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Mini Review

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Memory in Autism: A Case of Remembering *Versus* Knowing

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According to the *Diagnostic and Statistical Manual Fifth Edition*, the DSM-5,[1] autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by persistent social communication deficits and repetitive patterns of behavior including intense preoccupations and inflexible adherence to routines. ASD may occur with or without accompanying intellectual impairment and the severity of the disorder may fluctuate over time. Previously, an ASD diagnosis based on the *Diagnostic and Statistical Manual Fourth Edition* (DSM-IV) fell into one of 5 subtypes, most prominently, Asperger's syndrome and autism, diagnoses that indicated a generally higher (Asperger's) or lower level of functioning (autism). This brief report attempts to review literature on memory in ASD with a special focus on the discrepancy between an intact, at times, even extraordinary memory for large amounts of factual information and an often impaired memory for autobiographical information. A look at memory patterns in ASD may be helpful in understanding learning differences and aid in the customization of targeted intervention strategies.

Tulving[2,3] divides human memory into 2 distinct systems that are open to conscious awareness: The semantic system stores timeless facts available mostly upon cued recall recognition, while the episodic system relies on an individual's ability to put stored memories into a spatio-temporal and self-referential context upon free recall.[4] The Remember/Know (R/K) procedure[3] is used in recognition tasks to study both memory systems. Participants are asked to study a list of words, and then have to respond whether they remember the episode of having seen the word (R), or if they merely know (K) the word without the recollection of the specific episode.

Early observational studies found that individuals with classic autism and Asperger's often possess extraordinary rote memory skills and are able to memorize large amount of factual information.[5,6] Experimental studies on memory in ASD reveal a pattern of unimpaired memory span alongside impaired free recall.[7,8] When asked to recall a sequence of dot locations in order, Bowler et al[9] revealed impairments in non-verbal short-term serial order memory in adults with ASD as compared to typical individuals. Together with parallel findings using verbal material,[10] these results indicate that order processing appears to be a cross-domain deficit in ASD.

Free recall and the ability of *mental time travel*[2] have been related to the comprehension of *a temporally extended self*,[11,12] the understanding that the "I" we experience now is the same as the "I" from memories past, and *episodic future thinking*,[13] the ability to project oneself into plausible future situations. Zelazo et al[14,15] have shown that children with ASD have problems with this type of episodic remembering in tasks involving 'if-then' rules.[15,16] Later studies revealed the neural correlates of R/K discrepancies in ASD: episodic recognition involving the recollection of contextual information (R), which is impaired in ASD, shows to be mediated by hippocampal processes while familiarity based recognition (K), which is intact in ASD, is mediated by perirhinal processes.[17-19]

Free recall and episodic memory impairments have been associated with deficits in

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theory of mind (ToM),[20] the understanding of others beliefs and perspectives, an ability that has shown to be delayed or impaired in ASD.[21,22] In order to have episodic memories, a person needs to be able to form a *metarepresentation* of an episode, i.e. they must be able to understand their own memory of an event as a representation of the actual event.[23] These *metarepresentations* help a person to hold a true and false understanding of an event which is necessary in false-belief tasks testing ToM. Based on problems with ToM in ASD and the association of ToM with episodic memory deficits, Bowler, Gardiner and Grice[24] predicted and found that participants with Asperger's had lower R scores on recognition tasks using the standard R/K procedure. However, both control group and Asperger individuals yielded more R responses of high-frequency than low-frequency words. Both groups also show reduced R but not K responses when attention during the encoding phase was divided.[25] This qualitative, but not quantitative, similarity between groups indicates that individuals with Asperger's can reconstitute some of the spatiotemporal and self-referential context needed in episodic memory tasks.

Lind et al[26] examined 20 high functioning elementary school children with ASD and compared them to 20 neurotypical controls to probe the possibility of interdependent atypical cognitive development and behavior on series of tasks. The ASD group exhibited impairments in spatial navigation, episodic memory, episodic future thinking, and central coherence but not ToM and relational memory as compared to controls. ToM was tested on a version of the "animations" task[27] which is sensitive to ToM impairments in high-functioning individuals with ASD contrary to the more traditional "false belief tasks".[23] Interestingly, spatial navigation as tested on the computer-simulated "memory island" task was significantly negatively correlated to repetitive behaviors in the ASD group.

In a recent functional magnetic resonance imaging or functional MRI (fMRI) study in which participants listened to four categories of names including their own first names, (Huemer S et al unpublished data, 2016) found that individuals with ASD with high verbal ability, just like neurotypical controls, activated right hippocampal processes when hearing their own first name, while individuals with ASD with low verbal ability scores activated left thalamic processes associated with the memorization of new events.[28] Since perirhinal areas receive afferents from the nucleus reuniens of the thalamus, these findings indicate that individuals with ASD who have lower verbal ability "know" their name like a recently learned fact whereas individuals with ASD with high verbal ability, who often find themselves on the higher functioning end of the autism spectrum, like neurotypical controls recollect contextual autobiographical information when processing their own name.

When looking for the causes of the uneven memory profile in ASD, the work of Hermelin and O'Connor[7] and ensuing supporting studies[24,29] indicate that individuals with ASD fail to encode word sequences in a meaningful way (*deep encoding*) as opposed to neurotypical controls who use semantic and syntactical strategies to aid recall. In *deep encoding,* we draw from semantic aspects of material to be remembered, for example, considering category membership of words, which typically leads to enhanced memory as opposed to shallower levels of encoding that involve the processing of non-semantic features, for example, counting the number of syllables.[30] A lack of encoding strategies will also lead to problems in remembering more complex materials. Happé[31] found that individuals with ASD performed significantly worse on memory tasks with more complexity, both visual and auditory, when compared to neurotypical controls due to a lack of strategy and task organization.

The use of strategy in memory tasks was further examined using the *relational and individual item paradigm*[32] that tests free recall on items related to each other in category (*relational processing*) as opposed to items with semantic information that specific only to the item itself (*item specific processing*). Gaigg et al[33] showed that participants with ASD recalled overall fewer categories and less items in smaller but not larger categories, and they were less likely than typical participants to cluster items into their respective categories during recall. As opposed to these selective differences in relational processing in ASD, no significant differences between groups were found in the item-related processing portion of the study. As opposed to the original Hunt and Seca[32] paradigm, Gaigg et al[33] presented participants with a baseline and an orienting task which provided more practice and helped the ASD group overcome difficulties in the orienting task by deploying their relational memory processes effectively, which indicates that relational processing strategies are available to individuals with ASD but their deployment needs to be aided. These findings further substantiate the *Task Support Hypothesis*[34] which states that the memory difficulties of individuals with ASD can be attenuated when the procedure includes meaningful cues to the remembered material at recall.

Solomon et al[35] used the Relational and Item Specific Encoding (RISE) task to compare 22 adolescents with ASD to 26 well-matched neurotypical control subjects. As opposed to predictions, the ASD group did more poorly thank controls on recognition for objects that had been encoded in the item-specific condition but showed no difference for objects that had been encoded relationally. The study also found that the ASD group relied relatively less on familiarity during item recognition following relational encoding than controls did. The ASD group exhibited weaker cognitive control related to strategic memory processes that produced less overall learning. Performance on item and associative recognition improved with age in the ASD group while performance in the control group was a product of strategic learning processes. While these results may contradict the general consensus of impaired relational memory processes and intact item-specific memory in ASD, Solomon et al's[35] findings may be largely influenced by the stimulus characteristics of the RISE task where item-specific encoding relies on judgments related to abstract features and relational encoding can be aided

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with strong visuo-spatial ability. Abstraction is shown to be difficult for individuals with ASD[36] while visuo-spatial abilities are considered strong.[37]

Neuroscientific evidence supports the theory of relational memory processes.[38] The hippocampus has been identified as the site of domain-general relational memory processes where individual features of an episode are integrated and organized.[19,39,40] Morphological abnormalities of the hippocampus are relatively well documented in ASD.[41,42] Areas outside the hippocampus, such as perirhinal, entorhinal and parahippocampal areas are found to mediate more domain-specific item and contextual processes.[43,44]

In summary, episodic remembering requires a person to put memories into a spatio-temporal and self-referential context, and relies on free recalls, which are areas of weakness in ASD. Anatomical and functional differences in hippocampal areas in ASD may be associated with these deficits. Environmental task support may help with the processing of relational and more complex information related to spontaneous recall. Item characteristics may play a role in some of the prior findings that contradicted general consensus findings. Age may be another factor in putting these findings into perspective since ASD studies have focused on younger age groups whereas episodic memory is known to develop considerably through adolescence and maturation does not occur until young adulthood.[45] Further, studies are needed to establish a more complete profile of memory processing in ASD including intellectually lower-functioning individuals and adults with ASD.

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