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Autobiographical Memory in Autism Spectrum Disorder through the Lens of Fuzzy Trace Theory

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Autobiographical memory is a form of memory intricately linked to the self, which requires integration of episodic, semantic, and procedural information (Marsh & Roediger, 2013). It provides an individual with a means of replaying specific past self-referential events in the mind's eye (Conway & Pleydell-Pierce, 2000; Cosentino, 2011). Forensically, it is of interest due to its importance in legal situations reliant on eyewitnesses to provide accounts of past events. Memory reports of events can make or break legal proceedings, and the veracity of memory reports is critical (Brainerd & Reyna, 1990a). Yet, some populations are viewed as having unreliable memories, for example, children (Block et al., 2012). These views can negatively impact how players in the legal system (e.g., judges, jurors, attorneys) value testimony provided from these sources. This has motivated research on factors that influence autobiographical memory in specific subgroups, such as children and the elderly, two of the most vulnerable populations (Odegard, Cooper, Holliday, & Ceci, 2010a; Toglia, Ross, Pozzulo, & Pica, 2014).

Our focus is on individuals with autism spectrum disorder (ASD), who represent a vulnerable population historically viewed as having impoverished memory function. Empirical data suggest that some individuals with ASD struggle to remember personally experienced events (Boucher, 1981; Boucher & Lewis, 1989; Kaney et al., 1999; Klein et al., 1999; Millward et al., 2000). However, the current literature on episodic memory in ASD is an amalgam of seemingly conflicting findings that do not clearly define which individuals will and will not have difficulty in this area (e.g., Crane, Lind, & Bowler, 2013b; Millward et al., 2000). The confusion stems from both methodological differences and heterogeneity of symptom profiles in the ASD community.

There is considerable need for a clearer understanding of factors that undergird memory function in this population. This will, in turn, aid in identifying boundary conditions to better gauge the reliability of their memories.

Here, we attempt to unpack one specific domain of episodic memory—autobiographical memory. We present current evidence within a well-established theoretical framework—Fuzzy Trace Theory (FTT)—that may account for some of the performance differences observed in individuals with ASD (see also Reyna & Brainerd, 2011). FTT describes the developmental shift from reliance on *verbatim representations*, or detailed encoding of information as it was presented, to *gist representations*, or broader encoding of the pattern of associated concepts related to the original input (Brainerd & Reyna, 1992; Reyna & Brainerd, 1991a, 1991b) and is supported by established process models (Bauer, Larkina, & Deocampo, 2011; Howe, 2011; Raj & Bell, 2010; Schneider, 2011; Shing & Lindenberger, 2011).

Within the framework of Fuzzy Trace Theory (FTT), there are three levels of processing at which autobiographical memory in ASD may break down: (a) encoding (was it stored), (b) availability (is it stored in a way that can be retrieved), and (c) retrieval (what cues are needed to access it). Two types of memory trace—verbatim and gist—support these processes. Verbatim-based versus gist-based influences on encoding, accessibility, and retrieval appear to be domain-specific in ASD, rather than global. Therefore, it is more straightforward to examine these processes as they pertain to each of the component skills required for autobiographical memory. In the following sections, we discuss the component skills required for autobiographical memory—language and narrative construction, spatiotemporal binding and self-projection backward in time, self-concept, and source-monitoring—and the evidence of dysfunction in ASD as it relates to aspects of FTT.

Overview of Fuzzy Trace Theory

FTT proposes that cognition consists of seven core components accounting for processes from perception and encoding to storage and retrieval. They are: (a) gist extraction, (b) fuzzy-to-verbatim continuum, (c) fuzzy-processing preference, (d) reconstructive short- and long-term memory, (e) output interference, (f) resource freedom, and (g) ontogenesis. Each of these components uniquely contributes to an individual's ability to interpret and maintain information for later use.

Within an FTT framework, information is encoded either as general, vague representations of the whole (fuzzy or gist traces) or as detailed, exact representations of a target (verbatim traces). Individuals sift through information in search of patterns or elements that characterize the whole (Brainerd & Reyna, 1990b; Reyna, 1995, Reyna, 2008; Reyna et al., 2014). This is the *fuzzy* end of the fuzzy-to-verbatim continuum. Across the lifespan, humans rely less on verbatim retrieval and more on fuzzy traces to remember and make inferences. An increased reliance on fuzzy traces stems from the fact that these traces are meaningful as well as easier to retrieve, process, and alter. Throughout the past two decades, researchers have amassed a great deal of evidence in support of this proposed developmental trajectory (Brainerd, Holliday, & Reyna, 2004; Brainerd, Reyna, & Zember, 2011; Farrar & Goodman, 1992; Ghetti & Angelini, 2008; Ghetti, Qin, & Goodman, 2002; Odegard, Cooper, Lampinen, Reyna, & Brainerd, 2009; Odegard, Jenkins, &

Koen, 2010b; Reyna, Chick, Corbin, & Hsia, 2014; Reyna & Kiernan, 1994; Reyna, Wilhelms, McCormick, & Weldon, 2015b).

Verbatim traces are more vulnerable to decay and interference than gist traces, perhaps in part, because of underlying differences in the neurological structures that support these separate forms of information (Brainerd, Reyna, & Brandse, 1995; Dennis, Kim, & Cabeza, 2008; Kintsch, Welsch, Schmalhofer, & Zimny, 1990; McDermott, 1996; Stäubli, Ivy, & Lynch, 1984; Toggia, Neuschatz, & Goodwin, 1999). Verbatim traces also suffer from the constraint of encoding specificity, which requires highly detailed retrieval cues and makes them more difficult to access (Tulving, 1983). Thus, a search for the most detailed and accurate information found in verbatim traces requires a significant amount of time and is subject to interference (Malmberg & Shiffrin, 2005; Reyna & Mills, 2007; Tun, Wingfield, Rosen, & Blanchard, 1998).

Although verbatim traces are limited in duration due to decay, enduring gist traces may contain the information necessary to overcome lost information and produce a successful response. Reyna and Brainerd (1995) posited that gist traces are more likely than verbatim traces to be fully encoded, and that they are more robust against the effects of forgetting. In fact, as Brainerd and Reyna (1988; 1990a; 1990b) proposed, humans have a bias toward the use of gist traces in cognition, using gist for both memory retrieval and information processing. In essence, this means that individuals search for the simplest, most readily accessible solution, which leads them to the preferential use of gist-based information.

However, as is the case with most heuristics, reliance on gist to “fill in the blanks” puts an individual at risk for error. Error may be introduced by way of content borrowing when associated information is activated during retrieval. Wrongly activated information may be reconsolidated into an existing trace, particularly if the original trace is weak because of forgetting or limited learning events, expanding the reach of the trace and allowing interference during subsequent retrievals (Brainerd & Reyna, 1990a; Ceci & Bruck, 1993; Ceci, Toggia, & Ross, 1988; Loftus, Miller, & Burns, 1978; Marche & Howe, 1995; Titcomb & Reyna, 1995). This reconsolidation process leads to strong feelings of familiarity with the falsely retrieved information, which becomes incorporated into the original memory as though it were present at the time of encoding (Bransford & Franks, 1971; Lampinen, Meier, Arnal, & Leding, 2005; Reyna, Corbin, Weldon, & Brainerd, 2016). This is particularly important to consider when attempting to elicit eyewitness or autobiographical memories from a person, especially when he or she is vulnerable to suggestion (e.g., children, certain clinical populations). Wrongly-activated information can taint related traces, interfering with a person’s ability to accurately reconstruct a memory, and the process of reconsolidation during retrieval increases confidence in that memory regardless of its accuracy.

Neither type of trace is superior to the other across all domains, as noted by Acredolo (1995), but, rather, both gist and verbatim memory traces support learning and information processing in unique and vital ways, and their relative strength depends largely on task demands and availability of cognitive resources. When considering the relation between FTT and autobiographical memory, it is important to appreciate that FTT specifies both the memory structure at a representational level and processes that act on these traces. Reliving a past event can arise from directly accessing a verbatim trace for a specific past event. Direct access to a verbatim trace leads to highly reliable memory reports with considerable detail. However, as we

highlighted, these traces are vulnerable to forgetting through a host of mechanisms that limit direct access to verbatim traces.

At the same time, an event can be relived through reconstruction of the past using gist representations. In this regard, individuals reconstruct the past using a fuzzy representation and their general understanding of the nature of the event that took place. Under these circumstances memory reports can contain accurate information but can also contain less than reliable details. In many contexts, such as comprehending a narrative or making a decision, knowing the gist of what took place can be highly functional, in spite of not having access to specific details (Reyna, Weldon, & McCormick, 2015a). Reconstructed memories are of concern in forensic settings because such settings are among the few times that accuracy in the details of a memorial experience is of utmost importance.

Autobiographical Memory in ASD

Autobiographical memory develops throughout childhood, beginning around age 2 or 3 (Fivush et al., 1987; Nelson & Fivush, 2004). However, while the literature on autobiographical memory in typical development is rich, there is a paucity of evidence available to support conclusions about autobiographical memory ability in ASD.

Within the broader body of evidence for memory deficits in ASD, some have suggested that individuals with ASD have differences in episodic memory across both encoding and retrieval processes, despite preserved function in semantic memory (Ben Shalom, 2003). Others have posited that deficits in elaborative encoding limit the availability of to-be-remembered information (Beversdorf et al., 2007; Bowler et al., 2000; Bowler, Gaigg, & Gardiner, 2014; Bowler, Gardiner, & Berthollier, 2004; Meyer, Gardiner, & Bowler, 2014), in turn, driving performance differences on memory tasks. To effectively support availability for retrieval, information must be encoded in a way that is both durable (i.e., resistant to decay), and accessible (e.g., cross-referenced with appropriate associative nodes in order to maximize retrieval through spreading activation). Specifically, individuals with ASD may not have difficulty with the durability of memory traces, but may instead have difficulty with elaborative encoding processes, including feature and temporal binding, that limit the availability of memory traces (Beversdorf et al., 2007; Bowler, Gaigg, & Gardiner, 2014; Meyer, Gardiner, & Bowler, 2014; for review, also see Miller, Odegard, & Allen, 2014). In particular, as we discuss in further detail, studies requiring narrative-based recall may present a unique set of challenges to individuals with ASD.

This topic is particularly relevant to eyewitness testimony, given that individuals are often asked to produce free-recall narratives when giving evidence. In the case of an individual with ASD, the narrative representing an autobiographical memory may appear disjointed and incoherent—a scattered set of details rather than a coherent story—in turn, undermining the credibility of the eyewitness. However, as we outline here, this reflects the difficulty that individuals with ASD have with spatiotemporal binding, narrative coherence, and gist-based processing, rather than indicating unreliability and inaccuracy in this population.

In our view, a combination of differences in spontaneous encoding, accessibility, and retrieval of verbatim and gist-based memory traces and differences in the development of self-concept likely drive autobiographical memory impairments in ASD.

Gist-based processing allows an individual to represent the world in a broader categorical or contextual fashion, and to subsequently use that representation to reconstruct the past when access to verbatim traces breaks down. If individuals with ASD do not adhere to a typical balance of reliance on gist and verbatim information, they may differ qualitatively in the way that they reconstruct autobiographical memories and the type of information those reconstructions contain.

To fully appreciate autobiographical memory in ASD, we must unpack the ability of individuals with ASD to construct personal narratives, to engage in spatiotemporal binding and project their self-concept backward in time to previously experienced events (Cosentino, 2011), and to form and maintain a sense of self (i.e., auto-noetic consciousness; Powell & Jordan, 1993).

Language and narrative construction

Nelson and Fivush (2004) proposed a central role of language and narrative construction in autobiographical memory formation and recollection. They suggested that autobiographical memory results from sharing narratives about past events, which in turn, provides opportunity for elaboration and rehearsal, strengthening memory traces (see also Nelson, 1995). However, individuals with ASD have differences in the use of gist to reconstruct narratives in a way that is consistent with the temporal order and relative importance of events (Diehl, Bennetto, & Young, 2006), which may impact coherent recall of autobiographical memories.

To effectively communicate and construct narratives, individuals must use the core processes described in FTT. To explore the influence of key FTT processes on language and narrative construction, consider the following examples:

- 1 **Gist impairment:** If a breakdown occurs at the level of gist extraction, the context of a memory will be obscured and may not be available to support spatiotemporal binding (connecting the features of an event with their spatial and temporal context in memory), source memory (memory for the source of learned information), contextualization (remembering the context of an event or piece of information), and coherent construction of a narrative during encoding. This will, in turn, negatively impact accessibility. In this instance, an individual would be compelled to rely heavily on the verbatim end of the fuzzy-to-verbatim continuum at retrieval.
- 2 **Gist intact, but over-reliance on verbatim:** If the fuzzy-processing preference is not strong in ASD, individuals may still be able to encode and retrieve gist-based traces, but they are not likely to do so in a typical manner. They may produce a highly detailed recounting of events, but without sufficient attention to temporal order or context, relying heavily on the verbatim end of the fuzzy-to-verbatim continuum.
- 3 **Gist impairment, forcing over-reliance on verbatim:** If an individual primarily encodes verbatim traces without also encoding gist-based traces, the result is likely to be difficulty with accessibility and retrieval. Verbatim traces may not be durable enough (i.e., inaccessible or unavailable) depending on the amount of time that elapses and the strength of the original encoding. If gist traces are not available to support the reconstructive nature of autobiographical memory, the resultant memory may be incomplete, riddled with information gaps.

- 4 **Gist intact, but output interference:** If the use of gist is intact, but there is too much output interference at retrieval, an individual may produce autobiographical memories laden with technically inaccurate information activated by relying on the gist of the situation. Insufficient encoding or accessibility of verbatim traces will increase this vulnerability to interference.

People with ASD consistently appear to struggle with spontaneous use of gist and heavily rely on verbatim traces, which are susceptible to decay. For example, Bruck et al. (2007) observed that children with ASD had generally poorer performance than controls during retrospective reporting of personally experienced events and interviews following staged events. The ASD group made more errors of omission, rather than errors of commission, during autobiographical memory recall, especially for early-life events. This suggests that gist-based traces were unavailable to (a) aid in retrieval of less-accessible information, or (b) produce output interference that would lead to errors of omission. However, Bruck and colleagues noted that core deficits in autobiographical memory persisted in their sample, independent of the question or response format. On the surface, this pattern of results could arise from primarily verbatim-based responding and limited access to gist representations. In addition, children with ASD were suggestible to the same degree as typically developing (TD) controls, incorporating inaccurate information from misleading questions.

McCrary, Henry, and Happé (2007) presented similar results, finding that adolescents with ASD were no less accurate and no more suggestible than TD controls when recalling personally experienced staged events in a classroom setting. Further, they found strong evidence of impaired gist-based memory in their sample, with the ASD group reporting significantly less gist-based information about salient aspects of the event (e.g., the actors had a broken piece of equipment) than controls during free recall. In addition to highlighting the role of gist in autobiographical memory, this finding underlines the importance of testing or interview format for assessing the memory ability of people with ASD, who may struggle with expressive language or narrative construction needed for free recall.

Evidence also suggests that individuals with ASD do not reconstruct personal narratives in the same self-referential context as TD peers, providing further evidence of impaired gist processing. Brown and colleagues (2012) asked children and adolescents to report their earliest memories, one positive emotional experience, and one negative emotional experience. They found that individuals with ASD included fewer emotional, cognitive, and perceptual terms when recounting personally-experienced events. Similarly, Tanweer and colleagues (2010) noted that adults with Asperger's lacked specificity and self-reference when recalling personally experienced events from three time points in their lives. Chaput et al. (2013) also observed that adults with ASD recalled fewer and less-detailed autobiographical memories, and used fewer possessive pronouns and fewer family-related words (e.g., *mother*, *father*, *sister*), than TD controls.

In contrast, Bang, Burns, and Nadig (2013) reported that adolescents with ASD were able to appropriately use cognitive terms to describe mental states, despite producing fewer personal narratives during conversations than TD peers. They were, in essence, able to effectively engage in source monitoring to identify and describe their own mental states, but less able to place those mental states into the context of personal narratives. This pattern of evidence underscores the importance of dissociating

between the ability to use self-concept to support source monitoring from the ability to spontaneously produce narratives, personal or otherwise. It is especially important to consider this distinction when considering eyewitness memory reconstruction. For example, individuals with ASD may be able to reliably identify the source of information, regardless of their ability to effectively and spontaneously place that information or its source into a coherent narrative context. Given the age difference between ASD and TD adolescents, it is also possible that developmental factors drive the discrepancy in results.

Most recently, Losh and Gordon (2014) observed that high-functioning children with ASD produced personal narratives that were similar in content to those produced by controls, despite being of lower semantic quality. Narratives of lower semantic quality, as measured by Latent Semantic Analysis (Landauer & Dumais, 1997), were those which contained irrelevant or tangential remarks, disjointed narrative timelines, and heavy reliance on external prompts. This finding, along with others (e.g., Lind, Williams, et al., 2014), suggests that autobiographical memory differences in ASD are somewhat independent of language and narrative construction difficulties.

Spatiotemporal context for episodic memory

Spatiotemporal binding may prove difficult for people with ASD. The ability to bind features of an environment or event based on temporal contingencies adds specificity and enriched context to memorial traces. Inefficient or absent temporal binding disrupts coherence in episodic memories, in turn, posing challenges to accurate retrieval. Inefficient or absent spatial memory may result in missing details about objects or persons in a scene that could prove valuable to eyewitness accounts. Broadly, difficulty with spatiotemporal binding at encoding can leave memories susceptible to output interference, or render them partially or entirely inaccessible. With respect to FTT, spatiotemporal binding offers this enriched context for both verbatim and gist-based traces, but may especially aid in cueing reconstruction of gist-based information when other verbatim information is absent or inaccessible by facilitating “mental time travel.” Spatiotemporal context may also aid in source monitoring, or the ability to differentiate personally experienced events from others’ experiences, which is a key component of autobiographical memory. With respect to eyewitness memory, spatiotemporal binding is especially important for enriched cueing of gist-based memory. The use of “mental time travel” offers an opportunity for context reinstatement, which increases opportunities for retrieval of gist-based spatial (e.g., location, elements of a scene, persons relative to objects in a scene) or temporal (e.g., duration of an event, sequence of events) elements of the memory.

Some studies have found evidence of intact or superior temporal binding in children and adolescents with ASD (Mostofsky et al., 2000; Wallace & Happé, 2008), while others report impairments in children and adolescents (Szelag et al., 2004; Bennetto, Pennington, & Rogers, 1996) and adults (Crane & Goddard, 2008; Gowen & Miall, 2005; Martin, Poirier, & Bowler, 2010) with Asperger’s or high-functioning autism. These studies employed a variety of measures of temporal processing, including reproducing intervals of time (Gowen & Miall, 2005; Martin et al., 2010; Szelag et al., 2004) and estimation or production (Wallace & Happé, 2008).

Reproduction—storing the original stimulus information in memory and reproducing it at the time of recall—is perhaps the most relevant to the discussion of eyewitness testimony, given its reliance on memory to maintain an accessible representation of the interval of time to be reproduced at retrieval. Notably, this is also the domain in which individuals with ASD have consistently demonstrated difficulty.

Crane and Goddard (2008; Crane, Goddard, & Pring, 2009) found that adults with ASD relied atypically on temporally nonspecific representations of events much like TD younger children. For example, individuals with ASD might be able to remember that an event occurred, but may be unable to place that event or its elements on a timeline (i.e., the memory is lacking temporal context). They recalled personal semantic memories at rates equal to TD controls, despite lower specificity for personal episodic memories in a narrative recall task. Crane and Goddard further observed that individuals with ASD did not demonstrate the typical reminiscence bump—enhanced recall for events of adolescence and early adulthood—often observed in the typical developmental literature (Conway & Pleydell-Pearce, 2000). They suggested that atypical development of self-concept may produce limitations in autobiographical memory for individuals with ASD, specifically with respect to recall of events in temporal context (Crane & Goddard, 2008; Crane, Goddard, & Pring, 2009). Recently, Goddard et al. (2014) replicated many of these findings, observing that individuals with ASD had difficulty retrieving autobiographical memories across the lifespan, with specific difficulty retrieving and referring to information in remote memories. Further study of this tendency under multiple retrieval conditions (e.g., manipulating the type and amount of cueing) might aid in determining whether this information is available but difficult to access in ASD, or entirely unavailable for retrieval.

The relation between temporal information processing and episodic memory is bidirectional, such that intact traces for temporal context (e.g., duration of an event) are necessary for accurate episodic memory, and complete episodic memory recall includes information about temporal context (Sederberg, Gershman, Polyn, & Norman, 2011). The same is true for many forms of temporal information (e.g., order of events, onset and offset of an event). This temporal information, like any other feature of an episodic memory, may be retrieved directly or inferred. Absent, incomplete, or decayed verbatim traces for temporal information are vulnerable to gist-based errors, in which inference is made based on a broader, conceptual reconstruction of the event. Inferences are made about information for which a precise verbatim trace is and is not present, but the latter encourages reliance on gist (Reyna et al., 2016). Bennetto et al. (1996) reported poor performance of children and adolescents with high-functioning autism on tasks requiring retrieval or inference of temporal information from remembered events, including temporal order judgments and recency discrimination. Thus, the results of Bennetto et al.'s study suggest that gist-based processing is limited in ASD, but the degree of limitation remains unknown. Frith and colleagues' weak central coherence hypothesis also has been the impetus for research supporting a similar distinction between unimpaired processing of details and impaired processing of meaningful inferences (Happé & Frith, 2006; see also Reyna & Brainerd, 2011).

More recently, Maister and Plaisted-Grant (2011) conducted a study of temporal perception in children with ASD wherein participants were required to reproduce short (4–30 sec) and long (45 sec) durations, with the novel addition of a concurrent

task that prevented chronometric counting, a technique which may scaffold performance on duration-reproduction tasks. Duration reproduction is particularly relevant to autobiographical memory in instances where eyewitness recall of a timeline or duration of a given event is needed. Like Mostofsky et al. (2000) and Martin et al. (2010), Maister and Plaisted-Grant did not find any differences in perception of short time durations (i.e., 4–30 sec) between individuals with ASD and TD controls. However, they did observe impairments in the ASD group for long durations of 45 seconds, which did not relate to measures of attentional variability. Mimura et al. (2000) and others have suggested that durations of >30 seconds (especially with an interfering task) are reliant on episodic, rather than short-term, memory. Thus, Maister and Plaisted-Grant concluded that this difference reflected impairments in episodic memory in the ASD group. Further supporting their conclusion, long-duration performance in the TD, but not ASD, group was correlated with greater reorganization in a free-recall episodic memory task.

Maister and Plaisted-Grant noted that methodological differences between their study and those that do not control for chronometric counting (e.g., Wallace & Happé, 2008) may explain the discrepant results reported in the literature. They suggested that not only do individuals with ASD struggle to retain episodic memories; they also neglect the typical strategy of spontaneously reorganizing and re-encoding temporal information. This reorganization and re-encoding of information in typical development is most efficiently done in a gist-based manner (e.g., encoding the approximate duration of an event based on one's own perception of time vs. chronometric counting), and supports episodic memory retrieval by providing context for inferences required during gist-based reconstruction. With respect to eyewitness memory, the failure to spontaneously and accurately re-encode the approximate duration of an event in a gist-based manner may hinder the ability of individuals with ASD to recall temporal context or duration of an event accurately, especially in situations where attentional resources are taxed.

Lind and colleagues (Lind & Bowler, 2010; Lind & Bowler, 2008, Lind, Bowler, & Raber, 2014a) have previously hypothesized that difficulty with temporal self-projection might drive episodic memory and spatial memory challenges. However, Lind et al. (2014a, 2014b) demonstrated that children and adults with ASD displayed equal impairment in spatial memory for fictitious scenes, which do not require self-projection. Lind and colleagues (2014a, 2014b) suggested that this pattern of results in ASD represents difficulty with generating cognitive maps of the environment and scene construction. Both of these skills are related to autobiographical memory in that they provide context for episodes, and in the case of eyewitnesses, spatial memory may contain important information about the presence and location of key objects or persons.

Spatial memory for specific scenes requires encoding and accessibility of both verbatim traces for details of the scene and gist-based traces that aid in reconstructing the scene as a whole. Of importance, the pattern of results observed by Lind et al. (2014a, 2014b) occurred independent of narrative ability. Thus, impaired scene reconstruction may drive spatial memory and episodic memory difficulties in ASD, rather than auto-noetic consciousness or the ability to self-project. Others have found additional evidence of the ability to engage in “mental time-travel” to some degree (Bowler et al., 2007). Given this limited body of work, questions remain regarding the specific degree to which the ability to project self-concept forward and backward in time to

support autobiographical memory is present in individuals with ASD, how these abilities differ between children and adults, and what measures could be used to differentiate subtypes of ASD based on this ability.

Self-concept and source monitoring

As a person's self-concept becomes more complex, opportunities for memory organization increase in complexity. Thus, memory performance is typically facilitated by involvement of the self (Rogers, Kuiper, & Kirker, 1977). However, the typical advantage that self-referential information has in memory (Baker-Ward, Hess, & Flannagan, 1990) appears to be reduced or absent in adolescents and adults with ASD (Grisdale et al., 2014), Asperger's/high-functioning autism (Jackson, Skirrow, & Hare, 2012; Toichi et al., 2002), and a co-morbid diagnosis of ASD and intellectual disability (Hare, Mellor, & Azmi, 2007).

Self-awareness is a critical factor in the ability to engage in accurate source monitoring, which is important for correctly identifying the actor(s) or agent(s) in an autobiographical memory (Gardiner, 2001; Naito, 2003). Self-awareness may be generally impaired in ASD, which could impact the effectiveness of self-reference or source monitoring during encoding (Bowler, Gardiner, & Grice, 2000; Crane, Goddard, & Pring, 2009; for review, also see Lind, 2010). In support of this hypothesis, studies have reported reduced activity in ventromedial prefrontal cortex, an area related to judgments of self, when making self- versus other-judgments about personality traits or behavioral characteristics, in adults with ASD (Kennedy & Courchesne, 2008; Lombardo et al., 2010).

When considered in total, the developmental literature on self-awareness and self-concept in ASD reports somewhat mixed findings. Several studies have found intact self-recognition and metarepresentational ability in young children with ASD (Dawson & McKissick, 1984; Dissanayake, Shembrey, & Suddendorf, 2010), with exceptions for children functioning at a mental age lower than their chronological age (Ferrari & Matthews, 1983). However, Carmody and Lewis (2012) found that some children with ASD had deficits in self-representation ability that could not be explained by mental age alone. Thus, it may be that only a subset of children with ASD has reduced ability to form or maintain a typical self-representation or self-concept.

Although evidence suggests that many adults with ASD have the ability to perform just as well on memory tasks and some self-representation tasks as their TD counterparts, they may not report memories with the same confidence, perhaps because of differences in their self-awareness. For example, Elmoose and Happé (2014) observed that adults with ASD and TD controls were comparably accurate in memory for both social and nonsocial information. However, individuals with ASD were better at judging their memory accuracy for nonsocial than social stimuli. Conceptualization of agency and the ability to self-conceptualize from another's perspective also appears to differ in adolescents with ASD, as reported by Farley et al. (2010) and others.

Adults with ASD appear able to engage in source monitoring and affirm or deny whether a behavior or an observable characteristic is attributable to self versus other, despite difficulty differentiating between internal (e.g., psychological, personality) and external (e.g., physical) traits (David et al., 2010; Farrant et al., 1998; Kennedy & Courchesne, 2008; Lind, 2010). Some children with ASD also demonstrate the "enactment effect" observed in TD children—that is, self-performed actions are

better-remembered than other-performed actions (Hare, Mellor, & Azmi, 2007; Lind & Bowler, 2009; Williams & Happé, 2009). They are able to monitor source accurately (Hala et al., 2005; Hill & Russell, 2002), perhaps due to the tendency to encode verbatim memory traces more readily than error-prone gist (Reyna & Brainerd, 2011).

However, Lind and Bowler (2010) reported that, in their sample, adults with ASD were less likely than TD controls to re-experience past events from their own point of view, tending to recount events from the perspective of a third-person observer. They also demonstrated impaired episodic memory at a general level. Zalla et al. (2010) found mixed results with respect to the enactment effect. In their sample, adults with ASD did not consistently experience memory advantages for self-performed actions. However, Zalla et al. noted that their results may reflect difficulties specific to processing and encoding motor actions and proprioceptive signals rather than to memory in general.

Of interest, Crane and colleagues (Crane, Goddard, & Pring, 2010, 2013a; Crane, Pring, Jukes, & Goddard, 2012) have suggested that autobiographical memory differences in ASD may result in part from a failure to use personally experienced events to update the self. They observed that adults with ASD correctly distinguished between memories for self-defining events and memories for everyday events (Crane et al., 2010), despite extracting less meaning from their narratives and generating fewer specific memories than TD controls. This finding was paired with similar qualitative reports of memories between the two groups. Crane and colleagues (2012) further demonstrated differences in speed and specificity of recall for individuals with ASD versus controls, despite qualitative similarities in the memories retrieved. This important body of work suggests that individuals with ASD may not have broad episodic or autobiographical memory deficits, but rather differences in the availability, degree of recollective specificity, and perceived importance of memory traces for personally experienced events.

An earlier study of source monitoring further muddies the waters of this body of work, reporting that adults with ASD had greater reliability during recall of other-than self-performed actions (Russell & Jarrold, 1999). It has since been suggested that this differing finding may be due in part to sample characteristics—namely, that the sample reported in Russell and Jarrold's study had significantly greater cognitive impairments. At this time, a larger preponderance of evidence is needed to resolve the question of whether differences in self-concept impact memory for personally experienced events, and whether these differences vary in any systematic way within the ASD population.

Additional Factors That May Influence Autobiographical Memory in ASD

Theory of Mind

The relation between theory of mind (ToM) and autobiographical memory has been discussed elsewhere in the literature, but results have yet to clearly distinguish whether autobiographical memory impairments hinder ToM task performance, or whether underlying ToM deficits affect autobiographical memory encoding. The ability to distinguish self-knowledge from others may influence a person's ability to generate or elaboratively encode self-related memories. Adler and colleagues (2010) and Kristen,

Rossmann, and Sodian (2014) have reported a relation between ToM and autobiographical memory in ASD but not in TD controls. In Adler et al.'s (2010) sample, adolescents and young adults with ASD were less specific than age-matched controls in their references to time intervals and had lower overall performance on an autobiographical memory task, despite an equal number of references to self. This finding highlights the distinction between largely intact self-concept and impairment in temporal binding that likely produces impairments in autobiographical memory encoding and recall. Adler and colleagues concluded that differences in autobiographical memory ability in ASD drive impaired performance on ToM tasks.

Psychiatric co-morbidities

Some have drawn a theoretical link between atypical autobiographical memory and delusions in ASD and other psychiatric populations, with delusions attributed in part to difficulty with source monitoring (Corcoran, 2001; Kaney et al., 1999). However, the evidence presented here suggests that source monitoring is largely intact in adults with ASD. Abell and Hare (2005) found support for previous work suggesting that adolescents and adults with Asperger's/high-functioning autism experience more delusions than the general population, but fewer than people with psychosis. However, Abell and Hare did not find support for a link between delusions and autobiographical memory. Thus, the negative correlation between persecutory delusions and autobiographical memory recall observed by Kaney and colleagues (1999) may be due to clinical features of other psychiatric conditions and not necessarily relevant to ASD.

Recommendations for Facilitating Effective Retrieval of Autobiographical Memory in ASD

Some have suggested that adults with ASD may have atypically strong resistance to memory interference (Mottron et al., 1998), perhaps in part, due to a preference for the verbatim end of the fuzzy-to-verbatim continuum (although research suggests that verbatim is more susceptible to interference than gist memory; Reyna & Brainerd, 1995a, 1995b). Bruck and Ceci (1995, 1999, 2004) have described the circumstances that influence suggestibility in TD children (Brainerd et al., 2011). However, less is known about suggestibility of individuals with ASD, particularly with regard to autobiographical memory. Extrapolating from Bruck and Ceci's work, key factors influencing the suggestibility of individuals with ASD might include weak traces (whether due to less elaborative encoding, limited durability, or difficulty with retrieval), difficulty with source monitoring and self versus other distinctions, and limitations related to language and production of personal narratives. We have discussed the extant literature pertaining to these factors, but important questions remain regarding the degree to which development influences suggestibility in ASD.

For both TD children and adults, social demands can increase suggestibility (Bjorklund et al., 2000; Holliday, Douglas, & Hayes, 1999). Individuals with ASD who have intact autobiographical memory may have decreased sensitivity to social cues and pressures, thus reducing their susceptibility to suggestion. Conversely, individuals with ASD who have deficits in autobiographical memory may be more

susceptible due to impoverished verbatim memory traces for an event because they must rely on gist traces to fill in the gaps (e.g., Howe, 1991; Marche, 1999; Pezdek & Roe, 1995). In addition to the ability of individuals with ASD to monitor the source of information (e.g., their own experience versus suggestion from others), it is important to consider whether they would be able to accurately judge the credibility of a given source and resist suggestion from noncredible sources or those in positions of authority. This has important implications for the weight given to testimony provided by individuals with ASD, particularly in instances where information is obtained from another source rather than from direct experience. Several groups have demonstrated age-related trends in ability to judge credibility, resistance to suggestion from noncredible sources, and vulnerability to suggestion from credible sources in typical development (Lampinen & Smith, 1995; Skagerberg & Wright, 2008; French, Garry, & Mori, 2011). Ceci and colleagues (Ceci & Leichtmann, 1995; Ceci, Ross, & Toglia, 1987) also identified vulnerability to suggestion in younger and older children when misled by adult authority figures. These paradigms would be a useful addition to the ASD literature to answer questions about the specific circumstances under which suggestibility is increased for this clinical population.

From a complementary perspective proposed by Brezis (2015) and others, perhaps individuals with ASD do not spontaneously use self-concept as a tool in organizing episodic memories (e.g., Crane et al., 2009) and binding relevant features, potentially leading to deficits in autobiographical memory (see also Lind et al., 2014; Zmigrod et al., 2013). However, some advantages in memory accuracy may accompany a limited use of self-concept in memory organization. It may be the case that the tendency of TD individuals to rely on gist-based memory traces also supports a broader and more malleable self-concept, in turn, facilitating a positivity bias and leading indirectly to overconfidence in one's own memory accuracy. Thus, individuals with ASD who organize memories in a less self-referential way may be better able to avoid adjusting their memories for previously experienced events to avoid cognitive dissonance and fit their current self-concept, in the way that TD people often do.

Individuals with ASD may be less prone to strategic alterations to self-presentation under neutral conditions (Scheeren et al., 2010). Scheeren et al. noted that individuals with ASD did not strategically alter their self-presentation in response to information about audience preferences. However, positivity biases in self-presentation did surface in the presence of sufficient reward-based motivation. Of interest, Scheeren et al. noted that some individuals with ASD in their sample accurately identified a social expectation to modify self-presentation in response to task demands, but stated that they chose not to do so because it was dishonest. This particular study did not include direct examination of autobiographical memory or suggestibility, but the results reinforce the importance of using appropriate interviewing techniques in legal and law-enforcement settings to probe autobiographical memory in persons with ASD. Interviewers must remain neutral, avoiding any coercion or introduction of incentives, and should rely predominantly on open-ended questions to avoid reward-based motivation that could increase the likelihood of alterations to self-presentation. These aims can be achieved by using the cognitive interview (CI) (Fisher & Geiselman, 1992) or the NICHD structured interview (Lamb, Orbach, Hershkowitz, Esplin, & Horowitz, 2007). Under certain circumstances, evidence suggests that individuals with ASD are equally reliable, and perhaps even more so, compared to those who are TD (Maras & Bowler, 2014). Interviewers must be sensitive to the fact that a person

with ASD may only produce disjointed elements of a scene or event, rather than a coherent narrative, when presented with open-ended prompts. It is important to note that this approach may not be appropriate for all people with ASD, particularly in cases of nonverbal or minimally verbal individuals with marked expressive language deficits who might become easily frustrated by not being able to answer open-ended questions. For these individuals, a less verbally-dependent approach may be more appropriate (e.g., “show me,” drawing, writing, using picture cards or assistive communication devices to respond) depending on the situation and the specific strengths and challenges of the witness.

One possible technique for obtaining information about autobiographical memories is the cognitive interview (Fisher & Geiselman, 1992; Geiselman et al., 1984), which has demonstrated efficacy as a form of eliciting accurate eyewitness information from adults, children, the elderly, and individuals with learning disabilities (Davis et al., 2005; Bartlett & Memon, 2007; Milne et al., 1999; Wright & Holliday, 2007). The cognitive interview consists of context reinstatement, imagery-guided questioning, and changes to the order and perspective of recall.

However, Maras and Bowler (2010, 2012) suggested that the cognitive interview is not an appropriate tool for use in ASD. In one study (Maras & Bowler, 2010), they found that use of the cognitive interview reduced accuracy in the ASD group, an effect not observed when using a structured interview. It is possible that the scaffolding provided by context-reinstatement and imagery-guided aspects of the cognitive interview does not offer optimal support for those with ASD. As we have discussed here and elsewhere (Miller, Odegard, & Allen, 2014), individuals with ASD may not benefit from such scaffolding because of their tendency to rely heavily on individual verbatim memory traces for information not bound by features or context.

Indeed, in a later study, Maras and Bowler (2012) reported that individuals with ASD only benefitted from context reinstatement when the physical environment matched the contextual cues provided in the interview. This is not surprising given that individuals with ASD often have difficulty with remembering context or source during recall, relative to recognition, tasks (Bowler et al., 2004; Bowler, Gaigg, & Gardiner, 2008). Maras, Gaigg, and Bowler (2012) further observed that individuals with ASD had stronger recall and diminished forgetting for emotionally arousing events, similar to age-matched controls. However, the precise effect of emotional arousal on recall remains unclear since others have reported that negative emotion does not produce enhanced recall in ASD as in typical development (Deruelle et al., 2008).

It is notable that many of the studies discussed here were conducted using either videotaped events or photographic scenes, rather than personally experienced real or staged events. Results presented by Sigman et al. (2003) and Corona et al. (1998) suggested that individuals with ASD do not have equivocal emotional responses to videotaped versus real-life events. Indeed, Maras and colleagues (2013) found that adults with ASD demonstrated the enactment effect during recall for live, personally experienced events, despite several other studies failing to find this typical advantage for self- versus other-experienced events in ASD when using videos or photographs. This finding is in line with work demonstrating that reality monitoring—determining whether a memory is derived from actual experience or imagination—and source monitoring during enacted versus imagined events promotes greater encoding of kinesthetic details, which can provide additional context for memory reconstruction (Foley & Johnson, 1985; Foley,

Aman, & Gutch, 1987; Goff & Roediger, 1998; Johnson, Foley, Suengas, & Raye, 1988; Lindsay, Johnson, & Kwon, 1991; Sussman, 2001).

In light of somewhat mixed findings regarding the importance of context and personal experience, future study is needed to examine the efficacy of the cognitive interview for individuals with ASD. Specific attention should be paid to autobiographical memories for personally experienced events, which may have greater salience and emotional arousal and thereby lead to more effective feature- or temporal-binding at encoding. The NICHD structured interview protocol, which has an established record of productivity in TD populations (Lamb et al., 2007; Sternberg et al., 2001), may be a more appropriate alternative to the cognitive interview given the collective findings of Maras and colleagues (2010, 2012, 2013, 2014). In the structured interview, interviewers rely on open-ended prompts in an effort to elicit free recall. Free recall is less susceptible to commission errors—due to greater reliance on verbatim retrieval in standard free recall of unrelated items—than to errors of omission resulting from the absence, decay, or inaccessibility of verbatim traces (Brainerd et al., 2009). The more conservative approach of open-ended prompting may provide a means of eliciting more accurate, although perhaps less, information from a person with ASD.

Regardless of interview format, it is important to note that investigators who are not highly trained may become frustrated when a person with ASD does not produce a detailed, coherent narrative during free recall. The tendency may be to transition to more leading questions or context reinstatement as an attempt to elicit gist-based reconstruction. However, whereas gist-based reconstruction is generally less literally accurate regardless of whether a person is typically or atypically developing, it may be extremely difficult or even impossible under some circumstances for a person with ASD.

A lineup or photo book offers a tool to cue recognition memory. In a detailed meta-analysis, Steblay et al. (2001) found strong support for the use of sequential lineups, which may produce fewer correct identifications of targets, but fewer false-positives relative to simultaneous lineups. They are essentially a more conservative method in that they require individuals to make an absolute judgment for each target as it is presented. The use of sequential lineups is particularly appropriate for use when neither the witness nor the administrator knows how many photos are in the deck (Greathouse & Kovera, 2009). Simultaneous lineups, on the other hand, encourage relative judgments. While they are likely to yield higher rates of target identification, they may also result in more false positives by leading witnesses with weak memory traces to choose the target that is the best match to their memory, in essence constituting a calculated guess. Steblay et al. (2001) highlighted the possibility that these guesses might then be considered as evidence by the police or courts, which would be ill-advised. Recent evidence from real-world studies (vs. staged laboratory experiments) suggests that in typical development, simultaneous lineups may have an advantage over sequential lineups in terms of their overall results when considered with corroborating evidence (Amendola & Wixted, 2015; Wixted, Mickes, Dunn, Clark, & Wells, 2016). Since correct rejection rates are significantly higher for sequential than simultaneous lineups, and correct identification rates are nearly equal, especially when real-world conditions are approximated, Steblay and colleagues (2001) advocated for the use of sequential lineups in most situations. Given the recent questions surrounding best practices in target identification lineup procedures, it is important

to consider the risks and benefits of each approach when working with individuals with ASD who may be vulnerable to suggestion or susceptible to feeling pressured to guess under certain circumstances.

Ideally, these tools could be administered on a computer in order to limit the social demands of the situation. Although individuals with ASD do not spontaneously modify their responses to meet social demands as readily as TD peers, they are not completely immune to this pressure. Computer administration would also be appropriate for minimally or nonverbal individuals, provided their receptive language skills were strong enough to understand task instructions because they could behaviorally indicate a response (pointing/touching/clicking) rather than having to produce responses heavily dependent on expressive language or narrative production ability.

Drawing offers another possible method of eliciting information independent of expressive language skills. Mattison, Dando, and Ormerod (2015) recently tested the efficacy of a novel retrieval tool, sketch reinstatement of context. For sketch reinstatement of context, individuals are provided with paper and pencil, and asked to draw the event that they witnessed in as much detail as they wish and describe each element as they draw it, with no time limit (see also Dando, Wilcock, & Milne, 2009). Mattison et al. found that this approach was more effective than mental context reinstatement (i.e., the technique employed in the cognitive interview) or no support for recall. Although the sketch reinstatement approach was developed with TD individuals and traditionally involves a verbal description during sketching, it may be modifiable to meet the needs of individuals with ASD who have limited expressive language skills. Further work is needed to determine whether this approach is valid in the ASD population. Mental context reinstatement may prove challenging for individuals with ASD who have receptive language challenges or difficulty with imagination, spatiotemporal reconstruction, and abstract thinking. Alternative approaches are important to consider, so that the needs of a wide spectrum of individuals with ASD can be met during both memory research in laboratory settings and eyewitness interviews in investigative contexts.

Conclusion

Despite having some general impairments in autobiographical memory in the domain of errors of omission, people with ASD may actually be more reliable eyewitnesses when expressive language deficits do not limit their ability to provide detailed reports, consistent with predictions of FTT. In addition, extant data suggest that people with ASD are less susceptible to the biases inherent to self-concept and gist-based processing that lead to errors of commission in TD people. Errors of omission in ASD are likely related to over-reliance on verbatim traces, which are susceptible to (a) unavailability due to decay, and/or (b) inaccessibility due to impaired binding during encoding or difficulty activating appropriate retrieval cues.

The reconstructive nature of autobiographical memory is of critical importance to understanding ASD through the lens of FTT. Gist-based reconstruction is a double-edged sword for people with ASD. It can serve the purpose of binding features together to make a cohesive memory, but it can also introduce error. For individuals who are able to use gist-based processing in a more typical manner, the risk of commission errors and suggestibility may be heightened. Although current evidence does

not suggest that people with ASD are hyper-suggestible, as some previously thought, it is still important to monitor suggestibility and use appropriate interview techniques when eliciting autobiographical memories from people with ASD. As in typical development, suggestibility is especially important to consider when working with children with ASD; there is a dearth of literature on age-based differences in autobiographical memory in this population.

Verbatim traces are also interesting as related to reliability of memory in ASD. People with ASD seem to have intact verbatim memory traces, but these traces are often inaccessible. Contributing to issues with accessibility, verbatim traces may not be bound correctly with other episodic features because individuals with ASD do not seem to engage in spontaneous feature binding like TD people. Given the critical nature of elaborative retrieval processes, the remaining challenge for researchers and clinicians is finding ways to teach this skill to people with ASD.

Researchers must also find means to test autobiographical memory in ways that are not so dependent on language or narrative production skills. Language does not appear to be directly related to the *ability* to accurately recall personally experienced events, despite its significant role in the semantic sophistication of the recollective response. Therefore, a more appropriate means of testing autobiographical memory in ASD would be to use paradigms other than think-aloud or narrative reconstructions that are less dependent on language skills. This would enable researchers to determine the true nature of autobiographical memory in people with a wider range of ASD symptoms.

Take-Home Points

- Children and adults with ASD have notable differences in the way that they spontaneously encode and retrieve autobiographical memories.
- Autobiographical memory in ASD is less rooted in overarching self-concept than in specific facts or elements of episodic memories for personally experienced events.
- People with ASD are less susceptible to the biases inherent to self-concept and gist-based processing that lead to errors of commission.
- Errors of omission in ASD are likely related to over-reliance on verbatim traces, which may be unavailable or inaccessible.
- Source monitoring appears to be intact in ASD, but personally experienced events may be reported from the perspective of a third-party observer rather than in a self-referential manner.
- Children and adults with ASD can be reliable witnesses, but should be interviewed under carefully structured conditions to reduce suggestibility.

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