Williams, MacDermott, Ridley, Glasson, & Wray, 2008).

The type and severity of the associated deficits differs widely amongst individuals with ASD, resulting in a heterogeneous presentation of the disorder and a
diverse range of difficulties. The difficulties experienced by individuals with ASD are manifold, and have the potential to impact upon the individuals’ ability to function independently and adaptively across a range of social and occupational situations. The characteristic impairments in social interaction and communication have been observed to manifest as various difficulties in social situations, which include, but are not limited to, difficulty reciprocating social gestures, sustaining conversations, and difficulty building upon comments and opinions of others during conversation (Baron-Cohen, 1989a, 2000; Happé, 1993; Pennington & Ozonoff, 1996; Tager-Flusberg, 1991). Individuals with ASD also exhibit stereotypic actions, persistent preoccupations with particular objects, distress when there are changes in the environment, and a narrow repertoire of interests (Loth, Gómez, & Happé, 2008; Turner, 1997). In addition to these impairments, which typically serve as the diagnostic domains of the disorder (APA, 2013), individuals with ASD potentially exhibit a myriad of additional difficulties. These difficulties may not necessarily contribute to their diagnosis, but are commonly reported by parents and caregivers of individuals with ASD. Studies have reported an increased number of maladaptive behaviours such as yelling and breaking objects, tantrums in children with ASD (Goldin, Matson, Konst, & Adams, 2014; Matson & LoVullo, 2009; Tureck, Matson, May, & Turygin, 2013), psychiatric comorbidities (Ashwood et al., in press; Jang & Matson, in press; Matson & LoVullo, 2009), psychomotor and neurological problems such as reduced gross and fine motor skills as well as seizures, (Pan, Tsai, & Chu, 2009; Shetreat-Klein, Shinnar, & Rapin, 2014), and sleep disturbances (K. Singh & Zimmerman, in press). Individuals with ASD also exhibit lifelong impairments in adaptive functioning skills, which further limit their ability to function independently in everyday life, and in social and occupational settings (Ashwood et al., in press). This difficulty is notably more marked in the social domain, affecting how an individual with ASD forms and maintains social relationships,
though difficulties in other areas of adaptive functioning have also been documented (Ashwood et al., in press; Goldin et al., 2014; Pan et al., 2009; Shetreat-Klein et al., 2014).

Although there are clearly widespread difficulties associated with ASD, the current thesis will primarily focus on a specific ability that has received much less attention within the ASD literature, namely, memory updating ability. This will be investigated in the context of executive functioning, specifically, cognitive flexibility (or set-shifting ability) and its possible association with how individuals with ASD process ambiguous information and update initial mental representations in light of incoming information. The executive dysfunction theory of ASD, as well as the theoretical background regarding memory updating will be covered in greater detail in Section 1.5 of the current chapter, and the remaining chapters of this thesis.

1.2. A Broader Autism Phenotype

The difficulties and behavioural impairments associated with ASD are generally believed to exist on a continuum of severity, which provides leverage to the idea that autistic-like traits may be observable in the general population. Indeed, a plethora of research has investigated the existence of autistic-like traits in the general population, resulting in a broader autism phenotype in the general population in individuals with and without a family history of ASD (Bishop et al., 2004; Happé, Briskman, & Frith, 2001; Hughes, Leboyer, & Bouvard, 1997). One measure commonly used to assess the extent of autistic-like traits in individuals from the general population is the Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001). The AQ is a 50-item self-report questionnaire designed to measure the extent to which individuals in the general population exhibit autistic-like traits, with total AQ scores ranging from zero to 50 (but see Austin, 2005, who introduced a 4-point scoring system). The AQ has good test-
retest reliability $(r = .70)$, and has been found to be a useful measure that appropriately distinguishes individuals with a diagnosis of ASD from individuals without a diagnosis. A score of 32 or higher was originally reported to be representative of individuals with clinically-significant levels of autistic-like traits akin to individuals with ASD (Baron-Cohen et al., 2001). However, the clinical significant criterion remains under debate, as a systematic review of the use of the AQ by Ruzich and colleagues (2015), suggested that a score of 35 or higher is more representative of a clinical sample of individuals with ASD, whereas Broadbent, Galic, and Stokes (2013) found that a score of 29 or higher was most suitable in distinguishing individuals with ASD from typically-developing individuals in an Australian sample. Despite this debate it should be kept in mind that the AQ was primarily designed as a descriptive measure of autistic-like traits with which researchers can identify a broader autism phenotype in the general population, rather than a diagnostic tool (Ruzich et al., 2015).

The AQ has been used to investigate autistic-like traits in parents of children with ASD (Bishop et al., 2004), and has since been used extensively in numerous studies which have reported that individuals of the general population with high AQ scores (and thus exhibiting high levels of autistic-like traits) exhibit a similar cognitive profile to individuals with ASD (e.g., Almeida, Dickinson, Maybery, Badcock, & Badcock, 2010a, 2010b; Almeida et al., 2013; Burnett & Jellema, 2013; Chouinard, Parkington, Clements, & Landry, 2014; Grinter, Maybery, et al., 2009; Grinter, Van Beek, Maybery, & Badcock, 2009; Parkington, Clements, Landry, & Chouinard, in press). It thus follows that there is reasonable evidence to support the use of the AQ to investigate whether memory updating ability may be impaired in ASD by comparing a proxy sample of individuals with high levels of autistic-like traits to individuals selected for low levels of these traits.
As summarised above, individuals with ASD exhibit a wide range of difficulties, some of which do not contribute to a diagnosis but nonetheless impact heavily upon their ability to function independently. It is thus important to gain a better understanding of the underlying basis of the associated deficits. Some studies have shown that the characteristic deficits in ASD are associated with, and can be explained by, limited intellectual ability or non-verbal ability (e.g., Hermelin & O'Connor, 1970; Joseph & Tager-Flusberg, 2004). Others, however, have argued against a central role of limited intellectual ability, citing that some individuals with ASD have normal intelligence but continue to present with characteristic difficulties (Baron-Cohen, Leslie, & Frith, 1985; Grzadzinski, Huerta, & Lord, 2013). In support, Klin and colleagues (2007) showed that high-functioning individuals with ASD (i.e., those with at least average-range intellectual abilities) exhibited significant impairments in social adaptive behaviour. In addition, different theories are often proposed depending on the apparent difficulties they are able to account for, thus resulting in a lack of theoretical coherence regarding the underlying basis of ASD. Theory of Mind (ToM) deficit theory, for example, is often used to account for the social difficulties observed in individuals with ASD, but has been shown to be less suitable in accounting for the repetitive and stereotypic behaviours, and preference for local visual processing in this population (more details to follow below, and in Section 1.3.2 and Section 1.4).

Recent investigations and reviews have attempted to combine the various theories and examine whether the symptoms of ASD are able to be explained by integrating key aspects of the different theories to form a better general understanding of the nature of ASD. One area that has garnered increasing interest of late concerns the neurological basis of ASD (Brock, 2013; Brock, Brown, Boucher, & Rippon, 2002; Kana, Uddin, Kenet, Chugani, & Müller, 2014; Rippon, Brock, Brown, & Boucher, 2007). In this case, researchers attempt to combine neurological and cognitive theories
of ASD to identify the types of neural networks affected in the developing brain and how anomalies in neural connectivity may manifest in the atypical cognition and behaviour identified with the disorder (see Brock, 2013; Kana et al., 2014 for reviews). However, further investigations are required to definitively ascertain the relationships between the atypical cognition and neural anomalies associated with ASD (Brock, 2013), particularly in regards to reconciling the existing theories in accounting for the characteristic impairments. It thus remains that the underlying basis of ASD continues to lack consensus. The current thesis will focus on the three main cognitive theories that have resulted from previous efforts, namely Theory of Mind (ToM) deficit theory, Weak Central Coherence theory (WCC), and Executive Dysfunction theory. These three theories of ASD will be discussed in turn.

1.3. Explaining ASD: Theory of Mind Deficit Theory

Theory of mind refers to the ability to infer the mental states and beliefs of others and also of oneself, and to understand that one’s own thoughts and beliefs can differ from those of others. It encompasses the ability to use this knowledge of how others are thinking to predict what they may do in certain situations (Baron-Cohen et al., 1985; Premack & Woodruff, 1978). Many studies have found that individuals with ASD have a particular deficit in developing and subsequently using their ToM in various situations, particularly situations which involve some form of social interaction. Whilst ToM abilities are typically evident by the age of four years, studies have found that children of that age with ASD fail to comprehend the subjective nature of mental states and to use the information to predict the behaviour of others (Baron-Cohen et al., 1985).
1.3.1. Facets of ToM

One of the fundamental abilities in the development of ToM is the innate ability to distinguish between mental and physical phenomena (Baron-Cohen, 2000). This is commonly known as the mental-physical distinction. To assess for this, children are verbally presented with stories involving two characters. One character is depicted to have a mental experience such as thinking about an object, whilst the second character is depicted to have a physical experience such as holding an object. The children are then asked which character can perform a certain action (e.g., which character can stroke the object?; Baron-Cohen, 1989a). Studies have found that children with ASD have impaired ability in distinguishing between mental and physical events. That is, they tend to fail to make the distinction that having a mental experience about an action does not necessitate one to be able to physically perform an action (Baron-Cohen, 1989a).

Another fundamental aspect of ToM ability is the ability to acknowledge false beliefs (Joseph & Tager-Flusberg, 2004). Acknowledging false beliefs requires an understanding that one’s own mental representation of the world is subjective, and can be incongruent with what is represented in reality, and at times may also be incongruent with another person’s mental representation of the world (Astonington & Gopnik, 1991; Baron-Cohen, 1989b; Baron-Cohen et al., 1985; Joseph & Tager-Flusberg, 2004). Many studies have used false belief tasks such as the well-known Sally-Anne task (cf. Baron-Cohen et al., 1985) to investigate ToM ability in individuals with ASD. In this task, the child is presented with a scenario in which ‘Sally’ places a marble into her basket. She then leaves the scene, and ‘Anne’ hides the marble in a box. Sally then returns, and the child is asked where Sally would look for the marble. If the child responds with the marble’s initial location (i.e., the basket), this shows he/she appreciates Sally’s false belief about the marble’s location. Baron-Cohen, Leslie, and Frith (1985) found that
children with ASD (but not children with Down syndrome) responded to the critical question with the marble’s new location (i.e., the box). That is, children with ASD failed to appreciate the subjective nature of their own mental representations and assumed that Sally would hold the same belief as them, despite her not being privy to the information about the marble’s true current location. The authors concluded that this was evidence of reduced ToM ability specific to children with ASD. A number of studies have since replicated these results, thus reinforcing the finding that individuals with ASD have impaired false-belief ability, which characterises their later ToM development (e.g., Baron-Cohen, 1989b; Jolliffe & Baron-Cohen, 1999a). However, more recent studies have suggested ToM ability may improve over time in some individuals with ASD. Pellicano (2010) found that a large proportion of the children with ASD, who initially displayed difficulty completing false belief tasks relative to typically-developing children, were able to pass the same tasks at a three-year follow-up. In addition, Pellicano (2010) also found that some children with ASD were, in fact, able to complete the false belief tasks even at a young age. This suggests that not only does ToM ability appear to improve over time but also that some individuals with ASD do possess ToM ability comparable to typically-developing individuals (Pellicano, 2010). Similarly, Scheeren and colleagues (2013) found no difference in performance on more advanced false-belief tasks between typically-developing children and adolescents and those with ASD. In addition to this, reduced ToM ability does not appear specific to ASD, and impaired performance on false belief tasks has also been found in children and adolescents with schizophrenia (Pilowsky, Yirmiya, Arbelle, & Mozes, 2000), deaf children born to hearing and non-hearing parents (P. Russell et al., 1998; Woolfe, Want, & Siegel, 2002), and individuals with intellectual disability (Yirmiya, Solomonica-Levi, Shulman, & Pilowsky, 1996).
The appearance-reality distinction task has also been used to investigate impaired ToM ability in individuals with ASD. The task requires one to be able to detect incongruity between one’s own mental representation of an object and its objective appearance, and to subsequently use that knowledge in one’s responses (Baron-Cohen, 1989a). For example, a child may be shown a stone that looks like an egg. He/she is then shown that the ‘egg’ is, in fact, a stone. Later, he/she is asked two questions, namely ‘What does it look like?’ and ‘What is it really?’. In this example, the correct responses to the questions would be “egg” and “stone”, respectively. Baron-Cohen (1989a) found that children with ASD responded with “egg” for both questions, which showed that they failed to simultaneously represent the distinction between their own perception of the object’s appearance and their knowledge about its true nature (Baron-Cohen, 1989a; cf. also Gopnik & Astington, 1988).

Theory of mind ability may be related to the ability to understand non-literal communication (e.g., metaphors) in ASD, as understanding of such utterances often requires the ability to infer and understand the speaker’s intention behind the utterance (Ozonoff & Miller, 1996; Volden, Coolican, Garon, White, & Bryson, 2009; Young, Diehl, Morris, Hyman, & Bennetto, 2005). This may contribute to the significant social communication impairments and poor social interactions often observed in individuals with ASD. This is because an inability to represent the speaker’s intentions may lead to a subsequent breakdown of communication when understanding the meaning of the utterance is contingent on taking the speaker’s attitude into account during interpretation (Happé, 1993). To investigate non-literal communication in individuals with ASD, Happé (1993) presented a range of non-literal utterances (e.g., metaphors and irony) to children with ASD who were divided into groups based on their ToM ability. Happé (1993) found that the children with ASD who did not pass false-belief tasks (and thus deemed to have impaired ToM ability) were less able to interpret the
utterances in their correct non-literal meanings compared to children with ASD who passed false-belief tasks (and thus deemed to have intact ToM ability; Happé, 1993). This suggests that ToM ability is required in understanding non-literal communication.

More recent investigations of ToM ability in ASD have investigated the relationship between ToM ability and everyday behaviours and skills. Frith, Happé, and Siddons (1994) showed that poorer performance on ToM tasks is associated with poorer adaptive functioning, and reduced ability in performing real-world everyday activities such as interacting with others, and engagement in group play (see also Cervantes & Matson, in press; Klin et al., 2007). This can manifest as reduced pretend-play during childhood and extend to general social ineptness in adulthood (Ashwood et al., in press; Baron-Cohen, 2000). In further attempts to investigate the relationship between ToM ability and the symptoms associated with ASD, studies have also found an association between impaired ToM and the repetitive and stereotypic behaviours and thoughts exhibited by individuals with ASD (Baron-Cohen, 1989b; Turner, 1997). The above findings lend further support to ToM deficit theory as an important framework for understanding the underlying basis of ASD. The ToM deficit approach to explaining ASD is not, however, without its shortcomings.

### 1.3.2. Limitations of ToM Deficit Theory

Despite its theoretical importance, some studies have suggested that ToM deficit theory may be insufficient as a sole explanation for the difficulties seen in ASD. Bowler (1992) argued that ToM deficits were not generalised across all individuals with ASD. Specifically, high-functioning individuals with ASD have been observed to demonstrate ToM abilities comparable to typically-developing individuals, and were able to pass various false belief tasks such as the Sally-Anne task described above (Bowler, 1992; Pellicano, 2010; Scheeren et al., 2013). One would then assume that such individuals...
would be more socially-adept than individuals with reduced ToM ability. Contrary to this, however, individuals with ASD who passed tasks assessing ToM ability displayed deficient social adaptive behaviour, compared to what would be expected from their cognitive potential (see also Klin et al., 2007). Some authors have further argued that impaired ToM cannot adequately account for the origin and manifestation of repetitive behaviours in ASD (see Baron-Cohen, 2000; Burnett & Jellema, 2013; Turner, 1997 for a review).

Although individuals with ASD present with a myriad of impairments, as described previously, strengths in ability have also been observed, particularly in situations and tasks where performance benefits from local processing more so than global processing such as the Embedded Figures Test (EFT; e.g., Loth et al., 2008 see Section 1.4 for more discussion on local and global processing). The ToM deficit theory, however, does not appear to be able to account for this strength in local processing (Jarrold, Butler, Cottington, & Jimenez, 2000). In addition, many of the tasks used in investigations of ToM ability in ASD also require individuals to integrate information to form a holistic representation of an event or utterance, thus requiring not only processing and understanding of constituent pieces of information but also an ability to understand and integrate the relations between them (Happé, 1994; Jolliffe & Baron-Cohen, 1999a). These findings thus highlight gaps in ToM deficit theory in accounting for difficulties across all individuals with ASD. What then, does this mean for the role of the ToM deficit theory in accounting for the difficulties observed in ASD? This prompts the question of whether there is a more suitable alternative account for ASD. One such account is weak central coherence (WCC) theory.
1.4. Explaining ASD: Weak Central Coherence Theory

Weak central coherence theory offers an alternative account of the difficulties associated with ASD. The premise of the WCC theory, coined as such by Frith (1989), is that individuals with ASD have a specific difficulty extracting meaning from surrounding context. The WCC theory of ASD has been used to account for performance in various task domains, particularly the visual domain. Discussion of the application of WCC theory in the visual domain is, however, outside the scope of this thesis, and the focus will be primarily on more verbal-based tasks used within the context of the WCC theory (see Grinter, Maybery, & Badcock, 2010; Happé & Frith, 2006; Simmons et al., 2009 for investigations in the visual domain).

1.4.1. Central Coherence and Understanding Pragmatic Language

In terms of the application of WCC theory in the verbal domain, it is argued that individuals with ASD fail to incorporate contextual information surrounding an utterance to form a holistic representation and instead focus on local details as separate entities (Frith, 1989; Loth et al., 2008), thus resulting in a failure to comprehend events in a holistic manner. In fact, some findings that at face-value support ToM deficit theory may be better explained by an alternative WCC account: Happé (1994) investigated ToM ability in adolescents with ASD using complex verbal materials involving non-literal information that may be encountered in everyday social situations such as lies and sarcasm. The participants were required to attribute mental states to the protagonists in each narrative, and subsequently use this information to respond to questions targeting the protagonist’s intention (i.e., ‘Why did X say/do that?’). Happé (1994) found that participants who passed first-order false belief tasks (i.e., ToM tasks that require the ability to infer another person’s mental state) responded in a way that suggested some level of understanding of others’ mental states. If deficient ToM
abilities were a sufficient explanation for ASD symptomatology, one would not expect individuals with ASD to be able to adequately attribute mental states to fictitious characters. Happé (1994) thus speculated that the ToM deficit theory of ASD may be insufficient in explaining ASD difficulties. However, while participants’ responses seemed to reflect intact ToM abilities, their mental state attributions indicated they were not sensitive to the context of the narrative. For example, some participants responded with “she/he’s having a joke”, and whilst this is appropriate for the joke narrative, some participants used this response in other narratives, where the context made it clear that the situation actually involved sarcasm or lying (Happé, 1994, p. 143). Happé’s (1994) results suggest that difficulties on tasks involving non-literal information may not be attributed to a ToM deficit per se, but rather to a problem in integrating context to provide the correct response for the narrative, thus suggesting an interpretation based on WCC.

Difficulties comprehending pragmatic language have more often than not been the basis of investigations of WCC in the verbal domain in individuals with ASD (Loukusa & Moilanen, 2009; Ozonoff & Miller, 1996; Whyte & Nelson, 2015; Young et al., 2005). This is largely driven by the assumption that individuals with ASD are unable to take surrounding context into account to disambiguate the utterances that are often sensible only when interpreted in a non-literal manner. In a comprehensive investigation of what could underlie the pragmatic language difficulties in ASD, Ozonoff and Miller (1996) investigated several aspects of pragmatic language ability in individuals with ASD, such as comprehending jokes and misleading or ambiguous sentences. In their joke measure, the authors presented participants with a joke that was missing the punch-line (e.g., ‘A woman is taking a shower. All of a sudden, her doorbell rings. She yells, “Who’s there?” and a man answers, “Blind man.” Well, she’s a charitable lady, so she runs out of the shower naked and opens the door’; see Bihirle,
Brownell, Powelson, & Gardner, 1986, p. 6). The participants were required to select the correct ending for the joke that would either complete the joke in a humorous way (e.g., ‘The man says, “Where should I put these blinds, lady?”’, indicating the woman had misinterpreted his response and that he was, in fact, not blind thus making the body of the joke humorous) or in a non-humorous way (Bihrlie et al., 1986; Ozonoff & Miller, 1996). Although individuals with ASD understood the nature of jokes (i.e., that they are intended to be humorous), they performed significantly worse than the comparison typically-developing group in selecting the correct answer, in particular regarding the response that would complete the joke in a humorous way (Ozonoff & Miller, 1996). This suggests that individuals with ASD have difficulty utilising surrounding context to reinterpret their initial representations of the body of the joke, in line with the WCC theory.

In another task, Ozonoff and Miller (1996) presented their participants with two sentences, one of which was ambiguous whilst the other provided the disambiguating context (see also Jolliffe & Baron-Cohen, 1999b). Depending on condition, the disambiguating sentence could appear as the first or second sentence. One example is “Jane hurried into the dentist’s office. She saw her purse on the table in the waiting room.” (Ozonoff & Miller, 1996, p. 419). In this example, the first sentence (“Jane hurried into the dentist’s office”) is the ambiguous sentence, as it could be interpreted in terms of Jane running late for an appointment, dropping off something urgent, or that she had wanted to retrieve a possession she may have left there. The second sentence then provides the disambiguating context (“She saw her purse on the table...”), clarifying that Jane had rushed into the office because she had left her purse behind. After hearing the sentences, participants were presented with four statements to which they responded true or false. Of these statements, two assessed their inferential understanding of the sentences and two assessed mere factual information contained
within the sentences. Although the inference questions posed greater difficulty than the factual questions for both typically-developing participants and participants with ASD, this difference was more pronounced for participants with ASD (Ozonoff & Miller, 1996). Ozonoff and Miller did not report any effect of the order of the information, suggesting that participants with ASD experienced difficulty integrating different pieces of information to form a holistic understanding of an event, and in using this to inform their subsequent inferential reasoning and responses. Ozonoff and Miller (1996) concluded that compared to typically-developing individuals, individuals with ASD have a greater specific difficulty integrating surrounding context to inform them of their answers, which is consistent with predictions from the WCC account of ASD (cf. also Joliffe & Baron-Cohen, 1999b).

Similarly, Norbury and Bishop (2002) reported that high-functioning individuals with ASD who had language ability comparable to typically-developing individuals performed poorer than controls on questions requiring inferential reasoning compared to more literal fact-based questions. The authors argued that this provides further evidence for a difficulty associated with ASD in integrating surrounding contextual information to form a holistic representation of an event upon which inferences can be drawn.

Another type of task used to investigate the pragmatic language difficulties and WCC theory in individuals with ASD involves reading sentences containing ambiguous homographs, commonly known as the homograph-reading task (Frith & Snowling, 1983; Happé, 1997). A homograph refers to a word that is associated with more than one meaning, and depending on the meaning, the homograph may have a different pronunciation (e.g., the word tear; Happé, 1997).

Happé (1997) found that individuals with ASD had difficulties disambiguating sentences containing homographs; these difficulties were independent of ToM ability as they occurred even when there was no interpretation of social information involved that
would require ToM ability (Happé, 1997; see Chapter 2 for a more detailed explanation). Jolliffe and Baron-Cohen (1999b) also employed the homograph-reading task to investigate the WCC account of ASD. They presented their participants with 20 sentences that contained one of five homographs. The dominant or subordinate meaning of the homograph used in Jolliffe and Baron-Cohen’s (1999b) study was interpretable based on the context presented either before or after the homograph in the sentence. Results showed that individuals with ASD exhibited greater difficulty in providing the correct pronunciation of the homograph when the context required the subordinate meaning of the homograph. This suggests that individuals with ASD were unable to use the contextual information to determine the correct interpretation and subsequent pronunciation of the homograph (Happé, 1997; Jolliffe & Baron-Cohen, 1999b). The homograph-reading task has since been used widely to investigate how individuals with ASD process ambiguous information, and many studies have replicated the difficulties in using the surrounding context to determine the correct subordinate pronunciation or meaning of the homograph (López & Leekam, 2003; Norbury, 2005). I have employed the homograph task in a study to be presented in Chapter 4.

1.4.2. Limitations of WCC Theory

In sum, substantial evidence exists to suggest deficient abilities in integrating surrounding contextual information in individuals with ASD. However, as in the case of the ToM deficit theory, the WCC theory of ASD has also been criticised on the basis of its inability to account for a number of the symptoms associated with ASD. Using a variety of measures assessing visual and verbal central coherence (e.g., EFT, sentence completion tasks), Loth and colleagues (2008) found that WCC was not exhibited uniformly across all participants with ASD, with some even presenting adequate central coherence skills. In addition, individuals with ASD have been found to be able to
process visual information on a global level when explicitly directed to or pre-warned to attend to the global information (see Happé & Frith, 2006 for a review; Plaisted, Swettenham, & Rees, 1999). Additionally, Rinehart, Bradshaw, Moss, Brereton, and Tonge (2000) found that high-functioning individuals with ASD exhibited normal advantages and interference effects from global stimuli comparable to typically-developing individuals. According to WCC theory, individuals with ASD should exhibit less global interference due to less spontaneous global processing. Therefore, critics argued that interpretation of performance on such tasks should not be made on the basis of impaired global processing, but rather a weaker alternative, which is that individuals with ASD have a lower tendency to spontaneously process information on a global level without the provision of external cues (Happé & Frith, 2006).

The applicability of WCC theory to the understanding of ASD has also been critiqued on the basis of the characteristic social deficits associated with the disorder. Specifically, whilst a strength of WCC theory lies in its ability to account for the superior local processing ability often observed in individuals with ASD on tasks such as the EFT, it has been argued that WCC theory fails to account for the social deficits. On the one hand, Jarrold, Butler, Cottington, and Jimenez (2000) found that ToM deficits were associated with WCC in children with ASD, which led them to argue that WCC plays a role in ToM difficulties. However, this association was only significant when participants’ verbal ability was controlled for; when participants’ verbal ability was taken into account, the association no longer reached significance, thus suggesting that there is only a weak association between ToM and WCC abilities, which may be mediated by verbal ability. This finding is consistent with other studies that have failed to find an association between WCC, as assessed by the EFT, and social skills assessed through tasks of joint attention (e.g., measuring whether the child orientates his/her eye gaze to meet the researcher’s eye gaze; Phillips, Baron-Cohen, & Rutter, 1992), and
during pretend-play in pre-schoolers with ASD (e.g., Morgan, Maybery, & Durkin, 2003).

With regards to verbal abilities, Martin and McDonald (2004) examined the association between performance on a visual EFT-like task and various tasks assessing pragmatic language ability in high-functioning adolescents with ASD to examine whether WCC theory could provide an adequate explanation of the pragmatic language difficulties often observed in individuals with ASD. Although the ASD participants exhibited greater difficulty with the narratives presenting lies and jokes, there was no association between this difficulty and performance on the EFT-like task, suggesting that the presumed common factor underlying performance on both tasks (i.e., central coherence ability) was not evidenced. This further raises the question of the suitability of WCC theory to explain performance on both tasks. In addition, WCC theory does not appear to be able to account for the restrictive and repetitive behaviours that are often observed in individuals with ASD and required diagnostically (Pellicano, 2013), with some suggesting these behaviours may best be explained by executive functioning theory (Hill, 2004a), which is discussed in the next section of this chapter.

In addition to the lack of association between central coherence ability in individuals with ASD, and the central symptoms of the disorder, it is also possible to interpret the findings in the WCC theory literature using alternative accounts. A number of tasks used to assess ToM ability and WCC often require individuals (1) to hold more than one representation in memory concurrently and/or (2) to reinterpret initial representations. There are few studies, however, that consider this alternative explanation. This therefore raises the question of whether individuals with ASD have a general difficulty processing information that involves multiple interpretations. Ozonoff and Miller (1996) found that when misleading information was presented initially, before disambiguating information, participants with ASD performed worse than when
the misleading information was presented after disambiguating information. Whilst the authors argued this was due to difficulty using and integrating previous context to disambiguate the information, it is also possible that individuals with ASD may in fact have difficulty returning to initial representations and updating them with subsequent more correct information (Ozonoff & Miller, 1996). This directs attention to the possible role executive functioning may play in successfully understanding pragmatic language difficulties in ASD, and in particular the ability to shift from the initial representation to a newer one and updating the relevant information (Lam & Yeung, 2012). Rinehart and colleagues (2000) additionally suggested that differences in local and global processing between individuals with ASD compared to typically-developing individuals may, in fact, be due to difficulty shifting between the two processing styles in individuals with ASD, and a tendency to perseverate on local processing. In line with Hill’s (2004a) suggestion that the restrictive and repetitive behaviours associated with ASD cannot be addressed by WCC theory, it thus seems conceivable that executive dysfunction provides a more suitable account of ASD than WCC theory. Further discussion of the executive dysfunction theory of ASD follows.

### 1.5. Explaining ASD: Executive Dysfunction Theory

As mentioned earlier, some findings arising from investigations of the WCC theory of ASD highlight that WCC theory may not necessarily be able to account for some of the central symptoms associated with ASD (e.g., difficulty understanding pragmatic language). Thus it is important to consider possible alternative accounts which have been associated with ASD, such as the executive dysfunction theory. The term *executive functions* encompasses a wide range of higher-level cognitive abilities that enable an individual to flexibly change their thoughts and behaviours in accordance with environmental changes, in order to maintain appropriate goal-directed behaviour.
Executive functions have garnered a great amount of interest in the ASD literature, particularly in terms of the role they may play in explaining the characteristic repetitive behaviours and difficulties adjusting to changes in the environment (Hughes, 2001; Turner, 1997; Van Eylen, Boets, Steyaert, Wagemans, & Noens, in press). Additionally, Pellicano (2013) recently found that executive functioning ability predicted social communication ability three-years later in individuals with ASD more so than did ToM ability. Some studies have also previously shown that individuals with ASD have impairments in several executive functions, particularly inhibition and set-shifting ability. The focus of the current thesis is on memory updating ability which is related to set-shifting ability and thus, discussion will primarily centre upon this executive function.

1.5.1. Individuals with ASD have Impaired Set-shifting Ability

Set-shifting ability, also broadly referred to as cognitive flexibility, refers to the ability to shift to different tasks, concepts or strategies according to situational changes (Hill, 2004b; Miyake et al., 2000; Russo et al., 2007). Many studies have used the Wisconsin Card Sorting Test (WCST; Berg, 1948; see also Heaton, Chelune, Talley, Kay, & Curtis, 1993) to assess set-shifting ability (Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Miyake et al., 2000; Ozonoff & McEvoy, 1994; Van Eylen et al., in press). This task involves sorting symbol cards based on one of three possible dimensions—symbol colour, number, or shape. Unbeknownst to the individual, the sorting rule changes occasionally (e.g., from colour to shape) and feedback is given only...
in regards to whether a card has been sorted correctly or not (i.e., the current sorting rule is never explicitly given and must be inferred from the feedback). The key measure of set-shifting ability on this task is the frequency of perseverative responses following a change in sorting rule. A higher number of perseverative responses reflects greater difficulty in shifting one’s response strategy according to the new rule.

Using the WCST, Ozonoff and McEvoy (1994) found that individuals with ASD were impaired on the task relative to a control group. That is, they had a higher number of perseverative responses, and required more trials before they were able to successfully acquire a new rule (Geurts et al., 2004; Ozonoff & McEvoy, 1994). Despite its prolific use in investigations of cognitive flexibility in ASD, however, the WCST has been critiqued on the basis of its specificity in assessing set-shifting ability. Although Geurts and colleagues (2004) have shown impairment on the WCST in individuals with ASD, they later argued that success on the WCST also utilises various other executive functions such as inhibition and self-monitoring, and that it is therefore not possible to conclude with the WCST alone that impairment on this task is solely due to impaired set-shifting ability (Geurts, Corbett, & Solomon, 2008; Hill, 2004a). Geurts and colleagues (2008) further argued that investigations of set-shifting ability in ASD using the WCST are inconsistent due to differences in research methodologies, such as the size and characteristics of the participant groups, and participants’ level of general intelligence.

Such criticisms of the WCST prompted the use of tasks that would potentially provide a more specific measure of set-shifting ability in individuals with ASD. One alternative task that has been used, though to a much lesser extent compared to the WCST, is the Intradimensional/Extradimensional Shift task of the Cambridge Neuropsychological Test Automated Battery (CANTAB ID/ED; Robbins, Owen, Sahakian, McInnes, & Rabbitt, 1998; Sahakian & Owen, 1992). The CANTAB ID/ED
involves selecting between pink shapes and white lines. As the individual progresses through the trials, complexity increases and the rules change unbeknownst to the individual. Individuals initially select between two simple stimuli (two specific pink shapes or two specific white lines). The target stimulus switches occasionally after a certain number of correct choices (i.e., the alternative shape or line stimulus becomes the correct choice) and participants are required to maintain a correct choice rule, even when shape and line elements are combined. Eventually, stimuli are replaced (i.e., new shapes and lines are introduced) and participants are required to discover the new target stimulus while using the same categorical dimension (i.e., focusing only on the shapes or the lines); this is referred to as the intradimensional shift, as the stimuli change but the relevant categorical dimension remains constant. Finally, the relevant stimulus category changes (i.e., from shapes to lines or vice versa); this is referred to as the extradimensional shift. The primary measure of interest is the individual’s responses after this extradimensional shift. An elevated number of perseverative responses following the extradimensional shift indicates difficulty in set-shifting ability. The CANTAB ID/ED has been argued to be a more specific measure of set-shifting ability than the WCST, as it allows investigation of an individual’s ability to shift within a categorical dimension (e.g., selecting the correct shape out of two), and between dimensions (e.g., shifting the response style from shape to lines; Geurts et al., 2008; Hill, 2004b; Ozonoff et al., 2004).

Hughes, Russell, and Robbins (1994) reported that despite passing initial trials of the CANTAB ID/ED, which involve intradimensional set-shifting and inhibition, individuals with ASD exhibited difficulty in the later extradimensional shift stage, thus prompting the authors to conclude that this difficulty was primarily due to set-shifting ability. In a later study, Hughes and colleagues (1997) also reported that parents of children with ASD performed worse than parents of children with no ASD on the
extradimensional shift trials of the CANTAB ID/ED, suggesting that deficits in set-shifting ability are apparent not only in individuals with ASD, but also with reference to a broader autism phenotype. This supports the executive dysfunction theory of ASD and is also consistent with previous findings of individuals in the general population exhibiting similar profiles of cognitive functioning to individuals with ASD (e.g., Burnett & Jellema, 2013; Grinter, Van Beek, et al., 2009).

However, similar to the WCST, the CANTAB ID/ED is not without its critics. In order to progress through the trials and reach the extradimensional shift stage, individuals must pass the earlier trials (i.e., the intradimensional shift stage). If individuals fail on the earlier levels, the subsequent extradimensional shift trials are not administered. Geurts and colleagues (2008) argued that if individuals do not complete the extradimensional shift trials, it is impossible to determine impaired set-shifting ability, as the total score would not be entirely representative of their performance. Although the intradimensional shift also assesses set-shifting ability, the extradimensional shift has been argued to be more demanding as it requires not only a shift regarding the perceptual properties of the stimuli, but also a shift from one dimension to another (i.e., from shape to lines; Geurts et al., 2008). Some studies have also failed to find a difference in set-shifting ability between individuals with ASD and typically-developing individuals using this task (e.g., Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009).

1.5.2. Limitations of the Executive Dysfunction Theory

Similar to the ToM deficit theory and WCC theory accounts of ASD, the executive dysfunction theory of ASD is not without its limitations. Whilst various executive functions have been found to be impaired in individuals with ASD across a large range of ages including preschool-aged children (McEvoy, Rogers, & Pennington,
1993), children and adolescents (Ozonoff et al., 1991; Prior & Hoffman, 1990; Yerys et al., 2009), and adults (Hill, 2004a, 2004b; Rumsey, 1985; Rumsey & Hamburger, 1990), some studies have reported no impairments in executive functioning in this population (Happé, Booth, Charlton, & Hughes, 2006; J. Russell, Jarrold, & Hood, 1999). Despite these inconsistencies, findings of executive functioning difficulties with reference to a broader autism phenotype suggest the executive dysfunction theory has merit, and more consistent research is required in regards to the role of executive function impairments in ASD.

Despite the abundant research investigating executive functions in ASD, studies have primarily focused on inhibition, set-shifting, and planning abilities, and how these abilities may be associated with other symptoms related to ASD (Leung, Vogan, Powell, Anagnostou, & Taylor, in press; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008; Van Eylen et al., in press). However, an additional cognitive ability, identified by Miyake and colleagues (2000) as one of three central executive functions contributing most to success on a range of cognitive tasks, has received relatively little interest in the context of ASD: memory updating ability.

1.5.3. Memory Updating is a Central Executive Function

Memory updating is related to working memory, the ability to simultaneously maintain and process several pieces of information in memory over a short period of time in the service of higher-level cognition (Baddeley & Hitch, 1974; Oberauer, 2009). Memory updating refers to the process by which information in working memory is revised when new incoming information is received. When existing information in working memory is no longer relevant, it must be substituted with more relevant information (Ecker, Oberauer, & Lewandowsky, 2014; Morris & Jones, 1990; Oberauer, Lewandowsky, Farrell, Jarrold, & Greaves, 2012).
Memory updating is important in a number of common situations such as spatial navigation, problem-solving, and reading comprehension (Palladino, Cornoldi, De Beni, & Pazzaglia, 2001). A specific example is reading newspaper reports. In such instances, the reader is presented with information about an unfolding event or situation, upon which he/she builds a mental model of the event or situation, which is commonly known as a situation model (Albrecht & O'Brien, 1993; van Oostendorp & Bonebakker, 1999). As the reader follows the course of events throughout the report and new information is provided, the reader’s situation model of the unfolding event must be updated with the incoming information to aid interpretation of the depicted event (Glenberg & Langston, 1992).

In some cases, the reader may encounter information that is inconsistent with previous information and is thus required to update the situation model, removing any outdated or irrelevant information and replacing it with more current or valid information (Glenberg & Langston, 1992; Kurby & Zacks, 2012; Morrow, Bower, & Greenspan, 1989; Rapp, Hinze, Kohlhepp, & Ryskin, 2014; van Oostendorp & Bonebakker, 1999). Hence, memory updating is especially important in situations where one must remove outdated and potentially false information from memory and replace the information with new, more valid information. If the incorrect information fails to be successfully updated, this can have a negative impact on reasoning and subsequent decision-making (see Johnson & Seifert, 1994; Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012b; Wilkes & Leatherbarrow, 1988). It follows that memory updating initiates a transformation or replacement of existing information in the situation model that may no longer be relevant, and is thus necessary to maintain a coherent and accurate understanding of a passage. Indeed, Palladino and colleagues (2001) found a direct relationship between reading comprehension skills and performance on simple memory updating tasks. Their results showed that individuals with poorer reading
comprehension skills tended to show poorer performance on memory updating tasks compared to individuals with good reading comprehension skills. Erroneous situational awareness and beliefs resulting from updating failure can also impact on decision-making behaviour (e.g., Ecker, Lewandowsky, Chang, & Pillai, 2014; Wilkes & Leatherbarrow, 1988).

The lack of investigations into memory updating ability in individuals with ASD is surprising, particularly given the emergence of the executive dysfunction theory and the impairments in set-shifting ability found in individuals with ASD. Including memory updating ability in investigations of executive functions in individuals with ASD is important for a number of reasons. First, memory updating is an executive function and thus profiles of executive functioning in ASD should, as a matter of principle, include an assessment of memory updating.

Second, parallels can be drawn between memory updating and cognitive flexibility, as both involve changes in mental representations to accommodate new information, which in turn can influence resulting behaviours and decisions. One area of research that is often used as evidence for cognitive flexibility is set-shifting ability. As discussed earlier, several studies have shown that, relative to controls, individuals with ASD experience greater difficulty on set-shifting tasks, which suggests cognitive flexibility may be compromised in general. This raises the question of whether there may also be difficulties with basic memory updating in this population.

Third, existing literature investigating ToM ability and WCC in individuals with ASD have used some tasks that appear to require updating of information. Specifically, some tasks require individuals to reassess their initial interpretation in light of incoming information that may be contradictory or ambiguous, depending on the information presented (Baron-Cohen, 1997; Frith & Snowling, 1983; Hala, Pexman, & Glenwright, 2007). It follows that previous findings that have been used as evidence in support of
the ToM deficit and WCC theories may be interpretable in terms of memory updating. One particular example regards the appearance-reality task discussed in Section 1.3.1 that is so often used to investigate ToM (Baron-Cohen, 1989a). When an individual is first presented with the object, he/she forms a mental representation of it being, for example, an egg. The object is later revealed to be a stone, thus requiring the individual to update his/her initial representation of the object and use this more current and more valid information to inform his/her responses. Hence, whilst success on this task does require ToM ability, it also requires memory updating ability to update the individual’s mental representation of the object (Gopnik & Astington, 1988; J. Russell, Mauthner, Sharpe, & Tidswell, 1991). In addition, the difficulty inferring ideas and information from narrative texts observed in individuals with ASD, particularly when initial interpretations of the passage must be revisited and revised, suggests there may be a different pattern of memory updating ability in individuals with ASD compared to typically-developing counterparts (Frith, 1989; Joliffe & Baron-Cohen, 1999b; Ozonoff & Miller, 1996; Palladino et al., 2001). In sum memory updating ability relates to much of the existing ASD literature, and it is thus possible that memory updating ability offers an alternative and potentially more suitable account for the observed difficulties. However, few investigations have considered this alternative account.

1.6. General Aims

As I have discussed, various cognitive deficits have been observed in individuals with ASD, but one seemingly important cognitive function that appears to play a role in many deficits has been largely overlooked, and that is memory updating ability. The overarching aim of the present research is to explore memory updating ability in individuals with low and high levels of autistic-like traits using various paradigms. These include more complex narrative tasks involving corrections of misinformation.
and a basic computerised memory updating task; these paradigms will be discussed in
greater detail in the following chapters.
CHAPTER 2

Updating Initial Situation Models in Individuals with Low and High Levels of Autistic-like Traits
In this chapter, various explanations for the difficulties understanding pragmatic and non-literal information observed in individuals with ASD will first be discussed in terms of the three main cognitive theories of ASD introduced in Chapter 1. The potential role memory updating ability may play in interpreting these previous findings will then be discussed, followed by the current findings of Experiments 1 and 2.

Experiments 1 and 2 present an investigation of memory updating ability in individuals with high levels of autistic-like traits compared to individuals with low levels of autistic-like traits as a proxy to estimate ability in individuals with ASD. Specifically, updating was investigated using narratives that involved the retraction of initially presented false information. Investigating how individuals with ASD understand complex narratives that may involve false information is important as false information occurs naturally in many real-world situations. A small number of studies have investigated how individuals with ASD process false information that is presented after encoding of an event, and though findings largely do not present evidence suggesting individuals with ASD have greater difficulty processing false information (McCrorry, Henry, & Happé, 2007; North, Russell, & Gudjonsson, 2008), the methodology used previously does not provide a measure of memory updating ability per se, as will be discussed in this chapter.

2.1. Memory Updating and the Processing of Ambiguous Information

As discussed in the previous chapter, various executive functioning difficulties have been documented in individuals with ASD, particularly in the domain of set-shifting or cognitive flexibility (Corbett et al., 2009; Hill, 2004a; Kleinhans, Akshoomoff, & Delis, 2005; Van Eylen et al., in press). As explained earlier, one additional executive function that has received less attention within the literature is memory updating, which has been identified as one of the three central executive
functions that contribute most to success on various cognitive and executive functioning tasks (e.g., WCST; Miyake et al., 2000). Memory updating has been found to be related to but separate from set-shifting (e.g., Miyake et al., 2000); specifically, while set-shifting typically involves a change in response strategy or task set, memory updating refers to a change in a specific mnemonic representation.

There are various lines of research that suggest memory updating ability may play a larger role in ASD than what has currently been considered. One such area of research examines processing and understanding of ambiguous information. I have introduced in Chapter 1 that individuals with ASD have difficulties with various types of ambiguous information, and investigations have been conducted in both the verbal (e.g., jokes, homographs, and drawing inferences; Brock, Norbury, Einav, & Nation, 2008; Frith & Snowling, 1983; Happé, 1993, 1997; Henderson, Clarke, & Snowling, 2011; Ozonoff & Miller, 1996; Saldaña & Frith, 2007) and visual (e.g., ambiguous figures and visual events; Au-Yeung, Benson, Castelhano, & Rayner, 2011; Au-Yeung, Kaakinen, & Benson, 2014; Klin & Jones, 2006; Ropar, Mitchell, & Ackroyd, 2003; Wimmer & Doherty, 2010) domains. Although difficulty with ambiguous information has been found quite consistently in individuals with ASD, the question that must be considered is why this is the case.

As I have discussed earlier, there are a number of accounts used to explain the underlying basis of the atypical behaviour observed in individuals with ASD, with some attempts to integrate the different theories (e.g., neural connectivity; Brock, 2013; Kana et al., 2014; O’Hearn, Asato, Ordaz, & Luna, 2008; Rippon et al., 2007). The following discussion will focus on the three main cognitive theories as described in Chapter 1. Two of the main theories that have resulted from attempts to explain the atypical behaviour exhibited in ASD—ToM deficit theory and WCC theory—have been used to explain the difficulty with processing and comprehending ambiguous information in
individuals with ASD. However, a general consensus has not yet been established as to which of the two theoretical accounts is most suitable.

Happé (1997) advocated for WCC theory, arguing that many studies confounded two characteristics of the utilised tasks, namely the presence of social information and the ability to read and understand sentences containing ambiguous information. This confound makes it difficult to distinguish whether inability to comprehend ambiguous sentences or the social information contained within the sentences is responsible for poorer performance in individuals with ASD. Happé (1997) addressed this issue by presenting her participants with two types of ambiguous sentences containing homographs (viz. the homograph-reading task). One type of sentence contained information requiring participants to infer others’ state of mind, whilst the other did not contain any social context, and thus did not require ToM. Results showed that individuals with ASD continued to experience difficulty choosing the correct pronunciation of the homograph even in the absence of social information, thus suggesting that a ToM deficit is not sufficient to explain the difficulties with ambiguous information in individuals with ASD; instead, these may reflect a primary difficulty with integrating local information with the surrounding context.

On the other hand, Jolliffe and Baron-Cohen (1999a) advocated for the ToM deficit theory in explaining difficulties with ambiguous information in ASD, using the Strange Stories test (see also Happé, 1994). The Strange Stories test is thought to be more representative of everyday situations compared to other ToM tasks (e.g., the appearance-reality test), and high-functioning individuals with ASD who pass other ToM tasks continue to have difficulty with the Strange Stories test (Happé, 1994). The test comprises various short stories of two main types: mentalistic stories, which feature statements that require participants to make inferences about a character’s intention such as jokes and lies, and physical stories, which refer primarily to physical state
properties (e.g., an object’s appearance) and thus do not require any ToM ability. The primary measure of interest in this test is the number of context-appropriate and context-inappropriate responses, particularly with reference to the character’s mental state (i.e., “Why did X say that?”).

Jolliffe and Baron-Cohen (1999a) found that individuals with ASD provided more context-inappropriate mental state justifications than the control group, despite having intact reading comprehension skills. Furthermore, this group difference was observed only for the mentalistic stories that contained mental state information, and not for the physical stories that did not contain mental state information. This increased number of context-inappropriate responses suggests that individuals with ASD exhibit difficulties integrating information from surrounding context to inform their responses (Jolliffe & Baron-Cohen, 1999a). Weak central coherence theory may therefore appear to provide an appropriate explanation of such effects. However, the fact that there were no differences in performance between the ASD and control groups for the physical stories suggests that the ASD group may have had difficulty incorporating the contextual information due to the social information contained within the passage, a difficulty consistent with reduced ToM ability (Jolliffe & Baron-Cohen, 1999a). The results are thus inconsistent with the predictions from WCC theory, as one would expect individuals with ASD to have difficulties integrating context on both types of passages. Jolliffe and Baron-Cohen (1999a) thus concluded that difficulty integrating context in their study may be due to underlying impairments in ToM ability.

 Likewise, López and Leekam (2003) observed intact use of contextual information in the visual domain, but not for verbal information, in an ASD group. In their study, children with ASD were able to use visual semantic context (e.g., a picture of a kitchen) to select appropriate objects that would belong in the picture, but experienced difficulty using surrounding context to determine the correct pronunciation
of homographs on a homograph-reading task (López & Leekam, 2003). López and Leekam argued that if WCC theory offered a sufficient explanation, then difficulties utilising context to resolve ambiguity would be evident across both the visual and verbal domains.

Arguments against the capacity of WCC theory to explain difficulties with ambiguous information also come from studies looking at passage-reading time. When reading narrative passages, situation models are formed based on the information presented within the passages. Newer information is typically incorporated into an existing situation model of the event to enable the reader to hold the most up-to-date representation of the event in their memory (Albrecht & O'Brien, 1993; Kurby & Zacks, 2012; Morrow et al., 1989). Subsequent understanding and inferential reasoning about the event is based on the situation model formed, and thus it is important to incorporate newer incoming information into the initial situational model. One particular study by Saldaña and Frith (2007) presented participants with short passages that required participants to form inferences in order to respond to a general knowledge question pertaining to the passage. The general knowledge question was designed such that it was relevant to the context of the inference formed from the preceding passage, or irrelevant. Using reading time as the primary measure, it was expected that participants would take longer reading and responding to context-irrelevant questions compared to context-relevant questions (Saldaña & Frith, 2007). Saldaña and Frith found that the reading time for the context-relevant questions was faster than the reading time for context-irrelevant questions in both adolescents with ASD and typically-developing adolescents, thus providing evidence that adolescents with ASD were able to use surrounding context to facilitate their reading of the questions. The authors, however, did not measure accuracy of responses to the questions. It is therefore difficult to determine whether there may be a trade-off between reading speed and accuracy: It is
possible that even though the ASD group did not differ from the control group in terms of reading time, they may have given a greater number of incorrect responses, which would suggest reduced understanding and inappropriate use of inferences.

In an earlier study, Norbury (2005) found that whilst children with language impairments exhibited difficulty linking ideas between ambiguous sentences and benefited less from contextual facilitation, children with ASD performed similar to typically-developing children, and were equally able to resolve ambiguity within the sentences used.

As is evident, the mixed findings make it difficult to ascertain why individuals with ASD may have difficulty with ambiguous information. On the one hand, some studies have not adequately controlled for social information within their materials, thus making it difficult to differentiate whether the difficulties comprehending and resolving ambiguity were due to the social aspect of the materials, deficient integration of contextual information, their combination, or another alternative. On the other hand, even when social information is controlled for, studies have reported that individuals with ASD exhibited difficulties in using contextual information—although these difficulties appear to arise only under certain conditions (e.g., when resolving ambiguity in the verbal but not the visual domain; López & Leekam, 2003), and in some studies did not manifest at all, thus suggesting integration of contextual information is not globally deficient in individuals with ASD. This prompts an alternative explanation, and one such potential alternative is memory updating ability.

2.2. Memory Updating and the Processing of False Information

Previous findings suggest memory updating offers a possible alternate explanation for the difficulties with ambiguous and non-literal verbal information observed in individuals with ASD. For example, although Ozonoff and Miller (1996)
concluded that WCC underlies difficulties comprehending jokes and making inferences between sentences in ASD, it is possible to interpret their findings in terms of memory updating. The authors themselves stated that successful understanding of jokes often requires revisiting the beginning of the joke to re-evaluate and reinterpret its meaning in light of the latter part of the joke (Ozonoff & Miller, 1996). Simply put, one must update one’s initial interpretation to incorporate new information contained in the latter part of the joke.

The same rationale applies to Ozonoff and Miller’s (1996) inference measure. In this task, as I have described in Section 1.4, two sentences were presented. One sentence was ambiguous, followed by a second sentence which provided the disambiguating contextual information. After reading such two-sentence scenarios, individuals with ASD had greater difficulty responding to questions requiring them to draw inferences compared to responding to more fact-based questions (Ozonoff & Miller, 1996). In this case, when an individual reads the ambiguous sentence, a situation model is formed based on an initial interpretation. This initial interpretation must then be revisited and the situation model updated when the information from the context-providing sentence becomes available (Ozonoff & Miller, 1996). Thus, inferential reasoning performance will depend on successful updating of the individual’s situation model.

Previous findings interpreted in terms of WCC (or a ToM deficit, as discussed earlier) can thus also be interpreted in terms of limited memory updating ability, though none of the authors have considered this alternative. I am thus interested in how well individuals with ASD process and understand ambiguous information in relation to memory updating. One way to investigate this is with the use of false information, or misinformation, and examine how people update their situation models when faced with such misinformation. There are two types of misinformation effects discussed in the
literature: the post-event misinformation effect, and the continued influence effect, which will be discussed in turn.

2.3. The Post-event Misinformation Effect

The few studies that have investigated the effects of misinformation on memory and reasoning in individuals with ASD have all used the common post-event misinformation paradigm (e.g., Bruck, London, Landa, & Goodman, 2007; McCrory et al., 2007; North et al., 2008). In the post-event misinformation paradigm, the term misinformation is defined as suggestive misleading information that is presented after valid event information is encoded (Loftus, Miller, & Burns, 1978; McCrory et al., 2007). Typically, participants are presented with a visual sequence of an event (e.g., a car accident at a “stop” sign), and misinformation is subsequently introduced through misleading questioning (e.g., a question referring to the “stop” sign as a “yield” [or “give way”] sign). The primary measure of interest in post-event misinformation studies is a measure of ‘suggestibility’, the degree to which individuals accept the suggestive information (Loftus, 2005) when subsequently asked to recall the event.

Given that introducing misinformation leads to inconsistencies and ambiguity in an individual’s situation model of an event, surprisingly little research has investigated post-event misinformation effects in individuals with ASD to corroborate deficits in the processing of ambiguous information with complex real-world materials. The few studies that have employed the post-event misinformation paradigm have failed to show evidence of increased suggestibility in individuals with ASD compared to their typically-developing counterparts (e.g., Maras & Bowler, 2011, 2014; McCrory et al., 2007). North and colleagues (2008) found that individuals with Asperger’s Disorder and high-functioning autism were no more suggestible than matched control groups. In fact, their results showed the ASD groups had lower suggestibility scores. The authors
suggested that participants with Asperger’s Disorder and high-functioning autism may have difficulty shifting their cognitive set, and as misinformation is presented after valid event information, they are less likely to shift towards the misinformation in their understanding and reasoning of the event (North et al., 2008). A related alternative interpretation of the smaller post-event misinformation effect in individuals with ASD relates to memory updating ability. If individuals with ASD have generally reduced memory updating propensity, they should in fact show a smaller post-event misinformation effect because they will be less likely to update their initial—in this case, valid—situation model using subsequently encoded misinformation.

The above studies investigating post-event misinformation effects in individuals with ASD clearly show that there is no evidence of increased suggestibility in individuals with ASD. However, the notion of “suggestibility” in this context refers to one’s likelihood of accepting false information rather than provide a measure of how well a person is able to update existing (and potentially false) information in his/her situation model of an event. Thus, ability (or inability) to update existing information in memory, particularly misinformation, cannot be sufficiently assessed using the post-event misinformation paradigm, as it does not require one to reinterpret an initial situation model and replace existing information with more recent information. Therefore, investigations using the post-event misinformation paradigm simply do not address the question of whether there is impairment in memory updating ability in individuals with ASD. The continued-influence paradigm (Johnson & Seifert, 1994), on the other hand, is more suited to this as it requires one to revise an initial interpretation based on incoming information and update a false situation model with more recent correct information. Memory updating is thus at the centre of the continued influence effect (CIE).
2.4. The Continued Influence Effect

Whilst in the post-event misinformation paradigm, misinformation is defined as misleading information that is presented after valid event information, in the CIE paradigm, misinformation refers to information that is initially presented as factual and later retracted. Upon receiving the retraction, it is important to revise the mental representation of the event (i.e., the situation model) in memory, which involves memory updating.

As mentioned in the previous chapter, memory updating is important for reading comprehension in general. When reading about an unfolding event, the reader forms a situation model based on the initial information provided (Glenberg & Langston, 1992; Morrow et al., 1989), which must be continually updated with new incoming information to maintain an accurate understanding of the unfolding event (Glenberg & Langston, 1992; Morris & Jones, 1990; Rapp & van den Broek, 2005). Updating our situation models is thus generally important for us to ensure up-to-date mental representations of the world around us.

However, memory updating is of particular importance in instances where incorrect information is involved. Specifically, it is important when one must remove outdated or invalidated information from one’s situation model of an event, and replace it with newer, more valid information, as is the case when a report contains corrections or updates of earlier information, which is common for real-world news reports. Failure to successfully update a situation model with newer and more valid information can negatively impact on reasoning and subsequent decision making (Johnson & Seifert, 1994; Wilkes & Leatherbarrow, 1988).

For example, Wilkes and Leatherbarrow (1988) presented participants with a report of a warehouse fire, which initially stated the fire was caused by negligent storage of volatile materials in a wiring cabinet. Several messages later, this information
was retracted. That is, it was stated by a credible source that the fire was not caused by negligence. Wilkes and Leatherbarrow (1988) found that, when questioned, participants continued to refer to negligence as the cause of the fire despite recalling that the relevant information had been retracted. This effect of misinformation on people’s reasoning despite a correction has been termed the continued influence effect or CIE (Johnson & Seifert, 1994). The CIE has since been replicated in various scenarios (Ecker, Lewandowsky, & Apai, 2011; Ecker, Lewandowsky, & Tang, 2010; Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012a), including studies in real-world settings. One example of the latter is Kull, Ramsey, and Lewis’ (2003) study, where it was found that people continued to believe that weapons of mass destruction were found during the 2003 invasion of Iraq, despite extensive media coverage revealing that none were found during or after the war (cf. also Lewandowsky, Stritzke, Freund, Oberauer, & Krueger, 2013; Lewandowsky, Stritzke, Oberauer, & Morales, 2005). In addition, such beliefs did not appear to lessen over time, and people continued to believe in the discovery of weapons of mass destruction even several years after the war had ended (Kull et al., 2006).

Clearly, misinformation can heavily impact on one’s understanding of an event, and potentially lead to erroneous decision making if the misinformation is not discounted when making inferences. It is thus important to identify why people continue to rely on misinformation during subsequent reasoning despite having knowledge of a retraction, particularly as the CIE has also been observed in real-world settings and can remain influential for extended periods. One theory that has resulted from attempts to explain the CIE is the event model theory.
2.4.1. The Event Model Theory of the CIE

The event model theory posits memory updating as playing a central role in forming situation models of any given event. According to this theory, it is assumed that forming a situation model of an event involves binding the information provided by the narrative to model variables, or “placeholders” (Ecker, Lewandowsky, & Tang, 2010; Oberauer, 2005; Oberauer & Lange, 2009). According to the event model theory, misinformation (e.g., “volatile materials in the wiring cabinet” in the warehouse fire example) continues to prevail in memory and influence our subsequent reasoning because updating the situation model of an event is effortful, and requires an additional process than when the model is first formed, namely the unbinding of the incorrect information from the placeholders (Ecker, Lewandowsky, & Tang, 2010; Kessler & Meiran, 2008). Upon receiving a retraction (e.g., “the wiring cabinet was empty” in the warehouse fire example), the existing misinformation must be unbound from its placeholder in the situation model (i.e., as the cause of the fire) in order to reduce subsequent reliance on the misinformation (Ecker, Lewandowsky, & Oberauer, 2014; Ecker, Lewandowsky, & Tang, 2010; Rapp & Kendeou, 2009; van Oostendorp & Bonebakker, 1999).

Event model theory additionally proposes that central aspects of the situation model (i.e., those that play a causal role) are particularly difficult to update. Individuals may be reluctant to dismiss information if it plays a central causal role in the event, unless there is an alternative piece of information that can be used to fill the gap in the situation model that results from removing the misinformation (Cook & Lewandowsky, 2011; Johnson & Seifert, 1994, 1998). Even so, providing alternative causal explanations reduces reliance on misinformation but does not entirely eliminate the CIE (Johnson & Seifert, 1994; Lewandowsky et al., 2012a). According to event model theory, the CIE therefore results from memory updating failure. As such, individuals
who have limited memory updating ability may find it more difficult to update the situation model to remove initial misinformation, and thus may show a stronger CIE.

As I have discussed in the previous chapter, existing findings in the ASD literature give rise to the possibility of memory updating difficulties in individuals with ASD, particularly the findings of difficulties with pragmatic and non-literal language, and inference-making. For example, studies investigating inference-making ability in individuals with ASD have revealed that they give more incorrect responses to questions requiring them to draw inferences and change initial representations in memory compared to performance on fact-based questions (e.g., Ozonoff & Miller, 1996).

A comprehensive investigation of executive functioning ability in individuals with ASD should also include an examination of memory updating ability. The CIE paradigm offers an opportunity to test memory updating abilities in a manner that can also be extended into real-world situations. There are, however, currently no studies that have employed the CIE paradigm within the ASD literature. In fact, the effect of misinformation on memory and reasoning has received very little attention in individuals with ASD. As discussed in Section 2.3, there are only four published investigations of misinformation effects on memory and reasoning in individuals with ASD. In addition, these few studies have employed the post-event misinformation paradigm which, as discussed, does not provide a measure of memory updating per se (e.g., Bruck et al., 2007; McCrory et al., 2007; North et al., 2008).

2.5. Current Study (Experiments 1 and 2)

2.5.1. Aim

The current study was designed to investigate memory updating ability in individuals with low and high levels of autistic-like traits using narratives to implement
the CIE paradigm. Specifically, I was interested in how participants with high levels of autistic-like traits process a retraction of previously-presented information (which, when retracted constitutes misinformation), and how this may influence their subsequent memory and reasoning. To assess for level of autistic-like traits, the AQ (Baron-Cohen et al., 2001) was used as a pre-screening measure.

In Experiment 1, we presented participants with two fictitious scenarios. In some conditions, the cause of the respective event was first presented as factual and later retracted; in other conditions, there was no retraction of the cause. The primary interest was in participants’ reliance on the critical causal information in response to subsequent inferential reasoning questions, particularly in conditions where the critical causal information was retracted. Experiment 2 was designed to replicate Experiment 1 using six different fictitious scenarios that were unrelated to those used in Experiment 1.

In both experiments, a secondary aim was to explore the effect of a retraction on participants’ reading time for the target message, that is, the message that presented either a retraction or no retraction. Previous studies have found reading times of passages and sentences containing ambiguous information, or those requiring the reader to draw inferences, were longer in individuals with ASD compared to typically-developing individuals (e.g., Saldaña & Frith, 2007), potentially providing an on-line measure of memory updating difficulties in ASD.

2.5.2. Hypotheses

The study was, to some extent, exploratory, as no previous studies have investigated processing of misinformation using the CIE paradigm in individuals with either ASD or with high levels of autistic-like traits. However, based on previous findings of difficulties processing information requiring re-interpretation of initial information in individuals with ASD, I expected the low-AQ and high-AQ groups to
differ in their post-retraction reliance on misinformation. Specifically, the high-AQ individuals should show greater reliance on misinformation than the low-AQ individuals. Secondly, I also hypothesised that reading time for the retraction message would be slower for the high-AQ group compared to the low-AQ group.

2.6. Experiment 1

2.6.1. Method

Design

The experiment used a 2 (AQ group) × 2 (retraction condition) × 2 (misinformation-scenario control factor) mixed design. Participants were pre-screened based on level of autistic-like traits and subsequently assigned to a low- or high-AQ group (see below for details); this was therefore a between-subjects factor. Each participant received two scenarios of differing themes (relating to a school bus accident vs. an incident involving a spider bite). The school bus scenario detailed an accident involving a school bus, the cause of which was initially stated as a ‘burst tyre’. The spider bite scenario detailed a woman’s collapse, the cause of which was initially stated as a ‘spider bite’. For each scenario, there were two versions: One version featured a retraction while the other did not. Participants received one scenario featuring a retraction, and the other scenario with no retraction. The retraction factor (no-retraction vs. retraction) was thus a within-subjects factor. The assignment of retraction conditions to scenarios (i.e., whether a person received the retraction in the school bus or spider bite scenario) was counter-balanced across participants (see Table 2.1). This constituted the misinformation-scenario factor.

Measures of general ability, tolerance of ambiguity, and fear of spiders were also administered. The Digit Symbol Rotation task (Gignac & Vernon, 2003) was used to assess whether the low-AQ and high-AQ participants were matched in general ability.
To investigate participants’ general level of tolerance to ambiguous situations and information, participants completed the Tolerance of Ambiguity Scale (TAS; Herman, Stevens, Bird, Mendenhall, & Oddou, 2010). The TAS ratings for each individual allowed us to investigate whether the low-AQ and high-AQ groups differed, and if so, if participants’ level of ambiguity tolerance mediated the number of references they made to the critical causal information. As the central theme of one of the scenarios concerned a spider bite, participants also completed the Fear of Spiders Questionnaire (FSQ; Szymanski & O'Donohue, 1995) to assess whether they had an intense fear of spiders, which may influence (and specifically increase) their post-retraction reliance on spider-related misinformation. Further details for the Digit Symbol Rotation task, TAS, FSQ are provided below.

<table>
<thead>
<tr>
<th>First Scenario</th>
<th>School Bus</th>
<th>Spider Bite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spider Bite</td>
<td>Spider Bite—NR, School Bus—R</td>
<td>Spider Bite—R, School Bus—NR</td>
</tr>
</tbody>
</table>

Note: R, retraction; NR, no-retraction

**Participants**

Initially, 1375 first-year psychology students from the University of Western Australia completed the AQ (Baron-Cohen et al., 2001; M = 15.46, SD = 6.38, range 1-43), a measure commonly used to assess the level of autistic-like traits in the general population. Students from the lower and upper quartiles of the AQ distribution (using AQ cut-off scores of 14 or less and 22 or more) were invited to participate in the second phase. The final sample consisted of 100 participants, with 50 in the low-AQ

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1 Various studies have previously used similar cut-off scores for the AQ. For example, Grinter et al. (2009) used cut-off scores of 12 or less and 23 or more, and Russell-Smith, Maybery, and Bayliss (2010) used cut-off scores of 14 or less and 20 or more.
group (29 females) and 50 in the high-AQ group (26 females). The mean age across the sample was $M = 19.32$ years ($SD = 4.78$, range 17-46 years). Descriptive statistics for the low-AQ and high-AQ groups are presented in Table 2.2, collapsed into the two misinformation-scenario conditions. Autism-spectrum quotient scores did not differ across these two conditions within each of the low-AQ ($p = .44$) and high-AQ ($p = .99$) groups. Participation was entirely voluntary, and all participants provided informed consent prior to being randomly assigned to one of the four experimental conditions (see Table 2.1).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age</th>
<th>AQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-AQ</td>
<td>50</td>
<td>19.84 (6.50)</td>
<td>7.94 (2.16)</td>
</tr>
<tr>
<td>High-AQ</td>
<td>50</td>
<td>18.80 (1.80)</td>
<td>26.64 (3.34)</td>
</tr>
</tbody>
</table>

Materials

**Autism-Spectrum Quotient.** The AQ was used as a screening measure to distinguish participants with low and high levels of autistic-like traits. The use of the AQ to recruit participants varying in the level of autistic-like traits allows investigations to overcome various methodological difficulties associated with clinical ASD samples. Some of these methodological difficulties include medication use in the ASD group, sample size, and adequate matching of the ASD and comparison groups (Jarrold & Brock, 2004; Russo et al., 2007). As discussed in Section 1.2, the AQ has been used extensively to assess levels of autistic-like traits in the general population, with higher AQ scores indicating higher levels of autistic-like traits (e.g., Almeida et al., 2010b; Bishop et al., 2004; Grinter, Maybery, et al., 2009). This indicates that the cognitive profile of high-AQ individuals can be used to approximate the cognitive profile of individuals with ASD.
**Scenarios.** Two separate fictitious scenarios were used, detailing either a school bus accident or a woman collapsing after a spider bite (see Tables 2.3 and 2.4). In both scenarios, Message 4 provided the causal explanation for the respective incident. In the retraction conditions, Message 9 presented the retraction message. This message was replaced by a neutral statement that made no reference to the cause in the no-retraction control condition. In a pilot test, the two scenarios were presented to $N = 8$ participants in a counter-balanced retraction and no-retraction order, and the scenarios were found to be of comparable plausibility.

Scenarios were presented as news reports using a MATLAB program, designed using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Each scenario consisted of 11 messages presented individually. The participant prompted the next message by key press when he/she had successfully read and encoded the current message. Each slide was set to stay onscreen for at least 2.5 s. This was to prevent participants from rapidly progressing through the messages without properly reading and encoding them. Each slide was also set to appear for a maximum of 35 s to ensure participants progressed through all messages in due time. This maximum slide transition time ensured that a message was presented for a maximum of 600 ms per word; this value has been used in previous research to ensure comfortable reading without excessive slack time (Cheung, 2010). Participants’ reading time for each message was recorded by the program.
Table 2.3
*Messages in the School Bus Scenario Used in Experiment 1*

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A report has come into the police headquarters on Tuesday about a serious accident involving a school bus on Spring St. The school bus had hit a cyclist on the side of the road before crashing into the window of a music store. The report was made by a driver who was driving past the scene of the accident.</td>
</tr>
<tr>
<td>2</td>
<td>An ambulance was dispatched to the scene immediately upon the report of the accident but due to bad road conditions from roadworks in the area, they arrived at the scene only after 15 minutes. When they arrived, they began assessing the cyclist and the bus-driver’s injuries, both of whom were found unconscious.</td>
</tr>
<tr>
<td>3</td>
<td>Police have stated the school bus was apparently on its way back from Spring Oaks Primary School after an outing at the bowling centre. The school’s headmaster was contacted and he explained that the bus-driver was a very reliable long-time employee.</td>
</tr>
<tr>
<td>4</td>
<td>Police investigating the cause of the accident have released a report, stating that the bus-driver lost control of the bus because a front tyre burst after a piece of scrap metal, believed to have come from the adjacent construction site, lodged in the tyre.</td>
</tr>
<tr>
<td>5</td>
<td>The police further stated that both the cyclist and the bus-driver were seriously injured and had been taken to St. Joseph’s hospital immediately. A few of the school kids who had been in the bus sustained minor injuries.</td>
</tr>
<tr>
<td>6</td>
<td>At the scene of the accident, police interviewed a number of eyewitnesses, some of whom claimed to have heard squeaking and rumbling sounds and then saw the bus hit the cyclist.</td>
</tr>
<tr>
<td>7</td>
<td>There was a gradual build-up of traffic in the Spring Street area due to the roadworks and police closing off the area of the accident.</td>
</tr>
<tr>
<td>8</td>
<td>Police had to calm the owner of the music store, who was very upset about his shop window being broken and a limited edition guitar being destroyed. He was attended to by paramedics.</td>
</tr>
<tr>
<td>9</td>
<td><em>(No-retraction condition).</em> A special report made by the police stated that both the cyclist and the bus-driver were in a stable condition.</td>
</tr>
<tr>
<td></td>
<td><em>(Retraction condition).</em> A special report made by the police stated that the burst tyre was not the cause of the accident. The tyre had actually burst when it hit the road kerb after hitting the cyclist.</td>
</tr>
<tr>
<td>10</td>
<td>More than three hours after the time of the accident, police have cleared the scene of the accident, and traffic on Spring Street slowly restored itself to normal.</td>
</tr>
<tr>
<td>11</td>
<td>Several days later, it has been revealed that both the cyclist and the bus-driver were making good progress in their recovery from the injuries sustained in the accident. The total damage was estimated to lie over $50,000.</td>
</tr>
</tbody>
</table>
Table 2.4
Messages in the Spider Bite Scenario Used in Experiment 1

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A woman was hospitalised on Sunday afternoon after collapsing in her orchard at her home in Sydney’s North. The mother of three, 55, was pruning apricot trees when she became weak and nauseous.</td>
</tr>
<tr>
<td>2</td>
<td>The woman’s 15 year-old son found her lying on the ground of the orchard when he returned home from swimming practice at 13:30. He called an ambulance immediately and told paramedics she was sweating, breathing rapidly, and appeared frightened. He also noticed that her skin had broken out in a rash.</td>
</tr>
<tr>
<td>3</td>
<td>The ambulance at the woman’s home at 13:50 and transported the woman to Eden Bay Hospital, approximately 25 minutes away. By the time the ambulance arrived at the hospital, the paramedics had stabilised her breathing.</td>
</tr>
</tbody>
</table>
| 4           | *Paramedics believed the woman’s symptoms were caused by a redback spider bite.*
*Redback spider bites are often not instantly noticed and can cause severe symptoms.* |
| 5           | It is alleged that when the woman arrived at the hospital, her rash had spread, and she appeared confused and disoriented. She was moved to the hospital’s Intensive Care Unit.                                             |
| 6           | Dr. Greg Kahn praised the son’s quick response in calling an ambulance, stating that there had been a recent trend in people not calling an ambulance, and instead waiting to see if symptoms persisted before seeking help.                               |
| 7           | Dr. Kahn wanted to keep the woman under supervision for two nights. He instructed nurses to perform several tests to determine the cause of the woman’s symptoms.                                                                 |
| 8           | The woman’s husband was notified of the collapse by their son and rushed to the hospital to see her. The woman was asleep when her husband arrived, and he and their son kept a bedside vigil throughout the night.                                          |
| 9           | *(No-retraction). After a two night stay, the woman had fully recovered from her symptoms, and she was released from hospital on Tuesday morning. Dr. Kahn stated that her tests results indicated a slightly raised white blood cell count.* |
|             | *(Retraction). After a two night stay, the woman had fully recovered from her symptoms, and she was released from hospital on Tuesday morning. Based on the test results, Dr. Kahn concluded that her symptoms had not been caused by a spider bite.* |
| 10          | After her release from hospital, the woman continues to tend to her apricot trees in the orchard. She is a regular grocer at the weekend farmers markets where she sells the apricots from her trees and the preserves she makes from them.                 |
| 11          | The woman and her husband also expressed it was lucky their son came looking for her. “Who knows what might have happened if he hadn’t come looking for me and called an ambulance straight away”, she said. “I’m very grateful”.                                               |

Open-ended Questionnaires. Two 18-item open-ended written questionnaires (one for each scenario) were used to assess participants’ memory and inferential
understanding of the respective reports. Each questionnaire consisted of nine inference and nine fact-recall questions (see Tables 2.5 and 2.6).

<p>| Table 2.5 |</p>
<table>
<thead>
<tr>
<th>Open-ended Questionnaire for the School Bus Scenario Used in Experiment 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inference Questions</strong></td>
</tr>
<tr>
<td>1. Who will most likely have to pay for the repairs of the school bus?</td>
</tr>
<tr>
<td>2. Why was the bus-driver unable to avoid the crash?</td>
</tr>
<tr>
<td>3. What do you think caused the squeaking and rumbling sounds before the bus hit the bicycle?</td>
</tr>
<tr>
<td>4. Why would the driver of the school bus be angry or upset?</td>
</tr>
<tr>
<td>5. What was the relevance of the road conditions?</td>
</tr>
<tr>
<td>6. Apart from the bus-driver and the pedestrian witnesses, who else should the police question?</td>
</tr>
<tr>
<td>7. Why would the school bus insurance refuse payments of the bicycle damage?</td>
</tr>
<tr>
<td>8. Why did the police investigations at the scene take so long?</td>
</tr>
<tr>
<td>9. Why did the school bus hit the cyclist?</td>
</tr>
<tr>
<td><strong>Fact-recall Questions</strong></td>
</tr>
<tr>
<td>1. On which day did the accident occur?</td>
</tr>
<tr>
<td>2. Who reported the accident to the police?</td>
</tr>
<tr>
<td>3. Where did the school bus crash into after hitting the cyclist?</td>
</tr>
<tr>
<td>4. Where did the accident occur?</td>
</tr>
<tr>
<td>5. Which hospital were the injured taken to?</td>
</tr>
<tr>
<td>6. Why did the owner of the music store require medical assistance?</td>
</tr>
<tr>
<td>7. Where was the school bus coming from?</td>
</tr>
<tr>
<td>8. How long did it take until police had cleared the scene?</td>
</tr>
<tr>
<td>9. What was the estimated cost of damage of the accident?</td>
</tr>
</tbody>
</table>
Table 2.6
Open-ended Questionnaire for the Spider Bite Scenario Used in Experiment 1

<table>
<thead>
<tr>
<th>Inference Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Why did the incident happen in the orchard?</td>
</tr>
<tr>
<td>2. Why did the woman appear frightened after her collapse?</td>
</tr>
<tr>
<td>3. What could have prevented this incident?</td>
</tr>
<tr>
<td>4. Why did the woman break out in a rash?</td>
</tr>
<tr>
<td>5. What should the doctor and the nurses test for at the hospital?</td>
</tr>
<tr>
<td>6. Why was the woman sweating?</td>
</tr>
<tr>
<td>7. Why did the doctors want to keep the woman under supervision for 48 hours?</td>
</tr>
<tr>
<td>8. What protective measures do you think the woman should take next time she works in the orchard?</td>
</tr>
<tr>
<td>9. Why was the woman hospitalised?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fact-recall Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What kind of trees was the woman pruning when she collapsed?</td>
</tr>
<tr>
<td>2. What time did the paramedics arrive at the woman’s home?</td>
</tr>
<tr>
<td>3. How old was the woman?</td>
</tr>
<tr>
<td>4. Who called the ambulance?</td>
</tr>
<tr>
<td>5. Which hospital was the woman taken to?</td>
</tr>
<tr>
<td>6. On which day did the woman collapse?</td>
</tr>
<tr>
<td>7. What was the name of the doctor who praised the woman’s son?</td>
</tr>
<tr>
<td>8. What area of the hospital was the woman moved to?</td>
</tr>
<tr>
<td>9. Where was the woman’s son returning home from?</td>
</tr>
</tbody>
</table>

The inference questions were designed to elicit references to the critical causal information (i.e., aspects of the incident that were directly or indirectly related to the cause of the incident). Inference questions could be answered by referring to the burst tyre (in the school bus scenario), the redback spider bite (in the spider bite scenario), or other information that may or may not have featured in the scenarios. Fact-recall questions were designed to assess participants’ memory for the factual details presented in the scenario. These questions were not directly related to the cause of the incident and thus did not prompt participants to make any reference to the cause. All questions were completed in the order presented in the tables for each scenario, with the exception of the final inference question which directly targeted the cause (i.e., the burst tyre, or the spider bite). This question was phrased like a fact-recall question and was hence presented last, after the fact-recall questions.

**Open-ended Questionnaires Coding Procedure.** The open-ended questionnaires, used to assess participants’ memory and inferential understanding of the
scenarios, were scored by the experimenter, who was blind to experimental conditions. Scoring was done following a written scoring guide adapted from Ecker, Lewandowsky, and Apai (2011). For the inference questions, any uncontroverted reference made to the critical information, viz. the relevant cause of the incident, was given a score of 1.

Examples of inferences that were given a score of 1 for the school bus scenario included ‘a piece of metal from roadworks burst his tyre, causing him to lose control’ or ‘the metal lodged in the tyre’. Examples of inferences given a score of 1 for the spider bite scenario were ‘the woman got bitten by a redback spider’ or ‘because spider bites cause that reaction’. If responses did not reflect the belief that the referenced circumstance was causally involved in the respective incidents, responses were given a score of 0. This applied, for example, when a participant in the retraction condition acknowledged the retraction (e.g., responses such as ‘initially they said it was a burst tyre, but then they said this wasn’t the case’ or ‘it could have been the spider bite but I’m not sure because the doctor said it wasn’t’). Higher inference scores were thus reflective of greater reliance on the critical causal information. It was expected that references to the critical causal information would be made mainly in response to the inference questions; the expected maximum inference score for each scenario was thus nine.

However, in the unlikely case that references were made in responses to the fact-recall questions, these also contributed to the inference score.

Fact-recall questions were scored 1 for a correct response and 0 for an incorrect response. If a response contained partially correct information, it was given a score of 0.5. For example, in the school bus scenario, a response to the question ‘Where did the bus crash into after hitting the cyclist?’ was given a score of 1 if the participants responded with ‘window of a music store’, and a score of 0.5 if they responded with ‘a store’. The maximum fact-recall score for each scenario was nine.
Twenty randomly-selected questionnaires (five from each condition—see Table 2.1) were scored by a second scorer as an inter-rater reliability check. For the school bus scenario, inter-rater reliability was $r = .93$ for the inferences questions, and $r = .96$ for the fact-recall questions. For the spider bite scenario, inter-rater reliability was $r = .98$ for inferences questions, and $r = .99$ for the fact-recall questions.

The main dependent measure of interest was participants’ ‘inference score’, calculated as the number of references made to the critical piece of information—that is, the burst tyre causing the accident in the school bus scenario or the spider bite causing the woman’s collapse in the spider bite scenario—in participants’ responses. Participants’ fact-recall score served as an additional measure of proper encoding of the scenarios.

**Digit Symbol Rotation.** The Digit Symbol Rotation task involves an upside-down reference table containing nine symbols, consecutively numbered 1-9, and rows of randomly numbered (with numbers 1-9) response boxes appearing below the reference table. The version used in the current experiment contained one row of response boxes on each page, alongside the identical reference table, with a total of 12 pages for the entire test (see Figure 2.1). Participants were to locate each number’s corresponding symbol in the table, mentally rotate the symbol and draw it the right way up in the appropriate response box. After a practice run consisting of five digits with error feedback, participants were given 90 s to complete as many rotations as possible, without skipping any response boxes. Scores from the Digit Symbol Rotation task have been shown to load highly on a general ability factor along with scores from standardised intelligence tests such as the Wechsler Adult Intelligence Scale—Revised

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2 This adaptation to the task was made due to participants’ tendency to copy their responses from previous response tables on the same page rather than returning to look at the inverted symbols in the reference table (Jamnadass, Badcock, & Maybery, 2014).
Edition (The Psychological Corporation, 1981), and have been argued to provide a brief but adequate measure of general intelligence (see Gignac & Vernon, 2003).

Table of Symbols

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Response Table 1

<table>
<thead>
<tr>
<th>8</th>
<th>6</th>
<th>3</th>
<th>7</th>
<th>2</th>
<th>4</th>
<th>9</th>
<th>1</th>
<th>5</th>
</tr>
</thead>
</table>

*Figure 2.1.* An example of one page of the Digit Symbol Rotation. Each page consisted of a response table consisting of numbers 1-9 in random order. There were 12 pages in total.

**Tolerance of Ambiguity Scale.** The TAS (Herman et al., 2010) is a 12-item self-report measure used to assess participants’ level of tolerance to ambiguous situations and information. Participants rated their agreement on 5-point Likert scales ranging from 0 (Strongly Disagree) to 4 (Strongly Agree).

**Fear of Spiders Questionnaire.** The FSQ (Szymanski & O'Donohue, 1995) is an 18-item self-report questionnaire designed to assess an individual’s level of fear of spiders. Participants rated their agreement with 18 statements on 8-point Likert scales ranging from 0 (Totally Disagree) to 7 (Totally Agree).
**General Procedure**

The task sequence of Experiment 1 following completion of the AQ is presented in Figure 2.2. Participants read the first scenario, which was followed by a short break during which they completed the TAS, the FSQ, and Digit Symbol Rotation task, in that order. They then completed the open-ended questionnaire relating to the first scenario. Following this, participants completed an unrelated word puzzle for approximately 10 min before reading the second news report. This was followed by another short break during which the participant completed a second unrelated word puzzle for 10 min, followed by the open-ended questionnaire relating to the second scenario. The entire testing session lasted approximately one hour.

*Figure 2.2. Sequence of events in Experiment 1. TAS, Tolerance of Ambiguity Scale; FSQ, Fear of Spiders questionnaire.*
2.6.2. Results

Open-ended Questionnaire

Data Screening. To ensure all participants read and understood the scenarios, preliminary analyses were performed to check no participant received a score of zero on the fact-recall questions. No data were removed based on this criterion. One participant failed to make any response on the inference questions for the school bus scenario, and was thus removed. The final sample for subsequent analyses was thus \( N = 99 \).

References to the Critical Causal Information. A mixed-factorial ANOVA was initially conducted on the inference scores, with the within-subjects factor retraction condition (retraction vs. no-retraction), and AQ group (low-AQ vs. high-AQ) and the misinformation-scenario control factor (school bus vs. spider bite retracted) as the between-subjects factors. There was an unexpected interaction between the retraction condition and retracted-scenario factors, \( F(1, 95) = 19.06, p < .001, \eta_p^2 = .17 \), and thus the data were analysed for the school bus and spider bite scenarios separately. To this end, two \( 2 \times 2 \) factorial ANOVAs were conducted, with mean inference score as the dependent variable, and AQ group (low-AQ vs. high-AQ) as a between-subjects factor. In this case, retraction condition (retraction vs. no-retraction) also constituted a between-subjects factors.

School Bus Scenario. Mean inference scores for each AQ group in the school bus scenario are presented in Figure 2.3. Results show a significant effect of retraction condition, \( F(1, 95) = 73.39, p < .001, \eta_p^2 = .44 \), with more references made to the critical causal information when there was no retraction than when there was a retraction. This suggests the retraction was efficient in reducing the number of post-retraction references to the critical causal information. There was no main effect of AQ group, \( F(1, 95) = 1.79, p = .18 \). The interaction between AQ group and retraction condition, however, was significant, \( F(1, 95) = 3.94, p = .049, \eta_p^2 = .04 \). Although the
mean number of references was reduced to approximately the same level for the two AQ groups when there was a retraction, there was a greater reduction for the low-AQ group than the high-AQ group relative to the no-retraction control condition (see Figure 2.3).

Separate one-sample t-tests were conducted for each AQ group to further investigate participants’ post-retraction reliance on the critical causal information, that is, to determine whether the number of references to the critical information after a retraction was significantly different from zero. This was the case for both the low-AQ group, $t(23) = 6.25, p < .001, d = 2.61$, and high-AQ group, $t(23) = 6.21, p < .001, d = 2.59$.

![Figure 2.3](image.png)

*Figure 2.3.* Mean inference scores in the school bus scenario for each AQ group (low-AQ vs. high-AQ) in the no-retraction and retraction conditions in Experiment 1. Values in the bars denote the means. Error bars denote standard errors of the means.
**Spider Bite Scenario.** Mean inference scores for each AQ group in the spider bite scenario are presented in Figure 2.4. The $2 \times 2$ ANOVA performed for the spider bite scenario showed a significant main effect of retraction condition, $F(1, 95) = 47.16$, $p < .001$, $\eta^2_p = .33$, with more references to the critical information when there was no retraction than when there was a retraction. There was no difference between the two AQ groups, nor a significant interaction between retraction condition and AQ group, both $F < 1$.$^3$

As with the school bus scenario, separate one-sample t-tests were conducted for each AQ group to further investigate participants’ post-retraction reliance on the critical causal information. There was a continued reliance on the critical causal information for both the low-AQ group, $t(25) = 7.43$, $p < .001$, $d = 2.97$, and high-AQ group, $t(24) = 5.42$, $p < .001$, $d = 2.21$, following a retraction.

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$^3$ As the central theme of the spider bite scenario regarded a spider bite, as explained earlier, participants completed the FSQ to check if they had an intense fear of spiders, and whether the extent of spider fear was related to the extent of reliance on spider-related misinformation. I ran an Analysis of Covariance with participants’ scores on the FSQ score as a covariate. There was no effect of FSQ scores on the results, and hence further analysis of this variable is not reported.
Figure 2.4. Mean inference scores in the spider bite scenario for each AQ group (low-AQ vs. high-AQ) in the no-retraction and retraction conditions in Experiment 1. Values in the bars denote the means. Error bars denote standard error of the means.

**Fact-recall.** A mixed-design ANOVA was performed on the fact-recall scores, with retraction condition as the within-subjects factor, and AQ group and the retracted-scenario factor as between-subject factors. There was an unexpected interaction between retraction condition and the retracted-scenario factor, $F(1, 95) = 14.22$, $p < .001$, $\eta^2_p = .13$ and thus, fact-recall scores were analysed for the school bus and spider bite scenarios separately. To this end, two $2 \times 2$ factorial ANOVAs were conducted, with AQ group and retraction condition as the between-subject factors. For both the school bus and the spider bite scenarios (Figures 2.5 and 2.6, respectively), fact-recall scores did not differ between the two AQ groups, nor was there any difference between retraction conditions, or an interaction between AQ group and retraction condition (all $F < 1$).
Figure 2.5. Mean fact-recall score across AQ groups (low-AQ vs. high-AQ) for the no-retraction and retraction conditions in the school bus scenario in Experiment 1. Values in the bars denote the means. Error bars denote standard error of the means.
Figure 2.6. Mean fact-recall score across AQ groups (low-AQ vs. high-AQ) for the no-retraction and retraction conditions in the spider bite scenario in Experiment 1. Values in the bars denote the means. Error bars denote standard error of the means.

Reading Time Data

Data Screening. Three participants’ reading time data were removed, as they consistently waited for the maximum reading time of each message (i.e., 35 s) to elapse instead of progressing to the next slide by key press after reading each message.

In order to control for the effect of the different length of messages, the data were first standardised. This was achieved by dividing the reading time of each message by the number of syllables of that respective message. For example, if a reading time of 19.32 s was recorded for Message 1 of the school bus scenario, it was divided by the number of syllables in that message, which was 84, resulting in a reading time measure of 0.23 s per syllable. All reading time data are thus presented as seconds per syllable (s/syllable) in subsequent analyses.
We also anticipated large between-subjects variance in reading times. Therefore, the data were normalised using the Cousineau (2005) method to remove between-subjects variance while maintaining between-condition differences. This method involves (1) subtracting the individual participant’s mean across all data points from each of their data points, and (2) adding the grand mean of the relevant AQ group to each data point of that individual.

Reading time data were then assessed for outliers, based on Message 9 reading time—our main variable of interest (i.e., the target message that presented the retraction in the retraction versions of the scenarios). This was done in both the no-retraction and retraction conditions. Mean reading times more than 2.2 times the interquartile range away from the first and third quartiles of the individual participant’s reading time distribution (cf. Hoaglin & Iglewicz, 1987) were classified as outliers. Four outliers were identified based on this criterion. However, in order to preserve the maximum number of data points possible for subsequent analyses, these cases were not removed but instead reading time values were replaced using the outlier-criterion value. The final sample for subsequent analyses on reading time was thus $N = 97$.

**Effect of Retraction on Message 9 Reading Time.** Initially, a mixed-factorial ANOVA was conducted to contrast Message 9 reading time when a retraction was presented versus when there was no retraction (within-subjects factor retraction condition), with AQ group and misinformation-scenario as additional between-subjects factors. There was, however, an unexpected interaction between retraction condition and the misinformation-scenario factor, $F(1, 93) = 4.00, p = .049, \eta^2_p = .04$. The data were thus analysed for the school bus and spider bite scenarios separately. To this end, two $2 \times 2$ factorial ANOVAs were conducted, with Message 9 reading time as the dependent variable, and retraction condition and AQ group as between-subjects factors.
**School Bus Scenario.** Message 9 reading times in the school bus scenario for each AQ group in the retraction and no-retraction conditions are presented in Figure 2.7. The $2 \times 2$ ANOVA yielded a significant effect of retraction condition, $F(1, 93) = 14.74, p < .001, \eta_p^2 = .14$, but no main effect of AQ group, $F < 1$. The interaction between AQ group and retraction condition was marginally significant, $F(1, 93) = 3.04, p = .08, \eta_p^2 = .03$, such that a retraction increased reading time more prominently in the high-AQ group than the low-AQ group. A planned follow-up contrast analysis confirmed that the retraction slowed reading in the high-AQ group, $F(1, 93) = 15.43, p < .001$, but not in the low-AQ group, $F(1, 93) = 2.22, p = .14$.

Figure 2.7. Message 9 reading time in the school bus scenario for each AQ group (low-AQ vs. high-AQ) in the no-retraction and retraction conditions in Experiment 1. Values in the bars denote the means. Error bars denote standard errors of the means.
**Spider Bite Scenario.** Message 9 reading times in the spider bite scenario for each AQ group in the retraction and no-retraction conditions are presented in Figure 2.8. The $2 \times 2$ ANOVA performed on Message 9 reading times in the spider bite scenario revealed no significant effects of retraction condition, $F(1, 93) = 2.84, p = .10$, AQ group, or their interaction, both $F < 1$.

![Figure 2.8](image.png)

*Figure 2.8.* Message 9 reading time in the spider bite scenario for each AQ group (low-AQ vs. high-AQ) in the no-retraction and retraction conditions in Experiment 1. Values in the bars denote the means. Error bars denote standard errors of the means.

**Descriptive Measures**

**Digit Symbol Rotation.** As mentioned, the Digit Symbol Rotation task (Gignac & Vernon, 2003) was administered as a general ability check for the low-AQ and high-AQ groups. There was a marginal difference between the two AQ groups on this
measure, \( t(97) = 1.74, p = .08, d = 0.35 \), with the low-AQ participants performing worse \( (M = 12.28, SD = 7.96) \) than the high-AQ participants \( (M = 14.81, SD = 6.39) \)\(^4\).

**Tolerance of Ambiguity.** The TAS (Herman et al., 2010) was administered to investigate whether the low-AQ and high-AQ groups differed in their level of tolerance for ambiguous information. The two AQ groups did not differ on this scale, \( t(97) = .21, p = .79 \), and thus no further analyses were performed on this variable.

2.6.3. **Discussion**

Using the CIE paradigm, Experiment 1 was conducted as an initial investigation of how misinformation influences memory for and reasoning about an unfolding event in individuals with low and high levels of autistic-like traits. Individuals with ASD often have difficulty processing ambiguous information (Dennis, Lazenby, & Lockyer, 2001; Henderson et al., 2011; Norbury, 2005; Ozonoff & Miller, 1996). It was thus hypothesised that individuals with low and high levels of autistic-like traits should differ in their post-retraction reliance on misinformation during subsequent reasoning about an unfolding event. Specifically, if individuals with high levels of autistic-like traits have limited memory updating ability, they should show greater post-retraction reliance on misinformation than individuals with low levels of autistic-like traits.

Inference score results in the school bus scenario showed that the retraction was generally efficient in reducing the number of references to misinformation across both the low-AQ and high-AQ groups. Although the two groups did not differ in the number of post-retraction references made to the misinformation, there was a greater reduction in the number of references to misinformation relative to the no-retraction control condition in the low-AQ group compared to the high-AQ group. This suggests more

\(^4\) The two AQ-groups were not expected to differ in general ability as measured by the Digit Symbol Rotation test, and thus all of the analyses reported above were performed with and without this factor as a covariate. The pattern of results did not change, and the results reported are those without the covariate analyses.
efficient corrective updating in the low-AQ group. One explanation is that the high-AQ participants had greater difficulty discarding older information from their situation model compared to low-AQ participants. Alternatively, it may be possible that the high-AQ participants encoded the causal information less efficiently than the low-AQ participants.

The reading time data support the former explanation. The high-AQ participants took longer to read the target message 9 when it presented a retraction than when it presented a neutral message (i.e., in the no-retraction conditions). This pattern was not present in the low-AQ participants. This suggests that high-AQ participants may have experienced difficulty resolving the discord in the news report, and required more time updating their situation models when faced with a retraction, compared to low-AQ participants.

In the spider bite scenario, however, a different result pattern emerged. The retraction efficiently reduced the number of references to misinformation across both AQ groups to a comparable extent. Results were thus not suggestive of the retraction being more or less efficient for either the low-AQ or high-AQ group, nor was there an effect of a retraction on reading times for either the low-AQ and high-AQ groups.

Overall, the results of Experiment 1 provide preliminary evidence that high-AQ participants may find it more difficult to process retraction information than low-AQ participants under some circumstances. The finding that the retraction in the school bus scenario was more efficient in reducing references to misinformation in the low-AQ participants (vs. high-AQ participants) suggests that there may be some difference in the two AQ groups’ abilities to incorporate retraction information into existing situation models, or in other words, to discard initially believed information and update existing situation models. This was supported by the high-AQ participants showing longer reading times when there was a retraction than when there was none, an effect that was
not seen in the low-AQ participants. Thus, high-AQ participants may have specific
difficulty processing a misinformation retraction, and find it more effortful to resolve
ambiguity within a scenario and/or update their situation model developed from the
initial critical information. This difficulty resolving ambiguity and/or updating situation
models may be particularly accentuated in more complex materials such as those used
in Experiment 1, as individuals with ASD have previously been found to have
processing difficulties when information is presented in large amounts, or are of high
complexity (Minshew, Meyer, & Goldstein, 2002; D. Williams, Goldstein, & Minshew,
2006).

This conclusion is substantially weakened, however, by the difference in the
pattern of results for the two scenarios. The null findings in the spider bite scenario
suggest that there may be some fundamental differences between the two scenarios that
were not detected during the pilot test when the scenarios were presented to a separate
sample as a plausibility check. Although both scenarios were rated as equally likely to
occur in real-world situations, it is possible that they differed in the effectiveness of the
retraction message, potentially resulting in lowered sensitivity of the spider bite
scenario to detect differences between the two AQ groups. In addition, it is possible that
the spider bite scenario contained less information that could pertain to a spider bite as
the cause compared to the amount of information suggestive of a burst tyre as the cause
in the school bus scenario. I thus questioned the appropriateness of the spider bite
scenario in Experiment 1, and subsequently investigated whether the findings from the
school bus scenario could be replicated using a different set of scenarios. Experiment 2
was thus conducted as a follow-up to Experiment 1 to address this.
2.7. Experiment 2

Experiment 2 was conducted as an attempt to replicate the findings from the school bus scenario using a different set of scenarios. Specifically, six scenarios were developed, each with retraction and no-retraction versions. This was done to ascertain that the effects found with the school bus scenario in Experiment 1 were not specific to that scenario.

2.7.1. Method

Design

Experiment 2 adopted a 2 (AQ group) × 2 (retraction condition) mixed design. As in Experiment 1, participants were assigned to either a low-AQ or high-AQ group based on their pre-screening score (see below for details). Each participant received six fictitious scenarios of differing themes relating to either (1) an airplane’s emergency landing, (2) a bushfire, (3) a drug-dealer’s death, (4) a collapse at a nightclub, (5) an increase in seizure incidents, or (6) a large scale fish death incident. For each participant, three of the scenarios featured a retraction, and three did not. The retraction factor (i.e., no-retraction vs. retraction) was thus a within-subjects factor. The order of the scenarios and the assignment of retraction conditions to scenarios followed a Latin-square design, with an alternating sequence of no-retraction and retraction versions (i.e., NR-R-NR-R-NR-R; see Table 2.7) for all participants. Scenarios were presented in this sequence in order to avoid participants coming to expect retractions when reading the scenarios. An additional constraint on the presentation of the scenarios was that each scenario occurred with equal likelihood at each order position. The order of the scenarios and assignment of retraction conditions to scenarios was counterbalanced across participants in six counterbalancing presentation order conditions, to which
participants were randomly assigned. Presentation order was thus a between-subjects control factor.

Table 2.7

<table>
<thead>
<tr>
<th>Condition</th>
<th>Presentation Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NR1—R2—NR3—R4—NR5—R6</td>
</tr>
<tr>
<td>2</td>
<td>NR3—R6—NR5—R2—NR1—R4</td>
</tr>
<tr>
<td>3</td>
<td>NR5—R4—NR1—R6—NR3—R2</td>
</tr>
<tr>
<td>4</td>
<td>NR2—R3—NR4—R5—NR6—R1</td>
</tr>
<tr>
<td>5</td>
<td>NR4—R1—NR6—R3—NR2—R5</td>
</tr>
<tr>
<td>6</td>
<td>NR6—R5—NR2—R1—NR4—R3</td>
</tr>
</tbody>
</table>

Participants

As per the screening process used in Experiment 1, 1,933 first-year psychology students from the University of Western Australia first completed the AQ (Baron-Cohen et al., 2001; $M = 16.81$, $SD = 5.86$, range 1-38). Similar to Experiment 1, students from the lower and upper quartiles of the AQ distribution (using AQ cut-off scores of 9 or lower for the low-AQ group and 24 or higher for the high-AQ group) were invited to participate in the second phase. The final sample consisted of $N = 48$ participants, with 24 participants each in the low-AQ and high-AQ groups (17 females each), none of whom participated in Experiment 1. The mean age across the sample was $M = 20.29$ years ($SD = 6.79$, range 17-45 years). Participation was entirely voluntary, and informed consent was obtained.

Descriptive statistics for the low-AQ and high-AQ groups are presented in Table 2.8. Autism quotient scores did not differ across the six presentation order conditions within the low-AQ ($F < 1$) or the high-AQ ($F(5, 18) = 1.57, p = .22$) groups.
Table 2.8

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age</th>
<th>AQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-AQ</td>
<td>24</td>
<td>21.42 (9.11)</td>
<td>5.92 (2.15)</td>
</tr>
<tr>
<td>High-AQ</td>
<td>24</td>
<td>19.17 (2.94)</td>
<td>26.83 (2.48)</td>
</tr>
</tbody>
</table>

Materials

The AQ and Digit Symbol Rotation task used in the present experiment were identical to those used in Experiment 1.

Scenarios. The fictitious scenarios were adapted from Hogan (2012; see Tables 2.9 and 2.10, and Appendix A). Each scenario consisted of 10 messages, presented consecutively as two separate articles with five messages each. For all scenarios, the primary purpose of the first article was to introduce the fictitious event (e.g., an airplane’s emergency landing; see Table 2.9). In all scenarios, Message 3 of the first article provided the critical information, viz. the causal explanation for the respective event.

Table 2.9

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Passengers on a commercial flight en route to Los Angeles received a terrible fright yesterday as their plane required an emergency landing.</td>
</tr>
<tr>
<td>2</td>
<td>Peter Fern, the pilot of the aircraft, made the decision to land after he was having difficulties controlling the plane.</td>
</tr>
<tr>
<td>3</td>
<td>The Federal Aviation Administration believes the pilot made the right decision, and attributed difficulties controlling the aircraft to a fault caused by the extreme weather conditions he was flying in.</td>
</tr>
<tr>
<td>4</td>
<td>The aircraft was able to make a safe landing at Kansas City airport, and all 350 passengers on board were evacuated without problem.</td>
</tr>
<tr>
<td>5</td>
<td>The aircraft involved was an A380 Airbus, the largest passenger airplane in the world.</td>
</tr>
</tbody>
</table>
The second article of each scenario existed in two different versions: A retraction version and a no-retraction version (e.g., see Table 2.10 for Article 2 of the airplane’s emergency landing example). In the retraction versions, Message 3 presented the retraction message. In the no-retraction version, this was replaced by a neutral statement that made no reference to the cause.

Table 2.10
Messages in Article 2 of the Airplane’s Emergency Landing Scenario Used in Experiment 2

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Passengers on a commercial flight that had to make an emergency landing at Kansas City airport were forced to stay overnight while the airline arranged a suitable replacement aircraft. Marie Scott, a passenger on the flight, told reporters of her ordeal.</td>
</tr>
<tr>
<td>2</td>
<td>“It was horrible, all loose items were getting thrown around the cabin, and the seatbelt was hardly containing me. I’m glad I’m safe, but I just really want to go home to my family now.”</td>
</tr>
<tr>
<td>3 (target message)</td>
<td>(No-retraction condition). Meanwhile, Kansas City Airport provided passengers with complimentary food and drink on behalf of the airline. (Retraction condition). Meanwhile, air crash investigators have found no evidence for any impact of the weather conditions on the aircraft’s controls.</td>
</tr>
<tr>
<td>4</td>
<td>The landing at Kansas City Airport was complicated by the fact that the airport is yet to modify its facilities to accommodate the size of the A380.</td>
</tr>
<tr>
<td>5</td>
<td>Twenty hours after the emergency landing, a replacement aircraft had been organized and passengers expressed their gratitude to the airline for managing the situation professionally.</td>
</tr>
</tbody>
</table>

Each message was presented individually in the same manner as in Experiment 1. Minimum and maximum reading times for each message were identical to those used in Experiment 1, and participants progressed through the messages via key press. Reading time for each message was recorded by the program as in Experiment 1.

Open-ended Questionnaires. There were six 8-item open-ended questionnaires (adapted from Hogan, 2012; see Table 2.11 and Appendix B), one for each scenario. The questionnaires consisted of five open-ended inference questions designed to elicit
references to the critical causal information (i.e., the reported cause of the incident), and 
three multiple-choice questions to assess memory for general facts presented in the 
scenario. The inference questions were largely similar in format to those used in 
Experiment 1 with the exception of item 1 which required the participants to provide a 
brief summary of the scenario.

Table 2.11

<table>
<thead>
<tr>
<th>Questions in the Open-ended Questionnaire for the Airplane’s Emergency Landing Scenario Used in Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inference Questions</strong></td>
</tr>
<tr>
<td>1. Briefly summarise the ‘airplane landing’ article.</td>
</tr>
<tr>
<td>2. How could such events be prevented in the future?</td>
</tr>
<tr>
<td>3. What would be a good newspaper headline for what happened?</td>
</tr>
<tr>
<td>4. What could be a reason to be upset about this incident?</td>
</tr>
<tr>
<td>5. Why was the pilot having difficulties controlling the airplane?</td>
</tr>
</tbody>
</table>

| **Memory Questions** |
| 1. What airport did the airplane land at? |
| a) Kansas | b) Denver | c) Orlando | d) Seattle |
| 2. How many passengers were on board? |
| a) 50 | b) 150 | c) 250 | d) 350 |
| 3. What type of aircraft was involved? |
| a) Boeing 747 | b) Airbus A380 | c) Boeing 777 | d) A319 |

*Note.* Inference question item 1 was completed first, followed by the memory questions 
and the remaining four inference questions.

**Open-ended Questionnaires Coding Procedure.** The open-ended 
questionnaires, used to assess participants’ memory and inferential understanding of the 
scenarios, were scored by the experimenter, who was blind to the conditions. This was 
done following a written scoring guide adapted from Hogan (2012). As with 
Experiment 1, the main dependent measure of interest was participants’ ‘total inference 
score’, calculated as the total number of references made to the critical pieces of 
information (i.e., the causal explanations) across all six scenarios in response to the 
inference questions. Any uncontroverted reference made to the critical causal 
explanation relevant to the scenario was given a score of 1. For the airplane’s 
emergency landing example, an inference score of 1 was given to responses such as
‘...because the plane flew in extreme weather conditions’ or ‘There was a fault in the plane because of bad weather’. Any response that did not reflect the belief that the referenced circumstance was causally involved in the incident was given a score of 0. Examples of responses that received an inference score of 0 in the airplane’s emergency landing scenario included ‘...a commercial plane was flying to Los Angeles’ and ‘The pilot landed safely’. The total number of inference questions in each scenario was 5, thus resulting in a maximum score of 15 across the three scenarios used for each of the no-retraction and retraction conditions.

Memory scores were calculated from three multiple-choice memory questions (i.e., memory questions 1-3, inclusive; see Table 2.11), in addition to the item that required participants to give a brief summary of the scenario (labelled inference question 1 in Table 2.11). This item was scored based on specific, predetermined propositions or ‘idea units’ (see also Hogan, 2012). For each scenario, there were two major idea units—that is, information that conveyed the major theme of the scenarios. One example of a major idea unit in the airplane’s emergency landing scenario was ‘emergency landing of a plane’. There were also two minor idea units for each scenario—that is, information that conveyed minor details of the scenario. One example was ‘it was a commercial flight’ in the airplane’s emergency landing scenario. A score of 1 was given for each major idea unit, and a score of 0.5 was given for each minor idea unit. Thus, the maximum memory score for the summary item was 3. The multiple-choice questions were given a score of 1 for correct responses, and 0 for incorrect responses, resulting in a maximum score of 3 for the three multiple-choice questions. The total maximum memory score for each scenario was thus 6, and 18 for the three scenarios taken together for each of the retraction and no-retraction conditions.
A subset of 30 questionnaires (5 from each counterbalancing condition) were scored by a second scorer to assess inter-rater reliability, which was found to be $r = .92$ for the inference scores, and $r = .89$ for the memory scores.

**General Procedure**

Participants first completed the Digit Symbol Rotation task prior to reading the scenarios. They then completed an unrelated word puzzle for approximately 10 min, which was followed by the open-ended questionnaires. The order of the open-ended questionnaires matched the presentation order of the scenarios for each participant. The entire testing session lasted approximately one hour.

### 2.7.2. Results

**Open-ended Questionnaire**

**Data Screening.** The data were screened to ensure all participants had read and understood the scenarios. To this end, participants who received a score of zero on the memory questions for two or more scenarios were deemed unacceptable. No data were removed based on this criterion. Two participants failed to make any responses on the inference questions for the majority of the scenarios, and were thus removed, resulting in $N = 46$ for subsequent analyses.

**References to the Critical Causal Information.** Total inference scores across the scenarios for each retraction condition and AQ group are presented in Figure 2.9. A mixed-factorial ANOVA was first conducted to contrast participants’ total inference scores when there was a retraction and when there was no retraction (within-subjects factor retraction condition), with AQ group (low-AQ vs. high-AQ) as the between-subjects factor. There was a main effect of the retraction on the number of references made to the critical causal information across all scenarios, $F(1, 44) = 9.72, p < .01,$
η_{p}^{2} = .18, with more references made to the critical causal information when there was no retraction than when there was a retraction. This suggests the retraction was at least somewhat efficient in reducing the number of post-retraction references to the critical causal information. There was, however, no effect of group, nor was there a significant interaction between retraction condition and group, both $F < 1$.

![Bar chart showing mean inference scores across all scenarios for each AQ group (low-AQ vs. high-AQ) in the no-retraction and retraction conditions in Experiment 2. Values in the bars denote the means. Error bars denote standard errors the means.](image)

*Figure 2.9.* Mean inference scores across all scenarios for each AQ group (low-AQ vs. high-AQ) in the no-retraction and retraction conditions in Experiment 2. Values in the bars denote the means. Error bars denote standard errors the means.

Separate one-sample t-tests were conducted for each AQ group to further investigate participants’ post-retraction reliance on the critical causal information. There was a continued reliance on the critical causal information for both the low-AQ group, $t(21) = 12.12, p < .001, d = 5.29$, and high-AQ group, $t(23) = 11.02, p < .001, d = 4.60$, following a retraction.
**Memory.** Memory scores for each AQ group across all of the scenarios in each of the no-retraction and retraction conditions are presented in Figure 2.10. A mixed-factorial ANOVA was conducted on the memory scores with the retraction condition as the within-subjects factor, and AQ group as the between-subjects factor. There was no difference in memory scores between the retraction conditions, $F < 1$, nor was there any difference between the two groups, $F(1, 44) = 2.62, p = .11$. There was also no interaction, $F(1, 44) = 1.31, p = .26$.

![Memory scores for each AQ group across all scenarios in Figure 2.10.](image)

*Figure 2.10.* Mean memory score across all scenarios in the no-retraction and retraction conditions for each AQ group (low-AQ vs. high-AQ) in Experiment 2. Values in bars denote the means. Error bars denote standard errors of the means.

**Reading Time**

As previously mentioned, all participants received six fictitious scenarios of differing themes (see Appendix A), three of which presented a retraction and three of which did not. As one of the main variables of interest was reading time for the target message (i.e., Message 3 of Article 2 for each scenario which presented a retraction),
mean reading time for Message 3 was calculated across the three scenarios presenting a retraction and the three presenting no retraction, for each participant. The data screening process was identical to that used in Experiment 1 for the two mean reading times.

**Effect of a Retraction on Reading Time.** Message 3 reading times for each AQ group in the retraction and no-retraction conditions are presented in Figure 2.11. An omnibus mixed-design ANOVA was first performed to contrast Message 3 reading time when there was a retraction versus when there was no retraction, with AQ group as an additional between-subjects factor. There was no main effect of group, retraction condition, nor an interaction between group and retraction condition on reading time, all \( F < 1 \).

![Figure 2.11](image)

*Figure 2.11. Message 3 reading time for the no-retraction and retraction conditions for each AQ group (low-AQ vs. high-AQ). Values in bars denote the means. Error bars denote standard errors of the means.*
Digit Symbol Rotation\(^4\).

Contrary to expectations, the two AQ groups differed on this measure, \(t(44) = 2.58, p = .01, d = 0.76\), with the low-AQ group \((M = 10.80, SD = 6.14)\) performing worse than the high-AQ group \((M = 14.85, SD = 4.43)\).

2.7.3. Discussion

Experiment 2 was conducted as a follow-up attempt to replicate and possibly extend the pattern of results in the school bus scenario in Experiment 1. To this end, we presented each participant with six new fictitious scenarios; three of the scenarios contained a retraction and three did not.

As discussed in Section 2.6.3, findings from the school bus scenario of Experiment 1 suggested that a retraction was less efficient in reducing references to misinformation for the high-AQ participants. Contrary to this, Experiment 2 did not find retractions to be any more or less efficient with either AQ group, suggesting that the low-AQ and high-AQ participants were equally able to amend their situation model of the unfolding events in light of a retraction.

Reading time data from Experiment 1 also suggested that high-AQ participants may have difficulty processing a retraction, as they took longer to read the target message when it presented a retraction than when it contained neutral information. Unlike Experiment 1, a retraction did not have any effect on reading time in either the low-AQ or high-AQ group across the scenarios in Experiment 2, thus providing no evidence that the high-AQ participants had greater difficulty than the low-AQ participants reading and processing a retraction message.

\(^4\) The two AQ groups were not expected to differ in general ability as measured by the Digit Symbol Rotation task, and thus all of the analyses reported above were performed with and without this factor as a covariate. The pattern of results did not change, and the results reported are those without the covariate analyses.
2.8. General Discussion

In this study, I applied the CIE paradigm to explore how individuals with low and high levels of autistic-like traits resolve ambiguity within complex narratives when they are faced with retractions. Specifically, the aim was to explore whether retracted misinformation would affect memory for and inferential reasoning about an unfolding event differently for low-AQ individuals compared to high-AQ individuals.

Overall, Experiments 1 and 2 did not provide conclusive evidence that individuals with low and high levels of autistic-like traits are affected differentially by misinformation. Although Experiment 1 suggested that a retraction was more efficient in reducing references to misinformation in the low-AQ participants, this pattern was present for only one out of the two scenarios (i.e., the school bus scenario). Moreover, I was unable to replicate this effect in Experiment 2 with various different scenarios unrelated to those used in Experiment 1. Similarly, reading time in Experiment 1 showed that high-AQ participants were observed to read the target message slower when it presented a retraction than when it did not, a pattern that was not observed in the low-AQ participants. However, this effect was again only apparent in the school bus scenario of Experiment 1 and failed to replicate in Experiment 2.

On the one hand, the null findings are consistent with previous investigations using post-event misinformation, which found that individuals with ASD are no more suggestible than typically-developing counterparts (Bruck et al., 2007; Maras & Bowler, 2011; McCrory et al., 2007; North et al., 2008) to the effects of misinformation. It is possible that misinformation generally does not impact on memory for and subsequent reasoning about an unfolding event in individuals with ASD any more than it does in typically-developing individuals. On the other hand, as I discussed earlier, if individuals with ASD did have impaired memory updating ability, they should be expected to rely more on initially presented information. In the post-event misinformation paradigm,
where valid information precedes the presentation of misleading information, this would result in smaller misinformation effects (as observed by North et al., 2008). However, in the CIE paradigm, where invalid information is presented initially, this should result in larger misinformation effects. This notion could not be corroborated with the current results with individuals exhibiting low and high levels of autistic-like traits, however, as I was unable to replicate the preliminary significant findings in Experiment 1.

There was an incidental finding that the high-AQ participants performed marginally better than the low-AQ participants on Digit Symbol Rotation in both Experiment 1 and Experiment 2. This suggests that the two AQ groups differed in general ability. More specifically, individuals with ASD have been found to utilise visual-based processing strategies more spontaneously and efficiently than verbal-based strategies during problem-solving (Kana, Keller, Cherkassky, Minshew, & Just, 2006; Koshino et al., 2005; see also Section 5.5). Given that the Digit Symbol Rotation task involves manipulation of visual symbols, it is possible that this preference for visual-based strategies facilitated the high-AQ participants’ performance on this task. However, when Digit Symbol Rotation performance was included in analyses as a covariate, it did not appear to have any effect on the pattern of results, and thus it is unlikely that the present findings can be explained by differences in general ability.

2.8.1. Limitations of the Study

There are a number of limitations to the study that may account for the non-significant findings across the various measures used. The first concerns the use of reading time to measure misinformation effects. Reading times have not previously been used within the CIE literature as a measure of how misinformation influences inferential understanding of an unfolding event. Whilst the results of Experiment 1 suggest high-AQ participants take longer reading a retraction, and thus may have
greater difficulty than low-AQ participants interpreting a retraction message and updating their situation model, the effect was not replicated in Experiment 2 and thus no definitive conclusions can be drawn at present. Moreover, there was in general no difference in reading times between the no-retraction and retraction conditions in Experiment 2, and thus it is possible that reading time may not be a sensitive enough measure to assess participants’ restructuring of situation models. It is thus worthwhile to consider alternative measures of performance, particularly methods that may provide additional information in regards to the process of reading a retraction message, as this will provide insight into where difficulties processing misinformation, if any, may lie in individuals with high levels of autistic-like traits. Some examples are a “think-aloud” method, during which participants are required to verbalise their thoughts following each message (Kurby & Zacks, 2012), eye-tracking methods to assess where individuals primarily focus when processing misinformation (Caruana, 2011; see also Section 6.3), or electrophysiological or neuroimaging measures (for example, updating of situation models has been linked to enhanced activity in the left inferior frontal gyrus and the hippocampi; Anderson & Hanslmayr, 2014).

Another potential limitation concerns the scenarios used. The results from the school bus scenario in Experiment 1 provided preliminary evidence that high-AQ individuals may find it more difficult to process a retraction, and subsequently incorporate the retraction information into their situation model, under some conditions, compared to low-AQ individuals. However, these findings failed to replicate using various other scenarios (e.g., spider bite, airplane’s emergency landing, and so on) in both Experiment 1 and 2. One possibility is that the school bus scenario is more complex compared to the other scenarios. In fact, the Flesch-Kincaid Reading Ease test (Flesch, 1948; available online at https://readability-score.com) suggested that the school bus scenario was somewhat more difficult to read than the spider-bite scenario of
Experiment 1; however, using the same measure, the scenarios used in Experiment 2 were more difficult to read than the school bus scenario. I note that the scenarios used in Experiment 2 (as well as the spider bite scenario of Experiment 1) were shorter than the school bus scenario, which may have also affected participants’ processing of the materials and in particular processing of the retraction in the low-AQ and high-AQ groups. Previous studies have suggested that individuals with ASD have difficulties processing information when it is presented in large amounts and/or when it increases in complexity (Minshew & Goldstein, 2001; Minshew, Goldstein, & Siegel, 1997). Differences in updating ability between the low-AQ and high-AQ participants may thus be apparent only when the information is relatively complex, and/or when a large amount of information is presented. Although the scenarios were able to replicate the effect of a retraction in partially reducing references to misinformation, which has been widely documented within the literature (Ecker, Lewandowsky, & Apai, 2011; Ecker, Lewandowsky, & Tang, 2010; Lewandowsky et al., 2012a), they may not have had consistent sensitivity in detecting differences between the two AQ groups.

In sum, despite the inconclusive findings from the current study, it remains possible that the scenarios did not place sufficient demand on participants’ ability to update their situation models and resolve ambiguities for any true difficulties in resolving ambiguity from the retraction to arise. Scenarios that are more complex may be more efficient in detecting differences between low-AQ and high-AQ individuals’ abilities. Lopez and Leekam (2003) suggested difficulty with ambiguous information in individuals with ASD may arise primarily due to having to hold two (or more) different representations in memory simultaneously, and subsequently having to select the most appropriate one to resolve the apparent ambiguity. Further investigation is clearly required to assess this possibility, particularly in the context of misinformation effects. This was the objective of Experiment 3, discussed in the next chapter.
CHAPTER 3

Do Low- and High-AQ Individuals Process Complex Ambiguous Information Differently?
As I discussed in Chapter 2, previous research using the post-event misinformation paradigm to investigate how individuals with ASD process misinformation has found little evidence to suggest greater reliance on suggestive post-event misinformation. However, the post-event misinformation paradigm does not allow for the assessment of memory updating ability per se. If there is limited memory updating ability in individuals with high levels of autistic-like traits, greater misinformation effects would be expected only in tasks that require individuals to revise and substitute existing information in memory. With regards to misinformation, the CIE paradigm allows for the assessment of memory updating ability, as individuals are required to update initial situation models of an unfolding event that have been formed based on initial misinformation with subsequent corrective information.

Using the CIE paradigm, Experiment 1 suggested that high-AQ participants continued to rely on misinformation following a retraction to a greater extent than low-AQ participants, which provides preliminary evidence to suggest that high-AQ individuals may experience greater difficulty updating their situation models that were formed based on initial information. However, this finding failed to replicate in various other scenarios in Experiments 1 and 2, and thus it is premature to conclude that individuals with high levels of autistic-like traits have reduced ability in updating situation models compared to individuals with low levels of autistic-like traits.

### 3.1. Processing Information with Multiple Representations in Memory

As noted in Section 2.8, it is possible that differences between low-AQ and high-AQ individuals in processing ambiguous information may be evident primarily in instances where individuals are required to hold multiple competing or incompatible representations of a single unfolding event in memory simultaneously. Using the homograph-reading task (see Chapter 4 for a detailed discussion), López and Leekam
(2003) found that individuals with ASD exhibited greater difficulty in selecting the
correct pronunciation of a homograph compared to typically-developing counterparts
(cf. also Happé, 1997; Henderson et al., 2011). This suggests that individuals with ASD
exhibit difficulty using surrounding context and integrating the information presented to
inform their responses.

However, López and Leekam (2003) also found that individuals with ASD were,
in fact, able to use contextual information to differentiate between alternative
interpretations of an arbitrary object on a visual-based task at a level comparable to their
typically-developing counterparts, thus indicating that they are able to utilise
surrounding contextual information under some circumstances. In this visual-based task,
children were shown a picture of a scene (e.g., a kitchen or an office), which was then
followed by a picture of an object (e.g., a water jug or a lemon). The children were
required to determine whether the object was likely to appropriately appear in the scene
(e.g., a water jug in a kitchen) or whether it is was unlikely to appear (e.g., a lemon in
an office). The visual-based task, therefore, required children to use the contextual
information provided by the picture of the scene in order to determine which object was
most appropriate. Unlike the homograph-reading task, however, the visual-based task
was not likely to elicit more than one representation of the scene or the object, and thus
did not require children to hold multiple representations of a single item in memory at
the same time. Due to the difference in performance across the two tasks, which both
required integration of contextual information, López and Leekam (2003) argued that
the specific difficulty with the homograph-reading task may be due to having to hold
two rival representations of a single item of information in memory simultaneously, and
further difficulty selecting between the two representations, rather than using contextual
information to support their understanding per se. Such conclusions have yet to be
further explored using more complex narratives such as those used in Experiments 1 and 2.

In order to assess whether individuals with ASD may have specific difficulties in holding two conflicting representations in memory simultaneously, it is necessary to evoke more than one representation of a single event. Neither the standard post-event misinformation paradigm nor the standard CIE paradigm, however, allows investigation of this, as neither paradigm involves two causal explanations regarding a single unfolding event. Experiment 3 therefore used an alternative CIE paradigm involving a single scenario with two different consecutively presented causal explanations: this alternative CIE paradigm will be referred to hereafter as the dual-cause approach.

Only one study has previously adopted the dual-cause approach within the misinformation literature, investigating misinformation effects in the general population: Cheung (2010) investigated whether a retraction was more or less efficient if the to-be-retracted misinformation was presented before or after valid event information, and if this ordering of the information affected participants’ subsequent post-retraction inferential reasoning regarding an unfolding event. Overall, the results showed that misinformation presented later (i.e., after valid event information) was more difficult to retract and prevailed more at recall compared to misinformation presented before valid event information (Cheung, 2010).

This finding is inconsistent with the event-model theory outlined in Chapter 2, which would predict that misinformation presented early (i.e., before valid event information) should be more difficult to retract due to difficulty updating situation models formed based on the initial misinformation (Palladino et al., 2001). Cheung (2010) instead argued that results were more consistent with predictions from a temporal distinctiveness account of memory. According to temporal distinctiveness theory, more recently presented items should be more readily retrieved than items
presented earlier. This is because as an item in memory recedes further into the past, its representation becomes less discriminable from neighbouring items and thus less distinctive (Bjork & Whitten, 1974; Crowder, 1976). An item’s distinctiveness at the time of recall will then determine its ease of retrieval (Bright-Paul & Jarrold, 2009; Brown, Neath, & Chater, 2007; Ecker, Brown, & Lewandowsky, 2015). It follows that the more recent cause will be stronger in memory and thus more difficult to retract. On a similar note, previous studies have proposed that multiple situation models of an unfolding event may exist in memory at the same time, and the situation model that is more accessible may thus influence subsequent reasoning about an event even when that it is incorrect (Schul & Mayo, 2014).

As I have discussed previously, individuals with ASD exhibit difficulties processing ambiguous information (e.g., Dennis et al., 2001; Ozonoff & Miller, 1996). In addition to this, López and Leekam (2003) speculated that such difficulties with ambiguous information in individuals with ASD may be evident primarily in situations that require selection between two different representations in memory. This suggests that individuals with ASD may have difficulty resolving ambiguity when two causal explanations of a single unfolding event are presented consecutively. On the one hand, if one of the causes is retracted, such a retraction may be helpful in reducing such ambiguity between the two causal explanations, as it would provide specific information about the validity of one of the causes. On the other hand, the situation model must be updated with the retraction, and it is possible that individuals with ASD may have difficulty doing so. No studies to date provide insight into this.

There is some evidence in the ASD literature that suggests individuals with ASD present with enhanced recency effects during memory recall. Previous studies using word lists presented multiple times have found that, relative to controls, individuals with ASD tend to recall information presented more recently to a greater extent than
information presented earlier on. In addition, individuals with ASD recall initial items in the word list to a lesser extent than do their typically-developing counterparts, thus suggesting reduced primacy (Boucher, 1981; Bowler, Gaigg, & Gardiner, 2008; Bowler, Limoges, & Mottron, 2009). Bowler and colleagues (2008) also found that individuals with Asperger’s Disorder recalled information presented more recently to a greater extent than initial information, and argued that this could arise from a reduced tendency to spontaneously access stored representations of initial information in memory during recall.

In sum, if individuals with ASD exhibit memory updating difficulties in situations featuring complex ambiguous information, they should show stronger reliance on retracted misinformation if two causes of an event are presented and one is retracted. Event-model theory additionally predicts that this should occur primarily when the first-presented cause is retracted. Temporal distinctiveness theory, by contrast, predicts that stronger misinformation effects should occur when the more recently-presented cause is retracted; this is further supported by findings of enhanced recency in ASD (although it should be noted that investigations into recency effects in recall typically use word lists rather than event narratives, which makes it difficult to determine whether their findings can be applied in the present context).

The dual-cause approach to investigate the effects of contradictory information regarding a single event will also allow investigation of López and Leekam’s (2003) speculation that difficulty processing ambiguous information in individuals with ASD is primarily due to difficulty selecting between more than one representation of a piece of information in memory, rather than difficulty using contextual information to resolve the ambiguity. Thus, the present study could corroborate López and Leekam’s (2003) findings using a more complex narrative task that may be more relevant (compared to the homograph-reading task) in everyday situations such as reading comprehension and
social interactions that may involve multiple interpretations of a person’s utterance. The results may thus provide further insight into the underlying basis of the difficulties associated with ASD.

3.2. Aim

The current experiment was conducted to further explore how individuals with low and high levels of autistic-like traits process ambiguity and update their memory within complex narrative texts, particularly when more than one representation of an unfolding event is made available. To this end, I adopted the dual-cause approach by presenting participants with two causes of a single event consecutively within the same narrative. Either one—the initial or the more recent—cause or neither cause was subsequently retracted, thus potentially providing information about how later information is used to update existing situation models to resolve ambiguity between two potentially contradictory representations of a single event.

3.3. Hypotheses

As no previous studies have adopted the current methodology within the ASD literature, the present study is largely exploratory. Based on the event-model theory of the CIE, which predicts initial information is particularly difficult to correct and update, if individuals with ASD have reduced memory updating ability, then, relative to low-AQ participants, high-AQ participants should make disproportionately more post-retraction references to the first cause because it is the initial information that would prevail in responses. On the other hand, in the case of temporal distinctiveness theory, which predicts more recent information prevails at recall, participants should make more post-retraction references to the second cause. Consistent with this prediction from the temporal distinctiveness theory, previous findings of enhanced recency in
individuals with ASD would suggest that individuals with high levels of autistic-like traits should rely on the second cause more in their inferential understanding of the scenario, thus resulting in more references to the second cause when there is no retraction of either cause. Additionally, a retraction of the second cause should be less efficient, resulting in more post-retraction references to the second cause.

3.4. Experiment 3

3.4.1. Method

Design

Experiment 3 comprised a 2 (AQ group) × 3 (retraction condition) × 2 (control factor: order of actual causes) between-subjects design. As per Experiments 1 and 2, participants were pre-screened based on level of autistic-like traits and subsequently assigned to a low-AQ or high-AQ group. Each participant received a fictitious scenario in the form of a news report, which centred upon the theme of a school bus accident, similar to that of Experiment 1 (and also, Cheung, 2010). The fictitious scenario used in Experiment 1 was adapted to present two causal explanations consecutively, stating that the school bus accident was due to either a burst front tyre (burst tyre; BT) or a violently merging car (merging car; MC). These causes were designed to be somewhat contradictory but not mutually exclusive. The second factor of interest was the retraction factor (no-retraction, retract-1, retract-2); this factor determined which of the two causes—the one presented first or the one presented second—was retracted and hence deemed misinformation. The no-retraction condition served as a control condition against which the effects of a retraction were assessed. An additional control factor was the presentation order of the two causal explanations (burst tyre – merging car, BT-MC; merging car – burst tyre, MC-BT); this served to ensure that the two causal explanations were used equally often in the two positions in the passage.
Similar to the procedure for Experiments 1 and 2, participants’ memory for and inferential understanding of the news report, and in particular their reliance on the critical causal information, were assessed with an open-ended questionnaire.

Participants

Participants were first-year psychology students from the University of Western Australia. Participants were pre-screened based on their level of autistic-like traits using the AQ questionnaire (Baron-Cohen et al., 2001) as in Experiments 1 and 2. In the present study, 1393 students first completed the AQ questionnaire ($M = 15.87$, $SD = 6.04$, range 2-38). Students from the lower and upper quartiles of the AQ distribution (using AQ cut-off scores of 14 or less or 22 or more) were invited to participate in the second phase of testing. The final sample consisted of $N = 283$ participants with a mean age of $M = 19.80$ years ($SD = 5.30$, range 16-56 years). The low-AQ group comprised 142 participants ($n = 96$ females) with a mean AQ score of 10.77 ($SD = 3.23$, range 1-14), and the high-AQ group comprised 141 participants ($n = 107$ females) with a mean AQ score of 25.45 ($SD = 3.67$, range 22-40). Autism quotient scores did not differ across conditions within each of the low-AQ ($p = .54$) and high-AQ ($p = .81$) groups. Participants were then randomly assigned to one of six experimental conditions (see Table 3.1). Participation was entirely voluntary, and all participants provided informed consent prior to beginning the experiment.

Table 3.1
The Six Experimental Conditions used in Experiment 3.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cause 1</th>
<th>Cause 2</th>
<th>Retracted cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. BT-MC, R-BT</td>
<td>Burst Tyre</td>
<td>Merging Car</td>
<td>Burst Tyre</td>
</tr>
<tr>
<td>2. BT-MC, R-MC</td>
<td>Burst Tyre</td>
<td>Merging Car</td>
<td>Merging Car</td>
</tr>
<tr>
<td>3. BT-MC, NR</td>
<td>Burst Tyre</td>
<td>Merging Car</td>
<td>No-retraction</td>
</tr>
<tr>
<td>4. MC-BT, R-BT</td>
<td>Merging Car</td>
<td>Burst Tyre</td>
<td>Burst Tyre</td>
</tr>
<tr>
<td>5. MC-BT, R-MC</td>
<td>Merging Car</td>
<td>Burst Tyre</td>
<td>Merging Car</td>
</tr>
<tr>
<td>6. MC-BT, NR</td>
<td>Merging Car</td>
<td>Burst Tyre</td>
<td>No-retraction</td>
</tr>
</tbody>
</table>

Note. BT, burst tyre; MC, merging car; R-BT, retraction of burst tyre; R-MC, retraction of merging car; NR, no retraction.
Materials

Scenario and Procedure. A fictitious report adapted from Cheung (2010) was presented to each participant individually, using a Microsoft PowerPoint presentation. The scenario detailed a school bus accident and consisted of 17 messages (see Table 3.2 and Appendix C). Each message was presented on an individual presentation slide for a fixed time to control for individual differences in encoding time. Following Cheung (2010), presentation time was set to 400 ms per word, allowing for comfortable reading without excessive slack time.

The report consecutively presented two causal explanations of the event, a burst tyre and a violently merging car. The presentation order of the two causal explanations was counterbalanced. Either the first-presented or the second-presented cause (or neither in the no-retraction control condition) was subsequently retracted. Table 3.2 shows the report including the retractions of the burst tyre and merging car themes when the first-presented cause was retracted. The retraction message was replaced by a neutral message in the no-retraction control conditions, which stated ‘A special report made by the police stated that both the cyclist and the bus-driver were in a stable condition’ (see Appendix C).

The interval between the misinformation and its retraction, and the retention interval of the retracted cause were kept constant. To this end, the causes were presented at different message positions depending on the retraction condition. In order to control for the retention interval between the retraction message and recall, the retraction message was presented as Message 15 in all conditions. The structure of the presentation of the causes and their retraction is shown in Table 3.3.
Table 3.2
Messages Used in the Scenario in Experiment 3 for the Retract-1 Condition.

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A report has come into the police headquarters on Tuesday about a serious accident involving a school bus on Spring St. The school bus had hit a cyclist on the side of the road before crashing into the window of a music store. The report was made by a driver who was driving past the scene of the accident.</td>
</tr>
<tr>
<td>2</td>
<td>An ambulance was dispatched to the scene immediately upon the report of the accident but due to bad road conditions from roadworks in the area, they arrived at the scene only after 15 minutes. Upon arrival, they began assessing the cyclist and the bus-drivers’ injuries, both of whom were found unconscious.</td>
</tr>
<tr>
<td>3</td>
<td>Police have stated that the school bus was apparently on its way back to Spring Oaks Primary School after an outing at the bowling centre. The school’s headmaster was contacted and he explained that the bus-driver has not been involved in an accident before.</td>
</tr>
<tr>
<td>4</td>
<td>The police further stated that both the cyclist and the bus-driver were seriously injured and had been taken to hospital immediately. A few of the school kids who had been in the bus sustained minor injuries.</td>
</tr>
<tr>
<td>5</td>
<td>The injured arrived at the nearby St. Joseph’s hospital, where the cyclist and the bus-driver were warded for further observation while all school kids were discharged after treatment. Family members of the victims involved in the accident had been contacted and informed of the situation.</td>
</tr>
<tr>
<td>6</td>
<td>At the scene of the accident, police interviewed a number of eyewitnesses, some of whom claimed to have heard squeaking and rumbling sounds and then saw the bus hit the cyclist.</td>
</tr>
<tr>
<td>7</td>
<td><strong>(Burst tyre).</strong> Police investigating the cause of the accident have released a report, stating that the bus-driver apparently lost control of the bus because a front tyre burst after a piece of scrap metal, believed to have originated from the adjacent construction site, lodged in the tyre.</td>
</tr>
<tr>
<td>8</td>
<td><strong>(Merging car).</strong> The police released a second statement regarding the cause of the accident, stating that the bus-driver apparently lost control during an emergency braking on loose gravel after a car had violently merged into his lane.</td>
</tr>
<tr>
<td>9</td>
<td>There was a gradual build-up of traffic in the Spring Street area due to the roadworks and police cordoning off the area of the accident. Drivers were advised to avoid the area and bystanders were advised not to crowd the area.</td>
</tr>
<tr>
<td>10</td>
<td>The media released a statement that this had been the third accident on Spring Street within 6 months and urged the local council to attend to this issue. They also appealed to all cyclists to wear a helmet at all times.</td>
</tr>
<tr>
<td>11</td>
<td>Police continued to review evidence and interview witnesses, including the school kids. Police had difficulty interviewing some school kids as some of them were distressed and crying due to the shock and were asking for their parents.</td>
</tr>
<tr>
<td></td>
<td><strong>(Merging car).</strong> The police released a second statement regarding the cause of the accident, stating that the bus-driver apparently lost control during an emergency braking on loose gravel after a car had violently merged into his lane.</td>
</tr>
<tr>
<td></td>
<td><strong>(Burst tyre).</strong> Police investigating the cause of the accident have released a report, stating that the bus-driver apparently lost control of the bus because a front tyre burst after a piece of scrap metal, believed to have originated from the adjacent construction site, lodged in the tyre.</td>
</tr>
</tbody>
</table>
Table 3.2 (continued)

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>After police had interviewed the school kids, a police van took them to the nearest police station. Their parents had been informed to pick their children up from the police station.</td>
</tr>
<tr>
<td>13</td>
<td>Police had to calm the owner of the music store, who was very upset about his shop window being broken and a valuable limited edition guitar being destroyed. He was attended to by paramedics.</td>
</tr>
<tr>
<td>14</td>
<td>The police were under some pressure to clear the scene as quickly as possible due to the upcoming rush hour. A tow truck had been called to tow the bus out of the music store but there was a delay due to the roadworks.</td>
</tr>
<tr>
<td>15</td>
<td><em>(Retract cause Burst Tyre).</em> A special report made by the police stated that the burst tyre was not the cause of the accident. It had actually burst upon impact with the road kerb after hitting the cyclist.</td>
</tr>
<tr>
<td></td>
<td><em>(Retract cause Merging Car).</em> A special report made by the police stated that though there had been other vehicles present at the scene, none had been causally involved in the accident.</td>
</tr>
<tr>
<td>16</td>
<td>More than three hours after the time of the accident, the police have cleared the scene and traffic on Spring Street slowly restored itself to normal.</td>
</tr>
<tr>
<td>17</td>
<td>Several days later, it has been revealed that both the cyclist and the bus-driver were making good progress in their recovery from the injuries sustained in the accident. The total damage was estimated to lie over $50,000.</td>
</tr>
</tbody>
</table>

*Note.* Messages 7 and 11 presented the alternative cause; that is, if Message 7 presented burst tyre, Message 11 presented merging car.

Table 3.3

Structure of the Presentation of the Causes and Their Retractions in the News Report used in Experiment 3.

<table>
<thead>
<tr>
<th>Retraction Condition</th>
<th>Cause 1 Message</th>
<th>Cause 2 Message</th>
<th>Retraction Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-retraction</td>
<td>5</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Retract-1</td>
<td>7</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Retract-2</td>
<td>3</td>
<td>7</td>
<td>15</td>
</tr>
</tbody>
</table>

*Note.* Retract-1, Retraction of cause 1; Retract-2, Retraction of cause 2. Bold numbers indicate retracted causes, non-bolded numbers indicate non-retracted causes.

Open-ended Questionnaire. The 18-item open-ended questionnaire used in the present study was identical to the questionnaire used for the school bus scenario in Experiment 1 with the following exception (see Table 3.4). One additional inference question relevant for the present scenario was included: ‘*Do you think this accident should lead the council to take any traffic-related measures? Why / Why not?*’.
total number of inference questions was thus ten. All questions were completed in the order presented in Table 3.4, with the exception of the final inference question which directly targeted the cause of the accident. This question was phrased like a fact-recall question and was hence presented last, after the fact-recall questions.

Table 3.4
Open-ended Questionnaire for the School Bus Scenario Used in Experiment 1

<table>
<thead>
<tr>
<th>Inference Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Who will most likely have to pay for the repairs of the school bus?</td>
</tr>
<tr>
<td>2. Why was the bus-driver unable to avoid the crash?</td>
</tr>
<tr>
<td>3. What do you think caused the squeaking and rumbling sounds before the bus hit the bicycle?</td>
</tr>
<tr>
<td>4. Why would the driver of the school bus be angry or upset?</td>
</tr>
<tr>
<td>5. What was the relevance of the road conditions?</td>
</tr>
<tr>
<td>6. Apart from the bus-driver and the pedestrian witnesses, who else should the police question?</td>
</tr>
<tr>
<td>7. Why would the school bus insurance refuse payments of the bicycle damage?</td>
</tr>
<tr>
<td>8. Why did the police investigations at the scene take so long?</td>
</tr>
<tr>
<td>9. Do you think this accident should lead the council to take any traffic-related measures? Why / Why not?</td>
</tr>
<tr>
<td>10. Why did the school bus hit the cyclist?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fact-recall Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. On which day did the accident occur?</td>
</tr>
<tr>
<td>2. Who reported the accident to the police?</td>
</tr>
<tr>
<td>3. Where did the school bus crash into after hitting the cyclist?</td>
</tr>
<tr>
<td>4. Where did the accident occur?</td>
</tr>
<tr>
<td>5. Which hospital were the injured taken to?</td>
</tr>
<tr>
<td>6. Why did the owner of the music store require medical assistance?</td>
</tr>
<tr>
<td>7. Where was the school bus coming from?</td>
</tr>
<tr>
<td>8. How long did it take until police had cleared the scene?</td>
</tr>
</tbody>
</table>

Open-ended Questionnaire Coding Procedure. The open-ended questionnaires were scored by the experimenter, who was blind to the conditions. The scoring process was identical to that of Cheung (2010). A subset of 30 questionnaires (5 from each condition) was then scored by a second scorer as an inter-rater reliability check. Inter-rater reliability was .92 for references made to the burst tyre, .96 for references made to the merging car, and .95 for the fact-recall questions.

Rating Task. An additional rating task was included to measure participants’ belief in the two causes (see Table 3.5). This novel measure consisted of 16 statements with a two-choice response style. Five statements presented the burst tyre theme and
five statements presented the merging car theme. Additionally, three statements presented a blending of the two causes, and three statements were completely false. Participants were to select either ‘Correct’ if they believed a statement to be completely correct, or ‘Incorrect’ if they did not believe the statement to be completely correct. Participants were instructed that any statement they did not believe to be completely correct should be answered ‘Incorrect’. This was done in order to ensure participants did not arbitrarily accept all statements as true, and that ‘Correct’ responses can be taken as an indication of participants’ true belief in the statement, and thus as an indication of their reliance on the critical causal information referred to in the statement.

The items in the rating task were presented in a fixed random order for all participants (see Table 3.5). Statements with the burst tyre theme (items 2, 4, 8, 11, 12) were designed to be rejected by participants in conditions where cause A was retracted and otherwise endorsed as correct. Similarly, the statements with the merging car theme (items 3, 5, 7, 10, 13) were designed to be rejected by participants in conditions where cause B was retracted and otherwise endorsed as correct.
Table 3.5
Rating Task Used in Experiment 3

<table>
<thead>
<tr>
<th>Cause A Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item 2.</strong> Police should check streets adjacent to the construction site for scrap metal and other dangerous objects.</td>
</tr>
<tr>
<td><strong>Item 4.</strong> A piece of scrap metal on the road was causally involved in the crash.</td>
</tr>
<tr>
<td><strong>Item 5.</strong> The accident was causally related to a blown tyre.</td>
</tr>
<tr>
<td><strong>Item 11.</strong> The building company operating the construction site should at least partially pay for the damage to the school bus.</td>
</tr>
<tr>
<td><strong>Item 12.</strong> The condition of the tyre causing the accident should be accessed.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cause B Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item 3.</strong> Police should check the license of the driver who merged in front of the bus.</td>
</tr>
<tr>
<td><strong>Item 5.</strong> The driver of the car causing the accident should be questioned.</td>
</tr>
<tr>
<td><strong>Item 7.</strong> Loose gravel on the road was causally related to the crash.</td>
</tr>
<tr>
<td><strong>Item 10.</strong> A violation of road rules by a car was causally involved in the crash.</td>
</tr>
<tr>
<td><strong>Item 13.</strong> The insurance of the car driver should at least partially pay for the damage to the school bus.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blended Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item 6.</strong> The bus-driver didn’t notice the car merging in front because he was focused on avoiding pieces of scrap metal on the road.</td>
</tr>
<tr>
<td><strong>Item 9.</strong> Loose gravel made it difficult for the bus-driver to regain control after the tyre burst.</td>
</tr>
<tr>
<td><strong>Item 16.</strong> The bus’ emergency braking failed because of a flat tyre.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wrong Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item 1.</strong> The cyclist merged in front of the bus.</td>
</tr>
<tr>
<td><strong>Item 14.</strong> The school bus crashed due to a malfunction of the brakes.</td>
</tr>
<tr>
<td><strong>Item 15.</strong> The driver fell unconscious at the wheel and the bus veered off course.</td>
</tr>
</tbody>
</table>

**Note.** Item number indicates position of the statement in the rating task.

The ‘blended statements’ presented a blend of both the burst tyre and merging car causes (items 6, 9, 16). The blended statements were included to provide additional information regarding the memory representations people form when facing partially contradictory (but not mutually exclusive) information, and how separate the two causal explanations are kept in memory. I expected these blended statements to be accepted as true in the no-retraction condition if participants blended information from both causal explanations. It is also possible for the blended statements to be accepted as true in the retraction conditions more so than the statements presenting only the retracted causes, as the non-retracted cause would remain true and participants may attempt to resolve the conflict caused by the retraction by blending the retracted cause with the valid cause.
The statements that were completely false (items 1, 14, 15) were designed to be rejected by all participants regardless of condition, containing information not alluded to in any of the messages in the scenario.

**Rating Task Coding Procedure.** The rating task was scored by the experimenter, who was blind to the conditions. A score of 1 was given for a ‘Yes’ response, and a score of 0 was given for a ‘No’ response for all statement types in each retraction condition.

**Digit Symbol Rotation.** The Digit Symbol Rotation test used in Chapter 2 was used in the same manner in the present study.

**General Procedure**

Participants first completed the Digit Symbol Rotation test, after which they read the news report. Following this, participants completed an unrelated word puzzle for approximately 10 minutes before completing the open-ended questionnaire and rating task, in that order. The entire testing session lasted approximately one hour.

### 3.4.2. Results

**Open-ended Questionnaire**

**Data Screening.** The data were screened for outliers based on participants’ fact-recall scores. Three participants who received a fact-recall score of zero and did not respond to all questions were removed. Two participants received fact-recall scores of zero but responded appropriately to the inference questions and were thus retained for analyses. The final sample for subsequent data analyses was thus $N = 280$.

**References to the Critical Causal Information.** A $2 \times 3$ MANOVA was conducted on participants’ references to cause 1 and references to cause 2, which served

---

6 All subsequent analyses were performed on data with and without these participants and the pattern of results did not differ. The results presented are thus inclusive of these two participants.
as the dependent measures, with AQ group (low-AQ vs. high-AQ) and retraction condition (no-retraction vs. retract-1 vs. retract-2) as the between-subjects factors. Mean inference scores for the low-AQ and high-AQ groups are presented in Figure 3.1. Overall, the analysis revealed a reliable effect of a retraction on both references to cause 1 and references to cause 2, $F(4, 546) = 8.38, p < .001, \eta_p^2 = .06$. That is, the number of references to cause 1 and cause 2 differed across the three retraction conditions. The low-AQ and high-AQ groups differed in the overall number of inferences, with the low-AQ group ($M = 2.58, SD = 1.51$) making more references overall than the high-AQ groups ($M = 2.27, SD = 1.51$), $F(2, 273) = 3.81, p = .02, \eta_p^2 = .03$. There was no significant interaction between retraction condition and AQ group, $F(4, 546) = 1.25, p = .29$.

---

7 An additional mixed-model ANOVA was performed with presentation order (cause A-B, cause B-A) as an additional between-subjects control factor. Contrary to expectations and previous findings (e.g., Cheung, 2010), there was an unexpected interaction between presentation order and retraction on the number of inferences. Upon closer inspection, however, the interaction affected only the no-retraction condition and thus, all analyses presented were conducted on data collapsed across both presentation orders.
Planned follow-up contrasts were performed to further investigate how the AQ groups differed in their reliance on the critical causal information. To this end, I conducted separate $2 \times 2$ interaction contrasts on references to cause 1 and references to cause 2 in the low-AQ group compared to the high-AQ group for each retraction condition. When there was no retraction of the causes, there was a significant interaction between the number of references to the two causes and AQ group, $F(1, 274) = 4.60, p = .03$. The low-AQ group made more references to cause 2 compared to cause 1, and this difference was larger than in the high-AQ group (which did not differ in the number of references made to either cause).

When cause 1 was retracted (i.e., retract-1), an interaction contrast showed that the two AQ groups did not differ in their referencing of causes 1 and 2,
Both the low-AQ and high-AQ groups made fewer references to cause 1 ($M = 1.43$, $SD = 1.81$) than to cause 2 ($M = 3.60$, $SD = 2.19$), $F(1, 274) = 36.28, p < .001$.

When cause 2 was retracted (i.e., retract-2), an interaction contrast showed no difference between the low-AQ and high-AQ groups, $F < 1$. There was also no difference between the number of references made to cause 1 and cause 2, $F < 1$.

To further assess participants’ updating of the critical causal information when there is a retraction, I conducted separate paired-samples contrasts on inference scores in the no-retraction condition compared to the retraction condition for cause 1 and cause 2 for each AQ group. For the low-AQ group, there was no difference between the number of references to cause 1 when there was no retraction compared to when cause 1 was retracted, $F < 1$, suggesting that retracting cause 1 did not reduce the number of references to that cause for the low-AQ participants. There was, however, a difference observed for cause 2, and the low-AQ group made fewer references to cause 2 when it was retracted ($M = 2.11$, $SD = .32$) than when there was no retraction of either cause ($M = 3.73$, $SD = .32$), $F(1, 274) = 12.89, p < .001$. This indicates that retracting cause 2 efficiently reduced the number of references to cause 2 for the low-AQ participants.

Whilst there was no effect of a retraction on references to cause 1 for the low-AQ group, the high-AQ group, on the other hand, made fewer references to cause 1 when it was retracted ($M = 1.46$, $SD = .27$) than when there was no retraction ($M = 2.38$, $SD = .26$), $F(1, 274) = 6.03, p = .01$. This indicates that retracting cause 1 reduced high-AQ participants’ reliance on cause 1. Similarly, the high-AQ group made fewer references to cause 2 when it was retracted ($M = 1.82$, $SD = .32$) than when there was no retraction of either cause ($M = 2.82$, $SD = .32$), $F(1, 274) = 4.95, p = .03$. This indicates that a retraction was efficient in reducing references to both cause 1 and cause 2 when
the respective causes were retracted in the high-AQ participants, whilst only a retraction of cause 2 was efficient in the low-AQ participants.

**Fact-recall**. Fact-recall scores are presented in Figure 3.2. A two-way ANOVA was conducted on fact recall scores with AQ group (low-AQ vs. high-AQ) and retraction condition (no-retraction vs. retract-1 vs. retract-2) as the factors. There was no difference in fact recall scores between the two AQ groups, $F < 1$, nor was there any difference between the retraction conditions, $F(2, 274) = 1.82$, $p = .16$, or an interaction between AQ group and retraction condition, $F < 1$.

![Figure 3.2. Mean fact-recall scores across groups (low-AQ vs. high-AQ) for each retraction condition. Retract-1, retraction of cause 1; Retract-2, retraction of cause 2. Error bars denote standard errors of the means.](image)

8 The presentation order of the causes was entered as an additional between-subjects control factor, and there was no difference in the pattern of results. The analyses were thus conducted without this factor.
Rating Task

As mentioned, the rating task consisted of four types of statements—(1) statements that presented the theme of cause A, (2) statements that presented the theme of cause B, (3) statements that presented both themes (i.e., blended statements), and (4) statements that were completely wrong. Rating task scores were converted into acceptance rates (i.e., the proportion of ‘Yes’ responses), which reflected participants’ endorsement of each statement type (see Section 3.4.1 for details). Acceptance rates of each statement type in each retraction condition for the low-AQ and high-AQ groups are presented in Table 3.6 and Table 3.7, respectively.

Table 3.6
Acceptance Rates of Each Statement Type for Each Retraction Condition (No-retraction, Retract-1, Retract-2) for the Low-AQ group

<table>
<thead>
<tr>
<th>Statement Type</th>
<th>Retraction Condition</th>
<th>Cause 1</th>
<th>Cause 2</th>
<th>Blended</th>
<th>Wrong</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No-retraction</td>
<td>.65</td>
<td>.83</td>
<td>.34</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>Retract-1</td>
<td>.52</td>
<td>.78</td>
<td>.32</td>
<td>.09</td>
</tr>
<tr>
<td></td>
<td>Retract-2</td>
<td>.75</td>
<td>.60</td>
<td>.31</td>
<td>.08</td>
</tr>
</tbody>
</table>

*Note.* Retract-1, cause 1 is retracted; Retract-2, cause 2 is retracted.

Table 3.7
Acceptance Rates of Each Statement Type for Each Retraction Condition (No-retraction, Retract-1, Retract-2) for the High-AQ group.

<table>
<thead>
<tr>
<th>Statement Type</th>
<th>Retraction Condition</th>
<th>Cause 1</th>
<th>Cause 2</th>
<th>Blended</th>
<th>Wrong</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No-retraction</td>
<td>.70</td>
<td>.74</td>
<td>.34</td>
<td>.15</td>
</tr>
<tr>
<td></td>
<td>Retract-1</td>
<td>.51</td>
<td>.79</td>
<td>.38</td>
<td>.09</td>
</tr>
<tr>
<td></td>
<td>Retract-2</td>
<td>.63</td>
<td>.60</td>
<td>.35</td>
<td>.18</td>
</tr>
</tbody>
</table>

*Note.* Retract-1, cause 1 is retracted; Retract-2, cause 2 is retracted.

Initially, a 4 (statement type) × 2 (AQ group) × 3 (retraction condition) mixed-factorial ANOVA was conducted on the acceptance rates, with statement type as a within-subjects factor, and AQ group (low-AQ vs. high-AQ) and retraction condition
(no-retraction vs. retract-1 vs. retract-2) as between-subjects factors. There was a reliable effect of retraction on the participants' likelihood of endorsing statements as true, $F(2, 274) = 3.42, p = .03, \eta^2_p = .02$. There was no difference between the low-AQ and high-AQ groups' responses, nor was there a significant interaction between retraction condition and AQ group, both $F < 1$.

Overall, there was a reliable effect of the statement type on participants' endorsement of the statements as true, with cause 1 and cause 2 endorsed as true more than the blended and wrong statements across both AQ groups, $F(3, 822) = 301.66, p < .001, \eta^2_p = .52$. There was also a reliable interaction between statement type and retraction condition, $F(6, 822) = 7.94, p < .001, \eta^2_p = .05$, which indicates that participants' endorsement of the statements as true differed depending on the retraction condition. There was, however, no interaction between statement type and AQ group, $F(3, 822) = 1.43, p = .23$, nor was there a reliable three-way interaction, $F(6, 822) = 1.73, p = .11$.

Planned follow-up contrasts were conducted to further investigate whether there was a difference between the acceptance rates for cause-1 and cause-2 statements across both AQ groups. Overall, there was greater endorsement of cause-2 statements ($M = .72, SD = .33$) than cause-1 statements ($M = .63, SD = .33$), $F(1, 274) = 12.42, p < .001$. Follow-up contrasts also revealed the blended statements ($M = .34, SE = .02$) were accepted to a lesser extent overall than cause-1 statements, $F(1, 274) = 161.91, p < .001$, and cause-2 statements, $F(1, 274) = 286.77, p < .001$.

To further investigate whether there were any differences between the low-AQ and high-AQ groups in their response pattern across the statement types in the rating task, follow-up $2 \times 2$ interaction contrasts similar to those conducted on the open-ended questionnaire data were also conducted on the rating task scores. Contrary to the open-ended questionnaire data, there were no significant differences between the low-AQ and
high-AQ groups in their endorsement of the cause-1 statements vs. cause-2 statements when there was no retraction, $F(1, 274) = 2.73, p = .10$, when cause-1 was retracted, $F < 1$, or when cause-2 was retracted, $F(1, 274) = 1.86, p = .17$.

When there was no retraction, the low-AQ participants were more likely to endorse cause-2 statements ($M = .83, SD = .67$) than cause-1 statements ($M = .65, SD = .84$), $F(1, 274) = 8.01, p < .01$. The high-AQ participants, on the other hand, did not show a preference for endorsing either cause-1 or cause-2 statements as true, $F < 1$. These findings corroborate those of the inference scores, which also showed that the low-AQ participants made more references to cause 2 than cause 1 when there was no retraction, whilst the high-AQ participants did not show a preference for either cause.

As mentioned earlier, the blended statements were designed to assess the extent of blending of the critical pieces of causal information. To this end, I investigated whether the two AQ groups differed in their endorsement of the blended statements in each retraction condition. There was no difference between the low-AQ and high-AQ groups when there was no retraction, $F < 1$, when cause 1 was retracted, $F(1, 274) = 1.19, p = .28$, and when cause 2 was retracted, $F < 1$.

There was also no difference between the low-AQ and high-AQ groups in their endorsement of wrong statements in the no-retraction and retract-1 conditions, both $F < 1$. There was, however, a significant difference between the two AQ groups in the retract-2 condition, $F(1, 274) = 6.42, p = .01$, where the low-AQ participants were less likely to endorsement the wrong statements as true ($M = .08, SD = .50$), compared to the high-AQ participants ($M = .18, SD = .50$).
Digit Symbol Rotation

The two groups did not differ in general ability based on their composite scores on the Digit Symbol Rotation test, $t(278) = 1.45, p = .15$. Thus, the above results are not due to differences in general ability.

3.5. Discussion

The current study was conducted to explore how individuals with low and high levels of autistic-like traits resolve ambiguity between two different representations of a single event held concurrently in memory, and whether they differed in their reliance on misinformation when it was presented before or after valid event information. To introduce more than one mental representation of a single event in memory, I presented participants with an unfolding event that contained two causal explanations, and subsequently retracted either or none of the causes. This method not only allowed me to further investigate memory updating ability using the CIE paradigm, but it also enabled the investigation of whether previously-documented difficulties with ambiguous information in individuals with ASD extends to more complex narratives when more than one mental representation must be held in memory simultaneously (cf. also Happé, 1997; López & Leekam, 2003).

As stated in the introduction of this chapter, the current experiment was largely exploratory as no previous studies have adopted this novel CIE paradigm to individuals with low and high autistic-like traits. However, based on the event-model theory of the CIE, if high-AQ individuals have impaired memory updating ability, a retraction of cause 1 should be less efficient and thus result in more post-retraction references to cause 1. On the other hand, if high-AQ individuals exhibit more post-retraction references to cause 2, this would indicate a retraction of cause 2 is less efficient resulting in greater reliance on cause 2. Such findings would then be consistent with
predictions from a temporal distinctiveness theory point of view, and previous findings of enhanced recency in individuals with ASD.

Consistent with the overall findings from Chapter 2, the results of Experiment 3 do not provide any evidence to suggest high-AQ participants have greater difficulty updating situation models in light of a retraction compared to low-AQ participants: retractions appeared to reduce both low-AQ and high-AQ participants’ reliance on misinformation to a similar extent. Thus, holding more than one mental representation of an event in memory did not appear to make the updating of situation models more difficult for the high-AQ participants.

Interestingly, however, in the no-retraction control condition, low-AQ and high-AQ participants differed in their references to cause 1 and cause 2. In this condition, neither cause 1 nor cause 2 were deemed incorrect, and thus both causes remained credible. When neither cause was retracted, the low-AQ participants made more references to cause 2 than cause 1 in their subsequent inferential reasoning, suggesting that cause 2 was more dominant and influential in their memory than cause 1. This response pattern was not evident in the high-AQ participants who did not exhibit any preference for either cause, and were equally likely to refer to cause 1 or cause 2 in their subsequent inferential reasoning. This differential response pattern between the low-AQ and high-AQ participants suggests that when faced with ambiguous and somewhat contradictory information within a narrative of an unfolding event, the high-AQ participants have greater difficulty resolving the ambiguity between cause 1 and cause 2 compared to low-AQ participants. This may reflect a tendency in low-AQ participants to assume later information (i.e., cause 2) supersedes earlier information (i.e., cause 1), allowing them to spontaneously update their situation models to resolve the ambiguity. The observed pattern is also consistent with a difficulty to resolve ambiguity in the high-AQ participants relative to the low-AQ participants, who may be especially
inclined to spontaneously update their situation models to resolve ambiguity (cf. Ecker, Lewandowsky, Cheung, & Maybery, 2015).

These findings are consistent with previous studies that have shown individuals with ASD experience difficulties with information requiring reinterpretation of the initial representation of an event (Baron-Cohen, 1997; Jolliffe & Baron-Cohen, 1999b), and have difficulty resolving ambiguity between different mental representations when multiple representations of a single item must be held in memory simultaneously (Happé, 1997; cf. also López & Leekam, 2003).

With regards to the ability to update situation models following corrective information, I turn to the findings when either cause 1 or cause 2 was retracted. Whilst the two AQ groups displayed differences in the number of references made to cause 1 and cause 2 when there was no retraction, there was no difference between the low-AQ and high-AQ groups’ reliance on either cause when there was a retraction. That is, neither the low-AQ nor high-AQ participants found it particularly difficult to update their situation models following a retraction of the critical causal information. While a retraction of cause 1 was efficient in reducing post-retraction reliance on cause 1 only in the high-AQ participants but not the low-AQ participants, it seems likely that this effect merely reflects the low-AQ participants’ tendency to rely less on cause 1 even when there is no retraction.

While overall, there was a higher number of references made to cause 2 than to cause 1, the high-AQ participants made fewer references overall to cause 2 than the low-AQ participants. This finding is inconsistent with previous suggestions of enhanced recency (i.e., increased recall of more recent items) and reduced primacy (i.e., decreased recall of initial items) in individuals with ASD (Bennetto, Pennington, & Rogers, 1996; Boucher, 1981; Bowler et al., 2009; Poirier, Martin, Gaigg, & Bowler, 2011). If high-AQ participants exhibited enhanced recency, this would also predict that a retraction of
cause 2 should be less effective, as the information would be stronger in memory. On the contrary, retracting cause 2 reliably reduced reliance on cause 2 in subsequent inferential reasoning for both the low-AQ and high-AQ participants to a similar degree. Furthermore, high-AQ participants did not differ in the number of post-retraction references to cause 1 or cause 2 when the respective cause was retracted.

Although the current findings are inconsistent with predictions based on enhanced recency and reduced primacy in individuals with ASD, it is important to note the difference in methodology in the current experiment and previous studies. Previous studies have typically used word lists to assess learning of information repeated over multiple trials. Unlike the current experiment using misinformation and its retraction, word lists do not prompt individuals to update information in existing memory representations per se, but rather assess general mnemonic maintenance and retrieval abilities.

Participants also completed a rating task to further assess their ability to update their situation models accordingly. The findings from the rating task largely corroborated the findings from the open-ended questionnaire data. The high-AQ participants were less likely to endorse cause-2 statements as true compared to the low-AQ participants, particularly when neither cause was retracted. This is consistent with the finding in the open-ended questionnaire data that the low-AQ participants made more references to cause 2 than cause 1 when there was no retraction, whilst the high-AQ participants did not exhibit any particular preference for either cause. Thus, the rating task provides further supportive evidence of the suggestion that the high-AQ participants may have greater difficulty resolving the ambiguity in the narrative and/or low-AQ participants may be more inclined to spontaneously update their situation models with the more recent information.
The rating task additionally indicated that compared to the low-AQ participants, high-AQ participants were more likely to endorse the wrong statements when cause 2 was retracted (the low-AQ and high-AQ participants did not differ when there was no retraction and when cause 1 was retracted). This supports the suggestion that the high-AQ participants may have been more confused by the multiple causes, thus endorsing incorrect responses to a greater degree; however, it is unclear why this occurred only when cause 2 was retracted, as this should have confused low-AQ individuals (who tended to rely more on cause 2 in general) just as much.

One advantage of the rating task is its potential to provide information regarding the amount of blending of the causal information in participants’ situation models. If high-AQ participants did indeed have memory updating difficulties, they should exhibit greater blending of the information and thus endorse the blended statements as true to a higher degree than the low-AQ participants. This, however, was not evident. I note, however, that this was the first application of such a rating task in the CIE literature, and it may have lacked sensitivity in detecting differences, if any, between the low-AQ and high-AQ participants.

In sum, although the low-AQ and high-AQ participants did not appear to differ in their post-retraction reliance on misinformation, the present results suggest that high-AQ participants have greater difficulty resolving ambiguity in an unfolding event when two representations of the same event must be held in memory simultaneously, and both remain plausible. Whilst low-AQ participants tended to rely on later information (i.e., cause 2) more so than initial information (i.e., cause 1) in their subsequent inferential reasoning, the high-AQ participants did not show any marked preference for either cause 1 or cause 2. As this is the first study to adopt this novel CIE approach in individuals with low and high levels of autistic-like traits, further investigation is required, particularly with a clinical sample. Nevertheless, it provides suggestion that
individuals with high levels of autistic-like traits may have difficulty resolving ambiguity between two possible representations of a single event, and subsequently respond differently to individuals with low levels of autistic-like traits in inferential reasoning tasks.
CHAPTER 4

Updating Situation Models of Initial Interpretations of Homographs in Sentences in Low- and High-AQ Individuals
In the experiments presented in Chapters 2 and 3, I investigated whether low-AQ and high-AQ individuals may differ in their ability to update situation models of an unfolding event using the CIE paradigm. I presented participants with misinformation and explored if high-AQ participants, relative to low-AQ participants, may have greater difficulty updating situation models of an unfolding event in light of a retraction, and subsequently using this updated situation model to inform their responses in later reasoning regarding the event. As discussed in the previous chapters, individuals with ASD have difficulty with information that requires non-literal interpretations, or reinterpretation of initial information. This raised the question of whether this difficulty arises from deficiencies in memory updating, or more specifically, impairments in updating situation models already held in memory.

Contrary to expectations, Experiments 1 and 2 found no clear difference in post-retraction reliance on misinformation between the two AQ groups; that is, the high-AQ participants did not appear to have any greater difficulty updating information in their existing situation models than the low-AQ participants. There may thus not be any memory updating deficit in individuals with high levels of autistic-like traits. However, it is also possible that difficulties arise primarily when two potentially opposing mental representations about a single event are held in memory, and individuals are required to resolve the ambiguity without the ‘aid’ of a retraction. The results from Chapter 3 support this notion. When there was no retraction of either of two causes, and thus both causes could be assumed to be true, low-AQ and high-AQ participants differed in their pattern of responses. Whilst the low-AQ participants referred to the second cause to a greater extent than the first, the high-AQ participants showed no preference for either cause.

This pattern of results is consistent with suggestions that individuals with ASD show no general deficit in contextual integration (Bowler et al., 2008; Saldaña & Frith,
but show atypical performance when there are two or more mental representations of the same entity within memory simultaneously (see López & Leekam, 2003). It is important to investigate this further, particularly as the novel dual-cause design used in Experiment 3 has not previously been used with reference to a broader autism phenotype, or in individuals with ASD. One other way to investigate an individual’s ability to process ambiguous information is the homograph-reading task, which was used in Experiment 4 to investigate how individuals with low and high levels of autistic-like traits process ambiguous information in a more established task that has been used previously in both individuals with ASD and individuals with low and high levels of autistic-like traits.

4.1. Homograph-reading Task

The homograph-reading task (Frith & Snowling, 1983) has been used extensively within the ASD literature to investigate how individuals with ASD process ambiguous information presented in text (Brock & Bzishvili, 2013; Happé, 1997; Jolliffe & Baron-Cohen, 1999b; López & Leekam, 2003), particularly with regard to evaluating the WCC theory of ASD. A homograph is a word associated with multiple meanings (Happé, 1997). One example of a homograph is the word *date*, which can refer to the particular day, month, and year but can also refer to the dried fruit, a social appointment, or in fact the person with whom one has a social appointment. As there are multiple meanings associated with a homograph, there is typically a dominant meaning and one or multiple subordinate meanings. In the earlier example *date*, the calendar date is the dominant meaning, while the fruit and appointment meanings are the subordinate meanings. Swaab, Brown, and Hagoort (2003) suggested that a homograph’s dominant meaning is activated to some extent at all times, and exposure to the homograph brings the dominant meaning to the reader’s awareness. When a subordinate meaning is
relevant, the appropriate meaning is usually derived from the surrounding contextual information (Happé, 1997). In some cases, a homograph may involve a different pronunciation depending on its meaning. For example, while the pronunciation of the word *date* remains the same regardless of meaning, the word *tear* requires different pronunciations of the word depending on the meaning evoked (e.g., damage to a fabric or tissue, or the liquid excreted while crying; Brock & Bzishvili, 2013; Hala et al., 2007).

The homograph-reading task involves reading the homographs in isolation (i.e., the homograph is presented by itself) to assess awareness of the multiple meanings and associated pronunciations. The homographs are then presented in sentences that are designed to elicit either the dominant or the subordinate meaning(s). The homograph typically occurs early in the sentence, thus eliciting the dominant meaning. However, as the reader continues, the information contained in the latter part of the sentence may be consistent with the initial dominant meaning, or the disambiguating context may lead the reader to derive the homograph’s subordinate meaning (Tabossi & Zardon, 1993). Often, homographs with varying pronunciation are used, and the main variable of interest in the homograph-reading task is the reader’s pronunciation of the homograph. That is, the correct pronunciation would indicate that the reader has taken the context into account and that his/her understanding of the homograph’s meaning is consistent with the sentence’s intention.

As mentioned earlier, the homograph-reading task has been widely used to investigate how individuals with ASD process ambiguous information in text, and whether they are able to use surrounding context to facilitate their understanding of the homograph, and to provide the correct pronunciation. Overall findings show impaired performance on the homograph-reading task in individuals with ASD compared to typically-developing individuals, and it has previously been argued that this is due to
difficulties integrating contextual information (e.g., Happé, 1997; Loukusa & Moilanen, 2009).

In their original task, Frith and Snowling (1983) presented children with ASD 10 sentences that contained one of five homographs. Half the sentences presented the homograph in its dominant meaning, with the remaining half presenting the homograph in its subordinate meaning. Results showed that children with ASD were able to provide the correct pronunciation of the homograph if it was presented in its dominant meaning. On the other hand, when the subordinate meaning was intended, they performed worse than the control group children. The authors concluded that children with ASD exhibited difficulty on the task due to deficient ability in using the sentence context to inform their responses where the subordinate meaning of the homograph was required.

Using the same materials, however, Snowling and Frith (1986) provided participants with a training session that served as a warning that the homographs may appear in subsequent sentences. With this warning, individuals with ASD performed comparably to typically-developing individuals. Snowling and Frith (1986) thus concluded that difficulties on the homograph-reading task could be reduced if individuals with ASD were explicitly oriented to the task and the potential ambiguity of the homograph, which served to facilitate performance as they were able to learn the task requirements during the training session. This then suggests that individuals with ASD are, in fact, able to integrate contextual information under certain conditions.

As mentioned in previous chapters, various tasks that have been used to investigate how individuals process ambiguous information have confounded ambiguity and the presence of social information (Happé, 1994). To address this, Happé (1997) used the homograph-reading task and divided her participants into three groups based on ToM ability, namely those who failed ToM tasks, those who were able to pass first-order ToM tasks (i.e., understanding others’ thoughts), and those who were able to pass
second-order ToM tasks (i.e., inferring what another person will think about a third person’s thoughts). In addition, Happé (1997) also ensured the sentences used in the homograph-reading task did not contain social or mentalistic information that may place individuals with ASD at a disadvantage. If the reduced performance on the homograph-reading task was due to difficulty processing ambiguous information and using contextual information in individuals with ASD, then individuals who pass ToM tasks should show difficulty on the homograph-reading task as much as individuals who do not pass ToM tasks (assuming contextual integration and ToM abilities are independent). Indeed, Happé (1997) found that performance on the homograph-reading task was impaired in all participants with ASD, regardless of their ToM ability, thus suggesting ToM did not play a role in the findings of Frith and Snowling (1986) of impaired performance on the homograph-reading task. Many studies have since used the homograph-reading task, and have reported consistent results (Burnette et al., 2005; Jolliffe & Baron-Cohen, 1999b; Saldaña & Frith, 2007).

4.2. Explaining Performance on the Homograph-reading Task

As mentioned, the WCC theory of ASD has typically been used to account for the impaired performance on the homograph-reading task exhibited by individuals with ASD (Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 1999b). According to WCC theory, difficulty on this task arises from the inability to use contextual information to inform correct interpretation of the homograph’s meaning. One would then expect individuals with ASD to perform poorly on various tasks that require consideration of surrounding contextual information to provide correct responses.

This, however, is not always the case, and studies have suggested other abilities may also play a role in performance on the homograph-reading task (Happé & Frith,
As mentioned in Chapter 3, in addition to the homograph-reading task, López and Leekam (2003) also presented children with ASD and typically-developing children with a visual-based context task that also required contextual integration. In the visual-based context task, for example, the children were asked to determine whether an object (e.g., a water jug) was likely to appear in a previously-presented visual context scene (e.g., a kitchen; see also Section 3.1 for a discussion), thus requiring them to take the context of the scene into account (López & Leekam, 2003). If difficulty deriving the correct subordinate meaning of a homograph is due to deficient contextual integration, then the children with ASD should also fail at the visual-based context task, in addition to the homograph-reading task (López & Leekam, 2003). Contrary to this, results showed impaired performance was specific to the homograph-reading task. López and Leekam (2003) further noted that only the homograph-reading task involved holding multiple representations of the same entity in memory simultaneously (i.e., dominant and subordinate meanings of the homograph), whereas the visual-based context task required only the use of context to determine whether the stimulus (e.g., a picture of a water jug) was appropriate for the context (e.g., a scene of a kitchen). López and Leekam (2003) thus argued that difficulty on the homograph-reading task may lie within the ambiguity and the associated need to select between multiple representations of a single entity to resolve the ambiguity, rather than using context per se.

Henderson and colleagues (2011) also reported findings that were inconsistent with predictions from WCC theory. They used semantic priming of homonyms (i.e., words such as date that are identical in pronunciation but are associated with multiple meanings) to investigate the ability of children with ASD to use semantically-relevant contextual information. Henderson and colleagues (2011) manipulated the presentation interval between a disambiguating prime (e.g., a sentence containing the homonym) and
a target picture participants were required to name. When the target picture occurred shortly after the prime, the prime sentence facilitated the correct naming of the target picture in children with ASD. This shows that the children with ASD were sensitive to sentence context, and were able to utilise this information to activate the appropriate meaning of the homonym, which in turn facilitated picture naming if the prime and target picture occurred in close temporal proximity. Such findings thus suggest that the WCC theory may not offer an adequate account of diminished performance on the homograph-reading task. However, further studies are required to substantiate this claim.

An alternative explanation is the possible role of set-shifting ability. Hala and colleagues (2007) adapted the homograph-reading task and presented the homograph twice to children with ASD, with priming cues that elicited the dominant or subordinate interpretation of the homograph. Hala and colleagues found that children with ASD performed comparably to typically-developing children when the homograph was first presented. This shows they were able to use contextual information to disambiguate the correct pronunciation of the homograph, which is contrary to the predictions of WCC theory and many previous findings (cf. Jolliffe & Baron-Cohen, 1999b; López & Leekam, 2003; Saldaña & Frith, 2007). However, upon the homograph’s second presentation (during which the alternative interpretation would be required), children with ASD performed worse than typically-developing children. In fact, Hala and colleagues (2007) found that children with ASD tended to perseverate on their initial interpretation and pronunciation of the homograph. This suggests that children with ASD may have difficulty shifting from their first interpretation of the homograph. The authors thus concluded that executive functioning difficulties, namely set-shifting ability, may play a significant role in performance on the homograph-reading task.

Happé and Frith (2006) also speculated the role of set-shifting ability, and questioned whether difficulty with the homograph-reading task could be due to
difficulties shifting between local and global processing fluidly during the task (see also Rinehart et al., 2000). As I have discussed in the previous chapters, individuals with ASD have impaired set-shifting ability (Bennetto et al., 1996; Ozonoff et al., 2004; South, Ozonoff, & McMahon, 2007) which should be considered when assessing their performance on the homograph-reading task. The role of set-shifting ability in the homograph-reading task is not limited to instances where the homograph is presented twice; set-shifting also seems relevant when the homograph is presented only once. Upon initial exposure of the homograph, the dominant meaning of the word is most often activated and the sentence is thus interpreted based on the dominant meaning, thus processing the homograph in isolation (Henderson et al., 2011). However, upon reading the remainder of the sentence, which may be incompatible with the initial interpretation of the homograph, the individual must then switch to interpreting the homograph in a global sense in relation to the entire sentence and contextual information (see also Happé & Frith, 2006).

On a related note, memory updating may also explain performance on the homograph-reading task, though this should be differentiated from set-shifting ability, the latter of which does not highlight the need to revise and update initial interpretations. As I have mentioned, when the latter part of a sentence is suggestive of a homograph’s subordinate meaning, individuals must update their initial representation—which would typically be based on the dominant meaning with a representation based on the homograph’s subordinate meaning. Individuals with ASD may have trouble updating their representation of the homograph in memory to allow reinterpretation of its meaning. It is currently unclear from such findings whether difficulty on the homograph-reading task may lie with contextual integration, set-shifting ability, or with the updating of initial interpretations of the homograph. Although it was outside the scope of this thesis to attempt to differentiate between these
various accounts of performance on the homograph-reading task, I will be taking a memory updating perspective.

No studies to date have taken the memory updating perspective in regards to the homograph-reading task, and few studies have used the homograph-reading task to investigate ambiguity resolution with reference to a broader autism phenotype. To this end, I presented low-AQ and high-AQ participants with ambiguous and non-ambiguous sentences containing homographs. The beginning of the sentences was designed to elicit the homograph’s dominant meaning. In the ambiguous sentences, the latter part of the sentences was inconsistent with the dominant meaning and instead elicited the homograph’s subordinate meaning, thus requiring updating of the initial interpretation of the homograph. The non-ambiguous sentences, on the other hand, contained information consistent with the homograph’s dominant meaning.

Whilst previous studies have traditionally recorded pronunciation accuracy of the homograph as the main index of performance, more recent studies have focused on other outcome measures. For example, Caruana and Brock (2014) used eye-movement tracking analyses. They recruited low-AQ and high-AQ individuals to investigate whether a homograph influenced where participants focused during reading, and if fixation duration depended on whether the homograph was used in its dominant or subordinate meaning. Caruana and Brock (2014) found that low-AQ and high-AQ participants did not differ in their eye-gaze patterns during their reading of the sentences, regardless of whether the dominant or subordinate meaning of the homograph was used. However, the authors also noted that fixation durations on the homograph did not differ between the ambiguous and non-ambiguous sentences, which suggests their ambiguity manipulation was unsuccessful, thus making it difficult to ascertain whether or not the two AQ groups truly differed. Reading times and reaction times have also been used to measure performance on the homograph-reading task (Hala et al., 2007; Henderson et
al., 2011; López & Leekam, 2003). Hala and colleagues (2007) investigated priming effects on the homograph-reading task and measured participants’ time taken to pronounce the homographs, in addition to accuracy of pronunciation. The authors found that when paired with a semantically-related prime, children with ASD responded quicker to the homographs than when they were paired with a non-related prime, a pattern of performance that was comparable to that of typically-developing children (Hala et al., 2007). Reading times, which I have used in the current experiment, have also been found to be sensitive to differences in reading comprehension ability and the ability to understand pragmatic language (Kurby & Zacks, 2008; Saldaña & Frith, 2007). In addition, as an implicit behavioural measure, using reading time as a measure allows investigators to overcome factors that may interfere with participants’ responses, such as output interference in memory-based measures (see Kurby & Zacks, 2008, for a review). Previous research has shown that results from reading time measures largely corroborate those of other measures such as verbal responses and under some circumstances may be more sensitive to subtle differences between participant groups (Rinck & Weber, 2003).

4.3. Aim

The primary aim of the present study was to further investigate memory updating ability in individuals with low and high levels of autistic-like traits. I primarily sought to extend the findings from the no-retraction condition of Experiment 3, which showed that when presented with two causes of an unfolding event, the low-AQ participants made more references to the second rather than the first cause, whereas the high-AQ participants did not show a preference for either of the causes. It seems that the low-AQ participants had a greater tendency to assume the second cause as superseding the first cause, whilst the high-AQ participants appeared to remain in a more confused
state. I was thus interested to investigate whether this preference for one cause may also be apparent using a more established task such as the homograph-reading task, and whether low-AQ and high-AQ participants may differ in their ability to update their initial interpretations of the homograph’s meaning.

A secondary aim was to extend previous findings of difficulties on the homograph-reading task in individuals with ASD to a broader autism phenotype using a sample of individuals with low and high levels of autistic-like traits. I also aimed to avoid a potential confound with social factors (cf. Happé, 1997), and ensured the sentences differed in perceived ambiguity (cf. Caruana & Brock, 2014).

4.4. **Hypothesis**

I expected the reading times of ambiguous sentences to be higher than those of the non-ambiguous sentences for both the low-AQ and high-AQ participants. Although Caruana and Brock (2014) reported no difference between low-AQ and high-AQ individuals in reading ambiguous sentences containing homographs, it is noted that their ambiguity manipulation was unsuccessful. Thus, I expected that, with more stringent control of the ambiguity manipulation and making the ambiguity more salient, participants should take longer to read ambiguous sentences compared to non-ambiguous sentences, and this difference should be greater for the high-AQ participants relative to the low-AQ participants. This hypothesis was based on the assumption that high-AQ participants should experience greater difficulties than the low-AQ participants to update their initial situation model based on their first (i.e., dominant meaning) interpretation of the homograph.
4.5. **Experiment 4**

4.5.1. **Method**

**Design**

The task adopted a 2 (AQ group) × 3 (sentence type) mixed design. As in Experiments 1 to 3, participants were assigned to either a low-AQ or high-AQ group based on their pre-screening score on the AQ. Each participant received three types of sentences: ambiguous, non-ambiguous, and control (see below for more details regarding the sentence types); sentence type thus served as a within-subjects factor.

**Participants**

The same participants who participated in Experiment 2 completed the present task. Descriptive statistics for the low-AQ and high-AQ groups are presented in Section 2.7.1 of Chapter 2.

**Materials**

**Sentences.** Forty ambiguous sentences intended to convey the subordinate meaning of a homograph were used in this task (see Appendix D). Of these, 30 were taken from Caruana (2011; see also Kalikow, Stevens, & Elliott, 1977), and ten were newly created. The set of ten new homographs were selected based on the words’ $u$-values, to ensure they were in a similar range to Caruana’s (2011) materials. A homograph’s $u$-value indicates how ambiguous a homograph is, and is calculated as the ratio of the endorsements of each meaning associated with the homograph; the higher the $u$-value is, the more ambiguous is the homograph (Twilley, Dixon, Taylor, & Clark, 1994). The $u$-values of the homographs used in the ten newly created sentences ranged from .39 to 1.29, which was within the range used by Caruana (2011; 0-1.59). An example of an ambiguous sentence used in the current study is ‘The date had been eaten with other dried fruits’. 
In a pilot test, the original and new sentences were administered to ten undergraduate students (not participants in the main experiment) to assess whether the sentences suitably presented the subordinate meaning of the homograph. Four sentences from Caruana’s (2011) original set were replaced to better reflect the homograph’s subordinate meaning, as the pilot test revealed the homographs in these sentences were in fact used in their dominant meaning (see also Twilley et al., 1994). To create the corresponding non-ambiguous version of each ambiguous sentence, the homograph was replaced with a non-homograph word whilst retaining the meaning of the sentence. For the above example, the corresponding non-ambiguous version was thus ‘The *raisin* had been eaten with the other dried fruits’. There were hence 40 sentences in parallel ambiguous and non-ambiguous versions.

For each participant, a MATLAB program (designed using the Psychophysics Toolbox; Brainard, 1997) randomly selected 20 sentences to be presented in their ambiguous version; the remaining 20 sentences of the set were presented in their non-ambiguous version. In addition, all participants received an identical set of 20 arbitrary and unambiguous control sentences unrelated to the ambiguous and non-ambiguous sentences. This was done to ensure the ambiguous sentences were masked as best as possible to reduce the likelihood of participants detecting the use of subordinate-meaning homographs in the sentences. Brock and Bzishvili (2013) found that Snowling and Frith’s (1986) stimuli were subject to practice and learning effects, and eye-movement analyses showed healthy undergraduate university students tended to preempt the homographs when reading the sentences by first focusing on the area in which the homograph was most likely to occur. Ten of these control sentences contained a different set of homographs that were used in their dominant meaning to further mask

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9 The sentences contained the same homographs but were rewritten to better reflect the homograph’s subordinate meaning (e.g., “*The company* was apparently not bankrupt according to the report” was changed to “*His company* was not welcome at the party” for the current study). The corresponding non-ambiguous sentences were also changed to reflect this.
the use of the subordinate meanings in the ambiguous sentences (e.g., ‘The sign was designed by a well-known illustrator’), and the remaining ten were entirely arbitrary and did not contain a homograph (e.g., ‘He forgot to return the book to her yesterday’).

The sentences were presented individually in a pseudo-random order by the program, with the constraint that no more than two ambiguous sentences were presented consecutively. Participants were instructed to read each sentence in their own time, and prompted the next sentence by key press when they had successfully read and encoded the current sentence. To ensure participants completed the task within an adequate time-frame, the sentences remained onscreen for a maximum of 10 s, which allowed for comfortable reading without excessive slack time. Participants’ reading time for each sentence was recorded by the program at key press.

Sentence-recognition Questionnaire. A forced-choice recognition task was used to assess whether participants paid adequate attention to the sentences, and read them as they were presented on-screen (see Table 4.1). The questionnaire comprised 20 sentences, 10 of which were control sentences that participants had read (“old sentences”) and 10 of which were random sentences that had not been presented (“new sentences”). Some new sentences contained homographs. Participants responded ‘Yes’ for sentences they believed they had read earlier, and ‘No’ for sentences they did not believe they had read earlier. Sentences were presented in random order.
### Table 4.1

*Sentences Used in the Sentence-recognition Questionnaire in Experiment 4.*

<table>
<thead>
<tr>
<th>Old Sentences</th>
<th>New Sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It was cool enough to have the party outside.</td>
<td>1. The band played at the bar that night.</td>
</tr>
<tr>
<td>2. She put the photo frames on her shelf.</td>
<td>2. He wound the cord tightly around the pole.</td>
</tr>
<tr>
<td>3. She plans to play tennis today.</td>
<td>3. They beat the other team at the relay.</td>
</tr>
<tr>
<td>4. The flowers in the vase had a nice fragrance.</td>
<td>4. The rock was heavy enough to use as a doorstop.</td>
</tr>
<tr>
<td>5. The sink was full of dirty dishes.</td>
<td>5. The chest of drawers was full of clothes.</td>
</tr>
<tr>
<td>6. The light flickered on and off.</td>
<td>6. He drives his car to school every day.</td>
</tr>
<tr>
<td>7. He wrote the time of the appointment in his diary.</td>
<td>7. The truck broke down in the middle of the road.</td>
</tr>
<tr>
<td>8. The jam was made with home-grown strawberries.</td>
<td>8. She went to the library to return her books.</td>
</tr>
<tr>
<td>9. The sign was designed by a well-known illustrator.</td>
<td>9. The carpet was dirty and stained.</td>
</tr>
<tr>
<td>10. The new intern was helping with the data entry.</td>
<td>10. The cake was prepared for tomorrow's party.</td>
</tr>
</tbody>
</table>

### General Procedure

Participants completed the experiment individually. They first read the sentences, following which they completed an unrelated distractor task for approximately 10 min. They then completed the sentence-recognition questionnaire. The entire testing session lasted approximately 25 min.
4.5.2. Results

Data Screening\(^{10}\)

Two participants’ reading time data were removed, as they failed to follow instructions to prompt the next sentence and consistently waited for the maximum reading time of each sentence (i.e., 10 s) to elapse, thus resulting in \(N = 46\) participants. All reading times that reached the maximum reading time were also removed for each individual; 5.14% of all reading times were removed based on this criterion, of which 38% were from the low-AQ participants and 62% were from the high-AQ participants.

In order to control for the effect of sentence length on reading times across sentences, the data were first standardised as per the method used in the experiments in Chapter 2. All reading times are thus reported as seconds per syllable (s/syllable).

The data were then screened for outliers using the Outlier Labelling Rule (see Hoaglin & Iglewicz, 1987). First, reading times of individual sentences that were more than 2.2 times the interquartile range away from the first and third quartiles of the individual participant’s reading time distribution were deemed unacceptable. In order to retain numbers for subsequent data analyses, however, these reading times were not removed from the data, but were replaced using the outlier-criterion value.

Second, two participants with outlying mean reading times were removed, thus resulting in \(N = 44\) for subsequent analyses.

Effect of Sentence Ambiguity on Reading Time\(^{11}\). An omnibus mixed-design ANOVA was first performed to contrast reading times for the different sentence types (ambiguous vs. non-ambiguous vs. control). Sentence type served as the within-subjects

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\(^{10}\) As previously mentioned, a sentence-recognition task was designed to be used as a screening measure. A binomial test determined that a score of 14 out of 20 correctly recognised or rejected sentences would indicate performance better than chance level. A total of 14 participants failed this criterion. Data analyses were performed both with and without these participants; the pattern of results did not differ, and subsequent analyses were thus performed on data inclusive of these participants (i.e., \(N = 44\)).

\(^{11}\) As mentioned in Chapter 2, there was a significant difference between the low-AQ and high-AQ groups’ digit symbol rotation composite scores. As per data analyses in Experiment 2, the current analyses were also performed with and without the composite scores as a covariate. There was no difference between the two groups, and thus the analyses reported are those without the covariate analyses.
factor, with AQ group (low-AQ vs. high-AQ) as the between-subjects factor. Mean reading times for each sentence type and AQ group are presented Figure 4.1. There was a main effect of sentence type, $F(1, 84) = 11.69, p < .01, \eta^2_p = .22$. However, there was no difference in reading time between the two groups, nor was there an interaction, both $F < 1$.

![Graph showing mean reading times for each sentence type and AQ group](image)

**Figure 4.1.** Mean reading time for each sentence type (ambiguous vs. non-ambiguous vs. control) in the low-AQ and high-AQ groups. Values in bars denote the means. Error bars denote standard errors of the means.

Planned follow-up contrasts were used to further investigate the effect of sentence type on the two AQ groups’ reading times. Overall, the ambiguous sentences ($M = .36, SD = .08$) were read more slowly compared to the non-ambiguous sentences ($M = .34, SD = .07$), $t(43) = 4.57, p < .01, d = .27$, and also to the control sentences
\( M = .35, SD = .08 \), \( t(43) = 2.09, p = .04, d = .13 \). The non-ambiguous sentences were read more quickly than the control sentences, \( t(43) = 2.83, p < .01, d = .13 \).

An additional follow-up contrast was then conducted to test the central hypothesis for the study, namely that the difference in reading times for the ambiguous and non-ambiguous sentences would be more pronounced for the high-AQ compared to the low-AQ group. However, this interaction contrast showed that the two AQ groups did not differ in the reading time difference between the ambiguous and non-ambiguous sentences, \( F(1, 42) = 1.15, p = .30 \).

4.6. Discussion

The aim of the present study was to further investigate how individuals with low and high levels of autistic-like traits process ambiguous information during reading in a homograph-reading task, as part of a broader investigation into their memory updating ability. I also sought to extend the findings of the no-retraction condition in Experiment 3, where low-AQ and high-AQ participants displayed different patterns of responses when two competing causes were held in memory.

First, although Caruana and Brock (2014) reported no difference between low-AQ and high-AQ participants in their patterns of eye gaze during a homograph-reading task, it is noted that the ambiguous and non-ambiguous sentences used in their study did not differentially influence reading across all participants. In addition, previous studies have shown healthy individuals experience practice effects using the original homograph-reading task, resulting in participants pre-empting the homograph’s occurrence and focusing on the part of the sentence expected to contain the homograph early in sentence processing (Brock & Bzishvili, 2013). I took these potential factors into consideration in the present study and attempted to more stringently control for the degree of ambiguity elicited by the sentences (by broadening the stimulus set and
measuring ambiguity in a pilot test), and to dilute the presence of the homographs (by using additional arbitrary control sentences), thereby making their occurrence less obvious to the participants.

The current results showed that the ambiguity manipulation of the sentences was successful, and affected participants’ reading times for the different sentence types. The ambiguous sentences were read more slowly compared to the non-ambiguous and control sentences. This was true across both low-AQ and high-AQ groups.

Contrary to my predictions, the present results showed no difference in overall reading times for the high-AQ participants compared to the low-AQ participants. There was also no interaction between AQ group and sentence type, neither in the omnibus analysis, nor in the specific contrast analysis. The current results thus do not provide evidence that high-AQ individuals have particular difficulties processing ambiguous sentences containing a homograph that requires them to interpret it based on its subordinate meaning. This is consistent with Caruana and Brock (2014), who also found that their low-AQ and high-AQ participants did not differ in their eye gaze behaviour whilst reading ambiguous sentences. Overall, using a homograph-reading task, the present study failed to substantiate the notion of impaired memory updating ability and deficits in ambiguity resolution in high-AQ participants.

There are, however, a number of factors that should be taken into account when considering the present findings. The first is participants’ language ability. Several studies have shown that general language ability may influence performance on the homograph-reading task. Snowling and Frith (1986) found that children with ASD who had good verbal language skills performed comparably to typically-developing children in providing the correct pronunciation of the homograph. This, however, was not the case for children with ASD who had poorer language skills, suggesting language ability may play a role (Snowling & Frith, 1986). More recent studies have also alluded to the
possible mediating effect of language ability on performance on the homograph-reading task, with results consistent with Snowling and Frith’s (1986) findings (e.g., Brock et al., 2008; Lucas & Norbury, 2014; Norbury, 2005). The sample used in the current study consisted of undergraduate university students, who can be assumed to be high-functioning and unlikely to have significant language difficulties. However, general language ability was not assessed in the current sample, and further investigation including an assessment of language ability would be required to delve into the question of whether language ability may influence performance on the current task, particularly in a wider general population.

Second, reading time was the primary measure of whether a homograph would influence reading of the sentences in the present study. Although reading time has been used to investigate reading comprehension in the literature (Joseph & Tager-Flusberg, 2004) and in the previous experiments of this thesis, it is possible that it may not be a sufficiently sensitive measure to capture subtle differences between low-AQ and high-AQ participants on the homograph-reading task, particularly in such high-functioning samples. Future studies should consider employing other methods that may prove to be more sensitive, such as electrophysiological measures (Brock & Bzishvili, 2013; Brock et al., 2008; Caruana & Brock, 2014). As I mentioned earlier, eye-movement tracking has shown that healthy individuals prepare for the presence of homographs by focusing on the part of the sentence most likely to contain the homograph before beginning to read the sentence (Brock & Bzishvili, 2013). It is possible that although there was no difference between the reading times in the low-AQ and high-AQ participants in the current experiment, they may display different eye gaze patterns which may or may not subsequently influence their reading times. However, this claim remains speculative and warrants further investigation. An alternative method would be to have the participants read the sentences aloud and record their voices (Brock & Bzishvili, 2013; Henderson et
This voice-recording method would enable closer inspection of whether the presence of a homograph in the sentences lead to the participants faltering or pausing upon approaching the homograph and/or after reading the homograph (Jolliffe & Baron-Cohen, 1999b).

One limitation of the present study is that it is unknown whether participants completely understood the sentences’ intended meanings. Although I administered the sentence-recognition questionnaire, it does not entirely assess participants’ understanding and comprehension of the sentences. Specifically, the sentence-recognition questionnaire did not provide information about whether the participants interpreted the homographs in their intended meanings. In Caruana and Brock’s (2014) study, comprehension questions comprising followed a portion (40%) of the sentences to ensure participants were reading and thinking about the sentences’ content and meaning, and appropriately attending to the stimuli. Each question related to the content provided by the preceding sentence. One example is the sentence ‘He addressed the little envelope and sealed it’. This was followed by the question ‘Did he mail the envelope?’, which required a ‘No’ response (Caruana & Brock, 2014). Such comprehension questions thus require the reader to interpret and understand the content and meaning present in the sentence. In order to provide further information regarding the understanding and process of reading during the homograph-reading task, future investigations should consider utilising such measures of sentence comprehension in a similar fashion.

In sum, the present results showed that reading times of ambiguous sentences were longer than those of non-ambiguous sentences across all participants. However, there was no difference in the pattern of reading times between individuals with low and high levels of autistic-like traits. Thus, the current results do not provide conclusive evidence to suggest that individuals with high levels of autistic-like traits have greater
difficulty on a homograph-reading task compared to individuals with low levels of autistic-like traits. In addition, the results do not substantiate the notion of impaired memory updating ability in individuals with high levels of autistic-like traits on a homograph-reading task.
CHAPTER 5

Measuring Basic Memory Updating Ability in Low- and High-AQ Individuals
In Experiments 1 to 4, I have used various paradigms to investigate how individuals with low and high levels of autistic-like traits process ambiguous information, and whether performance differences may be attributable to differences in memory updating ability. To this end, I adopted the CIE paradigm in Experiments 1 to 3, which entailed presenting participants with information that is initially presumed to be factual but is later retracted (i.e., misinformation). The use of the CIE paradigm allowed me to explore whether high-AQ participants have greater difficulty updating their initial situation models of an unfolding event compared to low-AQ participants, and whether the two AQ groups differ in their subsequent understanding of and reasoning about the event. In sum, I found no consistent evidence to suggest individuals with high levels of autistic-like traits have greater difficulty updating situation models compared to individuals with low levels of autistic-like traits. Although the results from Experiment 1 provided evidence suggesting high-AQ individuals may find it more difficult to process a retraction than low-AQ individuals, this finding was not replicated in various other scenarios (e.g., in Experiment 2). Experiment 3, which presented two independent causes of an event, suggested that when information is ambiguous and potentially contradictory, high-AQ individuals may have greater difficulty resolving such ambiguity. Experiment 4 utilised a homograph-reading task with ambiguous sentences to further explore whether high-AQ individuals have difficulty with ambiguous information, and if this may be related to memory updating ability. However, the results did not suggest any difference between the low-AQ and high-AQ participants in the time taken to read the ambiguous sentences.

The methods used in this thesis thus far have provided a way to infer participants’ memory updating ability, particularly in more applied contexts involving complex and ambiguous materials. Given the inconclusive evidence obtained from these experiments, it is also important to obtain a more direct measure of basic memory
updating ability—which can be considered the cognitive processing foundation of memory updating in more complex tasks—in individuals with low and high levels of autistic-like traits. To this end, in Experiment 5 I utilised a basic memory updating task designed as part of a working memory test battery (Lewandowsky, Oberauer, Yang, & Ecker, 2010).

5.1. Memory Updating Task

Working memory refers to the ability to keep information active in memory for both ongoing processing and storage (Baddeley & Hitch, 1974). According to Baddeley and Hitch (1974), working memory comprises two short-term memory stores, viz. the phonological loop and visuo-spatial sketchpad subsystems which correspond to verbal and visuo-spatial working memory ability, respectively. Information is communicated between each subsystem via an episodic buffer (Baddeley, 2001). The distinction between the two primary subsystems of working memory has led numerous studies to investigate ability in the constituent types of working memory and their relationship to other cognitive abilities in both the general population (e.g., Daneman & Carpenter, 1980; Palladino et al., 2001) and clinical populations (e.g., Corbett et al., 2009; Gathercole, Alloway, Willis, & Adams, 2006; J. Russell, Jarrold, & Henry, 1996).

As the world around us constantly changes, to ensure that working memory content is kept up-to-date, information held in working memory must frequently be revised and substituted with more current or relevant information (Morris & Jones, 1990), regardless of whether it is verbal or visuo-spatial information. The ability to update working memory contents is thus an important pre-requisite for accurate task performance on a variety of tasks, including spatial navigation, reading, mental arithmetic, and problem-solving.
The memory updating task employed in this experiment is a well-validated task (Lewandowsky et al., 2010) and variants of it have been used widely in the working memory literature (e.g., Ecker, Lewandowsky, & Oberauer, 2011; Ecker, Lewandowsky, Oberauer, & Chee, 2010; Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000; Salthouse, Babcock, & Shaw, 1991). The task involves encoding a set of single digits in separate frames, which is then followed by the application of a number of arithmetic updating operations to individual digits. Memorised digits are thereby replaced with the results of the arithmetic operations. Following a series of such updating operations, participants then recall the currently held set of digits (more details to follow). This memory updating task largely relies on verbal coding more so than visuo-spatial coding, and is therefore considered a verbal memory updating task (Lewandowsky et al., 2010).

No previous study has used the memory updating task with an ASD population, nor individuals of a broader autism phenotype. However, as discussed in earlier chapters, there is some evidence of impaired set-shifting ability and cognitive flexibility in individuals with ASD, which has also been observed in individuals high levels of autistic-like traits. This suggests that they may exhibit difficulty on other executive function tasks such as the memory updating task. I therefore expected that the high-AQ participants in the current experiment should perform more poorly than low-AQ participants on the memory updating task. If this is the case, it would suggest that high-AQ participants may have limited basic memory updating abilities which may extend to the clinical ASD population.

5.2. **Aim**

The aim of the current experiment was to obtain a more direct measure of basic memory updating ability in individuals with low and high levels of autistic-like traits, using a conventional working memory updating task.
5.3. **Hypothesis**

If high-AQ participants have impaired memory updating ability, they should perform more poorly on the memory updating task compared to low-AQ participants.

5.4. **Experiment 5**

5.4.1. **Method**

**Participants**

The same participants who participated in Experiment 3 completed the present task. Descriptive statistics for the low-AQ and high-AQ groups are presented in Section 3.4.1 of Chapter 3.

**Memory Updating Task**

The memory updating task used was identical to the task included in Lewandowsky and colleagues’ (2010) working memory test battery for MATLAB. The task involved individual digits presented in separate frames on the screen (see Figure 5.1). Participants were required to encode the initial set of between three and five digits, presented concurrently in individual frames for 1 s per digit. In a subsequent series of updating steps, simple arithmetic operations (e.g., +2) were presented in individual frames for 1.3 s each (with a 250 ms blank-screen inter-stimulus interval), and participants updated the currently held set of digits by applying each respective arithmetic operation to the digit they currently remembered for that particular frame. Updating operations were randomly presented, ranging from -7 to +7 (excluding 0), ensuring that the result remained between 1 and 9. After an unpredictable series of between two and six updating operations, recall of the final set of digits was then prompted by single question marks that appeared one by one in each frame. Participants
responded by typing the memorised digit for the prompted frame; there was no time constraint for recall, and no performance feedback was given.

As per the original study, the memory updating task was presented using a MATLAB program (designed using the Psychophysics Toolbox; Brainard, 1997), which recorded participants’ recall accuracy of the final digits. There were 15 trials in total, preceded by two practice trials, one of which used two frames and the other three. Each trial was prompted by participant key press.

![Diagram of sample trial sequence for the memory updating task.](Figure 5.1. Sample trial sequence for the memory updating task.)
5.4.2. Results

The main measure of performance was recall accuracy of the final digits following all updating operations, that is, the proportion of digits recalled correctly across all 15 trials, on a scale of 0 to 1. Six participants’ data were not recorded successfully by the program, and thus were unavailable for subsequent analyses. Participants’ recall accuracy scores were then screened for outliers using the Outlier Labelling Rule as per the previous experiments (see Hoaglin & Iglewicz, 1987). There were no outliers based on this criterion, and the final sample for subsequent analyses on recall accuracy scores was $N = 277$.

I was primarily interested in whether low-AQ and high-AQ participants differed in their performance on the memory updating task. To this end, a one-way ANOVA was performed on participants’ recall accuracy scores with AQ group as the sole factor. There was a main effect of AQ group on recall accuracy scores, with high-AQ ($M = .65$, $SD = .19$) participants performing better than low-AQ participants ($M = .56$, $SD = .17$), $F(1, 275) = 18.18, p < .01, \eta^2_p = .06$.

To further investigate if there was a relationship between participants’ AQ score and performance on the memory updating task, a correlation analysis was performed on participants’ AQ and recall accuracy scores. This was done for each AQ group separately due to the bimodal distribution of AQ scores across the two AQ groups. There was no relationship between AQ scores and recall accuracy in the low-AQ ($r = .06$) or the high-AQ ($r = .05$) group.

5.5. Discussion

The aim of Experiment 5 was to obtain a more direct measure of memory updating ability in individuals with low and high levels of autistic-like traits with the use of a basic memory updating task. Based on previous findings of impaired set-
shifting ability and cognitive flexibility, I expected the high-AQ participants to exhibit lower performance on the memory updating task than the low-AQ participants. Contrary to expectations, however, the results showed that the high-AQ participants had higher recall accuracy scores than the low-AQ participants. The current results are thus not in line with expectations, but at least are consistent with the general pattern of findings of Experiments 1 to 4, in that there was no impairment in memory updating ability in high-AQ participants compared to low-AQ participants. It may be possible that the high-AQ participants recruited from a university sample in the current experiment may generally possess better fundamental memory ability, and/or have higher levels of general intelligence than what would be expected from individuals with high levels of autistic-like traits recruited from a wider general population. This may enable them to compensate for specific impairments associated with high levels of autistic-like traits. In other words, if low-AQ and high-AQ participants were carefully matched on general intelligence and memory abilities, differences between the two AQ groups in memory updating abilities may arise in tasks requiring real-world updating and ambiguity resolution. However, the fact that low-AQ and high-AQ participants in the current experiment did not differ significant on the Digit Symbol Rotation task speaks against this interpretation, which thus remains entirely speculative.

As discussed earlier in this chapter, the memory updating task has been used in numerous previous investigations of working memory in the general population. Although this specific task has not been used within an ASD population, there have been several investigations of working memory ability in individuals with ASD (e.g., Kercood, Grskovic, Banda, & Begeske, 2014). As mentioned previously, working memory comprises verbal and visuo-spatial working memory. Numerous studies have investigated visuo-spatial working memory ability in individuals with ASD. Overall, findings have been mixed, with some studies reporting visuo-spatial working memory
difficulties in ASD (e.g., D. Williams, Goldstein, Carpenter, & Minshew, 2005) whilst others have reported no impairments (e.g., Ozonoff & Strayer, 2001; J. Russell et al., 1996). On the other hand, investigations of verbal working memory have generally shown no difference between individuals with high-functioning ASD and their typically-developing counterparts (Koshino et al., 2005; J. Russell et al., 1996; D. Williams et al., 2005). It is thus possible that the high-AQ participants in the current study did not exhibit any particular difficulty on the memory updating task—which as mentioned earlier largely relies on verbal coding—due to their generally intact verbal working memory ability.

However, the high-AQ participants’ performance was in fact superior to performance in the low-AQ participants, so intact verbal working memory ability is necessarily insufficient in accounting for the results of the current study. One alternate explanation regards the way in which information is coded during processing, specifically the use of verbal-based or visuo-spatial strategies. Various tasks can be completed using either a verbal-based strategy or a visuo-spatial strategy. It is possible that a preference for verbal-based or visuo-based strategies may influence an individual’s performance on certain tasks. Individuals who tend to adopt more verbal-based strategies (i.e., verbalisers) have been shown to use inner speech or to verbally repeat the information presented to aid their understanding and memory of incoming information. On the other hand, some individuals may adopt more visuo-spatial strategies (i.e., visualisers) such as forming mental pictorial representations of information (Zarnhofer et al., 2012).

The strength exhibited by individuals with ASD on tasks relying predominantly on visuo-spatial ability such as the Block Design subtest of the Wechsler intelligence scales (e.g., the Weschsler Adult Intelligence Scale [WAIS]; The Psychological Corporation, 1981) and the EFT (Mottron, Morasse, & Belleville, 2001) has sparked
interest into whether individuals with ASD have a particular preference to adopt visuo-spatial strategies. In their investigation of strategy use in individuals with ASD, Koshino and colleagues (2005) used functional neuroimaging to investigate brain activation patterns in adults with high-functioning ASD on a letter $n$-back task. The $n$-back task is a memory updating task that involves the presentation of a sequence of letters, and requires participants to make a response when the letter presented matches a specific previous letter, depending on the experimental condition. There were three conditions in Koshino and colleagues’ (2005) study: 0-back, 1-back, and 2-back. In the 0-back control condition, participants were required to make a response whenever a target letter presented at the beginning of the trial sequence appeared in the sequence (i.e., the target letter remained constant for the duration of the trial). In the 1-back condition, participants responded when the letter presented was identical to the preceding letter. In the 2-back condition, participants responded when the letter presented was identical to the one presented two letters back. Therefore, the 1-back and 2-back conditions of the $n$-back task require the constant updating of a small set of letters held in working memory, similar to the memory updating task used in the present study. Koshino and colleagues (2005) found that high-functioning ASD participants performed comparably to typically-developing participants. However, results from the brain imaging implied a difference in the strategies used. During the $n$-back task, although participants with high-functioning ASD showed the same level of activation in right-hemisphere brain areas associated with visuo-spatial processing as typically-developing participants, they exhibited less activation of left-hemisphere brain areas typically associated with verbal processing. Koshino and colleagues (2005) thus concluded that high-functioning individuals with ASD have less tendency to spontaneously utilise verbal-based processing strategies (see also Holland & Low, 2010;
Kana et al., 2006; Koshino et al., 2008; Wallace, Silvers, Martin, & Kenworthy, 2009; Whitehouse, Maybery, & Durkin, 2006b).

Other studies investigating inner speech (i.e., the internal vocalisation of one’s thoughts) in individuals with ASD also converge to suggest reduced use of verbal-based strategies (Russell-Smith, Comerford, Maybery, & Whitehouse, 2014). One example is performance on card-sorting tasks such as the WCST, which has been suggested to typically involve use of inner speech (Baldo et al., 2005). In a recent paper, Russell-Smith and colleagues (2014) found that suppressing the use of inner speech (e.g., by means of repeating an irrelevant distractor word aloud; i.e., articulatory suppression) during card-sorting in children with and without ASD resulted in different patterns of performance. The authors found that whilst typically-developing children performed much worse when inner speech was suppressed, the children with ASD did not show impaired performance relative to standard conditions. In addition, the typically-developing children benefited from verbalising the sorting strategies aloud as they completed the task, whereas the children with ASD did not show any benefit of verbalising their sorting strategies (Russell-Smith et al., 2014). Holland and Low (2010) also reported findings consistent with reduced use of verbal-based strategies in children with ASD relative to typically-developing children. Using an arithmetic-based task, the authors found no effect of articulatory suppression on performance for the children with ASD. On the other hand, the typically-developing children performed worse during articulatory suppression. However, suppressing visuo-spatial strategies during the task disrupted performance for both groups of children to a similar degree. This suggests that the children with ASD were more likely to use visuo-spatial strategies than verbal-based strategies during the arithmetic-based task. Taken together, there is evidence of reduced use of inner speech in children with ASD, consistent with less frequent use of verbal-based strategies more generally.
Given the broader autism phenotype, as discussed in earlier chapters, it is possible that individuals with high levels of autistic-like traits may also exhibit a similar preference for visuo-spatial processing strategies, which may have influenced the high-AQ participants’ performance on the memory updating task. Previous studies have shown that numbers can be represented in memory in multiple forms (Zarnhofer et al., 2012). When processing numbers, verbal-based strategies may include verbal repetition of the numbers and results during calculation, both aloud and internally (i.e., using inner speech). More visuo-spatial strategies may include representing the numbers and results pictorially, imagining a mental number line, or imagining a mass that increases and decreases in size (Zarnhofer et al., 2012). Subtraction in particular has been shown to rely more on visuo-spatial abilities than verbal abilities (Lee & Kang, 2002; but see Cavdaroglu & Knops, in press). Thus, one can assume that reliance on visuo-spatial strategies may augment memory updating performance compared to a strong reliance on verbal-based strategies. To the extent that this assumption holds, if high-AQ participants exhibit a preference for visuo-spatial processing strategies (as is found in individuals with ASD), this preference may have facilitated their performance in the memory updating task, resulting in superior performance compared to low-AQ participants. However, the explanation remains speculative and further research is necessary to ascertain this.

5.5.1. Future research

In sum, the finding from the current experiment does not suggest that individuals with high levels of autistic-like traits have impaired memory updating ability, and in fact, showed that high-AQ participants performed better on the memory updating task than low-AQ participants. However, as this is the first study to employ the memory updating task in individuals with low and high levels of autistic-like traits, it is
important for future research to further investigate memory updating ability. Given the strengths on visuo-spatial tasks exhibited in individuals with ASD, future studies may consider using a wider range of materials to investigate updating abilities. This would allow investigation of whether enhanced performance on the memory updating task replicates using different stimulus modalities, such as letters (cf. Oberauer & Vockenberg, 2009). Previous research has shown that whilst images and visual information may be processed using both verbal-based and visuo-spatial strategies, letters and words have been argued to elicit primarily verbal-based strategies (Paivio, 1991; see also Whitehouse, Maybery, & Durkin, 2006a). If there is no enhanced performance on a memory updating task using such verbal-based information in individuals with high levels of autistic-like traits, this will contribute to the existing literature regarding a reduced tendency for verbal-based strategies in individuals with ASD. In addition, suppressing inner speech during the memory updating task may also prove insightful in delving further into the reasons underlying the enhanced performance of the high-AQ group on the memory updating task in the current experiment (Russell-Smith et al., 2014). If low-AQ participants or typically-developing controls exhibit reduced performance when inner speech is suppressed, and high-AQ participants or individuals with ASD do not, such findings would provide additional support for a preference for visuo-spatial rather than verbal-based strategies in individuals with high levels of autistic-like traits.
CHAPTER 6

General Discussion
As is evident from the discussion throughout the current thesis, a plethora of research has been dedicated to understand the underlying basis of the symptoms that characterise ASD. A number of theories have emerged from attempts to uncover the underlying basis of ASD. Three of these were discussed previous (see Chapter 1). Firstly, Theory of Mind (ToM) deficit theory assumes that difficulties inferring others’ mental states and beliefs, and limited understanding that these may differ from one’s own, lie at the heart of ASD. Secondly, Weak Central Coherence (WCC) theory argues that difficulties integrating surrounding contextual information during information-processing underlies the symptoms associated with ASD. A third important theory in the ASD literature, which is of greatest relevance for the current thesis, is executive dysfunction theory. The premise of executive dysfunction theory is that the symptoms associated with ASD arise from impaired higher-level cognitive abilities that enable flexible goal-directed changes in behaviour (see Hill, 2004a for a review). Most of the research investigating impairments in executive functions in individuals with ASD has primarily focused on inhibition, planning, and set-shifting. Research has shown that individuals with ASD have impaired set-shifting ability (Geurts et al., 2004; Ozonoff & McEvoy, 1994), and some studies have suggested that this deficit in set-shifting ability may underlie the social difficulties, as well as the repetitive and stereotypic patterns of thought and behaviour often exhibited by individuals with ASD (e.g., Berger, Aerts, van Spaendonck, Cools, & Teunisse, 2003; Lopez, Lincoln, Ozonoff, & Lai, 2005).

However, there is one other executive function that has received much less attention in individuals with ASD, namely memory updating.

Memory updating has been identified as one of the primary executive functions that underlie the performance on various executive functioning tasks (Miyake et al., 2000). In addition, memory updating is implicated in many everyday activities such as reading news reports. Previous observations of impaired set-shifting ability in
individuals with ASD raise the question of whether reduced memory updating ability may also be present, as set-shifting and memory updating are somewhat similar constructs that both involve cognitive flexibility. Additionally, individuals with ASD have consistently been found to have difficulties with pragmatic and non-literal language, and in handling various other types of ambiguous information in both the verbal (Brock et al., 2008; Happé, 1997; Saldaña & Frith, 2007) and visual (Au-Yeung et al., 2011; Au-Yeung et al., 2014; Ropar et al., 2003) domains. Although the ToM deficit and WCC theories have often been used to account for the impaired performance on tasks involving ambiguous information (e.g., Happé, 1997; Jolliffe & Baron-Cohen, 1999a), many of these tasks also require memory updating ability. Specifically, successfully dealing with ambiguous information requires memory updating because an initial incorrect representation of a word or situation needs to be replaced with an appropriate alternative. Despite this, no studies have considered this executive function in their investigations of the cognitive profiles in individuals with ASD.

It is by now well-accepted that the symptoms associated with ASD occur along a continuum of severity, and they have thus been observed to also manifest, to some degree, in non-diagnosed individuals of the general population. The continuous nature of autistic-like traits in the general population has given rise to the notion of a broader autism phenotype; that is, individuals who present with sub-clinical levels of autistic-like traits. One measure commonly used to assess autistic-like traits in typically-developing individuals with and without a family history of ASD is the Autism-Spectrum Quotient questionnaire (AQ; Baron-Cohen et al., 2001). Using the AQ, a number of studies have reported similar cognitive profiles in individuals with high levels of autistic-like traits and individuals with clinical ASD (Almeida et al., 2013; Grinter, Van Beek, et al., 2009; Poljac, Poljac, & Wagemans, 2013).
The gap in the literature regarding memory updating ability with reference to a broader autism phenotype was the basis of conducting the experiments in the current thesis. The primary aim was to explore memory updating ability with reference to a broader autism phenotype using individuals with low and high levels of autistic-like traits. Participants were recruited from a university student population. The AQ (Baron-Cohen et al., 2001) was used to select individuals with low and high levels of autistic-like traits. In a series of five experiments, various paradigms were used, including a basic computerised memory updating task as well as more complex narrative tasks involving corrections of misinformation. The current chapter will present a discussion of the main findings of Experiments 1 to 5, followed by a discussion of the main findings from the existing literature, recommendations for future research, and concluding remarks.

6.1. Review of Main Findings

6.1.1. Experiment 1

Memory updating ability is implicated in various everyday situations such as reading, navigation, or mental arithmetic (Palladino et al., 2001). Regarding reading comprehension, memory updating is particularly important when reports of ongoing events contain false information, or misinformation, which is subsequently retracted or corrected. In such circumstances, in order to hold a correct up-to-date representation of the event, it is important to constantly revise one’s mental situation model and update any outdated information with more recent and relevant information (Glenberg & Langston, 1992; Morrow et al., 1989). Difficulties updating situation models can result in erroneous reasoning and decision-making (Johnson & Seifert, 1994). Despite this potentially damaging effect of misinformation on reasoning and decision-making, no
studies have investigated how corrections of misinformation are processed by individuals representing a broader autism phenotype.

The ongoing impact of corrected misinformation on memory for and reasoning about an unfolding event is known as the Continued Influence Effect (CIE; Ecker, Lewandowsky, & Apai, 2011; Ecker, Lewandowsky, & Tang, 2010; Johnson & Seifert, 1994; Wilkes & Leatherbarrow, 1988). The CIE paradigm involves presentation of a news report that contains a piece of critical information that is retracted in one condition but is not challenged in a control condition (see Section 2.4 for a detailed discussion). In the retraction condition of the task, the participant is therefore required to revise and update an initial situation model they had formed based on misinformation. The CIE paradigm thus provides an approach to investigate memory updating ability in an applied context that is not dissimilar to everyday reading tasks. To date, however, there are no published studies that have employed the CIE paradigm to investigate the effects of misinformation with reference to a broader autism phenotype, and few studies, in fact, have investigated misinformation effects in individuals with ASD.

The few studies that have investigated misinformation effects in the ASD literature (e.g., Bruck et al., 2007) have used a different paradigm, namely the post-event misinformation paradigm (Loftus et al., 1978; McCrory et al., 2007; Rapp et al., 2014). In this paradigm, misleading information is provided to participants after they have experienced an event—as I have argued in Chapter 2, this paradigm is not suitable for investigations of memory updating because it does not require memory updating, and rather assesses the general susceptibility of accepting false information.

Experiment 1 was conducted to investigate the effects of misinformation on later memory for and reasoning about an unfolding event in individuals with low and high levels of autistic-like traits. To this end, I adopted the CIE paradigm using two scenarios that detailed different events (i.e., a school bus accident and a spider bite). Within each
scenario, I presented a cause that was first presumed to be true, but later retracted. The main measures of Experiment 1 were the number of references made to the critical causal information in response to a questionnaire targeting participants’ understanding of the event, and reading time for the message that presented the retraction (relative to the reading time of the corresponding neutral message in the no-retraction condition). Findings from Experiment 1 showed that a retraction reduced participants’ reliance on the critical causal information overall. However, differences between the low-AQ and high-AQ groups were apparent only in the school bus scenario: Whilst there was no difference between AQ groups in the overall number of references to the critical causal information, the retraction appeared more efficient in reducing the number of references to the critical causal information in the low-AQ participants than in the high-AQ participants. This suggests that the high-AQ participants had greater difficulty updating their initial situation model when presented with a retraction. Furthermore, the high-AQ participants read a retraction message more slowly than a neutral message; this was not observed in the low-AQ participants for whom there was no difference in reading time for the retraction and neutral messages. By contrast, the spider bite scenario did not reveal any differences between the two AQ groups with regards to reliance on the critical causal information and reading time.

The findings from Experiment 1 thus provide preliminary evidence of subtle difficulties in updating situation models in high-AQ individuals. However, as this experiment was the first study in the ASD literature to employ the CIE paradigm, and differences between the AQ groups were observed only in one of the two scenarios, it was important to attempt to replicate the pattern of the effect observed with the school bus scenario in Experiment 1.
6.1.2. Experiment 2

Experiment 2 was an extension of Experiment 1, designed to further assess the findings from the school bus scenario by checking that the key results were not purely an artefact of the scenario used. I thus presented low-AQ and high-AQ participants with six scenarios of differing themes unrelated to the two scenarios in Experiment 1. Similar to Experiment 1, the main measures of Experiment 2 were the number of references to the critical causal information, and reading time for the retraction message. Overall, consistent with Experiment 1, the retraction reduced participants’ reliance on the critical causal information. However, the low-AQ and high-AQ participants did not differ in their references to the critical causal information, nor in their reading times across the six scenarios used. The findings from Experiment 2 thus did not replicate those found with the school bus scenario in Experiment 1.

In sum, the use of the standard CIE paradigm in Experiments 1 and 2 revealed no strong evidence to suggest that high-AQ individuals find it more difficult to update their situation models of an unfolding event. Although Experiment 1 provided some preliminary evidence of a difference between the two AQ groups, this finding was not replicated with different scenarios in Experiment 2, and thus it is not possible to conclude that high-AQ individuals have difficulties with memory updating.

6.1.3. Experiment 3

Previous studies from the ASD literature suggest individuals with ASD may experience difficulties processing and understanding ambiguous information, particularly when more than one representation of the information must be held in memory at the one time (López & Leekam, 2003). Although the standard CIE paradigm used in Experiments 1 and 2 enables inferences to be made regarding an individual’s ability to update initial situation models formed based on false information, it is not well
suited to explore the notion of having to hold multiple representations of an event in mind at once. Experiment 3 was thus conducted to explore this capability further. To this end, I used a novel dual-cause variant of the CIE paradigm, which consecutively presented participants with two unrelated (but not mutually exclusive) causes of a single event. Overall, there were no differences between the low-AQ and the high-AQ participants in their reliance on either cause 1 (i.e., the first cause presented) or cause 2 (i.e., the second cause presented) when there was a retraction. This is consistent with Experiments 1 and 2 in showing that the high-AQ participants did not find it more difficult to update their situation models than the low-AQ participants. However, when neither cause was retracted—and thus both cause 1 and cause 2 could be assumed correct—the low-AQ participants showed a preference for cause 2 over cause 1 in their subsequent reasoning. The high-AQ participants, on the other hand, did not show a preference for either cause and were equally likely to rely on cause 1 or cause 2. This suggests that the low-AQ participants were more likely to presume that later information (i.e., cause 2) superseded initial information compared to the high-AQ participants. In other words, the low-AQ participants were more inclined to resolve ambiguity by spontaneously updating their situation model with new incoming information (i.e., replacing cause 1 with cause 2 even in the absence of a retraction), whereas the high-AQ participants remained in a more equivocal state maintaining two rival representations. This finding is consistent with Lopez and Leekam’s (2003) speculation that difficulties processing and understanding ambiguous information in individuals with ASD may be specific to instances when more than one representation must be held in memory at the one time. However, as there was no difference between the low-AQ and high-AQ participants in their post-retraction reliance on cause 1 or cause 2, the findings of Experiment 3 do not provide substantial evidence to suggest that
high-AQ individuals have difficulty with memory updating when it is clearly called for, that is, in the presence of a retraction.

6.1.4. Experiment 4

The findings from Experiment 3 suggest that when a situation model concurrently contains multiple competing causal explanations of an unfolding event, high-AQ participants may find it more difficult to resolve the ambiguity inherent in the model. To examine the issue of ambiguity resolution more directly in a more tightly controlled paradigm, Experiment 4 was conducted using a homograph-reading task (Frith & Snowling, 1983). A secondary aim was to extend previous findings within the ASD literature of impaired performance on the homograph-reading task with reference to a broader autism phenotype.

As I have discussed in Chapter 4, the homograph-reading task has been used widely within the ASD literature to investigate processing of ambiguous information in individuals with ASD (Brock & Bzishvili, 2013; Happé, 1997; López & Leekam, 2003). However, these studies have mostly been conducted within the general framework of WCC theory (Happé, 1997). Studies have since highlighted the possible role of other cognitive abilities such as set-shifting ability in performance on the homograph-reading task (Hala et al., 2007; Happé & Frith, 2006). As discussed in Chapter 4, when the initial interpretation of a homograph becomes incompatible with the meaning conveyed in the subsequent part of a sentence, initial situation models based on the first interpretation of the homograph must be reassessed and revised accordingly. As this arguably requires memory updating, performance on the homograph-reading task can be linked to memory updating ability. The homograph-reading task I used in Experiment 4 employed reading time for ambiguous and non-ambiguous sentences as the dependent variable. I was interested specifically in the reading time differences between the
ambiguous and non-ambiguous sentences when comparing the low-AQ and high-AQ participants. The findings from Experiment 4 did not show any difference between the low-AQ and high-AQ participants in the time taken to read ambiguous and non-ambiguous sentences. Therefore, using a homograph-reading task, Experiment 4 yielded no evidence to suggest that high-AQ participants may have memory updating difficulties.

6.1.5. Experiment 5

Whilst the methods used in Experiments 1 to 4 provide a way to assess memory updating ability indirectly in applied contexts, it is also important to obtain a more direct and basic measure of memory updating ability. Experiment 5 was conducted in order to explore memory updating ability in groups selected to differ in levels of autistic-like traits using a basic memory updating task that has been well-validated and widely used in studies of the general population (Ecker, Lewandowsky, & Oberauer, 2011; Lewandowsky et al., 2010). The task involved participants memorising a set of digits and then updating them by applying arithmetic operations (e.g., +4; see Figure 5.1), thereby repeatedly replacing a memorised digit (e.g., 2) with the result of the operation (e.g., 6). The main dependent measure was recall of the final set of digits following all updating operations. Contrary to expectations and previous findings of impaired executive function in individuals with ASD, the findings showed that high-AQ participants performed better than low-AQ participants on this numerical updating task. It is difficult to interpret this finding as no other study has used the memory updating task in this population. However, research has shown that numbers and digits can be represented in various formats, including visual-based formats (e.g., imagining a mental number line; Zarnhofer et al., 2012), and individuals with ASD have been found to preferably adopt visual-based strategies compared to verbal-based strategies (e.g.,
Koshino et al., 2005; Koshino et al., 2008; Mottron et al., 2001). It is possible that this preference for visual-based strategies is also apparent with reference to a broader autism phenotype, and may thus have facilitated the high-AQ participants’ performance on the memory updating task. It is also possible that this outcome may have resulted from a generally more high-functioning sample of high-AQ participants as the sample was recruited from a university population. However, given the non-significant difference in general ability between the low-AQ and high-AQ groups (as measured by the Digit Symbol Rotation task), this seems an unlikely explanation.

In summary, the current findings do not support the hypothesised impairment in memory updating in high-AQ individuals. In order to explore the potential theoretical implications of this research, in the following sections I discuss the relevant literature in relation to the current findings. Specifically, the literature investigating performance with reference to a broader autism phenotype, and the literature on memory updating and general cognitive abilities will be discussed in turn.

6.2. A Broader Autism Phenotype and the Current Findings

As mentioned previously, the characteristic symptoms of ASD are also exhibited, but to a lesser degree, by individuals without ASD. These individuals not only include family members of individuals with ASD, but also individuals of the general population with no family history of ASD. Individuals who report high levels of autistic-like traits have been shown to exhibit a similar cognitive profile to individuals with ASD in some aspects of cognition. The following sections will present a discussion of the main findings of the research conducted to investigate cognitive abilities with reference to a broader autism phenotype, including relatives of individuals with ASD and individuals in the general population, in relation to the main findings of this thesis. To foreshadow, this discussion will clarify that despite the notion that high levels of autistic-like traits
can be observed in individuals without a clinical diagnosis of ASD—a notion that has underpinned many investigations into atypical processing in the context of ASD—and that individuals with high levels of autistic-like traits may exhibit similar performance to individuals with ASD, this may not always be the case, and some cognitive tendencies observed in ASD may not always be apparent with reference to a broader autism phenotype. This implies that while findings of atypical processing with reference to a broader autism phenotype may reliably point to corresponding deficits in ASD, null findings within samples of individuals with sub-clinical levels of autistic-like traits do not rule out corresponding deficits in ASD. This position will assist interpretation of the results of the current series of experiments.

### 6.2.1. Autistic-like Traits in Relatives of Individuals with ASD

Compared to relatives of individuals without ASD, first-degree relatives of individuals with ASD not only report a higher number of autistic-like traits, but also exhibit similar cognitive profiles to individuals with ASD (Happé et al., 2001; Hughes et al., 1997; Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010). This suggests that genetic liability may be a contributing factor to the underlying basis of ASD. In a recent comprehensive review of autistic-like traits in parents and siblings of individuals with ASD, Sucksmith, Roth, and Hoekstra (2011) presented considerable evidence to suggest that relatives of individuals with ASD exhibit similar difficulties with social interaction and communication to individuals with ASD, in addition to a higher frequency of repetitive and stereotypic behaviour and interests compared to relatives of non-ASD individuals. Furthermore, numerous studies have argued that that relatives of individuals with ASD exhibit cognitive tendencies similar to those seen in ASD, thus further indicating that autistic-like traits can occur at a sub-clinical level in individuals without a clinical diagnosis.
One area of research that supports this notion concerns face processing and emotion recognition. Impaired social functioning has long been documented in individuals with ASD and provides central diagnostic criteria for the disorder (APA, 2013). Studies investigating the underlying basis of such difficulties suggest that they may arise from difficulty extracting emotional information from facial expressions, and aberrant processing and understanding of the relations between constituent facial features in forming a holistic representation (Behrmann, Thomas, & Humphreys, 2006; Pelphrey et al., 2002). Several studies have found that recognition of emotional expressions was either impaired or more effortful in individuals with ASD compared to typically-developing individuals. For example, using static photographs of facial expressions, M. Falkmer, Bjällmark, Larsson, and T. Falkmer (2011) reported that high-functioning individuals with Asperger’s Disorder exhibited greater difficulty correctly recognising emotions from such photographs than did their typically-developing counterparts. The authors further found that participants with Asperger’s Disorder made fewer fixations to the eyes and more to the mouths of the photographs compared to their typically-developing counterparts (also see Begeer, Koot, Rieffe, Terwogt, & Stegge, 2008; Harms, Martin, & Wallace, 2010; Nuske, Vivanti, & Dissanayake, 2013 for reviews on emotion recognition and processing in ASD).

Similar patterns of performance have been documented in relatives of individuals with ASD. Palermo and colleagues (2006) reported that the parents of low-functioning children with ASD showed greater difficulty correctly identifying emotions in schematic drawings of faces compared to the parents of typically-developing children, even when sufficient time was provided for a response. Kadak, Demirel, Yavuz, and Demir (2014) found that the parents of children with ASD exhibited greater difficulty recognising emotions from photographs of happy, surprised, and neutral facial expressions, particularly for subtle expressions compared to parents of typically-
developing children (see also Wallace, Sebastian, Pellicano, Parr, & Bailey, 2010). This is consistent with observations in individuals with ASD (Evers, Steyaert, Noens, & Wagemans, 2015), which supports the notion of a continuum of emotion recognition difficulties in individuals with ASD and their relatives.

Similarly, consistent with findings in individuals with ASD, parallel difficulties understanding non-literal and pragmatic language have also been reported in relatives of individuals with ASD. As discussed in previous sections of this thesis (e.g., Chapter 1), a number of studies have reported difficulties understanding non-literal and ambiguous verbal information in individuals with ASD (e.g., Happé, 1993, 1997; Henderson et al., 2011; Ozonoff & Miller, 1996). Whitehouse, Barry, and Bishop (2007) compared language ability in parents of children with ASD, parents of children with Specific Language Impairment, and parents of typically-developing children, to investigate the language profile with reference to a broader autism phenotype. Whitehouse and colleagues reported that although the parents of children with ASD had intact structural language ability, they exhibited deficient social communication skills. In addition, results also showed that parents of children with ASD exhibited greater difficulties understanding pragmatic language compared to the parents of either children with specific language impairment or typically-developing children, despite having comparable reading skills as the parents of typically-developing children (Whitehouse et al., 2007). Piven and colleagues (1997) also reported that parents of children with ASD exhibited difficulties understanding pragmatic language relative to parents of children with Down Syndrome. Siblings of children with autism have also been reported to perform worse on measures of pragmatic language ability relative to siblings of typically-developing children (Ben-Yizhak et al., 2011). The above studies thus show that the difficulties understanding non-literal and pragmatic language associated with ASD are also evident with reference to a broader autism phenotype.
However, it is not always the case that one can draw parallels between the cognitive tendencies in individuals with ASD and non-ASD individuals with sub-clinical autistic-like traits. For example, numerous studies have previously reported that individuals with ASD exhibit superior performance on tasks that benefit from local processing such as the EFT and the Block Design subtest; this is believed to be due to both enhanced local processing and less spontaneous global processing (e.g., Jolliffe & Baron-Cohen, 1997; but see Muth, Hönekopp, & Falter, 2014). Some studies have reported similar patterns of superior performance in parents and siblings of individuals with ASD. For example, Baron-Cohen and Hammer (1997) reported that parents of children with ASD were faster on the EFT compared to parents of children with typically-developing children (see also Bölte & Poustka, 2006; Happé et al., 2001). Such findings indicate that parents of individuals with ASD exhibit a similar preference for local visual processing as individuals with ASD. There are, however, studies that failed to uncover differences on the EFT and Block Design subtest between relatives of individuals with and without ASD, and which also failed to find an association between the level of autistic-like traits and performance on such tasks (e.g., Happé et al., 2001; Losh et al., 2009; see also Sucksmith et al., 2011 for a review). This suggests that this preference for local processing may not always be present with reference to a broader autism phenotype, or at least, not always as readily detected.

Of particular relevance to the current thesis is the profile of executive functioning in individuals with sub-clinical autistic-like traits, and whether or not such individuals also present with similar executive functioning difficulties as individuals with ASD. As it is evident from previous discussions in this thesis (e.g., see Section 1.5), numerous studies have reported impaired executive functioning ability in individuals with ASD (see Hill, 2004a for a review). With reference to a broader autism phenotype, some studies have reported that, relative to control groups, parents and siblings of
individuals with ASD exhibit poorer performance on measures of planning (Hughes et al., 1997; Hughes, Plumet, & Leboyer, 1999; Ozonoff, Rogers, Farnham, & Pennington, 1993) and set-shifting ability (Hughes et al., 1997; Hughes et al., 1999), which is consistent with what has been reported in individuals with ASD. For example, using the CANTAB ID/ED, Hughes and colleagues (1997) reported that parents of children with ASD made more errors on the critical extradimensional shift stage compared to parents of learning-disabled and typically-developing children. In a later study, similar findings were also reported in siblings of children with ASD (Hughes et al., 1999). This pattern of performance on the CANTAB ID/ED is consistent with the pattern of performance that has been previously reported in individuals with ASD (e.g., Corbett et al., 2009; Geurts et al., 2008). Findings from such studies thus add strength to the ability in drawing conclusions of impaired set-shifting from relatives of individuals with ASD to reflect difficulties in individuals with ASD.

However, results are not always consistent; while Wong and colleagues (2006) also found impaired set-shifting ability on the CANTAB ID/ED in parents of children with ASD, this pattern was evident only in the fathers and not in the mothers, for reasons that are unclear. Other studies employing the WCST have failed to report impaired set-shifting in parents and siblings of individuals with ASD altogether. For example, Ozonoff and colleagues (1993) reported no difference between siblings of individuals with autism and siblings of learning-disabled individuals on the WCST. In a later study, Losh and colleagues (2009) failed to find any significant differences between parents of individuals with ASD and parents of typically-developing individuals on various measures of planning and cognitive flexibility. Likewise, in addition to reporting impaired set-shifting on the CANTAB ID/ED only in the fathers of children with ASD, Wong and colleagues (2006) also reported that siblings of
individuals with ASD performed comparably to siblings of typically-developing individuals on various measures of planning, set-shifting, and fluency.

In sum, it is unclear whether set-shifting ability is affected in parents and siblings of individuals with ASD. This may imply that an executive deficit that is present in ASD is not typically observed, or at least difficult to detect, with reference to a broader autism phenotype. This notion may also hold true with regard to memory updating. As I have mentioned previously, no studies have hitherto investigated memory updating ability in individuals with ASD, nor with reference to a broader autism phenotype including relatives of individuals with ASD. Although the current findings do not provide any strong evidence to suggest individuals with high levels of autistic-like traits have limited memory updating ability compared to individuals with low levels of autistic-like traits, it is possible that such a deficit does occur in ASD, or potentially even in relatives of individuals with ASD. As the participants recruited in the current thesis consisted of a university sample, however, this question cannot be addressed conclusively based on the available data, especially given the fact that some cognitive tendencies associated with ASD are not reported, at least not consistently, with reference to a broader autism phenotype. Thus, while the current results showed no impaired memory updating ability in a university sample of high-AQ individuals relative to low-AQ individuals, it cannot be inferred that there is no impaired memory updating ability in individuals with ASD.

6.2.2. Autistic-like Traits in Individuals of the General Population

In the previous section, I have discussed that relatives of individuals with ASD may exhibit similar patterns of performance to individuals with ASD in some aspects of cognition (e.g., face processing and emotion recognition). On the other hand, there are some instances in which non-ASD individuals high levels of autistic-like traits may not
present with similar patterns of performance to individuals with ASD, or at least they have not been consistently detected (e.g., set-shifting ability). This suggests that it is possible that certain cognitive tendencies associated with ASD may not be apparent and/or may not be as readily detected with reference to a broader autism phenotype. Although the presence of autistic-like traits in parents and siblings of individuals with ASD suggests a genetic liability to the characteristics associated with the disorder, the notion of a broader autism phenotype also extends to individuals in the general population (Gökçen, Petrides, Hudry, Frederickson, & Smillie, 2014; Hoekstra, Bartels, Verweji, & Boomsma, 2007; Richmond, Thorpe, Berryhill, Klugman, & Olson, 2013; Ridley, Homewood, & Walters, 2011).

The measurement of autistic-like traits in a broader autism phenotype is often achieved using self-report questionnaires such as the AQ (Baron-Cohen et al., 2001; see Section 1.2 for a discussion). The AQ has also been used with family members of individuals with ASD, and parents of individuals with ASD have been found to report high levels of autistic-like traits compared to parents of typically-developing individuals (Wheelwright et al., 2010). Studies using such self-report measures of autistic-like traits have also found that individuals in the general population also exhibit varying levels of autistic-like traits, and that those with high levels of autistic-like traits may also exhibit similar cognitive profiles to those seen in individuals with ASD.

Investigations of individuals from the general population with high levels of autistic-like traits, and their associated cognitive profiles, are advantageous for research delving into the intricacies of the disorder, and the extent to which specific cognitive capabilities may present in typically-developing individuals. In addition, recruiting individuals from the general population with high levels of autistic-like traits allows studies to overcome methodological constraints associated with sample size if larger clinical samples are difficult to obtain. This section will provide a discussion of the
research into the profile of individuals in the general population with low and high levels of autistic-like traits to further highlight that some difficulties may be present in individuals with ASD but may not necessarily be apparent with reference to a broader autism phenotype, and that it can therefore be difficult to draw conclusions from this research that apply unequivocally to ASD.

Consistent with findings in individuals with ASD and their relatives, individuals in the general population with high levels of autistic-like traits also exhibit difficulties processing emotions and faces. Poljac and colleagues (2013) investigated emotion processing in university students screened using the AQ. They found that, relative to low-AQ participants, high-AQ participants were less accurate in identifying emotions depicted in photographs that differed in the intensity of the emotion, particularly when the emotion intensity was relatively low. The ability to detect and correctly identify emotions from photographs at lower intensities is more heavily dependent on one’s sensitivity to the emotional information available in the photograph compared to high-intensity photographs (Poljac et al., 2013). This implies that the high-AQ had lower sensitivity to emotional information available in the face, which is consistent with limited emotion-recognition ability in individuals with ASD and their relatives (Enticott et al., 2014; Harms et al., 2010; Kadak et al., 2014; Poljac et al., 2013; Wallace et al., 2010). In a recent investigation of trait emotional intelligence and autistic-like traits in the general population, Gökçen and colleagues (2014) reported a negative association between the level of autistic-like traits, as measured using the AQ, and participants’ emotional intelligence and empathic ability. Although in sum, the findings seem to suggest that individuals who report high levels of autistic-like traits in a general population also exhibit similar emotion recognition and processing difficulties as individuals with ASD and their relatives, further investigation is necessary given the few studies available.
Similarly, studies have reported largely consistent results to suggest individuals with high levels of autistic-like traits in the general population also exhibit a preference for local processing as can be seen in individuals with ASD. Using the EFT and Block Design subtest, Grinter and colleagues (2009) investigated whether individuals with high levels of autistic-like traits may exhibit a similar preference for processing local or constituent details as shown by individuals with ASD. Results showed that participants with high levels of autistic-like traits achieved higher scaled scores on the Block Design subtest and required less time to identify embedded figures in the EFT relative to participants with low levels of autistic-like traits (see also Almeida et al., 2010b; Grinter, Van Beek, et al., 2009). This is consistent with the pattern of performance often seen in individuals with ASD (Jolliffe & Baron-Cohen, 1997; Ozonoff et al., 1991; Ropar & Mitchell, 2001), and also parents of children with ASD (see Section 6.2.1). Reed and colleagues (2011) investigated local and global visual processing in individuals screened for level of autistic-like traits using the Navon hierarchical figures task (Navon, 1977). The Navon hierarchical figures task uses stimuli in which a set of small letters comprise a larger letter (e.g., the letter H composed of small Ts; Reed et al., 2011). Typically-developing individuals are, at times, biased towards perceiving the larger letter, whilst individuals with ASD do not show this bias and are thus more efficient in identifying the smaller letters (Plaisted et al., 1999; but see Rinehart et al., 2000). Reed and colleagues (2011) found that participants with high levels of autistic-like traits exhibited a similar advantage in processing the smaller letters to individuals with ASD, whereas participants with low levels of autistic-like traits did not. In a more recent study, Parkington and colleagues (in press) found that undergraduate university students with high levels of autistic-like traits, screened using the AQ, displayed similar detail-focused processing and difficulties with attention-switching as is often observed in individuals with ASD (see also Best, Moffat, Power, Owens, & Johnstone, 2008). Such
findings provide further support for similar local-processing preferences in ASD and individuals with high levels of autistic-like traits in the general population. Kunihira and colleagues (2006), on the other hand, failed to find any differences between low-AQ and high-AQ university students on the EFT, though further research is necessary to support this particularly as previous studies have reported differences in performance between low-AQ and high-AQ participants (e.g., Grinter, Van Beek, et al., 2009). In sum, investigations of local processing in individuals with high levels of autistic-like traits in the general population are largely consistent with findings in individuals with ASD and their relatives.

As mentioned in the previous section, studies have reported difficulties understanding non-literal and pragmatic language in parents and siblings of individuals with ASD. Such findings suggest that pragmatic language difficulties extend into a broader autism phenotype. As discussed previously, the homograph-reading task (Frith & Snowling, 1983) has been used extensively to investigate pragmatic language abilities in individuals with ASD, and how they may process ambiguous information during reading, with most studies reporting poorer performance in individuals with ASD relative to typically-developing counterparts (e.g., Happé, 1997; Henderson et al., 2011; López & Leekam, 2003). In an investigation of performance on a homograph-reading task in individuals with low and high levels of autistic-like traits without a family history of ASD, Caruana and Brock (2014) reported no differences in eye-gaze patterns between low-AQ and high-AQ university students. The findings from Experiment 4 in the current thesis also showed no differences between low-AQ and high-AQ participants in the pattern of reading times for ambiguous and non-ambiguous sentences. It may be possible that difficulties with ambiguous language during reading may not be evident with reference to a broader autism phenotype in the general population, or at least, it is not as easily detected. However, few investigations exist in
the literature regarding pragmatic language ability with reference to a broader autism
phenotype in the general population, and as it will be discussed later, the samples used
in the current thesis, and Caruana and Brock’s (2014) study comprised university
students which limits the generalisability of the results. Thus, until further investigation
is conducted, it is premature to conclude that difficulties with pragmatic language and
ambiguous information are not apparent in individuals of the general population
exhibiting high levels of autistic-like traits.

Few studies have investigated executive functioning in individuals from the
general population based on the level of autistic-like traits, and findings are largely
mixed. Using a self-report measure of executive functioning in everyday activities,
Christ, Kanne, and Reiersen (2010) found that individuals with high levels of autistic-
like traits reported greater difficulties across several executive functions including
inhibition, planning, and cognitive flexibility, compared to individuals with low levels
of autistic like traits. By contrast, Ridley and colleagues (2011) reported no difference
in inhibitory control in individuals with high levels of autistic-like traits compared to
individuals with low levels of autistic-like traits. This is consistent with studies in
individuals with ASD that have reported comparable ability in inhibiting prepotent
responses compared to typically-developing counterparts (Kleinhans et al., 2005; Lopez
et al., 2005), but inconsistent with other studies in the ASD literature that report that
children with ASD exhibited impaired inhibition compared to typically-developing
individuals (e.g., Corbett et al., 2009; Geurts et al., 2004). Further investigation,
however, is imperative given the few published studies that are available, and the
differences in the measures used.

Studies specifically investigating set-shifting ability in individuals with low and
high levels of autistic-like traits in the general population have also reported equivocal
findings, thus posing difficulty in the ability to draw conclusions regarding set-shifting
ability in individuals with ASD based on performance in individuals with high levels of autistic-like traits. For example, Gökçen and colleagues (2014) reported that participants with low levels of autistic-like traits were more efficient on a card-sorting task, and made fewer perseverative responses than individuals with high levels of autistic-like traits. On the other hand, Kunihira and colleagues (2006) found no evidence to suggest a group difference between low-AQ and high-AQ participants on the WCST, which is inconsistent with findings reported in individuals with ASD (Geurts et al., 2004; Ozonoff et al., 1993) as well as their relatives (Hughes et al., 1997; Hughes et al., 1999).

The mixed findings from investigations of set-shifting ability with reference to a broader autism phenotype in the general population may be complicated by the use of different tasks to assess set-shifting ability. Christ and colleagues (2010), for example, reported that participants with high levels of autistic-like traits reported higher levels of executive functioning difficulties compared to low-AQ participants on the Behaviour Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), a self-report questionnaire that is commonly used to assess executive functioning difficulties in everyday situations. Although the BRIEF has sound psychometric properties, the lack of objective measures of set-shifting ability in this study makes comparison with other studies difficult. Best and colleagues (2008) used participants’ ability to reverse an ambiguous figure as their measure of set-shifting. Although their finding of reduced cognitive flexibility in college students with high levels of autistic-like traits is consistent with findings from the ASD literature (e.g., Sobel, Capps, & Gopnik, 2005), it is inconsistent with other findings from individuals with high levels of autistic-like traits in the general population using different measures of set-shifting (e.g., the WCST; Kunihira et al., 2006).

In summary, it is clear from this literature review that in some areas, parallel cognitive tendencies have been reported in ASD and with reference to a broader autism
phenotype; however, in other domains, in particular in the domain of executive functioning, the case for similar cognitive profiles across ASD and a broader autism phenotype is less well supported, and the profiles may in fact differ to some extent (e.g., for set-shifting). It follows that (1) it cannot be concluded from a null difference between groups with low versus high levels of autistic-like traits (as in the current thesis) that no corresponding deficits in executive functioning exist in ASD, and (2) future research should pay particular attention to areas of dissimilarity between the profiles associated with ASD and with reference to a broader autism phenotype, as these potential profile differences may have important clinical relevance.

The above-mentioned methodological differences across studies raise the question of whether findings from investigations with reference to a broader autism phenotype may have been influenced by the specific tasks used. In the current investigation of memory updating ability, however, there is no strong evidence to suggest that individuals with high levels of autistic-like traits have limited memory updating ability, irrespective of the task used. The use of a variety of methods to address the research question can be considered a strength of the current research; however, it remains possible that all tasks used in the current thesis were unable to detect subtle differences between the low-AQ and high-AQ groups. This is an important consideration particularly as the current experiments are the first to apply such methods (i.e., the CIE paradigm and memory updating task) to explore potential differences in performance in individuals with low versus high levels of autistic-like traits.

It is also important to note the sample differences in studies investigating cognitive profiles with reference to a broader autism phenotype. For example, Gökçen and colleagues (2014) recruited adults from the general population, whereas both Kunihira and colleagues (2006) and Richmond and colleagues (2013) recruited
university students who, as speculated by the authors, were of a high-functioning level. This aspect may also be relevant for the current thesis.

Contrary to expectations, the overall findings from the current thesis do not provide strong evidence of any difference in memory updating ability between individuals with low and high levels of autistic-like traits. However, in interpreting the current findings, a number of aspects of the nature of the current sample must be considered. First, the current samples comprised university students, and the homogeneity of the samples limits generalisability of the results. Given the well-documented genetic liability of autistic-like traits, and the potential differences in the cognitive profile between individuals with ASD and individuals of a broader autism phenotype, it is not possible to conclude from the current results that individuals with ASD do not have memory updating difficulties. Future studies investigating memory updating should not only recruit participants with low and high levels of autistic-like traits from the wider general population, but also endeavour to assess this ability in individuals with ASD, as well as their relatives. Second, given that participants were university students, it is assumed that they have a certain level of academic ability, and it is possible that the high-functioning nature of the sample masked any subtle difficulties that individuals with high levels of autistic-like traits may have. The current findings of normal memory updating ability are somewhat consistent with Kunihira and colleagues’ (2006) null findings of executive functioning difficulties in their university sample, but are inconsistent with findings from other studies (e.g., Gökçen et al., 2014). It may be possible that memory updating difficulties, if any, are evident in individuals with high levels of autistic-like traits recruited from a wider general population with potentially greater variation in functioning level. Future studies investigating memory updating ability should thus endeavour to recruit individuals with high levels of autistic-like traits from the general population.
In further support of the aforementioned argument regarding functioning level, the results from Experiment 5 showed that the high-AQ participants exhibited superior performance on a basic memory updating task compared to the low-AQ participants. As discussed in Section 5.5, although individuals with high levels of autistic-like traits have been shown to exhibit average-level verbal working memory (Richmond et al., 2013), it is unlikely that verbal working memory ability is able to account for the superior performance in the high-AQ participants. It seems likely that the highly efficient memory updating observed in the current sample of high-AQ participants is not typical of individuals with high levels of autistic-like traits in the general population, but should rather be interpreted as an artefact of the high-functioning nature of the current high-AQ sample of Experiment 5.

6.3. Memory Updating and General Ability and the Current Findings

As mentioned above, it is possible that the high-functioning nature of the current university sample may have masked any subtle difficulties with memory updating ability. This seems plausible as a reliable link between memory updating abilities and general ability has been reported. As discussed in the previous chapters, memory updating ability is one of the three primary executive-function capabilities that contribute most to performance across various tasks of executive functioning (Friedman et al., 2008; Miyake et al., 2000). Previous studies have specifically investigated the association between memory updating and intelligence, specifically fluid intelligence which reflects higher-level cognitive abilities such as reasoning and problem-solving (Friedman et al., 2006). Using latent variable analysis, Friedman and colleagues (2006) investigated inhibition, memory updating and set-shifting ability in young adults, testing whether performance on tasks assessing these executive functions was predictive of measures of fluid intelligence. Of the three executive functions, memory updating was
found to have the strongest association with measures of fluid intelligence, and accounted for the largest proportion of its variance (Friedman et al., 2006). The association between memory updating ability and general intelligence has also been documented in younger children and older adults (e.g., Chen & Li, 2007). Belacchi and colleagues (2010) also found a strong association between memory updating ability and fluid intelligence in children aged five to 11 years, and found that memory updating was the strongest predictor of fluid intelligence out of a battery that included other general working memory tests such as memory span (see also Lechuga, Pelegrina, Pelaez, Martin-Puga, & Justicia, in press). From this perspective, intact memory updating abilities may be necessary—and perhaps particularly so for high-AQ individuals—to develop the high levels of general ability necessary to pursue tertiary education.

Another important consideration is that none of the tasks used in the literature or the present research provide a pure measure of memory updating ability. The CIE and homograph-reading paradigms arguably also measure general verbal abilities, and even the basic memory updating task used in Experiment 5 is likely to measure generic memory maintenance and retrieval functions in addition to specific working memory updating processes. The association between general working memory capacity and general intelligence is well-known (Oberauer et al., 2000), and thus it is difficult to ascertain whether performance on such memory updating tasks is limited by memory updating ability per se or if it is also limited by the efficiency of general working memory processes.

Ecker, Lewandowsky, and Oberauer (2014) recently suggested that it is the substitution of information that characterises memory updating (also see Ecker, Lewandowsky, Oberauer, et al., 2010). They further argued that information substitution can be decomposed into the removal of old (outdated, irrelevant, or invalidated) information and the encoding of new information, and that it is the active
removal of information that is integral to memory updating and the ability to hold the most recent up-to-date representation of an event in memory (Ecker, Lewandowsky, & Oberauer, 2014). Based on this rationale, the authors identified a reaction-time-based measure of removal efficiency that may serve as a more specific measure of memory updating ability that is relatively independent of general working memory capacity (Ecker, Lewandowsky, & Oberauer, 2014; K. A. Singh, Ecker, & Gignac, 2015). Future investigations of memory updating ability in relation to autism could thus utilise this more specific measure of memory updating.

However, despite its relative independence from generic working memory functions, it remains unknown whether Ecker and colleagues’ (2014) specific measure of memory updating is associated with general intelligence, and thus any investigations of memory updating abilities in the context of ASD may still need to carefully control for differences in intelligence level between participant groups. Some evidence for a potential link between removal and intelligence comes from a study by Colzato, van Wouwe, Lavender, and Hommel (2006). Colzato and colleagues used a visuo-spatial task to investigate the relationship between stimulus feature removal (or in their terms “unbinding”) and fluid intelligence. They found that, relative to participants with lower intellectual ability, as measured by the Raven’s Progressive Matrices task, participants who had higher intellectual ability were more efficient in removing stimulus features from memory (Colzato et al., 2006). This suggests that there may be an association between general intelligence and the removal of information from working memory. If, however, removal efficiency is found to be unrelated to fluid intelligence, Ecker and colleagues’ (2014) measure of memory updating may be particularly amenable to use in future investigations of memory updating with reference

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12 Note that Ecker and colleagues’ (2014) conceptualisation of information-removal also invokes the concept of unbinding, namely the unbinding of item and context associations in a mnemonic network.
to a broader autism phenotype, as it would remove the potential confound with both
generic working memory functions and general intelligence.

6.4. Recommendations for Future Research

In addition to the recommendations mentioned in the above sections (e.g.,
recruiting individuals from the broader general population, and using a novel reaction-
time-based removal index as a more specific measure of memory updating ability) there
are several additional adaptations to the methodology of the current thesis that may
enhance future investigations of memory updating ability in individuals with high levels
of autistic-like traits, or individuals with ASD. Participants in the current experiments
were recruited on the total score they obtained on the AQ questionnaire. The items in
the AQ were designed to assess five areas of behaviours and symptoms associated with
ASD—(1) social skill, (2) attention switching, (3) attention to detail, (4) communication,
and (5) imagination (Baron-Cohen et al., 2001). Although empirical support for these
five subscales is mixed, with studies finding two-factor (Hoekstra, Bartels, Cath, &
Boomsma, 2008), three-factor (Austin, 2005; Palmer, Paton, Enticott, & Hohwy, 2015;
Russell-Smith, Maybery, & Bayliss, 2011), and four-factor (Stewart & Austin, 2009)
structures for the AQ, two factors have been consistently identified across all studies,
namely social skills/difficulties, and attention to detail. These two factors are only
weakly related in student populations (Russell-Smith et al., 2011). Thus while the total
AQ score provides information regarding the overall level of autistic-like traits in an
individual, the total score reflects somewhat independent trait dimensions, each of
which may influence performance on various tasks in a selective way. This has been
illustrated by Russell-Smith and colleagues (2012) who investigated the relationships
between the social skills/difficulties and attention to details AQ factors, and
performance on the EFT. As mentioned earlier, superior performance on the EFT
observed in individuals with ASD may be due to impaired global processing or enhanced local processing (e.g., Happé & Frith, 2006). Interestingly, Russell-Smith and colleagues (2012) found that superior EFT performance was related to higher scores on the social skills/difficulties factor, but EFT performance was not related to scores on the attention to details factor. Russell-Smith and colleagues (2012) argued that the link between poor social skills and superior EFT performance may reflect impaired global processing (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Happé & Frith, 2006; Jarrold et al., 2000; Russell-Smith et al., 2012). Nevertheless, the fact that Russell-Smith and colleagues (2012) found different patterns of performance between groups of participants depending on their levels of traits according to these two factors suggests that particularly low or high scores on specific factors underlying the AQ may contribute to performance on specific tasks in different ways (see also Chouinard et al., 2014). One could consider utilising such an approach, selecting participants based on subsets of autistic-like traits rather than the total AQ score (Palmer et al., 2015). For example, an additional factor—the “communication/mindreading” factor (Austin, 2005) which contains items such as “If there is an interruption, I can switch back to what I was doing very quickly”—could be of particular relevance for investigations of memory updating ability and the processing of ambiguous information.

Another consideration for future studies is the use of different methodologies to assess memory updating ability. It may be worthwhile to adapt the CIE paradigm, or other updating tasks, using more visuo-spatial or pictorial stimuli, particularly if a clinical sample of individuals with ASD is recruited. Such tasks will also provide information regarding performance on a wider range of task stimuli. One other adaptation to the methodology may be to incorporate alternative online measures of reading. Kurby and Zacks (2012) used a “think-aloud” method, whereby participants verbalised their thoughts following each message of an unfolding narrative. Rapp and
colleagues (2014) used “fact-checking” (i.e., editing the text and making corrections) during reading, with the intention of reducing reliance on misinformation. Utilising such “think-aloud” and “fact-checking” methods in the CIE paradigm, for example, would provide additional information about the online reasoning and thought processes that occur during reading, and would thus give insight into how participants use misinformation, and how it may influence their memory for and reasoning about an unfolding event in the CIE paradigm. Eye-tracking methods may also prove informative: Such methods have been used in the homograph-reading task, and can provide information regarding where participants focus their attention during reading and for how long (Brock et al., 2008; Caruana, 2011). Applying the eye-tracking method in misinformation paradigms could thus provide potential insight into how participants resolve conflict when they encounter retractions of misinformation.

Finally, to reiterate, more work is needed to more precisely describe the cognitive profiles of individuals with high levels of autistic-like traits and vis-à-vis individuals with ASD. It is possible that some difficulties observed in individuals with ASD may not be present with reference to a broader autism phenotype and these group differences may carry important clinical relevance. However, the current findings are limited to a university sample, and it would thus be premature to conclude that individuals with ASD do not have memory updating difficulties. For definitive conclusions to be made specifically regarding memory updating ability it is important that high-AQ participants from a general population, as well as individuals with ASD and their relatives are recruited in future research.

6.5. Concluding Remarks

The primary aim of the current thesis was to investigate memory updating ability with reference to a broader autism phenotype using individuals with low and
high levels of autistic-like traits. One theory that has emerged from attempts to uncover
the underlying basis of the impaired social interaction and communication, and
repetitive and stereotypic patterns of thoughts and behaviours associated with ASD is
the executive dysfunction theory. Memory updating ability has been identified as one of
three main executive functions (Miyake et al., 2000). Despite this, no studies within the
ASD literature have considered memory updating ability in their assessment of
executive functioning in individuals with ASD, nor with reference to a broader autism
phenotype. In sum, the current findings from Experiments 1 to 5 do not provide strong
evidence to suggest that high-AQ individuals, relative to their low-AQ counterparts,
have greater difficulty updating initial situation models in light of incoming information.
Therefore, suppositions about impaired memory updating ability with reference to a
broader autism phenotype cannot be confirmed with the current results, and further
investigation is necessary.
References


Caruana, N. (2011). Autistic traits and the ability to integrate context during reading: Assessing weak central coherence theory using eye-movement measures (Bachelor of Psychology (Honours)), Macquarie University.


Cheung, C. S. C. (2010). *He did it! She did it! No, she did not! The continued influence of contradictions and the effects of presentation order.* (Bachelor of Science (Honours) honour's thesis), The University of Western Australia, Perth.


Hogan, J. (2012). *Reminders and repetition of misinformation: Helping or hindering its retraction?* (Bachelor of Arts (Honours) honour's thesis), The University of Western Australia, Perth.


characteristics and relation to symptom severity. *European Child & Adolescent Psychiatry*.


### Scenario 2 (Bushfire)

#### Messages in Article 1 of the bushfire scenario used in Experiment 2

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Firefighters in Victoria have been battling a bushfire that raged out of control in the state’s North-east overnight.</td>
</tr>
<tr>
<td>2</td>
<td>The bushfire came dangerously close to homes in the town of Euroa, but it is believed that no damage was caused to property.</td>
</tr>
<tr>
<td>3</td>
<td>David Karle of the Country Fire Authority (CFA) indicated that authorities were looking into the cause of the fire, with early evidence suggesting that the fire had been deliberately lit.</td>
</tr>
<tr>
<td>4</td>
<td>Emergency services were still working tirelessly this morning to extinguish the flames, but were confident that the location of the remaining fire was unlikely to pose any further threat to local communities.</td>
</tr>
<tr>
<td>5</td>
<td>The suspected burn area is estimated to be roughly 50,000 hectares.</td>
</tr>
</tbody>
</table>

#### Messages in Article 2 of the bushfire scenario used in Experiment 2

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>After working throughout the day, firefighters have managed to bring a bushfire in the North-East of Victoria under control.</td>
</tr>
<tr>
<td>2</td>
<td>There have been no reported casualties or damage to property, with most land damage occurring in rural fringe areas and nearby forest reserves.</td>
</tr>
<tr>
<td>3</td>
<td>(No retraction). Due to the extent of the damage from the bushfire, authorities have announced a fundraising drive will be set up for the residents of Euroa.</td>
</tr>
<tr>
<td>4</td>
<td>(Retraction). After a full investigation and review of witness reports, authorities did not find any evidence that would suggest arson.</td>
</tr>
<tr>
<td>5</td>
<td>Casey Haas, a resident of Euroa, expressed her relief that no one had been harmed by the fire, and said she felt lucky that they had avoided disaster.</td>
</tr>
<tr>
<td></td>
<td>Even so, she feels that it is important for residents of the community to work together to ensure they are prepared for disaster if it ever strikes again.</td>
</tr>
</tbody>
</table>
### Scenario 3 (Death of a drug dealer)

#### Messages in Article 1 of the drug dealer scenario used in Experiment 2

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The death of a notorious drug dealer, known on the street as ‘Coach’, is being treated as suspicious.</td>
</tr>
<tr>
<td>2</td>
<td>He has been under investigation for several months by police regarding his alleged involvement in the trade of methamphetamines.</td>
</tr>
<tr>
<td>3</td>
<td>At this stage of the investigation, authorities believe the death was the result of an assault in what is believed to have been a drug deal gone wrong, and various members of the local drug scene are being investigated.</td>
</tr>
<tr>
<td>4</td>
<td>A neighbour discovered the man in his Frankston home during the early hours of Saturday morning.</td>
</tr>
<tr>
<td>5</td>
<td>Police believe the man had been dead for several hours before he was found. Sergeant Barry Wade from the Victorian Police Force has asked anybody who has witnessed any suspicious behaviour in the area to contact authorities.</td>
</tr>
</tbody>
</table>

#### Messages in Article 2 of the drug dealer scenario used in Experiment 2

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A drug dealer’s death comes after a string of violent brawls occurring at his Frankston residence.</td>
</tr>
<tr>
<td>2</td>
<td>A methamphetamine lab has been found in the back yard, and all drugs have been seized from the property.</td>
</tr>
<tr>
<td>3</td>
<td>(No retraction). Some members of the local community have been sighted at the drug-dealer’s home leaving flowers and paying their respect.</td>
</tr>
<tr>
<td>4</td>
<td>The funeral is scheduled for tomorrow afternoon, and will be attended by friends and family of the deceased under police observation.</td>
</tr>
<tr>
<td>5</td>
<td>A spokesperson for the family said they were extremely upset by their family member’s death.</td>
</tr>
</tbody>
</table>
Scenario 4 (Collapse at a nightclub)

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A woman has been taken to St. Mary’s hospital after losing consciousness whilst out partying at the Cable nightclub in London last night.</td>
</tr>
<tr>
<td>2</td>
<td>A friend of the woman said she had complained of hallucinations and nausea not long before falling unconscious. The woman herself has no memory of what happened.</td>
</tr>
<tr>
<td>3</td>
<td>After an initial observation, the woman’s blood pressure and heart rate stabilized and doctors believe the woman’s symptoms are the result of her drink getting spiked.</td>
</tr>
<tr>
<td>4</td>
<td>This is the latest in a series of drink spiking incidents at the club, which has renewed calls for it to introduce a bottled drinks only policy.</td>
</tr>
<tr>
<td>5</td>
<td>The incident also comes as a reminder to party-goers to be careful with their drinks, and to take measures to ensure they are not a victim of drink spiking.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A woman who fell unconscious while partying has remained in hospital. The woman was out celebrating with friends after graduating from The Regent Academy, where the group had studied photography together.</td>
</tr>
<tr>
<td>2</td>
<td>When she lost consciousness, it was the timely aid of her friends that saved her from further harm.</td>
</tr>
<tr>
<td>3</td>
<td><em>(No retraction).</em> The doctors informed the woman’s family that she had since regained consciousness and was responding well to treatment.</td>
</tr>
<tr>
<td></td>
<td><em>(Retraction).</em> After a series of blood tests, the woman’s doctors have ruled out drink-spiking as the cause of the symptoms.</td>
</tr>
<tr>
<td>4</td>
<td>A relative of the woman spoke on behalf of the family, stating that they were all relieved once they heard that she was recovering well.</td>
</tr>
<tr>
<td>5</td>
<td>The woman’s family were extremely proud of the strength she had shown, and she was discharged from the hospital after a 3-night stay.</td>
</tr>
</tbody>
</table>
Scenarios

### Scenario 5 (Seizure incident)

#### Messages in Article 1 of the seizure incident scenario used in Experiment 2

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>News headlines in NSW have been dominated by reports of a statewide increase in the number of hospitalizations of children up to 5 years-old in the recent months.</td>
</tr>
<tr>
<td>2</td>
<td>The children were rushed to several emergency departments across NSW after experiencing seizures and nausea.</td>
</tr>
<tr>
<td>3 (cause)</td>
<td>The recent increase in seizure-related hospitalizations in children in NSW coincides with the introduction of a new compound polio and chicken pox (CPV) vaccine.</td>
</tr>
<tr>
<td>4</td>
<td>The CPV vaccine, developed by scientists at the University of Sydney, combines the polio and chicken post (varicella) vaccines.</td>
</tr>
<tr>
<td>5</td>
<td>Scientists at the University of Sydney have been investigating the effects of the new compound polio and chicken pox (CPV) vaccine, after doctors reported majority of the children received the vaccine prior to experiencing seizures.</td>
</tr>
</tbody>
</table>

#### Messages in Article 2 of the seizure incident scenario used in Experiment 2

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hospitals across NSW have seen a sharp increase in the number of children being hospitalized after experiencing seizures and nausea.</td>
</tr>
<tr>
<td>2</td>
<td>Medical staff have been working day and night to ensure all children are monitored for any further seizures.</td>
</tr>
<tr>
<td>3 (target message)</td>
<td>(No retraction). The children have been recovering well after medical staff were able to control their seizures and many have since been discharged and returned home.</td>
</tr>
<tr>
<td></td>
<td>(Retraction). Professor Barnaby Norton, of the University of Sydney, made a special report stating that the CPV vaccine trial has been reviewed, and no relation was found between the CPV vaccine and the seizures.</td>
</tr>
<tr>
<td>4</td>
<td>The media have commended the medical staff for their dedication and attentive care in managing the overflow of admissions across NSW hospitals.</td>
</tr>
<tr>
<td>5</td>
<td>Several parents of the children have also expressed their gratitude to the doctors for their care and frequent updates on their children’s condition.</td>
</tr>
</tbody>
</table>
**Scenario 6 (Water catchment shutdown)**

*Messages in Article 1 of the water catchment shutdown scenario used in Experiment 2*

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Freemont Water Department was forced to shut down its water intake from its main water supply, the Denroy River, due to contamination concerns following reports of large scale fish deaths in the waterway.</td>
</tr>
<tr>
<td>2</td>
<td>The Freemont water department supplies water to the Shelby region.</td>
</tr>
<tr>
<td>3 (cause)</td>
<td><em>It is believed that the fish deaths are due to chemical waste dumping by a riverside pharmaceutical company, in violation of the Missouri Clean Water Act.</em></td>
</tr>
<tr>
<td>4</td>
<td>The Freemont Water Department stated it remained committed to ensuring customers can be confident that their water supply is of the purest quality.</td>
</tr>
<tr>
<td>5</td>
<td>Authorities have begun clearing the dead fish from the waterway.</td>
</tr>
</tbody>
</table>

*Messages in Article 2 of the water catchment shutdown scenario used in Experiment 2*

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Freemont Water Department has been given the all-clear to continue water intake from the Denroy River, after operations ceased for 5 days due to large scale fish deaths in the waterway.</td>
</tr>
<tr>
<td>2</td>
<td>The incident had occupied news headlines for more than one week.</td>
</tr>
<tr>
<td>3 (target message)</td>
<td><em>(No retraction). The Denroy River is popular with local recreational fishers and families, as well as tourists who enjoy the river cruises.</em></td>
</tr>
<tr>
<td></td>
<td><em>(Retraction). Tests by both the Water Department and an independent agency have revealed that the chemical levels in the water at no stage reached levels that would cause any harm to fish or consumers.</em></td>
</tr>
<tr>
<td>4</td>
<td>The water-intake shutdown was bad news for the Freemont Water Department, as recent draught periods have resulted in record low storage levels.</td>
</tr>
<tr>
<td>5</td>
<td>Despite these ongoing concerns, a spokesperson has assured customers that the local drinking water is as safe as it has ever been.</td>
</tr>
</tbody>
</table>
Appendix B – Experiment 2 Open-ended Questionnaires

Scenario 2 (Bushfire)

Open ended-questionnaire for the bushfire scenario used in Experiment 2

Inference Questions

6. Briefly summarise the ‘bushfire’ article
7. How could such events be prevented in the future?
8. What would be a good newspaper headline for what happened?
9. What could be a reason to further investigate this incident?
10. What was the cause of the bushfire?

Fact-recall Questions

4. Where did the bushfire occur?
   a) Shepparton  b) Euroa  c) Benalla  d) Kyneton
5. What was local resident Casey Hass relieved about?
   a) That no one had been harmed  b) That her house had not been affected
   c) That her pets had survived  d) That rain had set in
6. How many hectares of bushland were burnt?
   a) 100,000  b) 25,000  c) 50,000  d) 200,000

Scenario 3 (Death of a drug dealer)

Open ended-questionnaire for the drug dealer scenario used in Experiment 2

Inference Questions

1. Briefly summarise the ‘death of a drug dealer’ article
2. What would be a good newspaper headline for what happened?
3. How could this incident have been avoided?
4. What could be a reason to further investigate this incident?
5. What was the cause of the drug dealer’s death?

Fact-recall Questions

1. What was the nickname of the drug dealer?
   a) Coach  b) Shrink  c) Grandpa  d) Priest
2. Who found the body?
   a) His mother  b) Police  c) Neighbour  d) Priest
3. What kind of drug did police find on the property?
   a) Cannabis  b) Heroin  c) Methamphetamine  d) Ecstasy
Scenario 4 (Collapse at a nightclub)

Open ended-questionnaire for the drug dealer scenario used in Experiment 2

Inference Questions

6. Briefly summarise the ‘death of a drug dealer’ article
7. What would be a good newspaper headline for what happened?
8. How could this incident have been avoided?
9. What could be a reason to further investigate this incident?
10. What was the cause of the drug dealer’s death?

Fact-recall Questions

4. What was the nickname of the drug dealer?
   a) Coach      b) Shrink      c) Grandpa      d) Priest
5. Who found the body?
   a) His mother b) Police      c) Neighbour    d) Priest
6. What kind of drug did police find on the property?
   a) Cannabis   b) Heroin      c) Methamphetamine d) Ecstasy

Scenario 5 (Seizure incident)

Open ended-questionnaire for the collapse at a nightclub scenario used in Experiment 2

Inference Questions

1. Briefly summarise the ‘nightclub’ article
2. How could such events be prevented in future?
3. What would be a good newspaper headline for what happened?
4. What could be a reason to not visit the mentioned nightclub?
5. What was the cause of the woman’s symptoms?

Fact-recall Questions

1. What nightclub was the woman partying at?
   a) Loft      b) Fabric      c) Cable      d) Plastic People
2. In what city did the incident occur?
   a) London    b) Melbourne   c) New York   d) Munich
3. What subject did the woman study at the Regent Academy?
   a) Photography b) Interior design c) Fashion d) Beauty therapy
Scenario 6 (Water catchment shutdown)

Open ended-questionnaire for the water catchment shutdown scenario used in Experiment 2

Inference Questions
1. Briefly summarise the ‘vaccine’ article
2. Why would the introduction of the new CPV vaccine make people more skeptical about vaccinations?
3. What would be a good newspaper headline for what happened?
4. What could be a reason not to have the CPV vaccine?
5. Is there any harm associated with taking the CPV vaccine?

Fact-recall Questions
1. What water department was involved?
   a) Freemont   b) Wortworth   c) Patterson   d) Greenacre
2. What is the name of the river that the water supply comes from?
   a) Harding   b) Denroy   c) Frederick   d) Morgan
3. How many days was intake from the water supply shut down for?
   a) 1   b) 5   c) 13   d) 27
Appendix C – Experiment 3 Scenarios

Order of Messages in Conditions when Cause 1 was Retracted

Messages Used in the Scenario in Experiment 3 in the Retract-2 condition.

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A report has come into the police headquarters on Tuesday about a serious accident involving a school bus on Spring St. The school bus had hit a cyclist on the side of the road before crashing into the window of a music store. The report was made by a driver who was driving past the scene of the accident.</td>
</tr>
<tr>
<td>2</td>
<td>An ambulance was dispatched to the scene immediately upon the report of the accident but due to bad road conditions from roadworks in the area, they arrived at the scene only after 15 minutes. Upon arrival, they began assessing the cyclist and the bus-drivers’ injuries, both of whom were found unconscious.</td>
</tr>
<tr>
<td>3 (cause 1)</td>
<td>(Burst tyre). Police investigating the cause of the accident have released a report, stating that the bus-driver apparently lost control of the bus because a front tyre burst after a piece of scrap metal, believed to have originated from the adjacent construction site, lodged in the tyre.</td>
</tr>
<tr>
<td></td>
<td>(Merging car). The police released a second statement regarding the cause of the accident, stating that the bus-driver apparently lost control during an emergency braking on loose gravel after a car had violently merged into his lane.</td>
</tr>
<tr>
<td>4</td>
<td>The police further stated that both the cyclist and the bus-driver were seriously injured and had been taken to hospital immediately. A few of the school kids who had been in the bus sustained minor injuries</td>
</tr>
<tr>
<td>5</td>
<td>The injured arrived at the nearby St. Joseph’s hospital, where the cyclist and the bus-driver were warded for further observation while all school kids were discharged after treatment. Family members of the victims involved in the accident had been contacted and informed of the situation.</td>
</tr>
<tr>
<td>6</td>
<td>At the scene of the accident, police interviewed a number of eyewitnesses, some of whom claimed to have heard squeaking and rumbling sounds and then saw the bus hit the cyclist.</td>
</tr>
<tr>
<td>7 (cause 2)</td>
<td>(Merging car). The police released a second statement regarding the cause of the accident, stating that the bus-driver apparently lost control during an emergency braking on loose gravel after a car had violently merged into his lane.</td>
</tr>
<tr>
<td></td>
<td>(Burst tyre). Police investigating the cause of the accident have released a report, stating that the bus-driver apparently lost control of the bus because a front tyre burst after a piece of scrap metal, believed to have originated from the adjacent construction site, lodged in the tyre.</td>
</tr>
<tr>
<td>8</td>
<td>Police have stated that the school bus was apparently on its way back to Spring Oaks Primary School after an outing at the bowling centre. The school’s headmaster was contacted and he explained that the bus-driver has not been involved in an accident before.</td>
</tr>
<tr>
<td>9</td>
<td>There was a gradual build-up of traffic in the Spring Street area due to the roadworks and police cordoning off the area of the accident. Drivers were advised to avoid the area and bystanders were advised not to crowd the area.</td>
</tr>
<tr>
<td>10</td>
<td>The media released a statement that this had been the third accident on Spring Street within 6 months and urged the local council to attend to this issue. They also appealed to all cyclists to wear a helmet at all times.</td>
</tr>
<tr>
<td>Message No.</td>
<td>Message Content</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>11</td>
<td>Police had to calm the owner of the music store, who was very upset about his shop window being broken and a valuable limited edition guitar being destroyed. He was attended to by paramedics.</td>
</tr>
<tr>
<td>12</td>
<td>Police continued to review evidence and interview witnesses, including the school kids. Police had difficulty interviewing some school kids as some of them were distressed and crying due to the shock and were asking for their parents.</td>
</tr>
<tr>
<td>13</td>
<td>After police had interviewed the school kids, a police van took them to the nearest police station. Their parents had been informed to pick their children up from the police station.</td>
</tr>
<tr>
<td>14</td>
<td>The police were under some pressure to clear the scene as quickly as possible due to the upcoming rush hour. A tow truck had been called to tow the bus out of the music store but there was a delay due to the roadworks.</td>
</tr>
<tr>
<td>15</td>
<td><em>(Retract cause Merging Car).</em> A special report made by the police stated that though there had been other vehicles present at the scene, none had been causally involved in the accident.</td>
</tr>
<tr>
<td></td>
<td><em>(Retract cause Burst Tyre).</em> A special report made by the police stated that the burst tyre was not the cause of the accident. It had actually burst upon impact with the road kerb after hitting the cyclist.</td>
</tr>
<tr>
<td>16</td>
<td>More than three hours after the time of the accident, the police have cleared the scene and traffic on Spring Street slowly restored itself to normal.</td>
</tr>
<tr>
<td>17</td>
<td>Several days later, it has been revealed that both the cyclist and the bus-driver were making good progress in their recovery from the injuries sustained in the accident. The total damage was estimated to lie over $50,000.</td>
</tr>
</tbody>
</table>
Order of Messages in Conditions when there was No Retraction

Messages Used in the Scenario in Experiment 3 in the No-retraction Condition.

<table>
<thead>
<tr>
<th>Message No.</th>
<th>Message Content</th>
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</thead>
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<tr>
<td>1</td>
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<tr>
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</tr>
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</tr>
<tr>
<td>5</td>
<td>(Burst tyre). Police investigating the cause of the accident have released a report, stating that the bus-driver apparently lost control of the bus because a front tyre burst after a piece of scrap metal, believed to have originated from the adjacent construction site, lodged in the tyre.</td>
</tr>
<tr>
<td></td>
<td>(Merging car). The police released a second statement regarding the cause of the accident, stating that the bus-driver apparently lost control during an emergency braking on loose gravel after a car had violently merged into his lane.</td>
</tr>
<tr>
<td>6</td>
<td>The injured arrived at the nearby St. Joseph’s hospital, where the cyclist and the bus-driver were warded for further observation while all school kids were discharged after treatment. Family members of the victims involved in the accident had been contacted and informed of the situation.</td>
</tr>
<tr>
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<tr>
<td>9</td>
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<tr>
<td>10</td>
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<td>Message No.</td>
<td>Message Content</td>
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<tr>
<td>14</td>
<td>The police were under some pressure to clear the scene as quickly as possible due to the upcoming rush hour. A tow truck had been called to tow the bus out of the music store but there was a delay due to the roadworks.</td>
</tr>
<tr>
<td>15</td>
<td><strong>(No-retraction).</strong> A special report made by the police stated that both the cyclist and the bus-driver were in a stable condition.</td>
</tr>
<tr>
<td>16</td>
<td>More than three hours after the time of the accident, the police have cleared the scene and traffic on Spring Street slowly restored itself to normal.</td>
</tr>
<tr>
<td>17</td>
<td>Several days later, it has been revealed that both the cyclist and the bus-driver were making good progress in their recovery from the injuries sustained in the accident. The total damage was estimated to lie over $50,000.</td>
</tr>
<tr>
<td>Ambiguous Sentence</td>
<td>Non-ambiguous word</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>1. He <em>addressed</em> the little envelope and sealed it.</td>
<td>filled</td>
</tr>
<tr>
<td>2. Their <em>arms</em> were already loaded to shoot the enemy.</td>
<td>guns</td>
</tr>
<tr>
<td>3. The <em>band</em> had been worn around his arm.</td>
<td>strap</td>
</tr>
<tr>
<td>4. From the <em>bank</em> she decided to sail down the river.</td>
<td>jetty</td>
</tr>
<tr>
<td>5. The <em>beam</em> of great happiness on her face was uplifting.</td>
<td>beam</td>
</tr>
<tr>
<td>6. She saw the <em>bow</em> and decided to curtsy in response.</td>
<td>gesture</td>
</tr>
<tr>
<td>7. Her <em>calf</em> had been wandering in the fields.</td>
<td>cows</td>
</tr>
<tr>
<td>8. The <em>case</em> was already packed with souvenirs of his travels.</td>
<td>bag</td>
</tr>
<tr>
<td>9. His <em>charm</em> was not always worn around his neck.</td>
<td>necklace</td>
</tr>
<tr>
<td>10. There were <em>chips</em> on the windscreen after the hailstorm.</td>
<td>cracks</td>
</tr>
<tr>
<td>11. The <em>coach</em> was constantly braking all the way down the hill.</td>
<td>bus</td>
</tr>
<tr>
<td>12. His <em>company</em> was not welcome at the party.</td>
<td>friend</td>
</tr>
<tr>
<td>13. The <em>corn</em> that was on his foot was sore.</td>
<td>blister</td>
</tr>
<tr>
<td>14. The <em>course</em> was definitely rugged but the athletes were well trained.</td>
<td>equipment</td>
</tr>
<tr>
<td>15. At the <em>court</em> there were tennis balls littering the floor.</td>
<td>gym</td>
</tr>
<tr>
<td>16. The <em>crane</em> was slowly flying over the lake.</td>
<td>bird</td>
</tr>
<tr>
<td>17. Taking his <em>cue</em> from the snooker table he began to play.</td>
<td>drink</td>
</tr>
<tr>
<td>18. The <em>date</em> had been eaten with other dried fruits.</td>
<td>raisin</td>
</tr>
<tr>
<td>19. The <em>deck</em> was thoroughly shuffled by the dealer.</td>
<td>cards</td>
</tr>
<tr>
<td>20. The <em>fan</em> was constantly screaming with admiration for the band.</td>
<td>teenager</td>
</tr>
<tr>
<td>21. Bits of the <em>shell</em> were scattered after the bomb exploded</td>
<td>metal</td>
</tr>
<tr>
<td>22. The <em>organ</em> was going to be transplanted at the hospital.</td>
<td>kidney</td>
</tr>
<tr>
<td>23. The <em>port</em> was to be opened when the guests arrived.</td>
<td>wine</td>
</tr>
<tr>
<td>24. She noticed the <em>mole</em> and called the Wildlife Conservancy</td>
<td>parrot</td>
</tr>
<tr>
<td>25. Their <em>race</em> had been discriminated against.</td>
<td>religion</td>
</tr>
<tr>
<td>26. The <em>row</em> was the last conversation they had.</td>
<td>phoncall</td>
</tr>
<tr>
<td>27. The <em>sewer</em> had already begun to stitch the hem of her dress.</td>
<td>tailor</td>
</tr>
<tr>
<td>28. The <em>squash</em> was the last vegetable to be eaten.</td>
<td>pumpkin</td>
</tr>
<tr>
<td>29. The <em>tank</em> was full of soldiers and ammunition.</td>
<td>keep</td>
</tr>
<tr>
<td>30. The <em>tear</em> that was in her dress was noticed at the fashion show.</td>
<td>stain</td>
</tr>
<tr>
<td>31. A <em>belt</em> over his head was enough to knock him out</td>
<td>smack</td>
</tr>
<tr>
<td>32. She put the <em>bat</em> back in the feeding cage</td>
<td>dog</td>
</tr>
<tr>
<td>33. The <em>mobile</em> was placed above the baby’s cot</td>
<td>toy</td>
</tr>
<tr>
<td>34. She stared at the <em>star</em> and thought she was talented and beautiful</td>
<td>actress</td>
</tr>
<tr>
<td>35. The <em>match</em> was around 5cm long</td>
<td>string</td>
</tr>
<tr>
<td>36. The <em>bar</em> was made of dark chocolate</td>
<td>cake</td>
</tr>
<tr>
<td>37. The <em>mousse</em> was to be used for her hair</td>
<td>gel</td>
</tr>
<tr>
<td>38. He saw the <em>wave</em> as he exited the arrival gate</td>
<td>taxis</td>
</tr>
<tr>
<td>39. She looked at the <em>table</em> and she couldn’t see a caption for it.</td>
<td>painting</td>
</tr>
<tr>
<td>40. He saw the <em>crane</em> and noticed its clipped wings.</td>
<td>bird</td>
</tr>
</tbody>
</table>
Control Sentences
1. The light flickered on and off
2. He wrote the letter with a blue pen
3. The rose was a vibrant red colour
4. The wind was strong enough to move the cart
5. The sink was full of dirty dishes
6. The park near his house was perfect for soccer practice
7. The jam was made with home-grown strawberries.
8. It was cool enough to have the party outside
9. The sign was designed by a well-known illustrator
10. The bail was more than one million dollars
11. She took her clothes to the drycleaner
12. He wrote the time of the appointment in his diary
13. He forgot to return the book to her yesterday
14. The drive to the city took more than one hour
15. She plans to play tennis with her friend today
16. The food at the party was from a catering company
17. The new intern was helping with the data entry
18. She put the photo frames on her shelf
19. They wanted to paint the bedroom a different colour
20. The flowers in the vase had a nice fragrance