The development of episodic future thinking in typically and atypically developing children

Katherine Leah Dickerson

A thesis submitted for the degree of PhD
at the
University of St Andrews

2017

Identifier to use to cite or link to this thesis:

DOI: https://doi.org/10.17630/10023-16808

Abstract

Episodic future thinking is the ability to pre-experience events that have yet to come (Atance & O'Neill, 2001). In order to better understand this skill, this thesis investigates future thinking over the course of development. In three studies, we looked at the ways that we test episodic future thinking, developed a new test of this ability and used this in a population of children with Autism Spectrum Disorders (ASD). In the first, we found that behavioural tests of episodic future thinking correlate with verbal measures. Behavioural tests have been designed to evaluate episodic thought and have been used widely in the literature on memory and planning in non-verbal populations (Osvath & Osvath, 2008). Until now the degree to which performance on behavioural tests is related to the more standard verbal tests of future thinking has been unknown. This finding provides validation for the continued use of these behavioural methodologies. In my second study, we address one criticism of behavioural methodology to date; that it may be possible to rely on associative learning to pass these experiments (Atance, 2015). We evaluated children's reliance on this strategy by developing a new spoon test that controls for associative memory. We found that this change disrupted performance in a population of four-year-olds. When we removed controls for associative learning, this age group passed at a rate higher than chance, comparable to results from previous behavioural studies (Atance & Sommerville, 2014; Scarf, Gross, Colombo, & Hayne, 2013). These results suggest that associative learning does substantially impact performance on item-choice tasks in younger age groups. Finally, we piloted this new test in a group of children with ASD, a population that is known to have deficits in episodic memory. In keeping with the theory that it is necessary to remember past experience in order to flexibly prepare for the future, we found a significant difference between episodic future thinking skills in children with ASD as compared to a control group.

Acknowledgements

I cannot express enough gratitude towards the incredible people who have surrounded me over the course of this endeavour.

First and foremost, I would like to thank my supervisors, Drs Amanda Seed and Jamie Ainge. I feel so lucky to have met such brilliant, kind and dedicated mentors. Thank you for your teaching, your leadership and your inspiration. I look forward to our continued friendship.

Thank you to Emmie Bryant, the best lab-mate and out-of-lab mate a girl could ask for. You made running experiments a whole lot more fun.

Thank you to Geraldine Brown, the greatest partner there ever was, and to Frankie Sorrell and Paige Onouye for your help in data collection.

Thank you to the Fife Council School District and Autism network, without which none of this work would have been possible.

Thank you to Robert "Bobby" Tyre Jones, Jr. who provided the money for me to get here and who will forever be my inspiration along the way. Double thanks goes to the School of Psychology and Neuroscience at St Andrews, which has the best faculty anybody could ask for.

And last, but certainly not least, thank you to my family, Blake, my friends, and the St Andrews basketball and lacrosse teams, without whom I would never have completed this thesis.

Declarations

Candidate's declarations:

I, Katherine Dickerson, hereby certify that this thesis, which is approximately 40,600 words in length, has been written by me, and that it is the record of work carried out by me, or principally by myself in collaboration with others as acknowledged, and that it has not been submitted in any previous application for a higher degree.

I was admitted as a research student in August, 2013 and as a candidate for the degree of Doctor of Philosophy in March, 2014; the higher study for which this is a record was carried out in the University of St Andrews between 2013 and 2017.

February 28, 2017

Supervisor's declaration:

I hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of Doctor of Philosophy in the University of St Andrews and that the candidate is qualified to submit this thesis in application for that degree.

February 28, 2017

Permission for publication:

In submitting this thesis to the University of St Andrews I understand that I am giving permission for it to be made available for use in accordance with the regulations of the University Library for the time being in force, subject to any copyright vested in the work not being affected thereby. I also understand that the title and the abstract will be published, and that a copy of the work may be made and supplied to any bona fide library or research worker, that my thesis will be electronically accessible for personal or research use unless exempt by award of an embargo as requested below, and that the library has the right to migrate my thesis into new electronic forms as required to ensure continued access to the thesis. I have obtained any third-party copyright permissions that may be required in order to allow such access and migration, or have requested the appropriate embargo below.

The following is an agreed request by candidate and supervisor regarding the publication of this thesis:

PRINTED COPY

Embargo on all of print copy for a period of 2 years

We would like to place an embargo on the printed copy of this thesis for a period of two years in order to ensure we can publish the data included therein.

ELECTRONIC COPY

Embargo on all or part of electronic copy for a period of 2 years

We would like to place an embargo on the electronic copy of this thesis for a period of two years in order to ensure we can publish the data included therein.

February 28, 2017

Contents

Lists of Tables

List of Figures

with the inaccessible box and red demonstrates the novel token that the participant has never seen before.

Chapter 1 - Introduction

Introduction to Future Thinking

The capacity to envision events removed in time is a salient feature of human psychology that impacts our ability to learn and make decisions. While episodic memory allows us to remember events that have already happened, episodic future thinking enables us to pre-experience events that have yet to come (Atance & O'Neill, 2001). This flexible system draws on prior experience to craft a malleable projection of the future (Schacter, Addis, & Buckner, 2008). Through this mental representation and flexible evaluation of future scenarios, we are able to anticipate, plan and control events that have not yet come to fruition. Employing this to successfully envision and compare future outcomes turns the potential consequences of our actions into a motivating force that encourages prudent choices, even if they are less immediately rewarding (Munakata et al., 2011). While episodic memory research has been actively pursued for decades, episodic future thinking research has increased since the term was coined in 2001 (Atance & O'Neill, 2001). As such, there are several debated questions in the literature concerning this ability and how it develops throughout childhood (Atance, 2015). Developmental research affords researchers a unique opportunity to evaluate episodic future thinking as the ability comes online and therefore better identify and measure the impact of various component skills and related cognitive processes (Hudson, Mayhew, & Prabhakar, 2011). In order to better understand the nature of this ability, it is important to successfully develop and refine methodology that tests it in children. It has been suggested that performance on tasks designed to evaluate episodic future thinking in children may be impacted by their capacity for episodic memory (Atance & Sommerville, 2014; Martin-Ordas, Atance, & Louw, 2012). Intuitively, there appears to be a link between remembering the past and imagining the future, but the degree to which these are related and developmentally impact one another is still an ongoing topic of research (Martin-Ordas et al., 2012). Over the course of this thesis, I will evaluate and develop methods of testing episodic future thinking that take into account episodic memory in order to consider how these abilities are related and also how they might be distinct. Understanding this relationship can shed light on evolutionary hypotheses for the emergence of these potentially uniquely human skills (Tulving, 2005), and the nature of the underlying brain regions responsible (Spreng & Grady, 2010). Episodic future thinking is a critical developmental milestone that aids in the mental representation and, in turn, acquisition of future goals (Klein, Robertson, & Delton, 2010). It is important to effectively test this ability in children and understand how this affects their functional planning capabilities. This thesis will therefore critically evaluate behavioural tests of episodic cognition and what they are really testing, with an emphasis on the relationship between episodic future thinking and episodic memory. Additionally, I will create a test of planning that isolates this as distinct from other skills, such as associative learning in the form of classical conditioning. Finally, I will apply this test to better understand typical and atypical development of these essential skills, both because this is important in its own right and because doing so will shed light on the broader questions outlined above. In order to begin looking at the development of future thinking, I will start with an evaluation of the current theoretical and experimental evidence.

The Episodic System

Episodic future thinking is one term that has been used to describe the prospective experiencing of events (Atance & O'Neill, 2001), however there are several other terms that have been used to refer to this ability. Schacter, Addis and Buckner evaluate the “episodic simulation of future events” (Schacter, Addis, & Buckner, 2007), while others cite “prospection” (Gilbert & Wilson, 2007), “projection” (Buckner & Carroll, 2007) and “simulation” (Addis, Pan, Vu, Laiser, & Schacter, 2009). I will use episodic future thinking as an umbrella term encompassing all of these terms, without making a commitment as to the specific mechanism responsible (e.g. projection, construction or simulation). One hallmark of the episodic system is the need to disengage from current perspectives and motivations (Tulving, 2005). This creates a feeling of temporal separation based on the internal ordering of events within the course of a lifetime (Friedman, 2005). This ability grows and changes throughout the course of development, where simple representations of temporal order grow into more compound networks that can build upon this information and employ it in complex reasoning (Mccormack & Hoerl, 1999). This is true not just for time, but also for elements of motivation, where children can recognize over time that their motivations may vary in different events and circumstances, (Case, 1991), as well as scene perspective, which allows for spatial orientation and knowledge of patterns associated with place to play a role in guiding decision making (Raby & Clayton, 2009). These features interplay to provide a sense of autonoetic consciousness, or the ability to generate a subjective sense of time through self-recollection in our thoughts, allows us to distinguish between our internal environment and the external world (Tulving, 2002). This provides a distinction between behaviours that are oriented towards the future, versus an ability that allows for the integration of when, what and where to truly pre-experience an episode (Szpunar, Addis, McLelland, & Schacter, 2013). This is the definition of episodic future thinking that will has guided the work of this thesis and will be explored over the next few chapters.

The episodic system is most commonly thought of in relation to memory, as it is a well-defined subset of memory that is distinct from other kinds (Tulving, 1972). Episodic memory is a part of the long-term declarative memory system, meaning that the content of these memories is explicitly stored and retrieved (Tulving, 2002). It is defined as the memory for "temporally dated episodes or events, and the temporal-spatial relationship between them" (Tulving, 1972, p. 385). While semantic memory allows the user to remember facts, episodic memory involves an integration of details into a holistic event representation that can be subjectively relived in the mind's eye (Squire & Zola, 1998). Episodic memory has been shown to be functionally (Yonelinas, 2002) and neurologically (Eichenbaum, Yonelinas, & Ranganath, 2007) distinct from other forms of memory. The formation, storage and retrieval of episodic memories has been examined since before the term was coined by Tulving in 1972 (Tulving, 1972). Neilson, a neurologist from UCLA, wrote about "two pathways of memory", one of which was basic knowledge acquisition and the other being "memories of life experiences centering around the person himself and basically involving the element of time" (Nielsen, 1958). This idea was generated after a career of clinical observations, in which he noticed that amnesia can affect one or both of these pathways at a time. Others noticed this same distinction through work with amnesic patients (Kapur & Brooks, 1999; Squire & Zola, 1998). These studies have evaluated memory in patients with bilateral hippocampal damage and report varying levels in the ability to recall previously learned facts and experiences across cases. Notably, these seem to be separate functions, where patients with retrograde amnesia for personal events can still remember semantic detail and vice versa (Blumer, 1969). Over time, the episodic system has come to be understood as capable of integrating component parts (time, location, event) (Clayton & Dickinson, 1998). These component parts can be somewhat flexible, as they are only necessarily combined as a result of the "recollective experience" (Tulving, 2002). For example, we may remember that we read a certain news story without recalling sitting in the coffee shop where we picked it up last Tuesday. However, if we want to call the whole scene to mind, we can piece together these various elements to be consciously aware of the full episode. A similar phenomenological experience can accompany the creation of future episodes, i.e. the feeling of self and of experiencing a holistic event. For this reason it has been suggested that there is a single episodic system responsible for past and future 'mental time travel' (Suddendorf & Corballis, 2007). These processes allow an individual to view the content of what happens in an event and where it takes place while simultaneously identifying a subjective temporal component of when an event may happen (Tulving, 2005). While it makes sense that there would be a link between episodic memory and episodic future thinking, is there any evidence to support this suggestion at a cognitive or neural level?

The Evidence for a Common Mechanism

Lines of evidence in the literature that support a commonality between episodic memory and episodic future thinking include neuroimaging data, age-related changes and patient studies. This evidence is summarized in the following section, and I will then give an overview of the theories that have been proposed to explain it.

Neuroimaging

In a study by Szpunar, Watson and McDermott participants underwent functional magnetic resonance imaging (fMRI) while vividly imagining personal memories, events involving familiar individuals and personal future events (2007). These scenarios were created using short prompts paired with a tense, from the Galton-Crovitz word-cueing technique that has been long-used in the study of autobiographical memory (Crovitz & Sciffman, 1974). During the experiment there was significant overlap seen between areas of brain activation in past and future tasks (Szpunar et al., 2007). This was most noted in medial temporal lobe regions, including the parahippocampal gyrus and hippocampus, and in a posterior midline region near the precuneus and the prefrontal cortex. This neuroimaging data suggests a strong overlap between the brain systems involved in episodic future thinking and episodic memory. Interestingly, these areas were not activated to the same degree when participants were asked to talk about someone other than themselves, indicating that there may be an important categorical distinction between personal and non-personal episodes (Larsen, 1992). Studies using positron emission tomography (PET) have produced similar results (Okuda et al., 2003). In the study by Okuda et al., participants were asked to speak freely about events in the past and future. They found overlapping activation in a similar set of regions, including the hippocampus, parahippocampal gyrus and prefrontal cortex during episodic memory and future thinking that was distinct from that employed during a semantic retrieval task. These imaging studies have produced evidence that similar neurological pathways are activated during past and future episodic event generation. While this may provide evidence of an overlap between these abilities, this may also be the result of similarities in task demands or a product of the similar methods used to evaluate the various forms of episodic cognition.

Age-related changes

In healthy adult populations, there is an age-related reduction in the specificity of descriptions of past events (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). This has been shown to extend to future event generation (Addis, Wong, & Schacter, 2008). In an autobiographical interview older adults produce significantly fewer internal details (episodic information relating to the specific event being described) when imagining future events as compared to a younger population. However, this result is arguably partly attributable to age-related changes in narrative style. It has been shown that older adults minimize the structural complexity of their event descriptions, resulting in less cohesive stories (Kemper, Rash, Kynette, & Norman, 1990). This was demonstrated in an analysis of storytelling between individuals in their 60s, 70s and 80s. It may then follow that similar changes in narrative style occur across the lifespan and it is feasible that the inclusion of many external details may contribute to a lack of cohesion. While this may have played a role in the finding that older individuals generate poorer descriptions of future events, other studies have employed narrative generation of imagined scenes as a control and still found decreased performance in the future condition (Rendell et al., 2012). Rendell et al. showed that older adults displayed weaker performance in comparison with younger adults when they were asked to construct imagined scenes, future scenarios and narratives involving navigation. These descriptions were worse in the future than in the imagination condition across both groups, with a stronger difference in the older age group, reflecting a decreased capacity for event memory in keeping with previous studies demonstrating that episodic memory declines in aging populations, (Martinelli, Anssens, Sperduti, & Piolino, 2013). In general, these studies highlight the idea that aging produces similar declines in episodic memory and episodic future thinking. Future studies should disambiguate the role that changes in narrative style may play in this finding, but these abilities appear to follow similar trajectories across the lifespan, which supports the notion of a common mechanism for past and future mental time travel, or at least a mechanism common to the two skills.

Patient Studies

Converging evidence comes from the fact that in amnesiacs with lesions in these brain areas both of these abilities are selectively impaired. Simultaneous deficiency of both episodic memory and future thinking has been shown in studies of patients with lesions of the hippocampus (Mullally, Hassabis, & Maguire, 2012). Patient K.C. presented with a relatively circumcised lesion of the medial temporal lobes and suffered from a complete loss of episodic memory (Rosenbaum et al., 2005). He was additionally found to be unable to report a description of his own future when asked about 'next summer', 'tomorrow' or 'this afternoon' (Tulving, Schacter, McLachlan, & Moscovitch, 1988). Whenever asked about the details of his personal future or past he would reply that his mind was 'blank'. Similarly, patient D.B. suffered hypoxic brain damage and was thereafter unable to recall any element of his personal past (Klein, Loftus, & Kihlstrom, 2002). While he retained semantic memory capabilities, he could not remember any experience in which he was involved. When asked about his personal future, a similar pattern was shown: he could anticipate more general future events, but nothing involving his own experience. Patients with Alzheimer's disease also show impairments in both episodic memory and simulating future events (Addis, Sacchetti, Ally, Budson, & Schacter, 2009). Patient performance in tasks involving future thinking correlated with atrophy present in the parahippocampal gyrus, posterior cingulate and frontal pole, all of which are areas associated with episodic memory (Irish, Addis, Hodges, & Piguet, 2012). Korsakoff's syndrome is a chronic memory disorder resulting from a thiamine deficiency that is most commonly caused by alcohol abuse (Kopelman, 1995). While this is routinely referred to as a memory disorder, in the seminal monograph describing this disease, George Talland notes impaired planning and personal future event generation (Talland, 1965). This evidence of similarly degraded episodic memory and future thinking came from 29 patients, who underwent almost six years of evaluation (Blumer, 1969). Crucially, the changes in mental time travel abilities seen in patients with amnesia are not attributable to decline in other abilities, like general narrative construction (Race, Keane, & Verfaellie, 2011). In this study by Race et al., individuals with damage to the medial temporal lobe (MTL) were asked to construct narratives about the past, future and pictures. Only in the temporally removed conditions were deficits found in comparison to healthy controls. However, this is in conflict with other findings in the literature, which report widespread changes in spatial coherence across narratives in another set of patients with damage to the MTL regardless of tense (Mullally & Maguire, 2013). These studies both conducted autobiographical interviews. However, the study by Race and colleagues employed a scoring method that evaluates participant responses based on number of details (Levine et al., 2002). This method is commonly used, but does not take spatial coherence into account at any point. On the other hand, the study by Mullally and Maguire specifically evaluated this ability when scoring the interview transcripts. This could explain the difference between these two findings and consequently may be evidence of the fact that it may be important to separately evaluate each element of episodic memory: what, where and when, in order to fully assess this ability. Regardless, multiple patient studies evaluating episodic cognition have been conducted in individuals with lesions to areas known to be implicated in episodic memory. These studies report widespread similarities in presentation between episodic memory and episodic future thinking, with deficits being shown in both.

A relationship between episodic memory and episodic future thinking has been shown multiple times with different neuroimaging techniques and methodologies (Szpunar et al., 2007), in addition to having been demonstrated in patient studies and reflected in age-related changes (Addis, Sacchetti, et al., 2009; Levine et al., 2002). These lines of evidence are suggestive of a cognitive overlap between imagining one's personal future and remembering the past (Buckner & Carroll, 2007). While there may be a link between these two abilities, these studies do not offer much insight into the nature of this relationship. From these results, it is possible that there could be a complete or incomplete overlap. If there is a clear and specific relationship between memory and planning, it could be that one of these systems is dependent on the other. Alternatively, these could be two distinct systems that are interacting with a common third system, and this more generalized ability is at work in many of the tasks used to evaluate episodic cognition. The evidence presented thus far cannot distinguish between these possibilities. However, several theories have been put forward in the literature on episodic memory and future thinking that investigate these questions. In the following section, I will evaluate the existing theoretical discussions on the nature of the link between episodic memory and future thinking.

Theories for a Common Mechanism

Episodic memory and episodic future thinking are thought to be related, but the degree to which this is true and the nature of this relationship is still unclear (Atance, Louw, & Clayton, 2015). Several theoretical explanations describing the nature of this link have been put forward and are reviewed here to offer insight into the connection underlying episodic cognition.

Construction Hypothesis

Recently, in studies concerned with future thinking, there has been much attention given to the idea that our memories are not always accurate (Gerlach, Dornblaser, & Schacter, 2014). It has been shown that individuals routinely produce sincere but inaccurate memories of past events due to interference from similar events, the inherent decay of memories over time, suggestions from others and personal expectations (Loftus, Korf, & Schooler, 1989). The construction hypothesis posits that the main function of episodic memories may be their usage in the creation of future episodes and that "memory can be productively re-conceptualized in light of this idea" (Schacter et al., 2007). The ability to flexibly alter and recombine our past experiences may aid us in representing future scenarios and there has been speculation that this may be the reason our memories are not a literal reproduction of the past (Schnider, 2008). In fact, when our memories are more similar, they are harder to keep apart (Reyna & Brainerd, 1998). The constructive memory hypothesis states that a system built on flexible components enables us to use these individual pieces for future event generation (Schacter & Addis, 2007). However, it has also been shown that patients presenting with hippocampal amnesia cannot construct scenes that are fictitious and atemporal (Hassabis, Kumaran, Vann, & Maguire, 2007). Hassabis et al. asked patients to generate scenes in the past, present and future tenses and showed that, in addition to deficits in episodic memory and future thinking, the novel imagination condition was also impaired. If the construction hypothesis states that the central function of our memories is for the generation of personal scenarios in the future, then one shortcoming is that it does not explain why imagination in the present tense would also be weakened. As this task does not theoretically require any form of mental time travel, additional work is needed to further understand the mechanism behind this overlap and determine why this ability might be impaired alongside memory and future thinking. Though the neuroimaging and lesion studies used as evidence for the construction hypothesis may provide insight into the adaptive functions of episodic memory, they could also be interpreted in other ways. Another prominent theory in the literature argues that this data could be evidence of similar processing components in the internal simulation of events and places removed in time or space (Buckner & Carroll, 2007).

Self-Projection

Buckner and Carroll put forward the theory that various forms of mental simulation rely upon a similar network due to the inherently similar nature of these tasks (2007). In addition to the component parts of mental time travel, this theory encompasses navigation, defined as the ability to topographically orient oneself in a spatial environment (Maguire, Frith, Burgess, Donnett, & O'Keefe, 1998), as well as theory of mind, or the understanding that others may have different beliefs, thoughts and emotions that influence their behaviour (Garfield et al., 2001). These abilities have all been shown to be implicated in patients with hippocampal deficits (Buckner & Carroll, 2007). A common 'core network' is therefore thought to be responsible for mental exploration requiring an internal mode of stimulation that is separate from the incoming stimuli present in the external environment (Hopfield, 2010). This core network may then contribute to the specific abilities that are implicated in self-projection.

There are several lines of evidence that support this theory. In addition to the aforementioned neuroimaging studies linking episodic memory and episodic future thinking, a quantitative meta-analysis done by Spreng, Mar and Kim looked across multiple PET and fMRI studies and showed that during tasks evaluating episodic cognition, navigation and theory of mind activation overlap was demonstrated within the medial-temporal lobe, temporo-parietal junction, precuneus, retrosplenial cortex and posterior cingulate (Spreng, Mar, & Kim, 2009). It has also been shown that patients with hippocampal damage have impairments in spatial navigation (Burgess, Maguire, & O'Keefe, 2002). A study by Astur et al. performed a virtual replication of the Morris water maze (Morris, 1984) and demonstrated impaired performance on the task in patients with hippocampal damage (Astur, Taylor, Mamelak, Philpott, & Sutherland, 2002). In healthy individuals age-related declines in navigational abilities have also been demonstrated (Monacelli, Cushman, Kavcic, & Duffy, 2003). The authors of this study compared performance on spatial orientation and neuropsychological tests between normal young, middle-aged and older adults with that of Alzheimer's patients. They showed that older adults and the patient population demonstrated a severe deficit in spatial cognition, independent of their performance on other cognitive tasks, when compared to the younger populations. Theory of mind has also been shown to decline with old age (Maylor, Moulson, Muncer, & Taylor, 2002). Better performance on theory of mind tasks was shown, independent of memory load involved, in a young vs. old age group comparison (21 and 81 years mean ages, respectively). This age deficit was shown to be significant even when controlling for differences in executive function, processing speed and vocabulary. However, it should be noted that cohort differences such as this are difficult to interpret: converging evidence from a longitudinal study would be needed to reinforce the findings that age, rather than some other difference, underpins the difference between the younger and the older cohorts.

The self-projection account is a broader association than those previously touched upon in studies of episodic memory and episodic future thinking. Even so, the argument for the self-projection hypothesis does not account for all of the data. Patients with hippocampal damage do not appear to have deficits in relation to theory of mind (Gregory, 2002). This study shows evidence of performance similar to control groups in patient populations with hippocampal pathology, and only noted deficits when other brain areas, like the frontal lobe, were implicated in the disease. Only one study has shown impairment in relation to hippocampal damage, and this particular study used patients with a focal epilepsy that implicated the entire temporal lobe

(Giovagnoli et al., 2011). The deficit they found was also significantly less pronounced than that noted in patients with epilepsy impacting the frontal lobe. This seems to be counterintuitive, if theory of mind is directly related to a set of skills that have been shown to rely heavily on the hippocampus (Addis, Pan, et al., 2009). It also does not explain why patients with hippocampal damage also display evidence of being unable to visualize or construct extended scenes (Maguire & Mullally, 2013). Boundary extension (BE) occurs when an individual reports more of a stimulus than they were presented with, due to extrapolating beyond the borders of the original scene (Intraub & Richardson, 1989). An example of this can be seen below in Figure 1.1.

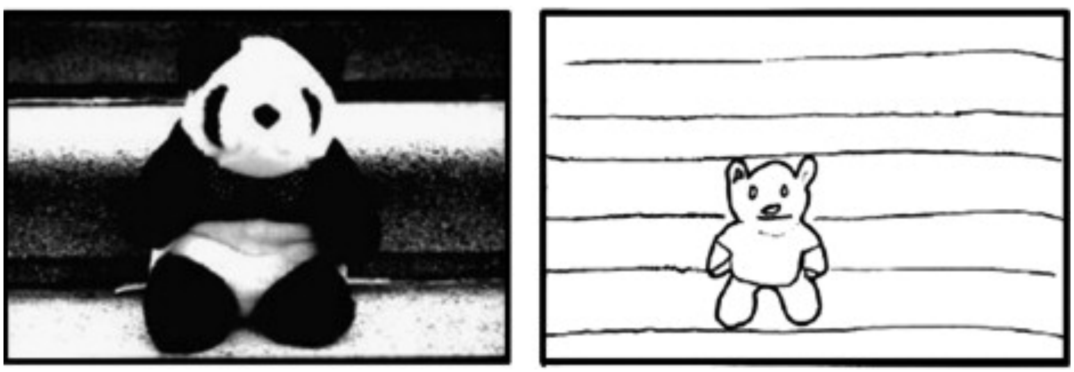


Figure 1.1: Participants were asked to draw pictures after having briefly seen them. A control participant drawing is shown above, where the background is significantly larger than in the original picture. This phenomenon is known as Boundary Extension. (Figure taken from Intraub, Gottesman, Willey, & Zuk, 1996)

Healthy individuals have been consistently shown to demonstrate this effect (Seamon, Schlegel, Hiester, Landau, & Blumenthal, 2002). However, patients with hippocampal damage, when presented with two identical scenes consecutively fail to make the same BE 'error' (judging the second scene as being "closer-up") that is deemed evidence of normal functioning (Mullally, Intraub, & Maguire, 2012). If the system is designed only to flexibly orient the self in space and time, then it does not make sense that in the immediate present patients do not extend scenes independent of the first person in their mind's eye.

Scene Construction

The scene construction theory (SCT) works to explain all of these data by reference to the fact that the hippocampus appears to be involved in the construction of scenes (Summerfield, Hassabis, & Maguire, 2010). This line of argument focuses most specifically on the hippocampus as key to the ability to coherently bind content to spatial contexts. This is a particularly attractive approach to me as many of the arguments against the first two theories centre on the idea that the brain regions involved in mental time travel and self-projection not only deal with events removed in time but with any task involving constructing a scene that includes one's self. It accounts for evidence that patients with hippocampal damage can flexibly recombine individual elements of scenes and imagine alternate temporal sequences of events but fail to create a coherent space in which the event could take place. Mullally and Maguire (2014) showed that a patient population with hippocampal damage could both identify the individual elements of a scene and realign the events in time but could not produce an internal spatial representation of the scene. According to the scene construction theory, this should be equally true in tasks situated in the past or future, but this same experiment has not yet been performed in these tenses.

However, this theory is not without shortcomings. For example, it does not explain why recent studies have shown that the hippocampus is preferentially activated in imagining future events as opposed to remembering (Addis, Cheng, Roberts, & Schacter, 2011). Theoretically these tasks should require the same level of spatial contextualizing and only differ in their temporal components. Though it is possible that the future could require more "construction" and therefore produce stronger activation, the spaces used in the experiment were all familiar to the participants. A follow-up study involving different levels of spatial familiarity or creating the exact same scenes in the past and future could clear up this inconsistency. Another challenging finding is the fact that patients with hippocampal damage generally perform more poorly on verbal memory tasks like word pair associates and remembering short stories (Ranganath, 2010). This challenges SCT because verbally mediated tasks should have nothing to do with spatial context. A counter argument to this is that it is possible that mnemonic strategies that use imagery could facilitate improved performance, but this has not been demonstrated (McCandliss, Cohen, & Dehaene, 2003).

While each of these theories emphasizes overlap, the degree to which episodic future thinking is related to one or all of these other abilities is still unclear. It is possible that the overlap is complete, incomplete, or that common reliance on another ability connects the two together. These possibilities are outlined below in Figure 1.2.

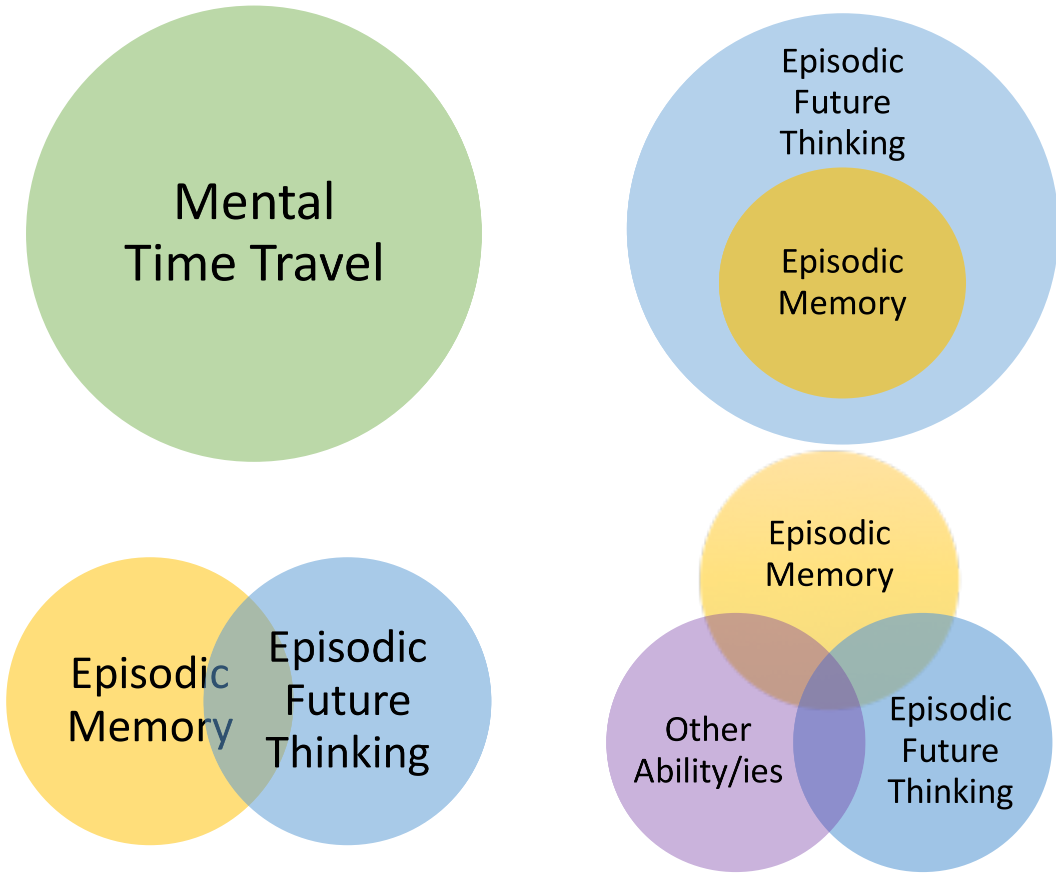


Figure 1.2: Potential relationships between episodic memory and episodic future thinking, based on the current research illustrating a link between the two

Some theories only refer to a shared mechanism for episodic cognition (Schacter), other suggest the overlap extends past episodic cognition to include scene construction (Mullaly), or navigation, theory of mind and imagination (Buckner & Carrol). It is possible that the net has not been widened enough, and that the relationship between memory and planning is simply the product of a more general ability that links these and other cognitive capabilities. While each one of these theories has claimed a relationship, it is possible that this conclusion is the result of confirmation bias in interpreting data caused by a more widespread overlap. In order to better understand the nature of this relationship, it may be important to look at what cognitive and neural mechanisms, if any, are distinct, as well as overlapping. This key information will help us to better analyse the extent to which these skills are related.

One method to go about answering this question is to look at comparative studies. This is another line of evidence, which uses evolutionary reasoning to help delineate overlapping or distinct processes between skills like memory and future thinking, and how they relate more broadly to prospective abilities.

Comparative Studies of Episodic Thinking

Tests of episodic thinking in other species offer us the opportunity to evaluate how these abilities developed in a broader, evolutionary sense, and whether or not these abilities came online in a simultaneous fashion. To this end, it has been important to develop behavioural methods that accurately tests memory and future thinking in non-verbal populations, (Scarf, Smith, & Stuart, 2014). One such method, known as the spoon test, was proposed by Endel Tulving (Tulving, 2005). This idea was based on an Estonian children's tale in which a young girl dreams about attending a party, where all of the guests are served chocolate pudding. However, the guests are expected to have brought their own spoons and, without having brought one, she is forced to watch everyone else eat her favourite dessert. The next evening, she goes to bed with a spoon under her pillow, determined to not have a repeat of this experience. This situation, according to Tulving, is evidence of autonoetic consciousness. The girl could remember her own personal past (episodic memory) and envision her future (episodic future thinking) in order to solve a problem that might reoccur. Evidence that a nonhuman participant could perform a comparable action would, according to Tulving, "force the rejection" of the hypothesis proposed by several prominent researchers that these abilities are unique to humans. This declaration has encouraged the scientific community to view the spoon test as a litmus test of mental time travel. Several comparative studies have employed variations of spoon tests, which offer mixed evidence for future planning in great apes. Mulcahy and Call showed that bonobos and orangutans can successfully learn to keep tools that might be necessary in the future (Mulcahy & Call, 2006). The animals were trained to get a reward from an apparatus using a certain tool. Then subjects were allowed to choose from six different tools in the test room, where two of the presented objects would work for the task. After five minutes the apes were taken outside into a waiting area and spent one hour there before being allowed back into the test room with the apparatus. Subjects (five bonobos and five orangutans) successfully chose and transported one of the correct tools back to the room on an average of seven out of sixteen trials. The previously successful subjects were tested in two follow-up experiments. These showed that some subjects could successfully complete the task after a longer delay of 14 hours and others could still pick and transport the correct tool when the original apparatus was removed from sight during the choice phase. This landmark study provided strong evidence that apes have the ability to save and transport tools, opening the door for future spoon test methodologies in non-verbal populations. The authors cite this as evidence of both memory and future thinking and emphasize a relationship between these abilities. However, it is difficult to determine the role of memory and planning in this experiment. It is possible that actions could have been driven by the positive memory of the training events (Shettleworth, 2010; Suddendorf & Corballis, 2007). Following this argument, these subjects could have chosen the correct tool and kept it with them because they associated it with previous reward. This is an important consideration to take into account when designing tests of future thinking, as often the correct item is emphasized during the encoding phase. Differentiating episodic memory or episodic future thinking capabilities from this more rudimentary form of conditioning through associative learning is an important area for research. It is hard to answer questions about the nature of an overlap between memory and future thinking more generally, when it is difficult to determine what is driving performance on the tasks that have been used to date.

In a similar experiment, Osvath and Osvath taught an orangutan and two chimpanzees to suck juice from a box using a plastic hose (2008). In a separate location they were then offered their choice of one from four items, including the hose. After an hour they could then access the testing room and return to the box. The subjects performed well (between 79% and 86%) across 14 trials. Further work by Osvath and Persson replicated the ability of great apes to prepare for the future when spatially and temporally displaced from the eventual reward (Osvath & Persson, 2013). One chimpanzee and two orangutans were tested on their ability to exchange a metal strip with an experimenter for a food reward. After selecting between four items, this exchange could be made following a 15-minute delay in an area out of sight from the original selection. All three animals performed above chance in the experiment (successfully obtaining rewards in 9/13, 12/13 and 11/14 trials, respectively). Other studies indicate positive evidence of memory and planning capabilities in monkeys, great apes and corvids (further reviews: Cheke & Clayton, 2010; Clayton, Bussey, & Dickinson, 2003; Clayton & Dickinson, 1998; Griffiths, Dickinson, & Clayton, 1999; Raby & Clayton, 2009).

While some of these studies do offer evidence of future thinking and episodic memory in primate species, the evidence is mixed and the methods may be too confounded to warrant drawing strong conclusions as to the presence or absence of an ability. Many of the studies can be passed with positive association alone and may not provide evidence of temporal, spatial and perspective separation that have been outlined as important component parts of episodic future thinking. While some of the authors still emphasize an overlap between these abilities, it is difficult to tell to what degree this exists in any of the species studied thus far. It may be important to develop tests that better isolate these abilities in order to determine whether or not either or both are present in a given species. Another opportunity to evaluate the emergence of these tasks comes in childhood. A developmental analysis provides the opportunity to look at episodic future thinking as it comes online and determine which other abilities may show similar developmental trajectories. This is important because it gives further insight into the nature of the relationship between memory and planning and may indicate the degree to which these abilities overlap in childhood.

Developmental Studies of Episodic Thinking

Many studies with children, whose linguistic skills are developing, use behavioural tasks like those previously discussed. But in addition children can be prompted for motivation and understanding, which may help to clarify the reason behind their choices and determine their reliance on episodic future thinking. Suddendorf and Busby performed an experiment that is similar to those used in the comparative literature, where children were judged on their ability to procure and transport toys to play with (Suddendorf & Busby, 2005). In this task, children were moved between two rooms, one of which contained a puzzle board with no puzzle pieces. After being taken to the other, they were presented with several items that they could take with them back to the original room, including puzzle pieces. Children between the ages of three and five were allowed to choose between several items and it was found that the older age groups (4- and 5-year-olds) routinely picked the target item above chance. A similar experiment was performed in children involving two rooms, one with and one without toys (Atance et al., 2015). After experiencing these two environments, and being asked questions to confirm that they understood the difference, children were asked where they wanted to place a new set of toys before coming back in the future. When asked about the distant future, four and five-year-olds could choose the correct room (current 'no-toy' room) at a rate higher than chance, while three-year-olds did not. When experimenters asked about the immediate future, four-year-olds were not significantly above chance, though they trended in that direction. This is an interesting finding, which may indicate a dissociation between short and long term planning. This is counterintuitive in light of findings by other researchers that suggest increasing temporal distance may make it harder for young children to pass future-oriented tasks (Russell, Alexis, & Clayton, 2010; Suddendorf, Nielsen, & Von Gehlen, 2011). It is possible that in the situation of the immediate future the younger children could have found it harder to separate their current location from another that they knew was nearby. The authors cite this difference as evidence of similar performance across conditions, but the subtle changes indicate that it may be important to further explore the influence of temporal distance when conducting experiments of mental time travel. Further research has also investigated how children respond to questions about the past or future when they are personal or involve another individual. Russell, Alexis and Clayton taught subjects how to play a novel table-top game called "blow football" (Russell et al., 2010). In this experiment, they asked children between the ages of three and five to choose from several items what would be needed to play the game tomorrow. In this case, the temporal displacement occurs immediately after the game is played through the usage of the future tense. While this is different from the spoon test as described by Tulving, this may be a way to eliminate a dependence on memory while evaluating future action. However, it also introduces the variant of verbal tense modification. Children as young as three have been shown to understand linguistic reference to the immediate past, distant past and immediate future, but are not capable of discussion of a delayed future until later in the fourth year of life (Harner, 1976). This could explain poor performance in younger age groups on this task and lend credence to the more popular notion of imposing an actual delay rather than a hypothetical one. In the study, 3-year-olds performed poorly on these questions, 4-year-olds could answer the question better if they were asked about what another person would need instead of what they themselves would require, and 5-year-olds could answer the question correctly regardless of condition (Atance et al., 2015). This may be incongruous with the self-projection theory, which focuses on the link between all abilities that require imagining a scenario in the mind's eye, including both episodic future thinking (self-oriented) and theory of mind (oriented towards another). Different performance between these conditions would suggest differences in the presentation and acquisition of skills like theory of mind and autonoetic future thinking in childhood.

As noted in this overview of some of the behavioural studies conducted with children, small changes in methodology can make a difference in performance. The following table highlights how various studies have looked at episodic memory and episodic future thinking in children. The most commonly cited studies on each are shown, with the percentage of children who pass at each age group. Highlighting indicates how this was analysed by the researchers. As there has not yet been an attempt made to determine the validity of different measures of testing episodic future thinking, (McCormack & Atance, 2011), a study using a verbal method is added for comparison purposes.

	3 Years	4 Years	5 Years	6 Years	DV
Perner & Ruffman, 1995 (EM) **12 pictures were presented on cards and children were later asked to recall what was on the cards.**	28.5%	58%	70%	89%	Recalled at least half of pictures presented
Busby & Suddendorf, 2005 (EM) **Children were asked to describe what they did the day before.**	25%	56%	75%		Gave plausible story of what did happen
Scarf, Gross, Columbo & Hayne, 2011 (EM) **After being taken to a sandbox, children found a locked treasure chest. 24 hours later they were offered a key (3 item choice) before returning.**	33%	75%			Chose the key (3 item choice) and referred to the original event in their justification
Busby & Suddendorf, 2005 (EFT) **Children were asked to describe what they might do the next day.**	31%	69%	63%		Gave a plausible example of what might happen
Atance & Sommerville, 2015 (EFT) **After being presented with a drawing missing one plastic eye, participants are offered (5 min delay) the opportunity to fix the art with glue.**	46%	79%	81%		Chose the glue (4 item choice) and referred to the original event in justification
Russell, Alexis & Clayton, 2009 (EFT) **A novel game called "blow football" was taught to children and they were then asked what they might need to play the game the next day**	0%	0%	33%		Said that they would need the box the next day to reach the higher side of the table
Suddendorf, Nielsen & von Gehlen, 2011 (EFT) **Participants were presented with**	29.4%	64.8%			Children chose the correctly shaped key to

puzzles and taken into a different room before being given the opportunity to secure a solution to take back with them.		take back to the puzzle box (4 item choice)

Table 1.1: Shows percentage of children in each age category who pass either episodic memory tasks (indicated in pink) or episodic future thinking tasks (blue) as reported by various developmental studies. Numbers highlighted in red reflect scores at or below chance. Yellow indicates that the age group was just above chance. Green highlighting indicates that the original authors interpret the results as being evidence of the fact that an age group can perform the task.

From this table we can deduce a few things about the current state of the developmental literature. The first is that between various tests of memory and prospection there is no exact agreement on when these abilities appear during childhood. However, when we look at each age group it appears that there is significant improvement across the pre-school and early educational years. While the criteria for success on each task were varied, three year olds are rarely above chance. Significant improvement seems to happen during the fourth year, as most studies point to a little over half of them passing the experiments. There have been relatively few verbal studies conducted to assess both memory and planning in young children. The one that is included in the table by Busby and Suddendorf was the first verbal study performed on children to assess mental time travel and was done by asking children two open-ended questions about what happened the day before and what might happen the next (Busby & Suddendorf, 2005). It was shown that children who can display episodic memory in the recollection of events that happened yesterday are more likely to construct a plausible sequence of events that could happen tomorrow. A majority of 4-year-olds and 5-year-olds were shown capable of reporting events that happened yesterday and could happen tomorrow, but only a handful of 3-year-olds demonstrated this ability. From this data, the experimenters were quick to conclude that the ability to mentally venture into the past and future develops simultaneously. However, as only 59% and 69% of 4-year-olds could correctly answer the questions in the past and future respectively, it may have been beneficial to do further analysis based on age in months. This experiment, while highly cited, used 16 children in each age category and only asked them two questions. Additionally, this example did not make any attempt to control for verbal IQ. It is therefore a good starting point for a verbal analysis of mental time travel, but is by no means thorough or sufficient. One key finding of this experiment is that by the age of four children have an understanding of the terminology "yesterday" and "tomorrow", which is an important establishment for future studies employing interview techniques. While one could argue that type of experimental design hinges too thoroughly on verbal abilities, we know that children in this age group can provide accurate descriptions of previously occurring events (Cleveland & Reese, 2008, Reese, Yan, Jack & Hayne, 2010). By age three, children demonstrate an awareness of events removed in time through their natural speech (Sachs, 1983). However, the development of more sophisticated anticipatory behaviours is generally not seen in children this young and is often more strongly reflected during early educational experiences when both planning and strategic development are encouraged in the classroom (Epistein, 2003). In light of these findings it may be possible that children are capable of mental time travel but have not yet learned the capacity to express themselves in verbal tasks. This is difficult to determine, as to date no studies have directly compared behavioural and verbal tests of episodic memory and episodic future thinking. This analysis could help to determine the developmental order by which these different abilities develop and how related they are.

These various approaches have produced different results by altering relatively small elements of the methodological design. Some of these differences may come from the fact that not all studies may have successfully required the children to imagine the future. It is possible that children could rely on past association to solve these problems, employing techniques more similar to classical conditioning. If something is deemed useful in one context, then it may be chosen later simply because it was previously useful. Though many of these studies employ spoon tests some of them interpret the results as being evidence of episodic memory, while others cite passing as episodic future thinking. This is indicative of the fact that it is difficult to dissociate episodic future thinking from episodic memory when the experimenter is creating an opportunity for children to plan. This could be further explored with tasks that are designed to test future thinking without directly prompting participants to rely on past knowledge. This would mean encouraging and assessing natural planning behaviours instead of instructing children to plan. Another critique of this literature as it currently stands is that many experiments have analysed group differences as opposed to looking at individual ability. It has been demonstrated that age-related improvements occur in episodic memory and episodic future thinking, but in order to determine whether or not a participant has these abilities may require a more comprehensive analysis of individual differences. Developing pass/fail criteria, while useful in some circumstances, does not give us much insight into the finer development of these skills. These behavioural tasks may not provide evidence of separable distinct components. Additionally, it is possible that other abilities, like those highlighted in the self-projection and scene construction theories, are playing into the ability to pass these tasks. To what extent do secondary abilities like memory, executive function and theory of mind play into the ability to pass a task of episodic future thinking? This could be confounding the results and providing evidence for an overlap that exists only through the acquisition of a skill that is different from the episodic system. As such, it may be necessary to consider the potential nature of the overlap between episodic memory and future thinking, particularly in relation to other abilities.

Aims and Outline

Over the course of this thesis, I will examine the developmental trajectory of episodic future thinking by exploring the validity of tests as tests of episodic future thinking and work to improve the specificity of these tests through experimental design. In the studies presented thus far, it is difficult to determine the nature of the relationship between episodic future thinking and episodic memory. One possible explanation is that these tasks are designed in such a way that both episodic memory and episodic future thinking are required to succeed, such that it would be impossible to distinguish between the relative contributions and independent presence of these skills. Another possibility is evidence of an overlap between specific cognitive traits is really being driven by a third factor, like associative learning. In order to make progress, it is important to look at both overlap and distinct features of performance on memory and planning tasks within a single study. The studies that follow aim to do just this, analysing and improving upon how we test episodic future thinking and examining how it related to episodic memory.

1. In order to determine whether or not behavioural and verbal tests of episodic future thinking are assessing the same cognitive mechanism, we propose to combine and compare these types of experiments in Study 1. This will allow us to determine whether or not these methods are comparable in future evaluations of the literature and hopefully bridge the gap between comparative and human studies. Additionally, this will permit us to investigate the validity of the spoon test for its continued use in exploring the developmental and phylogenetic roots of episodic cognition. Given that spoon tests to date have been used as evidence of both episodic memory and episodic future thinking,

we may find a relationship between a participant's ability to pass this task and talk about the future or past. As the literature currently presents mixed results as to how these different methodologies may align, is possible that after controlling for age-related improvement this relationship could persist for the verbal task in only the past or future tense, both or neither.

2. In Study 2, we will develop a new behavioural methodology that offers a more thorough assessment of future thinking as distinct from episodic memory. Previous experiments in the comparative and developmental literature have been criticized because preparatory actions in these studies can be explained by simpler mechanisms like associative learning and innate programming (Shettleworth, 2010). By controlling for these skills, we will provide a more thorough and definitive evaluation of mental time travel development. I predict that controlling for associative learning may make this test more difficult than previous behavioural tests of episodic future thinking.
3. Finally, in Study 3, we will use this new behavioural experiment to investigate episodic future thinking in a population with atypical episodic memory development. Determining whether or not episodic future thinking is also impaired will allow us to further look at the relationship between these skills. Autism Spectrum Disorders are characterized by diminished episodic memory and theory of mind, but very little work has been done to look at episodic future thinking in this population and the development of these abilities. I predict that episodic memory, theory of mind and episodic future thinking will all be impaired in this population and expect to find related performance within individuals, in keeping with the self-projection hypothesis (Buckner & Carroll, 2007).

This thesis will evaluate the development of episodic future thinking by both analysing and developing new methods of testing this ability. These will control for the alternative explanation of associative learning as being used for success in behavioural tasks. We will then look at the developmental trajectory of episodic future thinking in conjunction with episodic memory in both typically and atypically developing populations in order to determine the nature of the relationship between these abilities.

Chapter 2 - Acting for and talking about the future are related skills in early childhood: Validating the 'spoon test' as a measure of future thinking

Abstract

Our natural tendency to remember and engage emotionally with the past allows us to make future choices that are informed by these previous events (Tulving, 2002). Without the use of language, it is difficult for comparative and developmental researchers to determine the degree to which animals and/or young children possess episodic memory and episodic future thinking (Scarf et al., 2014). As such, behavioural tests have been designed to evaluate these abilities and have been used widely in the literature on memory and planning (Osvath & Osvath, 2008). This study investigates the relationship between verbal and behavioural methodologies. Differences were evaluated both within individuals and across development through an analysis of children between four and six years of age. The interview technique piloted in this study was carefully modified from those conducted on adults (Hassabis, 2007) for usage with this age group. During the experiment cue cards with black type were presented to participants and subjects were instructed to remember or create a scene in the past, present or future tense based on these prompts. Similar improvement with age was shown across all verbal conditions. Overall, performance in the future tense was weaker than that in the past and present, but children who did well in one category were more likely to do well in the others irrespective of receptive vocabulary and verbal IQ. A strong relationship was demonstrated between scores in the present and future tenses. This novel finding provides support for the idea that scene construction may play an important role in future thinking abilities. The experimental test we used is a version of the so-called 'spoon test' (Suddendorf, 2005) and a replication of a recent study performed to evaluate future thinking in this age group, (Atance, 2014). Children are presented with a drawing missing one plastic eye and later offered the opportunity to remedy this situation by

choosing glue among distractor items. Again, we saw improved performance on this task with age. In order to evaluate whether or not these methods independently evaluate the same cognitive ability, we looked at individual performance on both and compared interview scores for children who had passed vs. those who failed the spoon test. While it is possible that episodic memory and future thinking are not fully expressed in children due to a lack of the language skills necessary to express events removed in time, this study showed a strong positive correlation between behavioural and verbal tasks in this age group.

Introduction

The spoon test as described by Endel Tulving has been employed as a test of episodic memory and episodic future thinking in non-verbal populations (Tulving, 2005). This behavioural task has become the primary means of analysing these abilities in comparative and developmental studies. The spoon test offers an important functional assessment of real world performance. Ease of administration, adaptability and non-verbal application make this test a very useful tool for testing episodic cognition. However, the methodology has only one dependent variable, which makes it hard to assess the relative contributions of cognitive abilities like semantic memory, episodic memory and episodic foresight (Atance et al., 2015). To date, little work has been done to determine what the test itself practically assesses. Similarly executed tests have been cited as evidence of episodic memory and/or episodic future thinking. As introduced previously, the nature of the relationship between these abilities and the degree to which they are served by a common cognitive mechanism is currently under debate in the literature (Cuevas, Rajan, Morasch, & Bell, 2015). In order to address this, we compared performance on a spoon test to an interview methodology designed to assess episodic thinking. This technique provides a richer analysis of these capabilities and allows the past and future to be disambiguated.

In order to pass this task, participants must remember the initial event (encoding phase) and also be able to choose an item that will help them in the future return to the original problem (choice phase). Some researchers therefore argue that spoon tests are evidence of episodic memory (Scarf et al., 2013), while others emphasize participants' reliance on episodic future thinking (Osvath & Osvath, 2008). Others have suggested that the spoon test does not require episodic thought at all (Suddendorf & Corballis, 2010). In an experiment with pass/fail criteria, it is hard to determine what facilitates or inhibits success. In support of the notion that the spoon test is best seen as a measure of episodic memory, rather than future planning, Atance & Sommerville report no significant age-related changes in performance on a battery of spoon tests once they controlled for participant's memory of the problem (Atance & Sommerville, 2014). Similarly, Scarf et al 2013 report that children who select the wrong item in spoon tests often do so because of a failure to remember the problem (Scarf et al., 2013). In a test designed to assess young children's ability to remember that they needed a key to unlock an item, they found that three-year-olds chose the wrong item more than older children, but also did not remember the encoding event. As such, it has been argued that tests of episodic future thinking should be designed in such a way that they do not depend on memory (Hudson et al., 2011). Suddendorf and Corballis similarly argue that it is necessary to separate future thinking from memory, particularly in relation to cuing at the time of choice (Suddendorf & Corballis, 2010). In an overview assessing various studies of mental time travel in nonhumans, they offer several key criteria for establishing the golden standard in behavioural tests of episodic future thinking. The first is the usage of a single trial in order to prevent the subject learning over time. Second, they advocate for novel problems to prevent the individual's experience leading to learned associations that could play a role in their success. The third condition is clear temporal and spatial separation between the encoding phase and the choice phase. These, respectively, ensure the subject is relying on long-term memory and is not being cued by the environment during the time of object choice. Finally, their fourth criterion is the necessity of avoiding problems that could be explained by innate behaviour; for example, choosing to set aside food at a time when the participant could feasibly be hungry. They argue that human foresight encompasses diverse contexts and issues and therefore tests of this ability should aim to do the same. However, the nature of foresight often requires that we rely on our personal memories to create flexible representations of the future (Schacter et al., 2007). It may therefore be impossible to design tests of episodic future thinking that are independent of memory performance (Atance & Sommerville, 2014). It is therefore possible that memory is a necessary component for success on the spoon test, but it is not sufficient. Atance & Sommerville (2014) point out that though memory explained most of the variance in performance on the spoon test battery, it was not a perfect predictor, and there were some children that remembered the encoding phase but did not make the right selection.

One way to try to resolve what the spoon test methodology is measuring would be to compare performance on this simple test with a richer measure, in which the relevant contributions of semantic and episodic memory can be disambiguated, and thinking about the past and future can be compared. The interview methodology commonly employed in tests of adult populations is one such measure (Flick, 2000; Hassabis, Kumaran, Vann, et al., 2007; Kopelman, Wilson, & Baddeley, 1989). As interviews provide a unique opportunity to alter tense in an otherwise standardized procedure, these methods are well suited to analysing the individual components of mental time travel. This approach allows experimenters to evaluate the degree to which narratives bear the hallmarks of episodic thinking. Rich, vivid, spatially coherent, contextualized accounts in which the individual seems to project themselves to the past or future event score highly, while disjointed lists of relevant facts score poorly. The Autobiographical Interview (or Autobiographical Memory Interview/AI) asks participants to verbally recall events from their own life periods (Kopelman et al., 1989). This technique has been finely tuned to disassociate semantic vs. episodic retrieval (Levine et al., 2002). This is done in the scoring protocol, whereby raters independently evaluate relevant facts with details that add to the enhancement of an episode. Structural elements, such as place, time and event details are used as evidence of episodic retrieval to provide a more thorough evaluation of episodicity. This has been used to evaluate episodic memory in adults of all ages (Habermas, Diel, & Welzer, 2013), as well as in patient populations (Hassabis, Kumaran, Vann, et al., 2007; Schacter, Gaesser, & Addis, 2013). These studies have found that scores of episodic retrieval are reduced in aging when talking about the past, but the number of semantic details often remains unchanged (Levine et al., 2002). Performance on the autobiographical interview can also be compared across tenses (Addis et al., 2008). This is an important feature because it allows for the assessment of episodic memory as well as episodic future thinking, where the only changed element of the methodology is the tense in which the interview is conducted.

Previous developmental studies have shown that young children can also provide accurate descriptions of previously occurring events (Cleveland & Reese, 2008; Reese, Yan, Jack, & Hayne, 2010). By age three, children demonstrate an awareness of events removed in time through their natural speech (Sachs, 1983). However, the development of more sophisticated anticipatory behaviours is generally not seen in children this young and only starts to emerge during early educational experiences when both planning and strategic development are encouraged in the classroom (Epistein, 2003). Hayne, et al. also used interview methodology in order to assess episodic memory and episodic future thinking in children between the ages of three and five-years-old (Hayne, Gross, McNamee, Fitzgibbon, & Tustin, 2011). Children were individually interviewed using a personalized timeline that included photographs of themselves at various ages. They were then asked about events that happened previously and ones that might happen in the future. Children across all age groups could provide accurate answers to these questions. However, these events were limited to being no more than 24 hours prior to and 24 hours after the interview. There was found to be significant age related improvement in the amount of information provided across all conditions. Studies with older children have also employed interview tasks (Coughlin, Lyons, & Ghetti, 2014). Using cues to prompt episode development in the past and future, age related improvement was demonstrated in children between the ages of five and nine years. Interestingly, Coughlin and colleagues also noted poorer performance across middle childhood in the future tense as compared to the past tense. They cite this as evidence of the fact that prospection may require additional skills that are later developing than those used to recall memories. This difference could reflect young children's reliance on scripts to create a working knowledge of how common events might unfold (Myles-Worsley, Cromer, & Dodd, 1986). Assessing episodic thought through verbal reports offers a measure with high ecological validity, however, there are potential shortcomings, particularly in developmental studies. While it has been established that children can talk about the past and future, the degree to which they rely on semantic knowledge as opposed to episodic recollection has been debated (Hudson, Shapiro, McCabe, & Peterson, 1991). When Hudson and Shapiro asked children to provide a 'script' of what happens during common events, like going to the grocery store or beach, the older children were more likely to include preparatory behaviours as compared to the younger children. As children increased in age, the reported scripts had more information and more specific planning activities. This resulted in the development of a more coherent and cohesive story. These findings highlight the issue that even though children may be able to tell us about the past and future, much of their language ability may come from derived 'scripts', describing generic features of a category of event rather than a specific memory or imagining of the future. Previous research has shown that children younger than eight use information about how an event typically occurs when they are unsure of the actual memory. In order to mitigate this effect, it is important to develop scoring techniques that do not reward general event knowledge and instead encourage participants to craft a unique personal narrative. Employing this level of fine-tuned analysis is possible because these methods generate complete transcripts and these responses can be analysed in multiple different ways (Kopelman, 1994; Levine, 2004). However, though the data are rich, the sources of variability are many. Like in script employment, it may be possible to craft a complete story without having a full internal representation of the event (type I error). Additionally, a lack of verbal skills or poor narrative technique may mean that individuals with complete event generation still do poorly in comparison to participants who are better at storytelling (type II error). It is difficult to tell what other factors might drive performance. In order to determine whether or not these methods test the ability to generate internal representations of an event, especially in younger age groups, it may be important to also employ functional analysis of how these representations might be used to guide behaviour.

In this experiment, we compared performance on a functional test as well as a verbal methodology. We adapted the Experiential Index developed by Hassabis et al., to assess children's performance on interviews using a scoring method that takes into account not just the amount of detail, but also the various hallmarks of episodic thinking, like spatial reference and time coherence (Hassabis, Kumaran, Vann, et al., 2007). Using this rubric means that script-like descriptions receive low scores, while more rich scenes receive high scores. We chose to use three tenses for the interviews, in order to independently evaluate episodic memory, episodic future thinking and provide a control condition requiring imagination in the present tense. Adding this third condition allowed us to determine whether or not the temporal element of episodic memory is what lags behind (as would be demonstrated by successful performance in the present tense but not past or future) or whether or not verbal skills are the limiting ability (poor performance across all three categories). We compared interview performance with performance on an item choice task (spoon test) in order to determine how the episodicity shown in verbal reports relates to behavioural performance. As described above, while item choice tasks have the benefit of reduced peripheral demands, their chief shortcoming is that it is difficult to determine why a participant chose a certain object (Atance et al., 2015). While a child may make choose the correct item by chance, equally they could be capable of mental time travel but choose the wrong item simply because another one seemed more appealing at the time. To help disambiguate whether errors are truly evidence of weaker mental time travel ability, we looked at whether or not interview performance in any tense is related to item choice.

By performing interviews in different tenses we were able to further explore whether behavioural tests are more related to thinking in the past or present. Previous work has suggested that children's performance on interviews set in the past and future might follow different developmental trajectories (Coughlin et al.). It is therefore possible that the item choice task might be better related to one or other tense. Some previous studies have suggested that memory is a crucial component to success in item choice methodology (Atance & Sommerville, 2014; Scarf et al., 2013). However as explained above, memory might be necessary but not be sufficient. We therefore used multiple interview conditions to evaluate how the spoon test relates individually to memory, imagination and planning components. While the study of mental time travel has become an important focus across various branches of psychology, developing methods to evaluate future oriented thought has proven to be a challenging task. In order to truly analyse the developmental and evolutionary trajectories of this ability, we must agree on the criteria used as evidence. We hope to enable a more direct comparison of verbal studies done in adult populations and the behavioural tasks common in the comparative and developmental literature by determining the relationship between these tasks. We therefore chose a recently published spoon test to replicate (Atance & Sommerville, 2014) and compared this with an interview methodology developed through the age-appropriate modification of an experimental technique used with adult populations (Hassabis, Kumaran, Vann, et al., 2007). Comparing the aforementioned scores of episodicity in the interview task to a behavioural task provided me with a better examination of the real world consequence of differences in narrative content. We predicted that individual performance would correlate across all three conditions of the verbal test, because of the predicted relationship between episodic memory and episodic future thinking. We also hypothesized that behavioural task performance would be linked with performance on the verbal test in episodic memory, episodic future thinking, or both.

Methods

Participants

66 children participated in the experiment: 16 four-year olds (mean age = 54 months, range = 48 – 59 months), 19 five-year olds (mean age = 65 months, range = 60 – 71 months), 16 six-year-olds (mean age = 77.5 months, range = 72 – 83 months) and 15 seven-year-olds (mean age = 90 months, range = 82 – 94 months). Five additional children began testing, but dropped out either due to disruptive behaviour (n = 1, age 4,6) or unwillingness to participate further (n = 4, ages 4,3 | 4,7 | 4,9 | 5,1). Children were recruited from three local primary/nursery schools in Fife and were predominantly of British descent. Parents gave informed consent and had the opportunity to ask experimenters questions about the study. Participants were given stickers for their participation. Mean raw and standardized verbal scores are shown for each age group below in Table 2.1.

	Raw VIQ (mean)	Standardized VIQ (mean)
4-Year-Olds	119.81	111.06
5-Year-Olds	113.11	103.21
6-Year-Olds	117.13	95.06
7-Year-Olds	115.93	97.47

Table 2.1: Raw and standardized verbal IQ scores for different age groups

Verbal Experiment

Materials:

There were six prompts used in this experiment. The words “park”, “school”, “zoo”, “forest”, “friend’s house” and “birthday” were each written in large black type on individual pieces of white 21 cm x 29 cm cardstock.

The British Picture Vocabulary Scale:

Third Edition (BPVS-III) was used to assess receptive vocabulary. Additionally, verbal IQ (VIQ) scores were calculated using the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III).

Procedure

The interview procedure was based on that outlined by Maguire, Vargha-Khadem & Hassabis (2010). Testing was split into two days for each participant, with sessions lasting for approximately thirty minutes each day. Subjects were tested individually, sitting opposite the experimenter in a quiet room. Before the test phase the experimenter explained the participant should use the prompts given to mentally generate a picture in their head before describing everything that they can about the event they are thinking of (script: “Use this word to think of an event in your head and then tell me all about it”). During the experiment cue cards with black type were presented to participants and the contents were read aloud by the experimenter. Subjects were instructed to remember or create a scene based on these prompts. This was done in keeping with the protocol by Hassabis to ground the encounter on an object, even though younger children likely could not read the type face. As such, the card was read aloud to them. Subjects were told to either “Think of a time when you went to __(cue insert)__”; “Pretend you are at a __(cue insert)__ right now" or "Imagine that you are going to a __(cue insert)__ tomorrow." These trials therefore fell into three language categories: past, present and future respectively based on the prompt. For fictitious scene creation in both the present and future subjects were instructed to generate a novel scenario in their mind instead of relying on the memory of a past event. They were told to "think of something that is new and has not happened to you before". Conversely, cued events from the past were instructed to come from an actual memory and be the recounting of a real episode experienced by the participant. They were told "think about something that happened to you". The order of events was alternated between participants but the cue cards remained the same (see Figure 2.1).

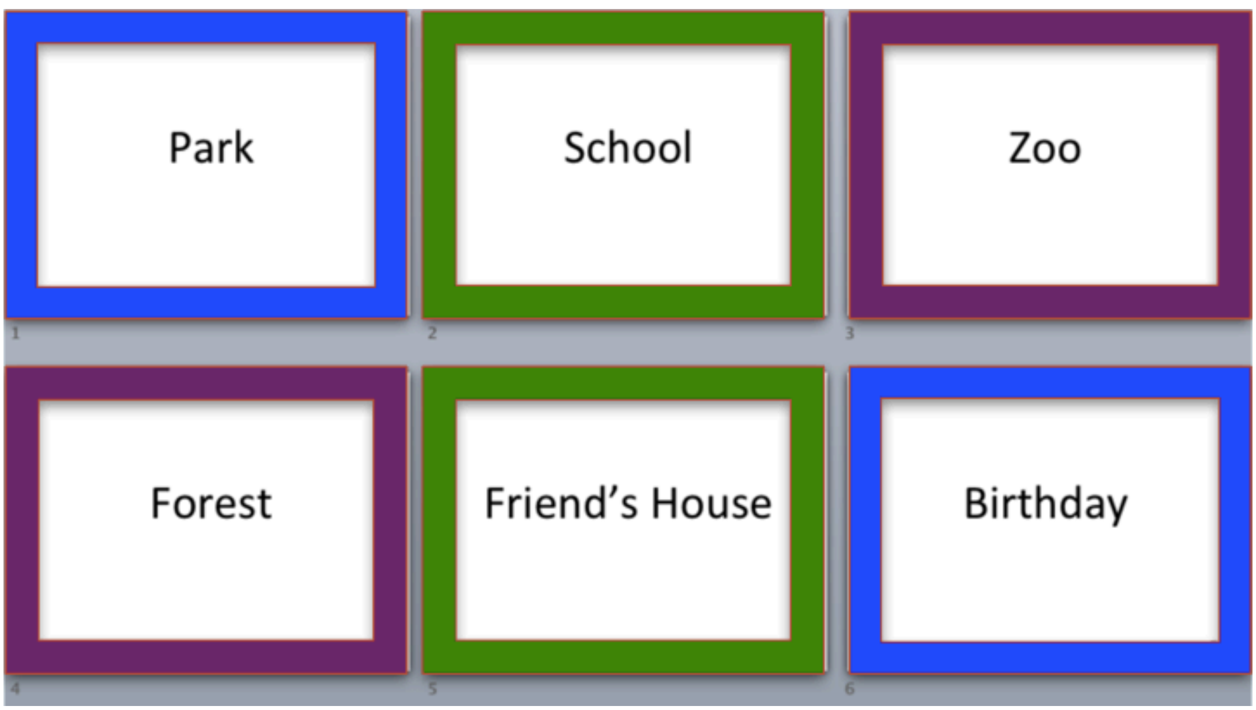


Figure 2.1: Cues and example of random shuffle, all participants received on day one: past, present, future and on day two: future, present, past, in that order. This can be shown above where blue is past, green is present and purple is future. Day one is on top and day two is on the bottom.

Each cue was given in the various tense scenarios in order to control for some cues being inherently more difficult than others and this was randomized between participants. After reading the statement, the physical cue card remained present on the table throughout the description phase and could be repeated aloud if the child asked for a reminder. Five questions were administered in each scene in the same order (as shown in Figure 2.2).

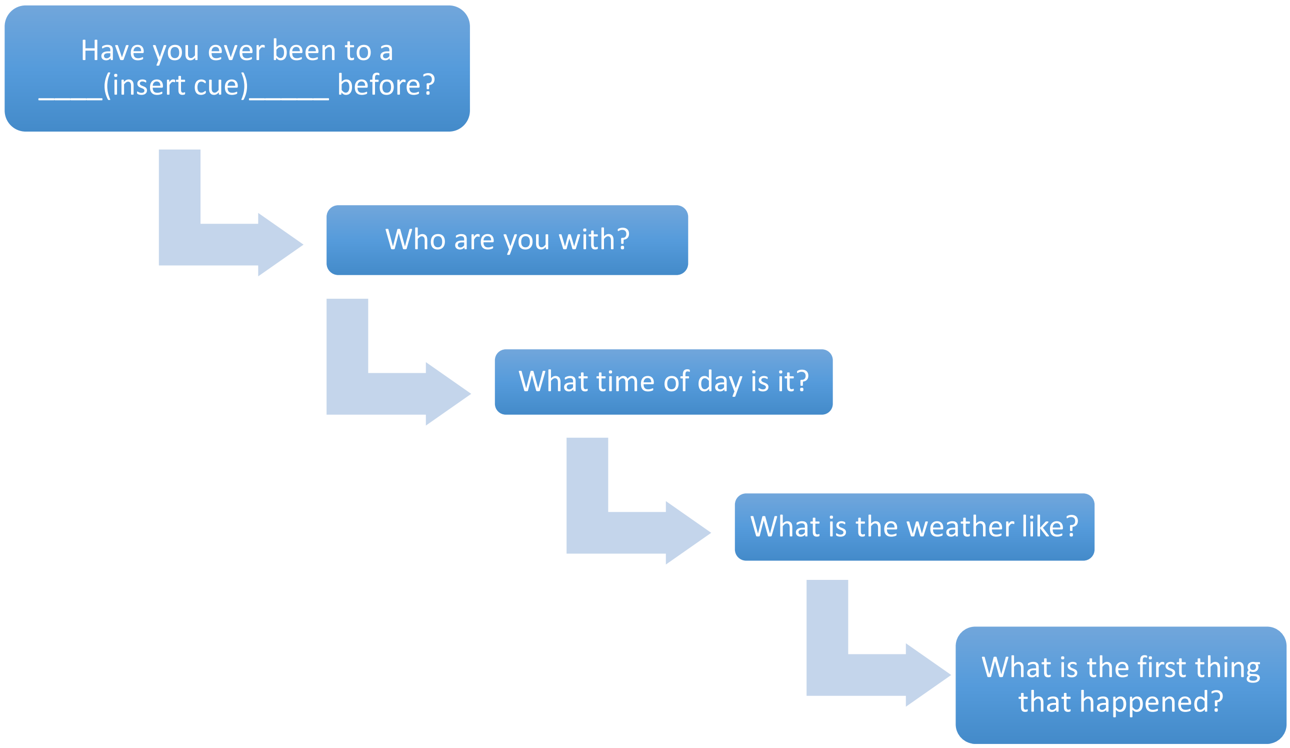


Figure 2.2: Script of questions asked for each cue word

These were designed in order to immerse the participant in the scene and then encourage participants to begin a story. General prompts were given until the subject was unable to provide more detail in order to encourage participants to elaborate further. This probing protocol was carefully administered so as to prevent the experimenter leading subjects and only included statements without scene-related content (exact questions shown in Figure 2.3).

Can you tell me more about it?
What was that like?
What else can you tell me?
Did you do anything else?
What more did you do?
What else did you do?
How was that?
Could you say any more?
Anything else?
Really?
Yeah?
And?

Figure 2.3: Open-ended probing questions asked of participants

Scoring

Each interview was transcribed and coded based on the detailed method guidelines given by Hassabis, et al. (2007) with minor modifications for the decreased age of participants. The interviews were scored based on the content of the description and a quality rating. In accordance with the pilot studies conducted by Hassabis et al. (2007) an evaluation of the "description content" was performed in order to determine how many details were given in each scenario. Audio recordings of the trials were transcribed and these scripts were used to produce independent quality ratings. Individuals who were blind to the hypotheses and had no access to the identity or video recordings of the participants each rated the transcripts (rubric can be found in Supplemental Information). They were given a rubric based on the scoring procedures outlined by Addis et al. 2008 emphasizing structure and content. Scores were given out of 10. This rubric gives independent scores for sense of space, sense of time, sense of self, meaning/logic and vividness. We used one lead rater for our analysis and compared scores from two other raters to their reports on 100% of transcripts. This generated Cronbach alphas of .891 and .914, respectively. As quality ratings were given out of 10 possible points, we divided description content scores by 5 so that the highest given score (50 details) was equal to 10 points. This gave the quality and content components equal weight in the total score (0 to 20 points, with 0 being an incoherent story with no detail and 20 being a well-told story with rich description).

Behavioural Experiment

Materials

A printed picture of Mickey Mouse and Pluto on white paper (non-glossy, size A4) was presented to each child with one plastic eye attached (see Figure 2.4).

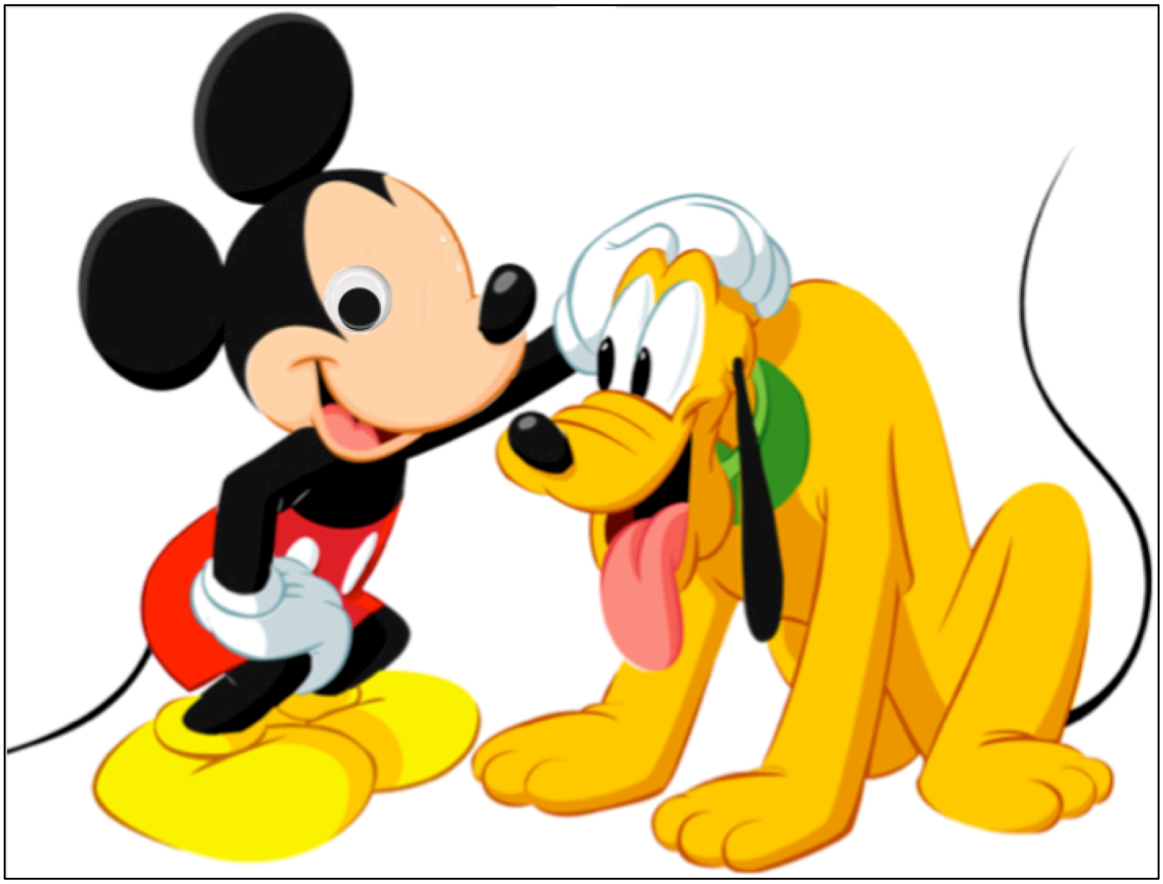


Figure 2.4: Smiley Face Task picture

There was additionally an unattached eye offered to each participant. Children were asked to identify and choose between several common household items, namely a glue stick, scissors, a small garden shovel and an eraser.

Procedure

This methodology was adapted from the Smiley Face Task as performed Atance and Sommerville (2014). In one room the experimenter informed children that she had a gift to give them. She then reached into her backpack and pulled out a drawing. This piece of paper had a drawing of Mickey Mouse and Pluto in which Mickey was given only one plastic “google” eye.

Upon seeing that the drawing was incomplete the experimenter expressed her dismay, lamenting that she could not give the picture to the child until the other eye was attached again. Children were led into a second room but told that the drawing would remain in the first. After participating in a memory game for approximately five minutes, they were asked to choose one item to take with them before going back into the first room. The choices consisted of scissors, an eraser, a shovel and glue. Glue was considered to be the correct option because it could be used to reattach the displaced eye. Children were asked to identify each of the items before being asked to choose one ("You may take one of these items with you back to the other room. Which one do you want to take?"). The children were not reminded of the previous task but were asked after making their choice to justify their pick. If they did not refer to the drawing in their answer, they were explicitly asked if they remembered the event ("What is on the table in the other room?"). Afterwards they were taken into the room and if they had chosen the correct item were permitted to use it to glue on the missing eye. If not, children were asked, with the items in front of them, which they could use to fix the drawing and could repair the picture to take home. All children were allowed to leave with a complete drawing.

Scoring

In keeping with the study by Atance and Sommerville (2014) a pass designation meant that the individual picked the correct item (glue) and gave proof of remembering the event either in their justification of their choice or during the memory question. The experimenter also noted whether or not the participant directly referred to glue during the encoding phase or distractor period prior to being presented with the items for selection. Children who chose the incorrect object were presented with all four objects for a second time in front of the drawing and asked to "fix it". At this point, all children in the study successfully used the glue to repair the drawing without further prompting.

Statistics

Our results were obtained using a SPSS statistical package (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). We ran independent samples t-test to evaluate the effect of sex on cumulative scores (S-W = .918, $p = .561$). There were no significant differences between male and female performance in the past, present and future tenses ($p = .78$, $p = .52$, $p = .31$, respectively). We therefore combine these scores in our analyses. We used a mixed ANOVA to evaluate the effects of age and tense on performance, used Pearson's correlations to compare performance within individuals and evaluated pass/fail performance for age groups on the Smiley Face Task using binomials (one-tailed).

Results

Interview performance: Experiential Index

Consistent with the developmental literature on mental time travel, performance across interviews improved with age (Figure 2.5). We performed a mixed design ANOVA with age (4-Year-Olds, 5-Year-Olds, 6-Year-Olds, 7-Year-Olds) as the between subjects variable and tense (past, present, future) as the within subjects variable. We found a significant main effect of age ($F(3,62) = 23.92$ $p = <.001$). 4- and 5-year-olds were found to be different from all other ages (Bonferroni, 4 and 5: $p = .048$, 4 and 6: $p = <.001$, 4 and 7: $p = <.001$, 5 and 6: $p = .001$, 5 and 7: $p = <.001$), but 6- and 7-year-olds did not differ significantly from one another (Bonferroni, $p = .975$) (Figure 2.5).

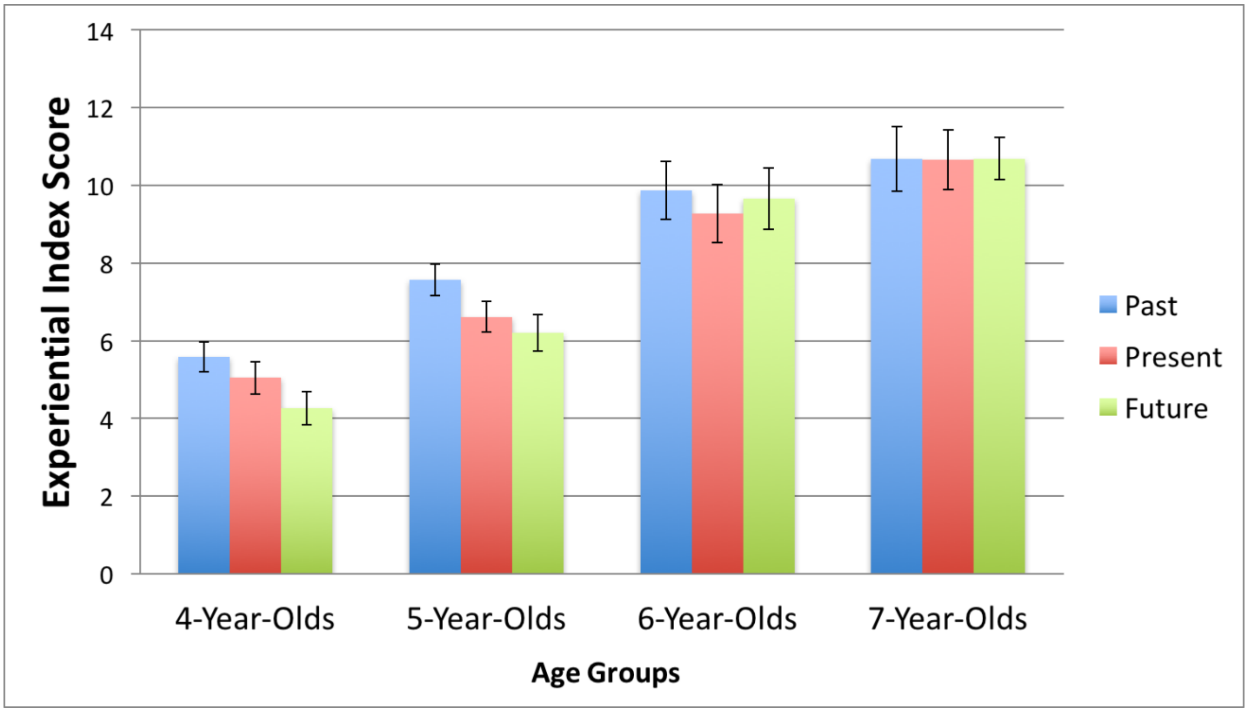


Figure 2.5: Mean (±SEM) composite experiential index scores are shown in each age category (4-Year-Olds (N = 16), 5-Year-Olds (N = 19), 6-Year-Olds (N = 16) and 7-Year-Olds (N = 15) for each tense.

The ANOVA also revealed a significant main effect of tense, $F(2,124) = 5.42$, $p = .006$. Post hoc tests (Bonferroni) revealed that there was a significant difference in scores between the past tense and present tense, ($p = .025$) and the past tense and future tense ($p = .004$), but not between the present and future tense ($p = .345$). Present and future tense performance appears more difficult for young children. However, there was not a significant interaction between age and tense, $F(6,124) = 1.46$ $p = .199$. From these results, it appears that the present and future tenses present a unique challenge as compared to the past tense in the interview methodology. Overall performance on the past tense was higher in four and five-year-olds, indicating that it is easier to talk about experiences that you have had than it is to imagine or pre-experience new events.

A hierarchical multiple regression analysis was performed on this data to parcel out the effect of verbal IQ and age. Age was a significant predictor of performance, but verbal IQ was not in any tense. The results can be seen below in Table 2.2.

	Past (R^2, p)	Present (R^2, p)	Future (R^2, p)
Model 1: Raw VIQ	.008, .666	.005, .584	-.002, .346
Model 2: add Age	.225, <.001	.296, <.001	.368, <.001

Table 2.2: Hierarchical regression taking into account raw verbal IQ scores and then VIQ scores and age for each tense.

Individual Differences

While these group level effects allowed us to examine the overall pattern of how children perform in the different conditions, we also wanted to look at results within individuals. We predicted that children who did well in one condition would be more likely to do well in the others, both due to verbal ability and because of an anticipated link between episodic memory and episodic future thinking. Indeed, we found a strong link between individual's performance across the various tenses, indicating similar relative performance across each category (Pearson's correlations, past and present = .826, p = <.001, past and future = .809, p = <.001, present and future = .868, p = <.001) (Table 2.2). This link was found to be independent of verbal ability, as judged by receptive vocabulary (BPVS-III) and verbal IQ (WPPSI-III) scores (Pearson's correlations, past and present = .808, p = <.001, past and future = .794, p = .001, present and future = .846, p = <.001). This provides support for the idea that there is a common mechanism between remembering, imagining and prospecting. These correlations can be seen below in Table 2.3.

	Past	Present	Future
Past		.826*	.809*
Present	.808*		.868*
Future	.794*	.846*	

* Indicates correlation is significant at the 0.01 level (2-tailed)

Table 2.3: Correlations between scores on description content in the past, present and future tense for each individual. Boxes in the top right represent Pearson correlations between tense categories and the three on the bottom left boxes are partial correlations controlling for receptive vocabulary and verbal IQ.

Spoon Test

One-tailed binomial tests indicated that in each age category the scores were above chance, (4-year-olds: p = .007, 5-year-olds: p = .029, 6-year-olds: p = .027, 7-year-olds: p = .001) (Figure 2.6).

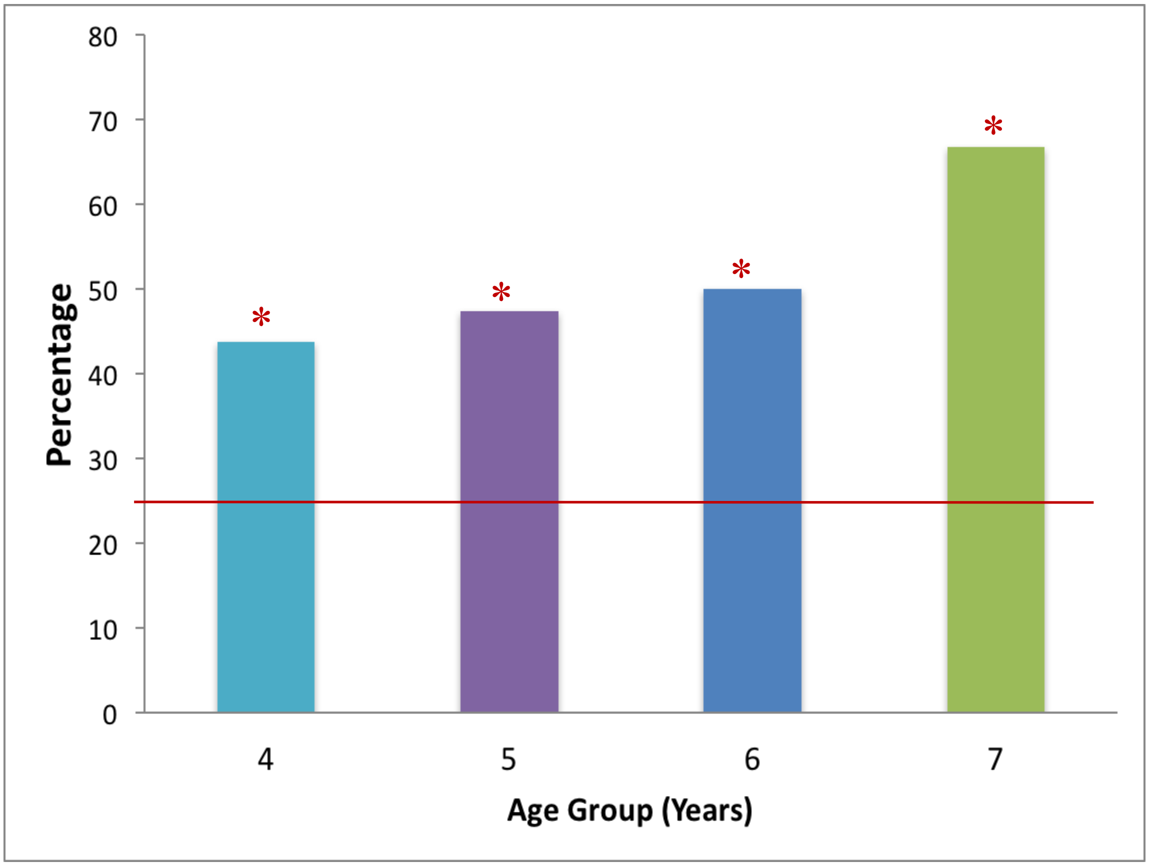


Figure 2.6: Percentage of children in different age groups that passed Smiley Face Task. The red line represents chance (25%) * indicates above chance according to a 1-tailed binomial test).

During the experiment, we noted that some children verbalized the potential need for "glue" at the time of encoding. We kept track of this difference and performed a chi-square analysis in order to compare performance between children who did and did not bring this up. We found that children who said glue during encoding were more likely to pass in the behavioural test, X^2 (1, N = 66) = 5.06, p =.02; Figure 2.7).

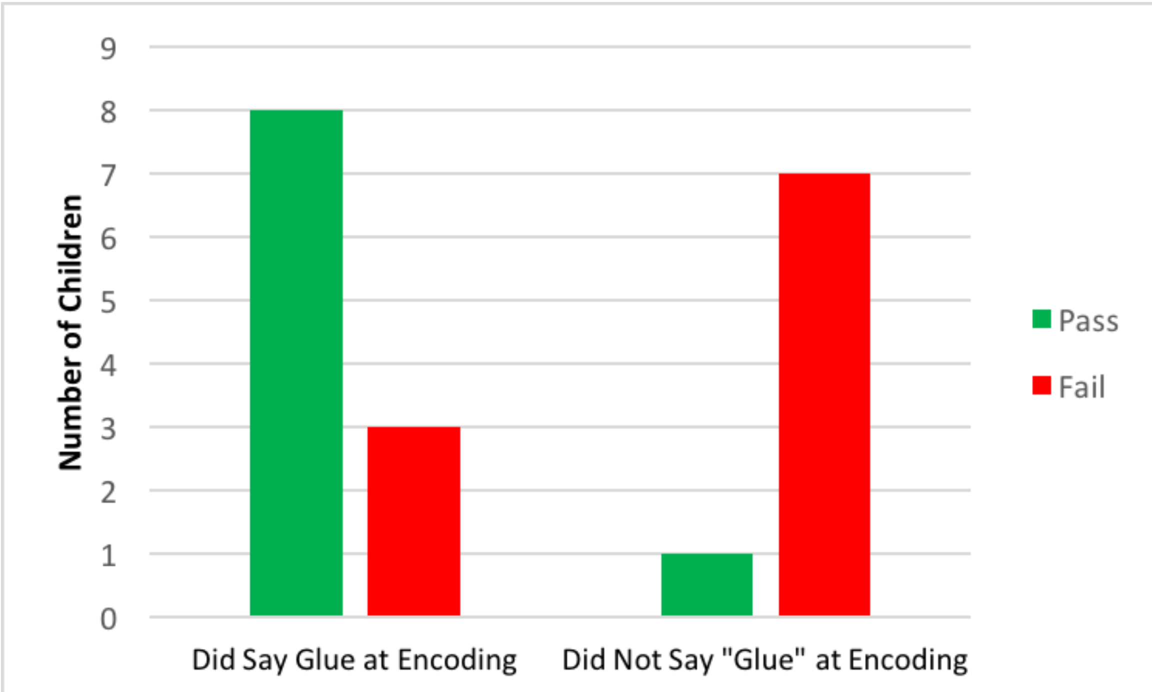


Figure 2.7: Children who passed and failed the Smiley Face Task in relation to whether or not they said "glue" at the time of encoding.

Comparison Between Verbal and Behavioural Tests

Performance on the behavioural and verbal tasks was compared using the Experiential Index scores from the interview and the pass/fail designation from the Smiley Face task. In order to evaluate whether or not these methods independently evaluate the same cognitive ability, we looked at individual performance on both by averaging the scores of those who had passed vs. those who failed the spoon test. We found that there were significant differences between these groups in the present and future tense but not in the past tense (Figure 2.8).

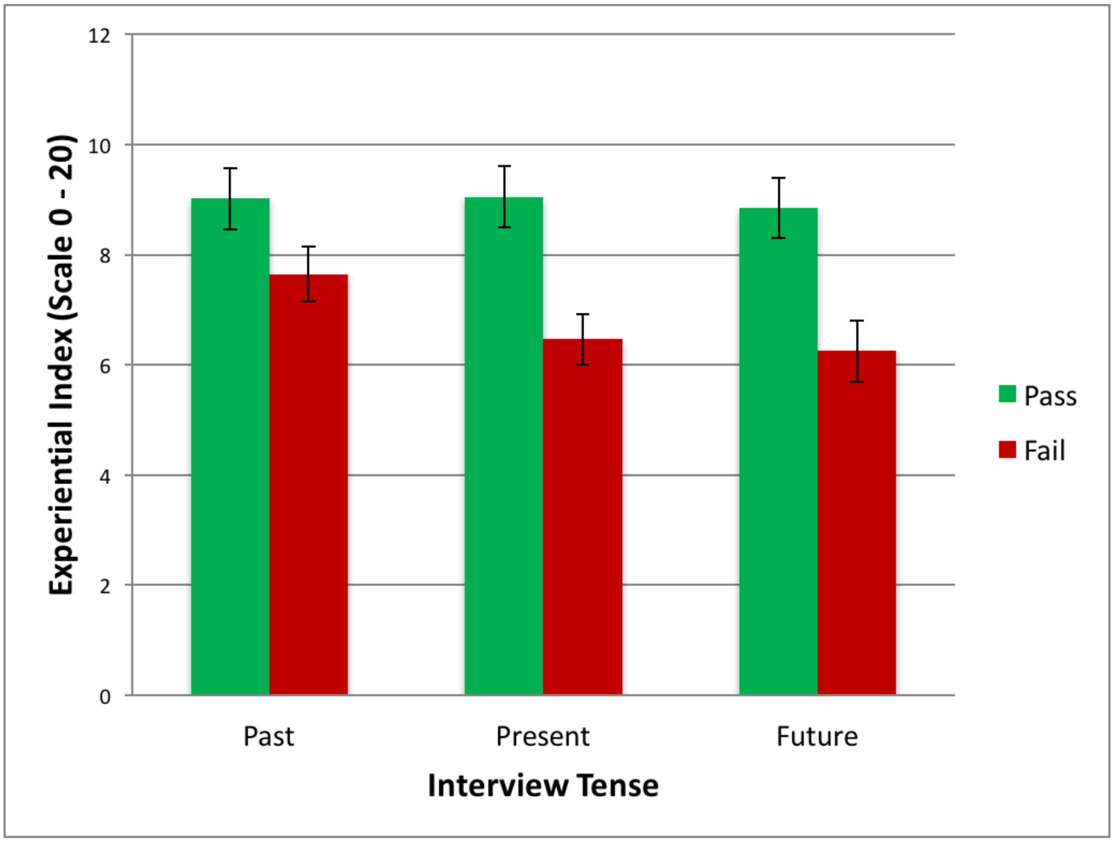


Figure 2.8: Mean experiential index scores (±SEM) for each interview tense for children who passed the Smiley Face Task and children who failed.

We performed a mixed design ANOVA with SFT performance (pass N = 34, fail N = 32) as the between subjects variable and tense (past, present, future) as the within subjects variable on the experiential index scores. The ANOVA revealed a significant interaction between pass/fail designation and tense, $F(2,128) = 4.95$, $p = .009$. Pairwise comparisons revealed that children with a pass designation on the SFT had higher experiential index scores in the interviews in the future (Bonferroni, $p = 0.001$), and present (Bonferroni, $p = 0.001$) tense. However, there was no significant difference in scores on the interviews set in the past tense between children that passed and failed the SFT (Bonferroni, $p = 0.07$). As before, there was a significant main effect of tense $F(2,128) = 6.64$, $p = .002$. There was also a significant main effect of pass/fail designation $F(1,64) = 9.63$, $p = .003$.

A hierarchical multiple regression analysis was performed on this data to parcel out the effect of verbal IQ and age on pass/fail data. Neither of these variables was a successful predictor of performance (p = .094 and .097, respectively). This indicates that independent of age and verbal IQ, the Smiley Face Task could be used to predict performance on the present and future tense. The results can be seen below in Table 2.4.

	SFT (R^2, p)
Model 1: Raw VIQ	.043, .094
Model 2: add Age	.071, .097
Model 3: add Past Interview	.075, .182
Model 3: add Present Interview	.239, .001
Model 3: add Future Interview	.228, .004

Table 2.4: Hierarchical regression looking at Smiley Face Task performance taking into account Model 1: raw verbal IQ scores, Model 2: VIQ scores and age, and Model 4: VIQ scores, age and interview performance for each tense.

In this study, success on the Smiley Face Task was a good predictor of performance on imagination and future thinking conditions, but was not related to the ability to generate descriptions of past events.

Discussion

Research on episodic memory and episodic future thinking in adult populations has long employed the Autobiographical Interview (or Autobiographical Memory Interview) to assess descriptions of past and future events (Kopelman et al., 1989), while the developmental and animal behaviour literature has focused on forced choice tasks as indicative of memory and/or planning (Scarf et al., 2014). In this experiment, we directly compared these methodologies in young children with the aim of validating the usage of 'spoon tests' in non-verbal populations, and exploring what cognitive mechanism they best index. We found a strong relationship between children's ability to pass the spoon test and their ability to generate verbal scenes in the present and future but not the past tense. This suggests that this particular spoon test is a good test of episodic future thinking. This implies that episodic memory and episodic future thinking possess some dissociable component parts.

Further evidence for dissociable components was found from the fact that interview performance in the future and present tenses was significantly weaker than in the past tense, consistent with the findings of a previous interview study in older children (Coughlin et al., 2014). As discussed previously, this study performed verbal interviews with children in middle childhood and found the future tense to be "developmentally delayed" as compared to the past tense. Our study extends this finding by showing how generation of scenes in the present fit in. This is a new addition to the work on episodic memory and episodic future thinking. We found the imagination condition to be more closely related to the future tense than that of the past. This is interesting because it indicates that temporal separation is likely not one of the limiting components of episodic memory and episodic future thinking in development. In a condition without the need for temporal separation, children still perform poorly as compared to the past tense. One possible explanation for this is that future thinking and present imagination require the generation of a representation of a novel spatial environment (referred to as scene construction by Maguire and colleagues (Maguire & Mullally, 2013)). Greater use of scene construction in the present and future conditions may simply be more difficult. However, while we did not find an interaction between age and condition, we found a larger difference between past and future performance in the younger age groups. If the nature of construction made those tenses inherently more difficult, we would expect the same difference in performance to persist throughout childhood. Tests in adults have shown that performance in the future tense "catches up" to that of the past (Addis et al., 2008). As of now, it is unclear when that happens (Coughlin et al., 2014). It is possible that this ability relies on cognitive mechanisms that are enhanced by later neural development. This would result in future and present performance catching up to that of the past tense, which is broadly consistent with our data where the differences between conditions is greatest in the young children and declines with increasing age.

However, we also found evidence for a relationship between the interview scores in the different tenses: children who did well in one tense were likely to do well in the others, and this relationship was not solely ascribable to Verbal IQ. These findings provide developmental evidence for an association between memory, imagination and planning, suggesting that, while there may be dissociable parts, all three tenses still have some common processes. This is in keeping with other lines of evidence in the literature showing a relationship between episodic memory and episodic future thinking (Schacter et al., 2008). This is consistent with our use of past experience to flexibly construct potential future scenarios (Schacter et al., 2007). Additionally, it has been shown that a common core network of brain regions is activated when people imagine their own personal past and personal future (Hassabis, Kumaran, & Maguire, 2007). While a relationship has been established, there are likely a number of processes that are encompassed by the term mental time travel (Anderson, Dewhurst, & Nash, 2012; Redshaw, 2014). The individual contributions of these various components to the core network has not yet been established (Atance, 2015). More work is needed to determine how memory relates to episodic future thinking, which is where this study provides an important contribution to the existing literature on mental time travel.

While these findings are interesting, there are important caveats to note in employing these types of tests, particularly with young children. It is likely that language development may play a role in interview performance in this age group. We therefore used a modified protocol that replaced temporal indicators like "past", "present" and "future" with words like "yesterday" and "tomorrow". This is in keeping with previous research that shows a majority of children are capable of telling you what they did yesterday and might do tomorrow by age four (Busby & Suddendorf, 2005). We also changed the tense of the verbs in the question, which has been shown to aid understanding in children from the age of two (Harner, 1975). While children reflect knowledge of the passage of time through their behaviour and speech as early as two years of age (Atance & O'Neill, 2001), the ability to anticipate events and make more sophisticated plans has been shown to increase dramatically from three to five years (Hudson et al., 1991). As previously mentioned, the ability of young children to verbally report future events may rely heavily on script-based knowledge. Our usage of a multidimensional scoring system, taking into account details like spatial features and first-person perspective, meant that scripted responses would not score as highly in our evaluation of 'episodicity'. By combining a more traditional evaluation of level of detail with the episodic rubric we attempted to partially control for differences in how talkative children were as driving the correlations between tenses. However, it is notable that performance across tenses was highly related within individuals. These strong correlations could be partially influenced by differences in how children answered the questions, because more talkative children were likely to score more highly on the description content score. While in this study, this measure only accounted for half of the total score, it could have influenced the strength of the correlations and is an important thing to take into consideration in the design of future scoring systems. We also encouraged open communication about personal experience through the usage of open questioning. After giving the ordered prompts, each interview used open questions to encourage individual detail. While it is possible that episodic memory and future thinking are not fully expressed in children due to a lack of the language skills necessary to express events removed in time, it is promising that the in the present and future conditions the verbal methodology used in this experiment correlated with behavioural performance. This indicates that these types of experiments are successfully evaluating cognitive mechanisms specific to imagination and prospection, providing further justification for using both designs in this age group. Also, it is important to note that the results of this Smiley Face Task were significantly lower than those from the original study, (4-year-olds passed at 79% and five-year-olds at 81%, compared to 47.3% and 60% in our study) (Atance & Sommerville, 2014). This could be because our distractor task was more cognitively difficult. We used a memory task in the interim that requires concerted focus, whereas the original paper uses colouring between the encoding and test phases. It is possible that while colouring children do not devote their full attention away from the original drawing and therefore find it easier to remember over the short interval. This change strengthens the task as it prevents good performance due to working memory mechanisms within the delay period.

However, from the results of this study it is difficult to determine whether or not prospective ability is necessarily relied upon during the choice phase, or could occur at the time of encoding.

We found that children who said “glue” at the time of encoding were more likely to choose the correct item later in the experiment. This is in keeping with previous research regarding the importance of memory to passing tests of future thinking (Atance & Sommerville, 2014), and may provide new evidence that children could rely upon forming a positive association with a tool that will be needed in the future, prior to it being presented, to be able to select that tool in the choice phase when away from the task, rather than having to imagine the near-future likelihood of encountering the task again. This has been a criticism of previously conducted comparative research, where critics argue that prior exposure could lead participants to choose the correct item regardless of what they intended to do with it (Roberts & Feeney, 2009). This view could be supported by the correlation between the behavioural experiment conducted here and performance on the verbal imagination condition. Children who could aptly imagine what item they might need to fulfil the requirement to reattach the plastic eye may have more likely formed a positive association towards glue at the time of encoding. This difference could have driven them to perform better on the experiment, perhaps because they were prompted to think of glue again when it was later presented to them, or because they chose the glue when it was placed in front of them simply because they deemed it more valuable. It is feasible that this pre-assigned value could have driven performance on this task. This is an important difference to explore; as behavioural tests are an important evaluation of future thinking capabilities in non-verbal populations. We will further investigate this idea in the next study, as this ability to imagine the solution to a problem when encountering it has been neglected as a possible explanation for success on item choice tasks.

This developmental study is an important addition to the gathering body of evidence suggesting similarities in the abilities encompassed by the term mental time travel. Correlations in performance within individuals across all three tenses offers novel insight into overlaps in the ability to remember the past, imagine new scenes and generate future scenarios. However, differences in performance across tenses highlight how necessary it is to independently evaluate episodic memory, scene construction and episodic future thinking (Atance et al., 2015; McCormack & Atance, 2011). Weaker performance in the present and future tense as compared to the past could provide evidence of increased difficulty associated with scene generation (Zheng, Luo, & Yu, 2014). Further usage and exploration of this new child interview technique will hopefully offer further insight how each of these skills presents throughout development. Combining this technique with a behavioural task allowed us to further dissociate performance across tenses, as differences in performance were only correlated between tasks in the present and future tenses. This highlights the idea that some 'spoon tests' may rely on prospective abilities. While memory of the event is needed to pass these experimental designs (Atance & Sommerville, 2014), there may still be an important planning component involved in passing the test. This is in keeping with the aforementioned theoretical framework behind the test design put forward by Endel Tulving (Tulving, 2005), and offers encouraging evidence for the continued use of behavioural tasks to evaluate future thinking. Additionally, the lack of a relationship with past event descriptions indicates that future research should cautiously interpret item choice tasks as evaluating episodic memory, as these tasks may rely on additional abilities. However, the relationship seen between saying glue at the time of encoding and passing the Smiley Face Task suggest that it is important to control for potential associations that could be formed during the encoding phase. The refinement of similar forced-choice tasks will open up new avenues of testing the episodic system in non-verbal populations, facilitating future work in young children, animals and patient groups. In the next study, we will work to create a better test of future thinking that controls for the contribution of associative learning and positive reinforcement in the encoding phase.

Chapter 3 - Learning from the past or imagining the future? Dissociating the contributions made by association, episodic memory and future planning to success on item choice tasks in 4 to 7-year-olds

Abstract

In behavioural evaluations of episodic future thinking, a participant often encounters a problem in one context and is later offered the opportunity to secure a solution to that problem (Tulving, 2005). One criticism of this methodology is that it may be possible to form a positive association with the object needed before it is offered during the choice phase (Atance, 2015). For example, if a subject is trained to use a tool before later being offered it, then this item has been assigned inherent value that may lead the participant to choose it over other items without necessarily planning for the future. We evaluated children's reliance on this strategy by developing a new spoon test that controls for associative learning. In this experiment, two of the items offered to children had previously been useful, but only one was useful at the time of choice. In an exchange-based task, children learned to operate two boxes using differently coloured tokens. Only one box was made available to them in the future. In order to pass this task, a child had to remember which token was still useful and inhibit their positive memory of another token. We administered this new design to 212 children between the ages of three and seven. We found a significant age-related improvement in performance on both token choice and on two explicit memory questions that were asked of participants. Younger children (3- and 4-year-olds) performed at or below chance on token choice, while older children (5-, 6- and 7-year-olds) choose the correct option at a rate higher than would be predicted by chance. We additionally evaluated whether or not children would spontaneously use the token they chose, using criteria comparable to that used to assess planning in the comparative literature. Just under half of the children who chose the correct token did not use it without direct prompting. In order to further

investigate factors that could impact performance in younger children, we performed two follow-up experiments with four-year-olds. When we removed the second associated token, this age group passed at a rate higher than chance, comparable to results from previous behavioural studies (Atance & Sommerville, 2014; Scarf et al., 2013). These results suggest that positive association does substantially impact performance on item-choice tasks in younger age groups.

Introduction

In Study 1, performance on the spoon test correlated exclusively with descriptions of scenes in the present and future tense. This supports the usage of spoon tests as a measure of imagination or future thinking. However, in keeping with other studies, we found that evidence of remembering the encoding event correlated with item-choice performance (Atance & Sommerville, 2014). This chapter is aimed at further teasing apart the contribution of memory and planning to performance on behavioural tasks, in order to get a more specific measure of episodic future thinking.

Without the use of language, it is difficult for comparative and developmental researchers to determine the degree to which animals and/or young children possess episodic memory and episodic future thinking (reviewed in Scarf et al., 2014). As such, Endel Tulving proposed a new behavioural test of this ability, known as the spoon test (Tulving, 2005). In this test a participant is exposed to a problem in one context, and then later offered a solution to that problem in another. A pass designation is achieved by choosing the correct object and transporting it back to the site of the original problem. Evidence that an animal could perform a comparable action would, according to Tulving, force the rejection of the hypothesis proposed by several prominent researchers that these abilities are unique to humans. This declaration has encouraged the scientific community to view the spoon test as a litmus test of mental time travel, a term coined by Suddendorf and Corbalis to encompass the ability to re-experience a past episode and pre-experience events to come (1997). In an overview assessing various studies of mental time travel, Suddendorf and Corballis offer several key criteria for establishing the gold standard in behavioural tests of future thinking (Suddendorf & Corballis, 2010). The first is the usage of a single trial in order to prevent the subject learning over time. Second, they advocate for novel problems to prevent the individual's previous experience from playing a role in their success. The third condition is clear temporal and spatial separation between the encoding phase and the choice phase. These, respectively, ensure the subject is relying on long-term memory and is not being cued by the environment during the time of object choice. Finally, the fourth criterion is the avoidance of problems whose solutions could be explained by innate behaviour. They argue that human foresight encompasses diverse contexts and issues and therefore tests of this ability should aim to do the same.

In the developmental literature, various methodologies testing episodic memory and episodic future thinking have demonstrated that these abilities come online roughly between the ages of three and five years (Atance, 2015). The first spoon test conducted on pre-schoolers was conducted by Suddendorf and Busby in 2005 (Suddendorf & Busby, 2005). In this task, children were moved between two rooms, one of which contained a puzzle board with no puzzle pieces. After being taken to the other, they were presented with several items that they could take with them back to the original room, including puzzle pieces. Children between the ages of three and five were allowed to choose between several items and it was found that the older age groups (4-

and 5-year-olds) routinely picked the target item above chance. While this preliminary study was the first to employ this methodology, it has been criticized because of the short time period between the encoding phase and item choice (Scarf et al., 2013). Children were asked immediately which item they wanted to take when they got into the other room, making an explanation based on working memory viable.

In order to address the issue, it is important to require a longer delay between encoding and choice. One spoon test methodology that employed this technique was put forward by Scarf et al., who showed that 4-year-olds could remember an event that happened 24 hours prior and plan accordingly (Scarf et al., 2013). In this study, children were taken to a sandbox where they found a locked treasure chest. The next day they were offered their choice of three items before returning to the area, one of which was a key that could be used to open the lock. 75% of 4-year-olds and only 33% of 3-year-olds (chance performance) chose the key, whereas both age groups passed above chance in a control condition where they were immediately offered the items to choose from. It is possible that a simpler mechanism, such as associative learning could be driving choice in this experiment. Children are prompted that they need a key in order to open the box at the time of encoding. It is therefore possible that these children have developed a positive association with the item that will be needed. This removes the need for foresight, because at the time of choice the participant simply needs to grab the thing that has been assigned salience or value. This is problematic because, if used to evaluate future thinking, this technique may produce false positives, where the child chose the correct item based on a positive association, rather than future thinking ability. It is important to note that Scarf, et al. interpret the results of this study as evidence of episodic memory rather than future planning. This was reinforced by their finding that three-year-olds failed the 24-hour condition, but passed the short delay. In order to modify this task to better evaluate future thinking, it is important to not explicitly name items at the time of encoding. If they can pass the task without thinking about accomplishing a future task, then it is not a true test of episodic foresight.

In order to address this concern, Atance and Sommerville designed a test battery to assess episodic future thinking in which none of the necessary items were explicitly labelled at the time of encoding (2014). For example, in one test the children were told that they were going to be shown a frog toy. The toy was then found to be submerged in a tall container of water and the experimenter told the child that they therefore could not show it to them. After five minutes, the children were offered their choice of several items, one of which was a set of salad tongs that could be used to retrieve the toy. The children were asked afterwards whether or not they remembered the original problem. There were four experiments of this kind conducted as a battery on the same participants. The authors report that once they controlled for a child's memory of the problem, they no longer found an age-related improvement in children's ability to choose the correct item. They therefore suggest that age-related changes on episodic foresight tasks may be driven by episodic memory ability. This finding could be interpreted in several ways. The first is that episodic memory is sufficient for success on this task, meaning that the methodology is not placing demands on future planning. Another possibility is that episodic memory and episodic future thinking are intimately linked so as soon as children can remember, they can plan, hence overlapping competence. This would hint that these abilities are inextricably linked and the development of one would drive the other. However, this view would not explain why some children can remember the event but do not choose the correct object. While these are the minority of children in this study, 23% of 3-year-olds, 29% of 4-year-olds and 15% of 5-year-olds had an intact memory but failed the task. This leaves open a third possibility, that there could be incomplete overlap between memory and planning. As shown in Study 1, some of the literature on episodic future thinking is suggestive of the fact that is inherently more demanding than episodic memory (Atance & O'Neill, 2005; Coughlin et al., 2014). This could be because of the constructive nature and characteristic uncertainty associated with generating future events (McColgan & McCormack, 2008) This would mean that with more robust testing of episodic memory and episodic future thinking as separate entities, it may be possible to further distinguish these abilities. However, it is debatable that if children can already envisage or articulate what they need at the time of encoding, this is in fact equivalent to the previous issue presented. Imagining and pre-planning for a need causes the appearance of the item to be a recognition test more than a true assessment of episodic future thinking. For example, in Chapter 2 I highlight the previous finding that during a spoon test children were more likely to pass if they had said the name of the necessary item at the time of encoding even though this was not a part of the experimental design and I did not prompt them in any way to do this. This type of data was not included in the aforementioned study by Atance and Sommerville, but may have told a similar story (2014). It may therefore be important to include associated distractors at the time of choice, that would be considered to be equally related to the problem at hand.

Russell, Alexis and Clayton did just this when they taught subjects how to play a novel table-top game called "blow football" (Russell et al., 2010). They asked children between the ages of three and five to choose from several items what would be needed to play the game tomorrow.

3-year-olds performed poorly on these questions, 4-year-olds could answer the question at above chance levels only if they were asked about what another person would need instead of what they themselves would require, and 5-year-olds could answer the question correctly regardless of condition (self or other). This methodology is a different interpretation of temporal displacement than previously discussed, in that instead of imposing an artificial delay children are asked to think about what they might need either now or tomorrow. This is an important difference, because it likely ensures that all children remember the event, but it also necessitates that children are able to interpret and use the future tense in verbal discussion. Therefore, studies of this kind are not as useful with very young children or non-verbal populations because they may not fully understand the temporal displacement. Additionally, when asking about what to use immediately after the child plays the game, it is possible that they may rely on working memory to know what would be useful. One could then argue that it is surprising that younger children seemed to perform worse on the future condition, but this could have been complicated by tense changes. It has been shown that children learn the future tense last in language acquisition and that usage of temporal terms is extremely variable in four-year-olds (Hudson, 2006). As many developmental studies are particularly focused on this age group, it seems prudent to consider inserting a natural temporal delay as opposed to one constructed by future terminology.

This study also introduced another variant in the spoon test literature, in that perspective was shown to play an important role in success rates. This has interesting implications for our current understanding of mental time travel because it indicates that autonoesis, or an awareness of one's self, may play a defining role in distinguishing the types of future oriented thought. Importantly, they used pictures of items in the choice phase that were "associated" with the game, like a player badge and a spectator (Russell et al., 2010). This introduced a new control as compared to previous versions of the spoon test, where the correct object in the choice phase is often the only one related to the original problem (Scarf et al., 2014). It is notable that four-year-olds performed less well than in previous spoon tests under these conditions (Russell et al., 2010): they performed at chance levels when asked about what they themselves would need in the future, though four year olds were above chance when they were instead asked about what someone else might need in the future. It is possible that having distractor items made this task more demanding, masking planning abilities in 4 year olds. This could be because some of the non-functional items presented were more attractive to children than the functional ones. They did not control for this by checking if the items had equal value outside of the planning context, however, they did use the same items across conditions and note differences in performance. Another possibility is that these experimental features make the task more diagnostic of future thinking, as they require the participant to employ the episodic system in order to pass: children cannot solve the task by choosing a non-functional but related item and have to instead think through future functionality. In this case, the inclusion of associated distractors could improve the robustness of the experiment and the relatively poor performance of younger children could be a true reflection of the protracted development of future planning.

As can be seen from these different studies, there are several important factors that affect performance on spoon tests. While there have been several evaluations of mental time travel abilities employing this methodology, they have not all adhered to the conditions put forward by Suddendorf and Corballis, like temporal and spatial separation between encoding and item choice (Suddendorf & Corballis, 2010). Additionally, in some tasks the correct choice is primed prior to it being offered. For example, in Scarf et al. they note a very high pass rate for 4-year-olds, but they also explicitly ask for a key at the time of encoding (Scarf et al., 2013). Other tasks were designed to require more productive planning, such as the Atance and Sommerville test battery. However, in our replication of one of these tasks, the Smiley Face Task, where children are presented with a detached item and must make the connection that glue could be used as a tool (Atance & Sommerville, 2014), we found that, this connection is not necessarily always made in the context of future thinking: we found that children who said "glue" at the time of encoding were more likely to pick this item during the choice phase (Study 1). While there is evidence that the ability to pass spoon tests improves in middle childhood, these variations have resulted in there being no precise agreement as to when children develop the ability to use an episodic memory of a past event to generate a novel future-oriented plan. This is arguably because none of the studies to date have successfully isolated and tested future thinking. Perhaps the idea of the spoon test itself is fatally flawed, as the girl in the fairy-tale could have taken the spoon to bed not because she anticipated a future scenario in which she needed it, but because over the course of her dream it had taken on associative value. In order to respond to this problem, it is important to develop a task which provides associated distractors without the confound of differential value. Additionally, the fact that she went out of her way to transport the item to the same context in which she had previously needed it does provide additional evidence of anticipation. All of the studies to date in the child literature directly instruct children to bring and use the item that they choose, but the comparative literature has instead focused on spontaneous transport and use. As such, this line of study may provide insight into how to better isolate future thinking ability in behavioural tests.

Several comparative studies have employed variations of spoon tests, which offer mixed evidence for future planning in great apes. Mulcahy and Call showed that bonobos and orangutans can successfully learn to keep tools that might be necessary in the future (2006). The animals were trained to get a reward from an apparatus using a certain tool. Over the training period, they learned that the apparatus would stay in a given room. Subjects were then blocked from the baited apparatus and allowed to choose from six different tools, where two of the presented objects would work for the task. After five minutes the apes were taken outside into a waiting area and spent one hour there before being allowed back into the test room and given access to the apparatus. Subjects (five bonobos and five orangutans) successfully chose and transported the correct tool back to the room on an average of seven out of sixteen trials, but only three of the apes passed on the first trial in Experiment 1. The requirement for tool transport seen here is more stringent than spoon tests administration in the developmental literature where children are told what to do and the only variable is what they choose (Scarf et al., 2014). However, there are several problems with the choice phase during this experiment, in that subjects were in the room with the apparatus when given the items, which could potentially have cued their choice. It is also possible that over the course of training they had formed a positive association with the type of tool that they then had to choose. This has led some critics to argue that the demonstrated future oriented behaviours may be the result of associative memory and not reflective of higher-level processes (Shettleworth, 2010). It is possible that forced choice tasks do not require the same level of constructive capacity as envisioning the future, perhaps due to the contrived nature of the problem. Employing tests that more creatively assess spontaneous behaviour may be a truer test of constructive capacities. Regardless, in order to explicitly test future thinking, it is necessary to control for associative learning in this experimental design.

To truly understand the development of future thinking we need to know what develops to enable success in forced choice tasks. Are younger children unable to retain a memory of the problem itself, unable to work out how to solve it, or truly only unable to plan? Answering this question will allow us to better understand the developmental relationship between memory and planning. In some of the aforementioned spoon test methodologies it is possible to form a positive association towards the item that will be needed before it is offered during the choice phase (Atance, 2015). We therefore propose to experimentally evaluate the contribution of both associative learning and episodic memory in item choice task performance. In order to test this, our novel spoon test controls for associative learning by including multiple items present during the choice phase that have been previously useful. We have therefore developed a 'vending machine' task where children learn to operate two boxes using differently coloured tokens. Only one box will be made available to them in the future. In order to pass this task a child must remember which token is still useful and inhibit their positive memory of another token. This will allow us to disentangle whether or not children are relying on associative learning strategies to pass spoon tests, because if they are we would expect them to choose at random between previously useful tokens. If choice is truly a reflection of children knowing what token to use based on episodic experience, then children should choose the correct token at rates comparable to previous studies. To ensure that poor performance is not ascribable to poor memory, will ask explicit memory questions to determine whether or not participants possess an intact episodic memory of the encoding event (i.e. which box is available and which token activates this box).

We predict that children who pick the right token will be more likely to answer the memory questions correctly, because an intact memory is needed for planning. But we also predict that if future thinking requires some additional cognitive skills that develop more slowly than episodic memory (Coughlin et al., 2014; McCormack & Atance, 2011), not all children that remember the encoding event will choose correctly. We will borrow from the comparative literature to introduce a spontaneous use measure, the better to evaluate whether or not choice is related to future plans or past associations. There will be an unprompted phase following token choice during which we can evaluate whether or not children spontaneously transport and use the token of their choosing. We will test children between the ages of three and seven years and expect to see improvement in performance across age groups on all conditions.

Experiment 1

Methods

Participants

The experimental group consisted of 220 children (109 females, 111 males). 8 children did not reach criterion (performing six correct activations in a row on the boxes), or answer the check questions (confirming that they knew which token worked with each box) and were therefore excluded from the experimental analysis (ages in years, months: 3,1 | 3,2 | 3,7 | 3,7 | 3.9 | 4,7 | 6,1 | 6,3). In the final group, there were 11 3-year-olds, 44 4-year-olds, 61 5-year-olds, 49 6-year-olds and 47 7-year-olds (see Table 3.1 below for age breakdown). While 3-year-olds were initially included in the experimental group, most members of this age group could not complete the training phase so we stopped recruiting them. Children were recruited from the Edinburgh

Zoo. Zoo visitors were approached and informed about the study prior to being asked to join and written consent was required from parents prior to participation.

Age Category	N	Males	Females	Mean Age (months)	Std. Deviation (months)
3-Year-Olds	11	8	3	41.27	4.52
4-Year-Olds	44	22	22	54.68	3.62
5-Year-Olds	61	30	31	65.70	3.63
6-Year-Olds	49	23	26	76.49	3.70
7-Year-Olds	47	23	24	88.96	3.32

Table 3.1: Age breakdown of participants

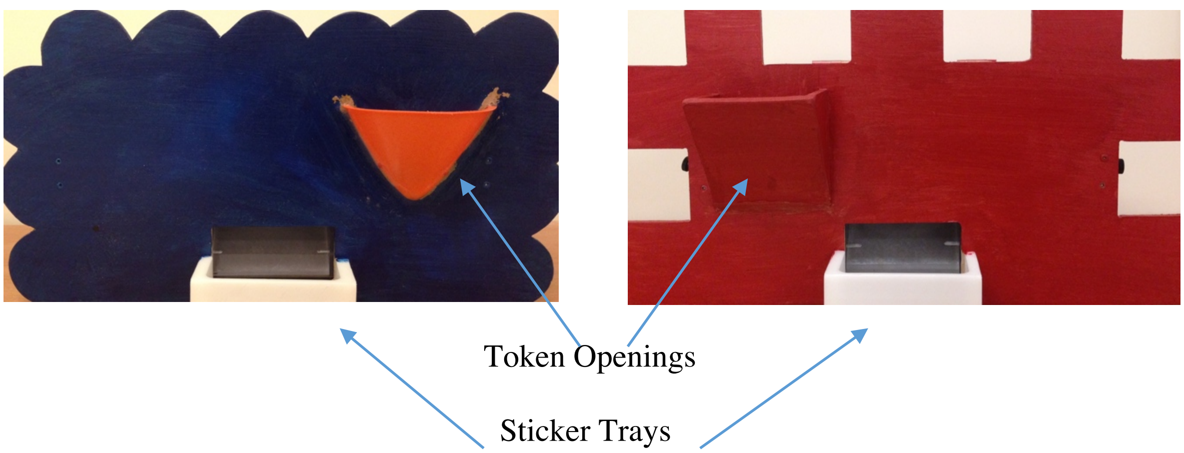
Materials and Apparatus

Participants were invited into a sectioned and covered area containing a table and two chairs. This area was placed inside of a walled tent so that it was visually isolated from another set of table and chairs, where the vocabulary test and item choice took place (see Figure 3.1). The puzzle boxes, measuring approximately 40cm x 25cm x25cm, contained a revolving dispenser that could be operated discretely by the experimenter. These rectangular boxes were visually distinct, in both colour (red vs. blue) and shape (sharp vs. rounded edges, respectively). Tokens measured approximately two inches in diameter and were distinct in both shape and colour. There were ten possible tokens, two of which were assigned as the operational token for one of the boxes and one of which was excluded from the training phase so that it was novel at the time of item choice. These were fully counterbalanced across participants.

a.

b.

c.



d.

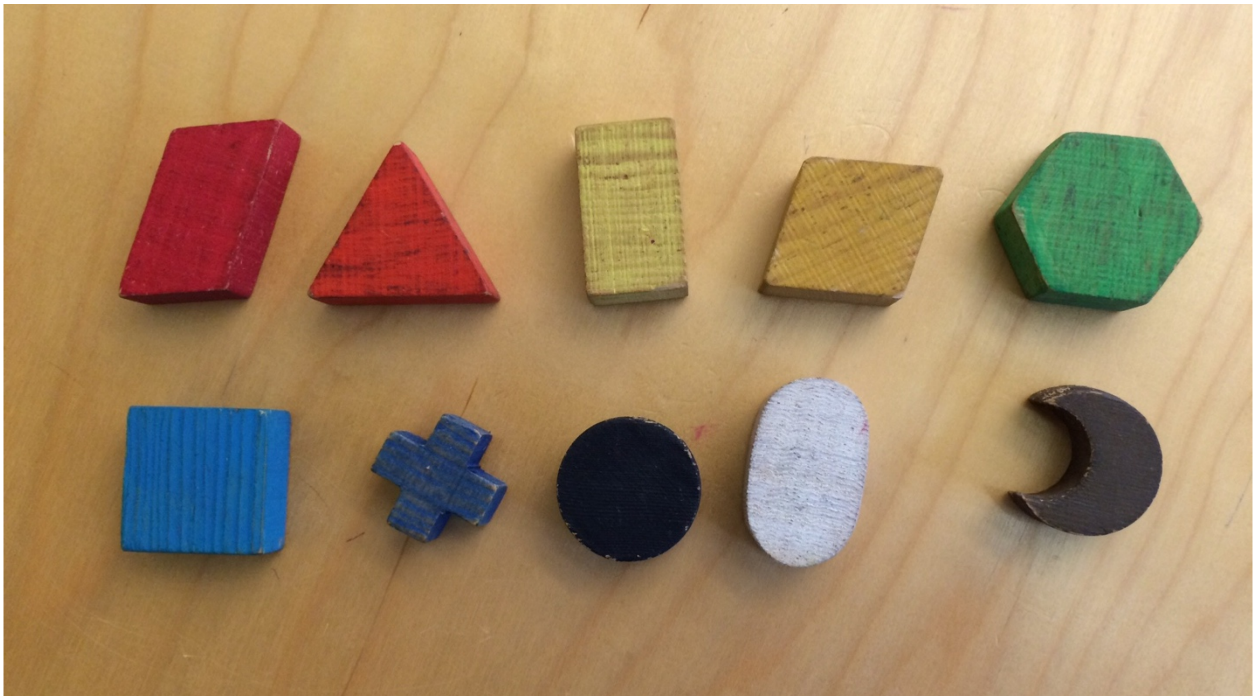


Figure 3.1: a. vocabulary test setup outside of the tent, b. puzzle box setup inside of the tent, c. two puzzle boxes with token placement and sticker trays labelled and d. the tokens that were offered to the individuals to operate the boxes.

Procedure

Children were invited to sit at the table, at which point the experimenter placed one of two puzzle boxes in front of the child. Figure 3.2 shows the various components of the training phase, which are further detailed below. Repetition was performed either until children performed 6 correct activations in a row at the end of training (3 on each box) or the experimenter had switched between the boxes 6 times.

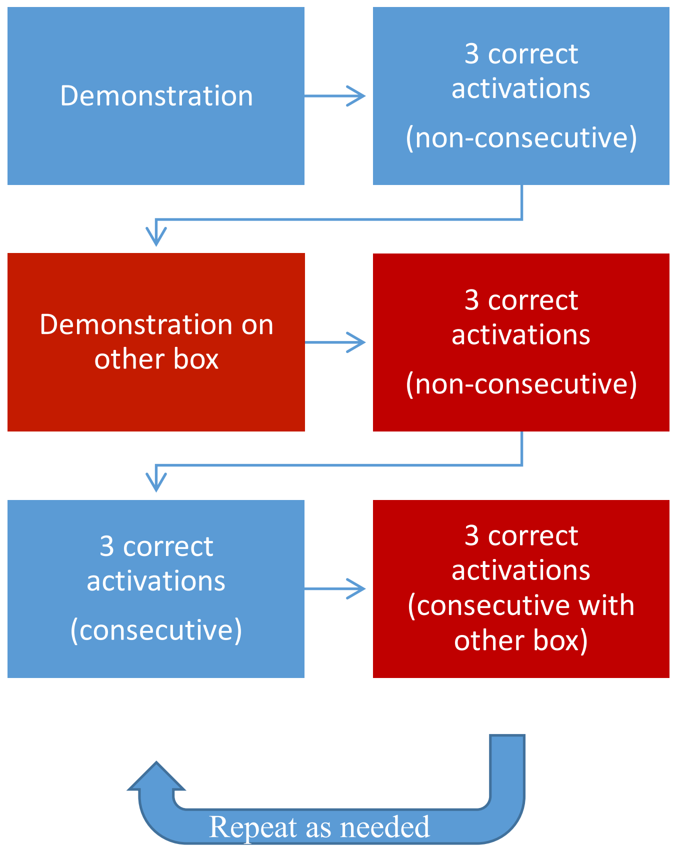


Figure 3.2: A flowchart showing the various stages of experimental training, showing the criterion for each stage.

The experimenter first demonstrated that when a particular token is placed into the opening of the puzzle box the box will dispense a sticker reward. An envelope was provided to each child to so that they could efficiently gather their rewards. Participants were then given the same token and allowed to copy the experimenter in order to obtain another sticker. After this, three tokens were placed in front of the children, one of which was the correct token to operate the box. The functional tokens were fully counterbalanced across participants. The other tokens were chosen at random from a stock of seven (excluding two functional tokens and one kept back as the final novel token during the item choice phase). The experimenter informed the child to choose one and "try for another sticker". Once the participant chose, the remaining tokens were removed from the table as the child attempted to activate the box. This training phase ended once children successfully activated the box a total of three times (did not have to be consecutive). The same procedure was then repeated on the other box. After a total of three successful activations on this box (again non-consecutive), the next phase of training began. At this point the participant had to consecutively choose the right token three times on the first box. After three consecutive activations the boxes were switched over. The same rule applied to the next box. This continued until children had activated each box three times without a mistake, for a total of six correct choices in a row. We switched between the boxes up to six times before ending the training phase regardless of whether or not the participant had reached criterion. At this point, if criterion had been reached, it was determined that the child knew which token was required for each box. Children were then instructed that they should leave their stickers on the table, because they would return to get them later. The experimenter then either drew the attention of the child to the box that was being removed from use: stating that they "can't play with that one anymore", or to the other: which, they were told, would "stay here on the table and you can play with it before you leave". At that point they would show them the other box, meaning that attention was either drawn last to the box that they could not play with or the one remaining on the table. The colour of the box left on the table was counterbalanced across participants, in addition to the box that they looked at last. This was done to ensure that participants did not always last look at the box that they could return to. We chose to do this in order to avoid the recency effect, whereby the last thing seen is often the first to be recalled (Baddeley, 1990). Further work has also demonstrated that children exhibit attentional shifts in regards to the presentation of events, which can impact their recall (Baddeley & Hitch, 1993; Renninger & Wozniak, 1985).

The experimenter then escorted the child into another area, where they performed the BPVS-III. In keeping with the standards of this diagnostic test, this portion of the experiment took approximately seven minutes. The table with the boxes was not visually accessible to the participants at this time. At the end of the test, children were offered the choice between one of three tokens. One token was the useful token for the box that would still be accessible to them. This was considered to be the *correct* choice. Another token was the one that could be used to activate the box that they could no longer use. We will refer to this as the *associate*. The final token was a novel token that they had never seen before or used in the training phase, which we will refer to as the *novel* token. Children were told that they were "going to go back to get their stickers" and that they could "pick one of these to take with them." They were all then asked if they remembered which colour box was on the table in the other room. After the child made a choice, they were taken directly back to the box and the experimenter waited to see if they would try to use the token. The experimenter acted preoccupied for approximately 20 seconds before making eye contact with the child and giving a firm nod. If the child used the token immediately or asked for permission to do so, we considered this to be evidence of successful transport and use, if not, they were prompted to transport and use the token. If they made an incorrect choice, we noted whether or not they tried to use this token on the box. All children who made an incorrect choice, or made a correct choice but did not used the token, were then given the opportunity to choose, as in the training phase, between one of the three tokens to use on the box.

This constituted the second memory question about token choice. Regardless of their choices, all children were allowed to operate the box once more before the end of the experiment.

Statistics/Design

Choosing six correct tokens in a row was considered reaching criterion. 4 3-year-olds, 2 4-year-olds, 1 5-year-old and 1 6-year-old did not reach criterion.

Our results were obtained using a SPSS statistical package (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). We conducted a binomial logistic regression to evaluate the effect of age on token choice and memory question. Additionally, we performed chi-square tests to compare performance on memory questions with whether or not participants picked the correct token. For the sake of this analysis we grouped children who picked either the associate or the novel token into the same category.

Results

The training phase consisted of a minimum of 12 trials. In order to better evaluate performance across this learning period, we looked at the number of trials to criterion across age groups. Three-year-olds took an average of 70.73 trials to complete the training phase. This could become frustrating for the participants and, when coupled with poor performance, meant that we only tested a small number of children in this age category before focusing solely on the older age groups. The results for each age category are shown below in Table 3.2.

Age (Years)	N	Minimum	Maximum	Mean	Standard Deviation
3	11	27	138	70.73	31.084
4	44	12	101	39.93	23.177
5	61	12	87	27.48	17.544
6	49	12	92	23.2	16.231
7	47	12	93	21.57	15.353

Table 3.2: Descriptive statistics of the trials to criterion for each age category

In keeping with previous studies using forced-choice task, we independently evaluated the choice phase across age groups using a binomial analysis. In order to look at how children performed, we broke up correct and incorrect choices for each age category. We saw differences in performance across age categories, with younger children (3- and 4-year-olds) displaying chance performance and older children choosing the correct token at above chance levels. This is shown graphically below in Figure 3.3. We performed binomial tests on the choices within each age category. 3- and 4-year-old performance was not found to be statistically different from chance (binomial, test prop = .33, observed = .09, p = .098 and binomial, test prop = .33, observed = .32, p = .998), respectively). Older children picked the correct option during the choice phase at a rate higher than chance (in 5-year-olds, binomial, test prop = .33, observed = .64, p = .047, 6-year-olds, binomial, test prop = .33, observed = .70, p = .038, and 7-year-olds, binomial, test prop = .33, observed = .77, p = .025).

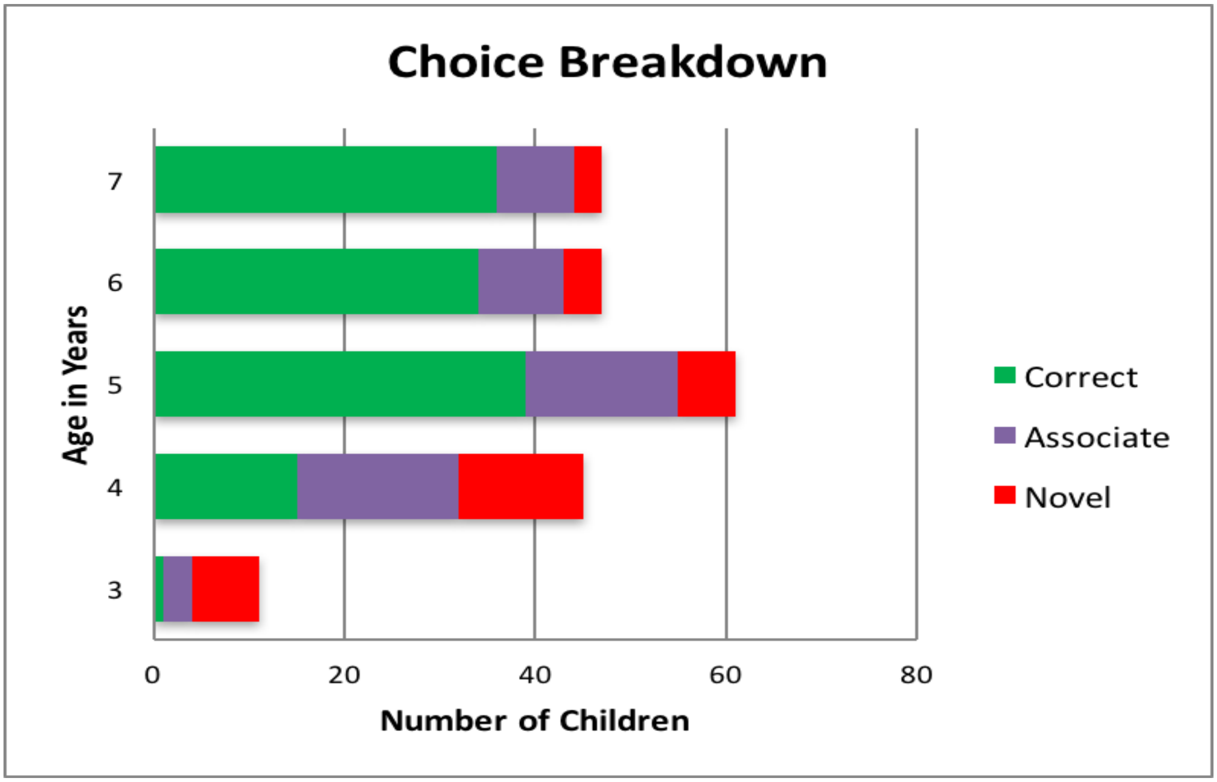


Figure 3.3: Choice distribution across age category. Green represents picking the correct token to use on the accessible box. Purple shows a choice for the token associated with the inaccessible box and red demonstrates the novel token that the participant has never seen before.

The exact percentages of children in each age category who picked each choice and, of these, the percentage that spontaneously used it on the box in the other room are shown below in Table 3.3.

Age	N	Correct	Spontaneous Use	Associate	Spontaneous Use	Novel	Spontaneous Use
3	11	1 (9%)	1 (100%)	3 (27%)	0 (0%)	7 (64%)	0 (0%)
4	44	14 (32%)	6 (43%)	17 (38%)	2 (12%)	13 (30%)	0 (0%)
5	61	*39 (64%)	19 (49%)	16 (26%)	0 (0%)	6 (10%)	0 (0%)
6	49	*34 (70%)	17 (50%)	10 (20%)	1 (10%)	5 (10%)	0 (0%)
7	47	*36 (77%)	29 (81%)	8 (17%)	2 (25%)	3 (6%)	0 (0%)

Table 3.3: The number and percentage of children in each age category who chose each token and whether or not children in each category spontaneously used it on the box in the other room. Starred values (*) show that correct responses were statistically above chance according to a binomial (two-tailed, p < .05).

In order to evaluate the effect of age on performance across categories we performed a binomial logistic regression to look at the impact of age (in years) on item choice. As expected, the logistic regression model for age and token choice was statistically significant, $\chi^2(1) = 26.37$, $p < .001$. The model explained 15.8% (Nagelkerke R^2) of the variance and correctly classified 67.5% of cases. Additionally, we found that children between 5- and 7-years-old who chose the incorrect option were more likely to choose the associate token than the novel one, X^2 (1, N = 46) = 8.70, p <.01. This was not true for 3- and 4-year-olds, p = .20 and p = .47, respectively. We did not find a significant correlation (Spearman rank-order correlation coefficient) between scores on the BPVS-III and performance on the choice task $r_S(210) = .66$, $p = .084$.

We were interested in whether or not children spontaneously used the token they chose, and the relationship between this and token choice (Table 3.3). The majority of children did not do this, but we noted that a large percentage of children in the older age groups who chose the correct token did use it spontaneously on the box (Table 3.3). Children who chose the correct token were more likely to use it spontaneously on the box than children who chose an incorrect token (associate or novel). A Fisher Exact test showed a significant relationship between token choice and spontaneous use ($p < .001$). This is shown in Figure 3.4, which illustrates the difference in spontaneous use between children who did and did not chose the correct token.

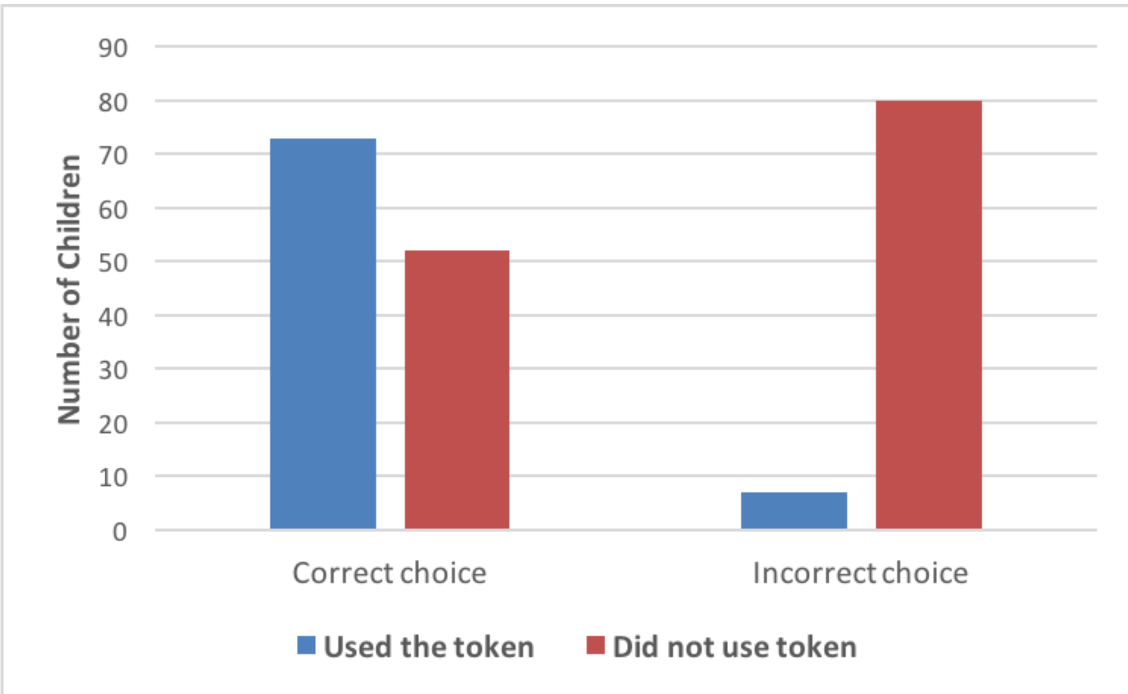


Figure 3.4: Children who spontaneously used the token in relation to whether or not they picked the correct token.

There were two memory-based questions asked of children. In order to evaluate the impact of age on memory question performance we performed a second binomial logistic regression model, $\chi^2(1) = 54.44, p < .001$. Age correctly predicted performance on the memory questions, explaining 39.1% (Nagelkerke R^2) of the variance and correctly classifying 88.7% of cases. The responses for these questions in each age group are shown below in Table 3.4.

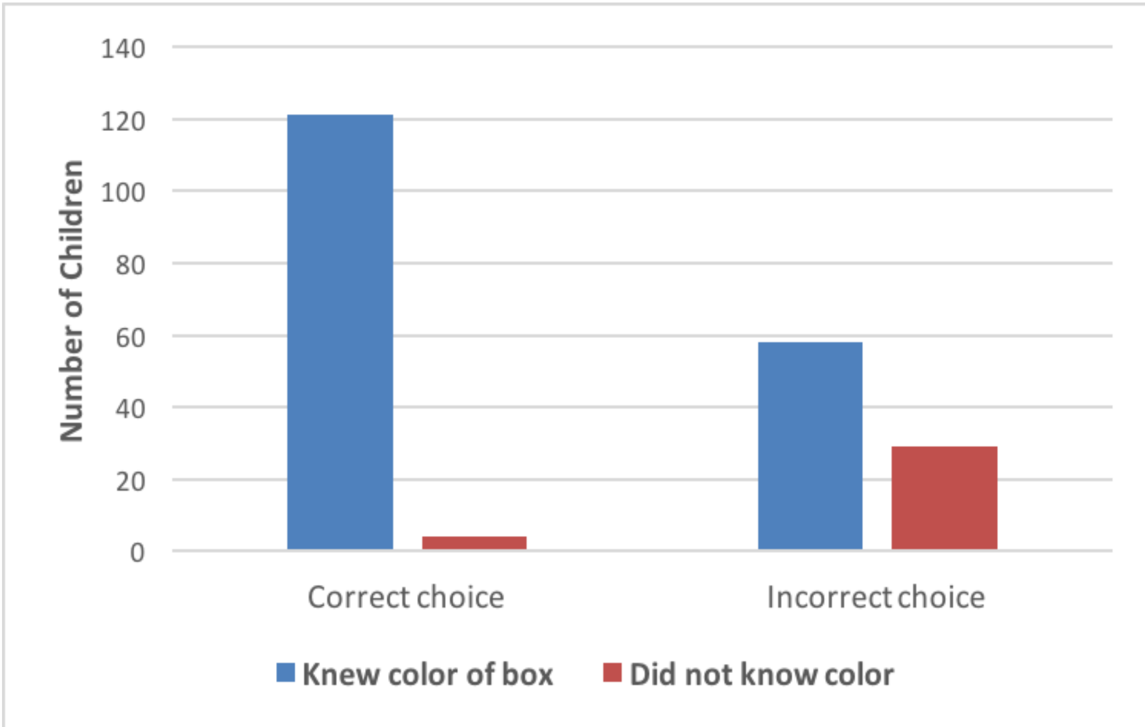
Age Group	N	Knew colour of available box	Knew which token to use on given box
3	11	2 (18%)	6 (55%)
4	44	25 (57%)	35 (80%)
5	61	58 (95%)	58 (95%)
6	49	49 (100%)	46 (94%)
7	47	45 (96%)	45 (96%)

Table 3.4: The number and percentage of children in each age category who correctly answered the memory questions about available box colour and token usage. Bold numbers reflect scores higher than chance (binomial test, $p < .05$).

In keeping with previous research on the impact that memory can have on performance in forced-choice tasks (Atance & Sommerville, 2014), we wanted to look at the impact these answers had on performance. There was a significant relationship between token choice and knowing the colour of the available box in the other room. Children who picked the correct token were significantly more likely to know the colour of the box on the table than those who did not (one-tailed Fisher's Exact test, $p < .001$). Figure 3.5a shows that a higher proportion of children who picked the correct token correctly answered the question regarding which colour box was on the table in the other room, though it should be noted that several children with an intact memory for the box identity failed to choose the correct token. We also looked at the memory question about which token to use on the given box and how it related to token choice performance. Once again, there was a positive relationship between the two in that children who chose the correct token were more likely to answer the memory question correctly. A Fisher's Exact test was run to determine the relationship between the two variables. There was a significant relationship between memory for token usage and choice, (one-tailed, $p < .001$).

Figure 3.5b shows that a higher proportion of children who picked the correct token correctly answered the question regarding which token could be used on the accessible box, compared to those that chose the incorrect token.

a.



b.

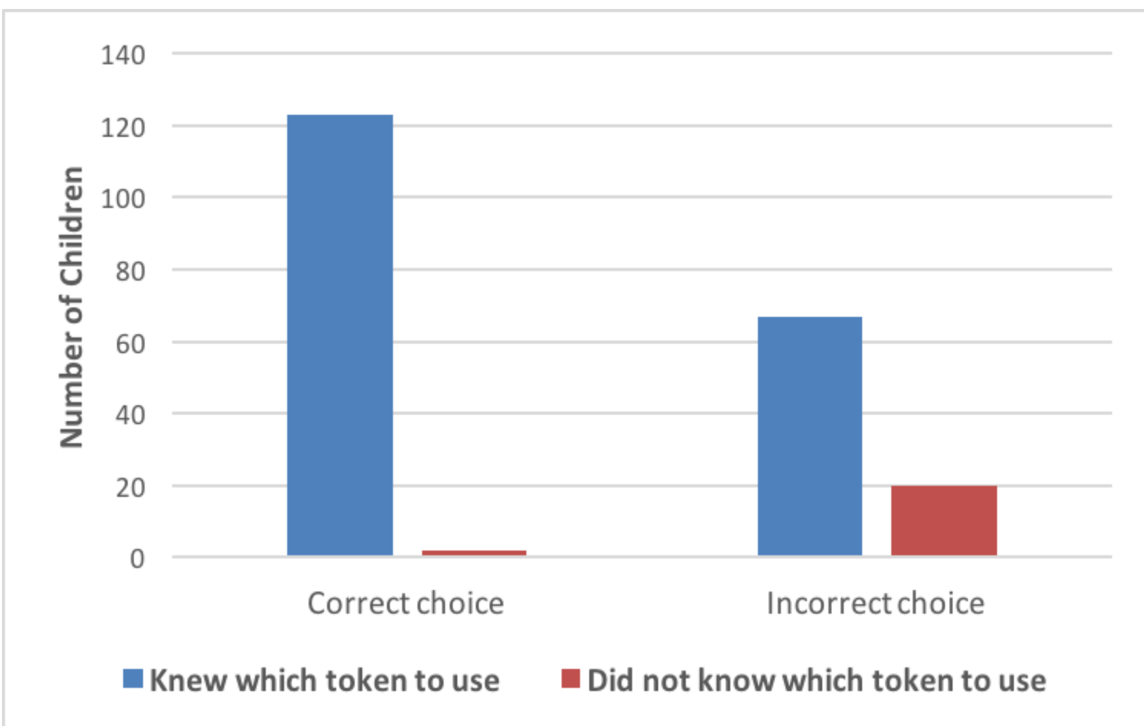


Figure 3.5: Children who answered the memory questions about (a) box colour and (b) token use correctly in relation to whether or not they chose the correct token.

Discussion

In this new behavioural task of memory and foresight, children were faced with a choice in which two of the three objects presented to them had previously been useful. This is an important modification from previous paradigms, in which subjects are in principle able to pass the test by having formed a positive association with the useful tool during encoding, either through direct prompting, problem-solving during encoding or semantic association. We hypothesized that this new change would make the item-choice task more difficult for younger age groups. Indeed, we found that four-year-olds chose items in the choice phase in a way that was not statistically different than chance, in contrast to most previous studies, which report that over half of four-year-olds can correctly pass forced-choice tasks (Atance & Meltzoff, 2005; Hayne et al., 2011; Hayne & Imuta, 2011; Payne, Taylor, Hayne, & Scarf, 2014; Prabhakar & Hudson, 2014; Redshaw & Suddendorf, 2013; Russell et al., 2010; Scarf et al., 2013; Suddendorf et al., 2011). This result calls into question whether or not these pass rates were driven by an episodic memory of the encoding phase coupled with a future plan, or a simpler mechanism like associative learning leading to one of the objects taking on greater value.

We attempted to further evaluate whether choice was driven by episodic future thinking or past association, by discretely observing whether or not children used their token of choice when they re-entered the room with the apparatus. This measure was designed to be comparable to the animal literature, where subjects are evaluated based on their ability to spontaneously transport a necessary tool to the point of use (Mulcahy & Call, 2006). As the relatively weak performance on this part of the task could have been due to a question of permission, we attempted to mitigate this effect by giving each participant an encouraging nod after they transported the item back to the original room. We observed a steady increase in performance across age groups, but did not see a majority meeting this criterion until children were seven-years-old. This is supportive of our suggestion that future planning abilities might have been overestimated in younger age groups by previous studies.

Though our interpretation is that the chance performance in four-year-olds reflects their reliance on assigning associative value to useful objects, one alternative explanation is that they were choosing at chance because the training phase in this experiment was too complicated for this age group, leading to them forgetting which token was needed. While four-year-olds knew which token to use once they were in front of the accessible box 80% of the time, they only remembered which box was on the table in the other room 57% of the time, which is not statistically different than chance. It is possible that this weakened memory performance could have disrupted token choice. In order to investigate this idea, in Experiment 2 we compared performance in this condition to a modified version of this task, in which only one of the items presented at choice has ever been useful (similar to the majority of previous studies in which only one object is useful among the distractors). If the relatively poor performance of 4 year-olds can be explained by a reliance on positive associations, resulting in choice being split between the two previously useful tokens, we would expect performance to improve when only one of the 3 tokens has been associated with success, to levels comparable to the majority of previous spoon test tasks. In contrast, if the complexity of the training period leads to poor memory of the encoding event, performance should remain poor in this experiment as the training phase will be identical.

Experiment 2

In Experiment 2 we conducted the same methodology as in Experiment 1, but removed the associate token (associated with the inaccessible box) at the time of choice and replaced it with a familiar but never-rewarded token.

Methods

Participants

The experimental group consisted of 20 4-year-olds (10 M, 10 F, *M* age = 53.45 months, SD = 3.76). No children dropped out of this Experiment. Children were recruited from the Edinburgh Zoo and Dundee Science Centre. Participants were recruited in the same way as in Experiment 1.

Materials and Apparatus

The general setup, training phase and criterion was the same as in Experiment 1, with the exception that the three tokens presented before returning to the box differed. In addition to the *correct* choice for the box that was accessible to them and a *novel* token that they had not seen before in any trial (as in Experiment 1), there was a token that they had seen before (as a distractor in the training phase) but that did not work on either of the boxes (this will be referred to as the *familiar* token). There was no *associate* token as there had been in Experiment 1.

Results

In this experiment, 70% of children chose the correct token during the choice phase and 30% chose one of the two non-usable tokens. A binomial test revealed that children picked the correct option at a rate above chance, binomial, test prop = .33, observed = .70, p = .038). The breakdown of individual choices is shown in Figure 3.6 for all 20 participants.

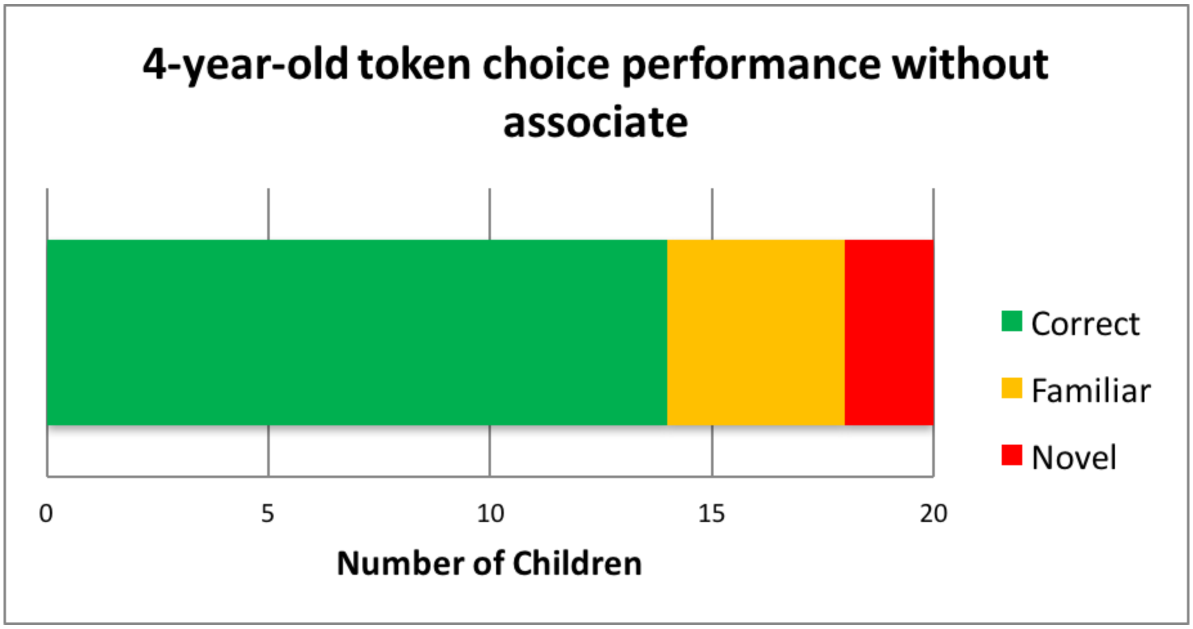


Figure 3.6: Choice breakdown for 4-year-olds, where a correct choice is shown in green, orange represents the familiar token which had been seen before but was not usable and a novel token choice is in red.

Once again, we asked two memory questions of participants. The numbers of children who passed these questions in each age category and the number of children who passed the future planning criteria can be seen in Table 3.5.

Token Choice	Knew colour of available box	Knew which token to use on given box	Spontaneous use of token
Correct	14 (100%)	14 (100%)	3 (15%)
Incorrect	6 (100%)	5 (83%)	0 (0%)

Table 3.5: Number of children (and percentage of those in each category) who knew the colour of the box, knew which token to use on the given box and spontaneously used the token after choosing it based on whether or not they chose the correct token.

Discussion

The conditions in Experiment 2 were similar to Experiment 1, but as in previous versions of the spoon test, there was only one item that had been previously associated with reward. We found that children performed at above chance levels, in contrast to their performance in Experiment 1 (70% vs. 33% correct). This success rate is comparable to that previously seen in the literature of item-choice tasks in 4-year-olds (McCormack & Atance, 2011). This shows that the difference between the results from Experiment 1 and previous item-choice tasks is not due to the complexity of the training phase, and so it seems to be attributable to the inclusion of the other associated token. This difference in performance across conditions highlights that it is necessary to distinguish between associative and episodic memory in the future exploration of memory development and planning.

Another interesting finding was that, in addition to demonstrating improved performance on the forced-choice portion, children answered the memory questions more accurately in this variation of the experiment. All children remembered the colour of the box that would be accessible to in the final part of the test. This is in contrast to Experiment 1, where only 57% of four-year-olds remembered the colour of the box. In this iteration, every subject could remember which colour box was on the table and all but one knew which token to use on the available box when given a choice with the box in sight. Could item choice be affecting the response to the memory question? In order to further evaluate this hypothesis, we decided to conduct a third variation in which the memory question about box colour was asked prior to item choice.

Experiment 3

In order to look at the relationship between memory and item choice, we conducted a second variation of our initial experiment (in which there were two previously useful tokens), in which we asked the memory question before children chose their token. Previous findings have suggested that memory for the encoding event is an important factor in determining whether or not children succeed on item-choice tasks (Atance & Sommerville, 2014). While our initial analysis in Experiment 1 was in keeping with this finding, the improved performance in Experiment 2 was coupled by an improvement in memory performance. This led us to question whether or not children's memories were being cued by the item they picked, because if memory was driving item choice, we would expect that memory performance would be comparable across all variations of the task. Memory performance in Experiment 2 could have been assisted by cuing: asking the memory question while the child held the correct token could have led to higher levels of responding with the box associated with that token. If levels of correct token choice were heightened by the greater associative value of one of the tokens compared to the other two this would lead to an overestimation of children's memory for the encoding event. In contrast, memory performance in Experiment 1 could have been negatively affected by token choice, because the choice of the incorrect token could cue a memory of the associated box, leading to an incorrect answer. In Experiment 3, in which no cuing from token choice would be provided, we therefore expected an intermediate level of memory performance between that found in Experiments 1 and 2. If this prediction was borne out, we also hypothesized that this could lead to improved performance on the task compared to Experiment 1, as cuing a correct episodic memory could lead to improved levels of choice of the token associated with this box (the *correct* token).

Method

Participants

The experimental group consisted of 20 4-year-olds (9 M, 11 F, *M* age = 53.45 months, SD = 3.47). Children were recruited from the Dundee Science Centre. Visitors were approached and informed about the study prior to being asked to join. Participants were recruited in the same was as in Experiments 1 and 2.

Materials and Apparatus

The general setup, training phase and criterion was the same in this experiment as in Experiment 1, with the exception of the order of the token choice and memory question phases. Before returning to the room with the box, children were asked if they remembered the colour of the box on the table in the other room prior to being given the choice between one of three tokens. As in Experiment 1, one of these tokens was the *correct* choice for the box that was accessible to them. The second was a token that they had been previously useful for the other box but could no longer be used (the *associate*). The last token was a *novel* token that they had not seen before in any trial.

Results

We found that children performed significantly above chance on the memory question in this experiment when it was asked prior to the item choice: 95% of them knew which box was on the table in the other room (binomial, test prop = .50, observed = .95, p = .005). This can be compared to Experiment 1 in which only 57% of 4-year-olds were correct, a performance that was not significantly different from chance (binomial, test prop = .50, observed = .57, p = .616). The memory performance of 4-year-olds in Experiment 1 (memory question after choice) and Experiment 3 (memory question before choice) can be seen broken down by token choice in Figure 3.7. The principle difference concerns children that chose the associate: if they did so before answering the memory question they were more likely to be incorrect, and respond with the box associated with the token they chose, than if they answered the memory question first.

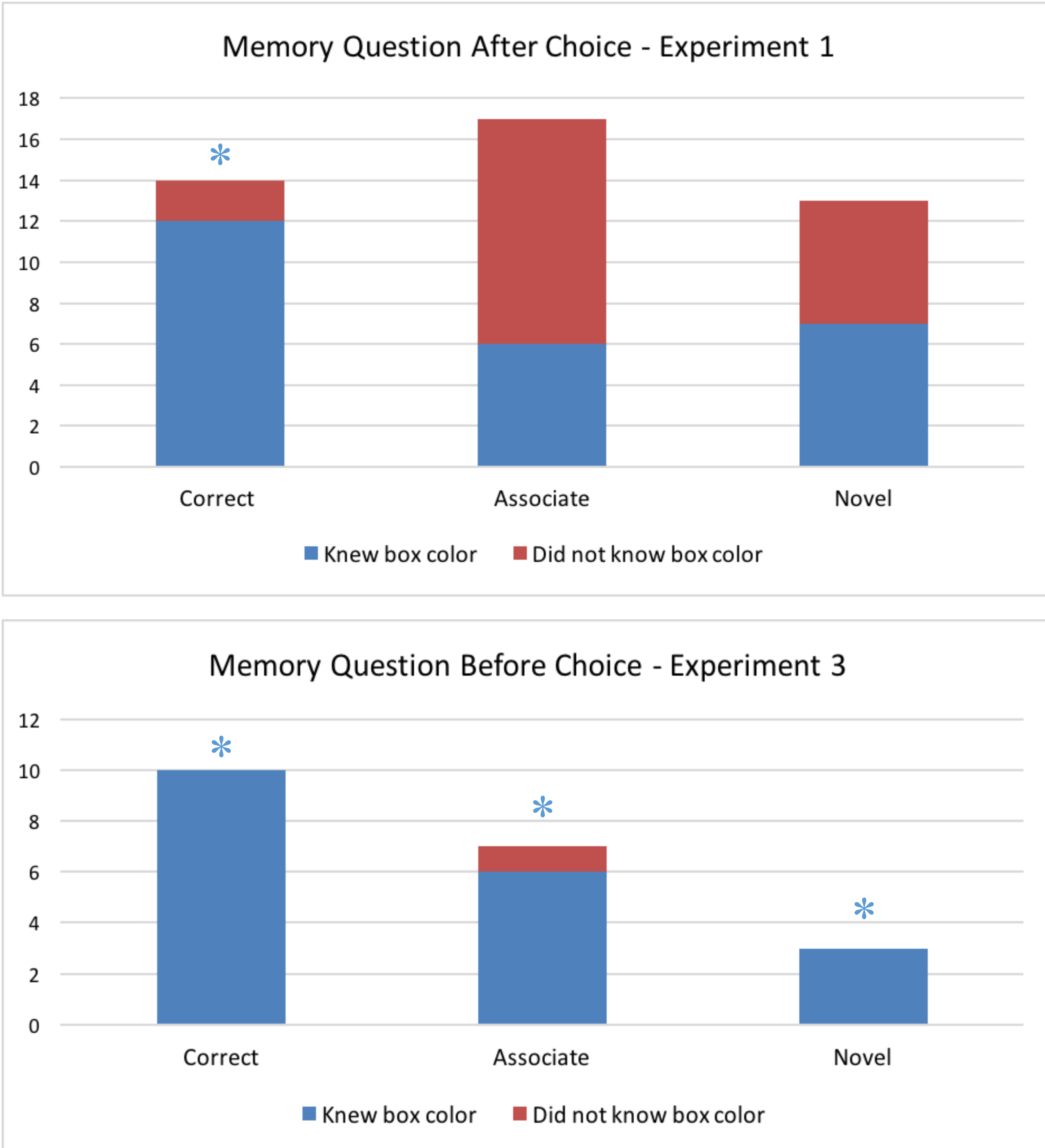


Figure 3.7: Number of individuals for each choice category who correctly reported the colour of the box on the table when the memory question was asked after or prior to the choice being made. *Asterisks note proportions that are statistically different from chance according to binomial ($p < .01$)

The numbers of children who passed these questions in each age category and the number of children who passed the future planning criteria can be seen in Table 3.6.

Token Choice	Knew the colour of the box	Knew which token to use on given box	Spontaneous use of token
Correct	10 (100%)	10 (100%)	5 (50%)
Incorrect	9 (90%)	8 (80%)	0 (0%)

Table 3.6: Answer pass/fail breakdown for the two memory questions asked of participants after they made their token choice based on whether or not they chose the correct token.

In this experiment 50% of children passed the token choice and 50% chose one of the two non-usable tokens. A binomial test revealed that this distribution was not statistically different from chance, (binomial, test prop = .33, observed = .50, p = .415). This is illustrated below in Figure 3.8.

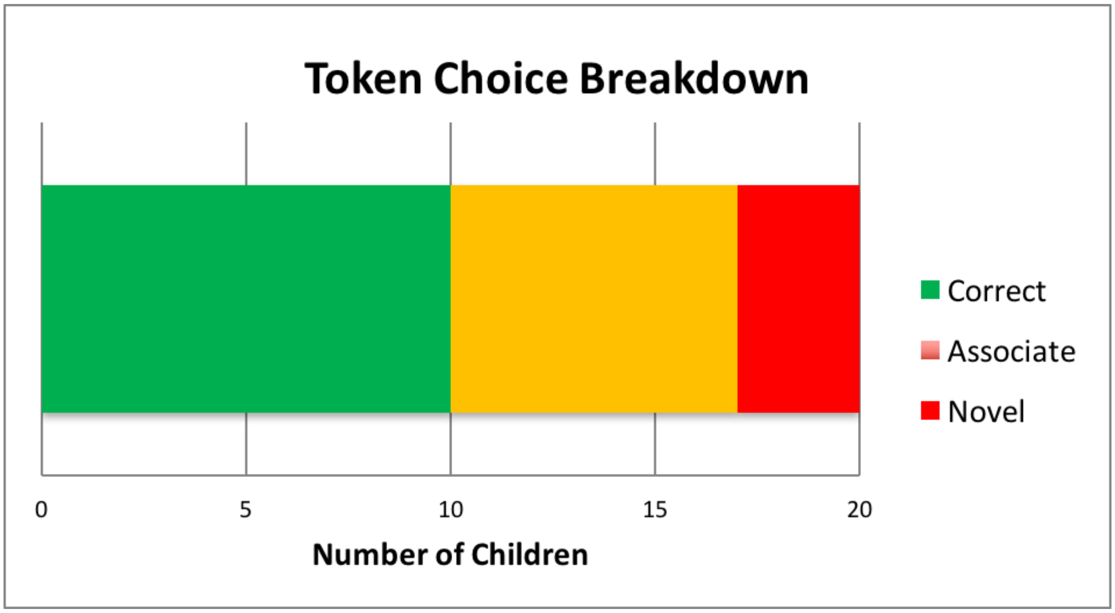


Figure 3.8: Choice breakdown for 4-year-olds, where a correct choice is shown in green, yellow represents the associate token which operates the box that is no longer accessible and a novel token choice is in red.

Discussion

In this experiment we examined memory performance prior to item choice. This gives a much clearer picture of how well the children remembered the event. We found that four-year-olds performed above chance on the explicit memory questions, with 95% of them remembering which box was available. This further dispels the notion that four-year-olds poor performance in Experiment 1 can be explained by an imperfect or confused memory of the encoding event. As children in Experiment 3 could consistently remember the encoding phase, we can conclude that choosing a token disrupted subjects' memory in Experiment 1. However, we found that even though 95% of participants in Experiment 3 correctly remembered the colour of the box that was still accessible to them and 90% knew which token to use on the box, they still only chose the correct option half of the time. This finding highlights that some children may fail item choice experiments even with an intact memory of the relevant information. It is notable, however, that while performance on the choice phase in Experiment 3 was no different than chance, it does seem to be slightly higher than in Experiment 1. This suggests that prompting children prior to their choice may encourage them to plan, or may heighten correct token choice through positive association with the box they just mentioned. Future work with more participants could be done to reveal how substantial this change is. It appears that some four-year-olds may have trouble inhibiting a positive association that was previously formed, even if this information is not useful to them in the present, as it was still difficult for participants in Experiment 3 to choose the correct token, even after being directly prompted to recall relevant information. Another possible explanation is that memory is not sufficient for planning. Children who could successfully answer the memory questions did not always display evidence of correct token choice or spontaneous use. This could mean that while memory aids future thinking it does not guarantee that children will plan ahead. We will further explore the lack of planning behaviour demonstrated by this age group in the general discussion.

General Discussion

Spoon tests have been employed as behavioural tests of mental time travel in both the comparative and developmental literature (Scarf et al., 2014). However, it is possible that spoon tests could be solved by choosing items that were previously rewarded (McCormack & Atance, 2011; Suddendorf & Corballis, 2007). In this study we administered a novel test in children between the ages of three and seven that controls for associative learning. This important methodological change suggests that previous behavioural tests aimed at evaluating episodic memory may have incurred false positives due to associative learning. In Experiment 1, we saw that four-year-olds did not perform at a rate above chance performance when two objects were presented in the choice phase had previously been useful. This was in contrast to previous results in the literature (Scarf et al., 2014) and we therefore sought to pinpoint the difference through two follow-up experiments. In Experiment 2, we found that children in this age group could perform above chance if there was only one token that had been previously associated with the boxes, revealing that a failure to remember the necessary information to pass the task cannot fully explain the results of Experiment 1. This is much closer to the previously published findings, which shows that we can replicate this level of performance in four-year-olds and reinforces the conclusion that their performance is heavily affected by previous positive associations. In Experiment 3, we determined that item choice can disrupt performance on explicit memory questions and that the majority of this age group can answer memory questions correctly if they are asked prior to item choice, though surprisingly this does not necessarily lead to a significant improvement in choice performance.

Recently, Atance & Sommerville have suggested that memory may drive children's success on experiments of planning (Atance & Sommerville, 2014). This previous study reported that when parsing out memory performance, there was no longer an age related difference in children's ability to pass the test. We found a comparable finding in Experiment 1, but further experimentation showed that this relationship was driven by token choice. We found that children who chose the associate in the choice phase were more likely to indicate that the box of the opposite colour was accessible to them. A potential implication of this finding is that error in memory questions may result from a desire to explain an incorrect choice. This idea is further supported by the improved performance on memory questions in the second and third experiment, where children were either not prompted by the associate token or were asked about the colour of the box prior to making their choice. However, Experiment 3 demonstrated that while children could answer the memory question, that did not necessarily mean they could pass the test. If memory alone is not sufficient to pass, then there must be a dissociation between memory and planning capabilities. These results are consistent with previous research, which has shown that children sometimes provide post-hoc explanations that are different from their initial reasoning (Atance, Metcalf, Martin-Ordas, & Walker, 2014). Atance et al. performed an experiment where younger children were asked to provide a dog with cheese. After bringing cheese back to the scene, they were confronted with a mouse. When asked why they delivered the cheese, the majority of three, four and five-year-olds claimed that they were trying to feed the mouse. This reflects the idea that children sometimes explain their actions through information that was only learned after the event.

This new methodology showed developmental improvement in children between the ages of three and seven years. We found that three-year-olds performed below chance. It has yet to be determined whether or not this is because they failed to form associations during encoding or if a correct choice is being outweighed by a novelty preference. Children in older age groups still have to inhibit associative processes but are able to do so more effectively. 5-, 6- and 7-year-olds passed at a rate higher than chance (64%, 70%, 77% successful, respectively). While they frequently chose the correct token, when they did make an error it was more likely to be the token that could have been used on the inaccessible box as opposed to the novel one. We also found that, when held to criteria similar to that used in the comparative literature, performance on the future thinking part of the experiment was much weaker than on the memory portion. Children were required to transport the token to the room containing the accessible box and use it without verbal encouragement. 31% of 5-year-olds spontaneously used the token, 37% of 6-year-olds and 67% of 7-year-olds. As evidenced by the markedly diminished performance as compared to token choice, choosing the correct token did not automatically mean they would do this, but only three children in the older age groups who chose an incorrect token tried to use it on the accessible box (out of 38 total children above five chose a wrong token).

Previous studies have provided support for the notion that episodic memory and future planning develop between three and five years of age (Cuevas et al., 2015; Hayne et al., 2011; Redshaw & Suddendorf, 2013). The majority of behavioural experiments report that at least half of four-year-olds are able to pass item-choice experiments (Scarf et al., 2013). Here we report a new finding that could call this developmental trajectory into question. In our experiment, four-year-olds did not perform better than chance until we introduced a version of the test that did not have a competing associate present at the time of choice. We therefore suggest that tests of both episodic memory and future planning should control for associative learning in performance. Different methodologies designed to assess planning show different pass rates during childhood (McCormack & Atance, 2011). We have argued that this discrepancy could be due in part to the variation to which subjects can rely on associative learning to solve the task. Another possibility is that, as episodic memory and future planning are late-developing (Suddendorf & Corballis, 2007), it could be these systems are somewhat fragile in younger age groups. Variations in performance across the same age group in previous experiments may be due to differences in the level of disruption, but not necessarily evidence of the fact that a certain age group could not perform the prerequisite skills under simpler conditions (i.e. without a distractor item).

However, diminished performance on the ‘spontaneous use’ criteria lends support to the idea that prospection undergoes a delayed developmental trajectory as compared to memory. This is in keeping with the other developmental evaluations of these abilities (Coughlin et al., 2014; McColgan & McCormack, 2008). While there was relatively poor performance on this condition, this is notably a conservative measure of testing future thinking because it requires taking action without direct prompting. However, we noted that every child we tested followed the direction to successfully transport the token they chose back to the room with the box (“You can choose one of these to take with you back to the other room”). Each subject was then given ample time to use the token. The experimenter allowed children to enter the other room before them, spent approximately twenty seconds absorbed in work and made eye contact to deliver an encouraging nod. Using the token or asking to use it at any point during this time was considered a pass. However, there is still the possibility that children were confused as to whether or not they had permission to use the box. We think this is an unlikely explanation, as children had been informed that they would be allowed to play with the box again before they left. Instead we think our findings are in line with the suggestion made by Suddendorf and Corbalis that creating an opportunity for the participant to generate a plan without being prompted may be more diagnostic of future planning capabilities (Suddendorf & Corballis, 2007). We suggest that these findings may further indicate that levels of self-initiated planning are lower in the pre-school years than previously thought. Many experiments rely on a trained version of the future; which critics have argued is not a realistic representation. The spontaneity required in this methodology may make it more difficult than previous versions of the spoon test administered in children, but is more comparable to that used in the comparative literature (Scarf et al., 2014). This extra step might reflect an important distinction between memory and planning. As the future has not yet been experienced, it requires an extra degree of imagination and innovation to prepare for it (McCormack & Atance, 2011). This added ingredient could be the source of a developmental difference between 4 and 5-7 year-olds in our study. This idea is in keeping with the developmental trajectory of other skills that require production capacity (Beck, Apperly, Chappell, Guthrie, & Cutting, 2011). Beck et al. showed that children between the ages of three and five can successfully use a tool once they have seen another person do it, but cannot innovate a new tool themselves. This simple test requires components of mental flexibility, innovation and planning that are comparable to those needed to prepare for the future. Further research is needed to determine the nature of innovation in future thinking and isolate whether or not this lags behind in the development of other forms of future-oriented behaviour.

In this set of experiments, we report several important findings from a novel spoon test that controls for associative learning. First, we found that this change disrupted future planning performance in four-year-old children, which provides evidence that at different times along the developmental trajectory children may rely on strategies that are separate from episodic memory to take action in the present. This helps us to better understand the emergence of future thinking in young children. Second, the spontaneous use measure in this experiment was designed to be comparable to that used in the comparative literature. Children who passed the initial measure of planning (token choice) often did not fulfil this more stringent requirement. This is an important finding for animal research because comparative studies have consistently relied on spontaneous use as evidence for passing. This new finding demonstrates that it may be unfair to compare this measure to the prompting typically seen in forced-choice tasks. It also may indicate that children in this age group are honing planning skills over time and that this ability does not emerge in an all-or-nothing fashion. Finally, some children could successfully answer explicit memory questions about an event, but did not follow through with a correct item choice. This shows that while memory is crucial for success on tests of future thinking, it is not sufficient, indicating evidence of a developmental dissociation between these abilities.

Chapter 4 - The Development of Episodic Future Thinking, Episodic Memory and Perspective Tracking in Children with and without Autism Spectrum Disorders

Abstract

The ability to mentally recreate past experiences and the ability to imagine future episodes are intimately connected in adults by a common network of brain regions, (Addis, 2007). Evidence that supports the case for a common mechanism underlying episodic memory and episodic future thinking includes theoretical reasoning, neuroimaging studies, lesion studies and age related changes, (Buckner, 2007). The explanation for this link at a cognitive level is debated, but one popular notion is that both draw upon the cognitive skill of 'scene construction' (Hassabis, 2007). Although Autism Spectrum Disorders (ASD) are characterized by diminished episodic memory (Crane & Goddard, 2008) and theory of mind (Simon Baron-Cohen, 2001), there are very few studies looking at episodic future thinking within this population (Lind, Bowler, & Raber, 2014). As the reason behind differences in performance on the former two abilities has not yet been established, it may be important to evaluate the possibility that a wider skill like scene construction may be implicated in ASD. In this study, we performed a behavioural test in order to assess for memory and planning capabilities in 60 children with and without ASD. We found significantly diminished performance in children with ASD as compared to a control group on a test of episodic future thinking. Additionally, we evaluated perspective tracking abilities via a modified 'Sally Anne' task in the 30 children with a diagnosis of ASD. We found that within the test group, children who passed one of these tasks was more likely to pass the others, providing evidence for cognitive overlap between episodic memory, episodic future thinking and perspective tracking. Performance across tasks was not related to diagnostic scores, offering support for the idea that ASD presents with high levels of individual variation and

targeted assessment may provide the best therapeutic benefit when designing educational tools for this population.

Introduction

Autism Spectrum Disorders (ASD) is an umbrella term, encompassing a wide range of neuropsychiatric disorders (Volkmar & McPartland, 2014). It has been established that ASD itself is characterized by diminished episodic memory (Crane & Goddard, 2008) and theory of mind (Simon Baron-Cohen, 2001), but the reason behind these differences has not yet been established. Additionally, there have been very few studies to date evaluating the impact of ASD on episodic future thinking (Lind, Williams, Bowler, & Peel, 2014). This population provides a unique opportunity to further evaluate the relationship between memory and future thinking in a population with known deficits in episodic memory. We hope to evaluate future thinking, using a newly developed test that controls more fully for associative memory. In addition, one potentially important component that theory of mind and episodic future thinking have in common is perspective tracking, or the ability to follow the perspective of another person (Rubio-Fernandez & Geurts, 2013). In order to assess the potential relationship between theory of mind and episodic future thinking, we want to evaluate the relationship between perspective tracking and future thinking in a population with known deficits in theory of mind. Assessing these abilities in ASD will allow us to further understand the relationship between these capacities and may have important implications for the development of therapeutic programs, teaching and intervention strategies for this population.

Thus far, most of the attention in the autism literature has focused on theory of mind deficits as being characteristic of the disorder (Simon Baron-Cohen, 2001). The "theory of mind hypothesis" of autism claims that the social deficits common in the presentation of autism stem from an inability to think about the mental states of others and resulting inability to understand the behaviour of others (Happé & Frith, 1995). A large number of studies done with autistic children have shown that they have difficulties reporting what someone else is thinking, and instead rely on what they know (Simon Baron-Cohen, Leslie, & Frith, 1985; Perner, Frith, Leslie, & Leekam, 1989; Swettenham, Baron-Cohen, Gomez, & Walsh, 1996). Additionally, autistic children find it difficult to determine whether or not someone has acquired information from an event that they witnessed (Leslie & Frith, 1988). Pratt and Bryant showed that three and four-year-old children understand that we acquire knowledge of something by seeing it (Pratt & Bryant, 1990), but children with autism were not above chance on the same test, despite rigorous control conditions (Simon Baron-Cohen & Goodhart, 1994). This inherent lack of the ability to understand the mental states of others, means that children with autism have difficulty with figurative speech (Happé, 1994), producing and understanding deception (Yirmiya, Solomonica-levi, & Shulman, 1993), holding joint attention (Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997), engaging in pretend play (Wing, Gould, Yeates, & Brierly, 1977) and even identifying emotional vocabulary (S. Baron-Cohen et al., 1994). The ramifications, which may stem from a theory of mind deficit in autism, contribute more generally to a weakness in emotional knowledge and social interaction (Simon Baron-Cohen, 2001). While the theory of mind hypothesis is but one potential explanation for the cognitive deficits underlying this disorder, it has been very influential and well documented in the literature on autism (Rajendran & Mitchell, 2007; Tager-Flusberg, 2007). The current research on autism supports that while a theory of mind deficit may exist, there are other aspects of executive functioning and social-affective information processing that are impaired in ASD. The causal routes to impaired theory of mind are still not understood, but likely involve complex interaction with a broader set of cognitive skills (Boucher, 2012).

As covered in the Introduction, one prominent theory in the literature on mental time travel hypothesizes that the relationship between past and future thinking may depend on the ability to shift to another perspective (Buckner & Carroll, 2007). This is implicated in other abilities, including theory of mind. It is possible that self-projection could link weakness in one ability to weakness in the others. Autism provides a unique opportunity to look at the relationship between episodic future thinking and these other skills, which are known to be impaired in the disorder. Studies of memory in autism have been conducted since 1970, when Hermelin and O'Connor conducted a test battery of psychological experiments on autistic children (Hermelin & O'Connor, 1970). This spurred a host of future studies on autism that found an asymmetry between semantic and episodic memory in this population (Shalom, 2003). There is a wealth of evidence that individuals with ASD show diminished episodic memory, as evidenced by poor performance on tests of source memory (Russell & Jarrold, 1999), free recall (Bennetto, Pennington, & Rogers, 1996) and memory of personally experienced events (Crane & Goddard, 2008). Crane and Goddard showed that adults with ASD lacked the same recall of events and details from childhood as compared to a control group.

This population could provide a unique insight into the relationship between the abilities that constitute mental time travel, because while episodic memory deficits have been established, future thinking is just beginning to be evaluated (Lind & Bowler, 2010). In the first study of episodic future thinking in autism, Lind and Bowler conducted interviews on adults with and without autism about personal events in the past and future. They report that the group with ASD produced fewer details, were less likely to take a first person perspective and more likely to talk about events in the third person than matched controls. This finding could provide supportive evidence of a lack of self-projection as compared to normal controls and/or a difference in narrative style. Additionally, this mirrored deficit in episodic memory and episodic future thinking provides support for the idea that these two processes rely on common cognitive underpinnings, as would be predicted by the self-projection hypothesis. It is important to note that this study did not employ a control such as picture description or present scene imagination condition, so it is difficult to tell whether or not poor performance was related to secondary factors like narrative style, scene construction or was specific to past and future event generation. Other studies looking at episodic future thinking in adult populations with autism report mixed results (Crane, Lind, & Bowler, 2013; Hanson & Atance, 2014; Lind, Williams, et al., 2014). Crane et al. tested 18 adults with ASD and age-matched controls on sentence completion tasks designed to probe past and future event generation (Crane et al., 2013). This study gave participants a phrase to finish, like "I still remember well how…' and asked them to provide a memory to complete the stem. Unlike previous studies, they found that adults with ASD performed equally well to the control group in the memory condition. However, while adults with ASD reported more specific events in the memory (past) condition, they used more semantic associates in the simulation (future) condition. For example, a specific memory of the beach could include details of what it felt like to swim in the waves, whereas a semantic associate may be the presence of sand. These trends are consistent with other research using interview methodologies in different tenses (Anderson & Dewhurst, 2009). However, the differences in findings between studies could reflect slight methodological differences, like a variance in the reliance on social interaction (Crane et al., 2013). For example, in this study by Crane participants were asked to finish sentences given by an interviewer at their request. It takes a prerequisite level of social savviness to determine what the facilitator may want to hear and respond accordingly. As theory of mind and social interaction are well known deficits of autism (Garfield et al., 2001), this may not be an appropriate approach. Therefore, it is important to advocate for methods that do not necessitate a high level of social interaction.

Developmental research on episodic future thinking in autism is also limited (Hanson, 2013; Hanson & Atance, 2014; Jackson & Atance, 2008; Terrett et al., 2013). This is surprising, as children with autism have documented deficits in theory of mind, executive function and self-knowledge, which have led some researchers to predict that they might have difficulty with episodic future thinking because these skills have previously been shown to correlate throughout development (Atance & Jackson, 2009; Suddendorf & Corballis, 1997). The studies of future thinking comparing children with and without ASD to date find somewhat conflicting results. Terret et al. report diminished performance after conducting Autobiographical Memory Interviews with 30 children with high-functioning ASD and 30 typically developing children (Terrett et al., 2013). The control group performed better on the interviews in both the past and future condition. Typically developing children were more likely to report internal details (feelings, personal experiences, etc.) across both conditions, whereas children with ASD reported a higher number of external details (facts, semantic associates, etc.). Hanson and Atance administered a battery of different tests to children with and without ASD, finding impairments in only some but not all of the tasks (Hanson & Atance, 2014). They performed 17 different tasks assessing episodic foresight, theory of mind and executive function. All of these tasks required instruction from the experimenter and verbal responses from the child. In an individual breakdown of the tasks, the children with ASD were only shown to have diminished performance as compared to the control group on 2/5 episodic foresight tasks, 2/5 theory of mind tasks and 1/7 executive function tasks. The first test of future thinking that showed differences in performance involved selecting items that one might need for a trip to a certain place and the second included reporting verbal plans for going to the grocery store and the beach. There were three other tasks of episodic future thinking where the children with ASD performed equally well to controls. One involved judging the temporal distance of future events, another had the children explain what they would be doing tomorrow and the last had the children plan where to put a toy camera in a zoo based on temporal order information. This study then combined the results from different tasks together in one composite score and found a small difference in performance across the various tasks when they separated out children who performed particularly poorly on these episodic foresight assessments. They included 25 children with ASD and cited a very small sample size as evidence for performing the analysis in this way. It is therefore difficult to tell whether or not there are any patterns in the deficits that they noted. However, it should be noted that these studies are all based on verbal responses. Social and communicative deficits are well established in autism (Baron-Cohen, 1995), so it is debatable whether verbal tasks based solely on interaction with a researcher are the best evidence of impairment of this ability in this population. However, this critique was true in the Hanson and Atance study of tasks that both showed and did not show group differences in performance (Hanson & Atance, 2014). It is therefore difficult to tell whether or not this could have played a role in the findings. Regardless, these studies are a good starting point and highlight how valuable it would be to find a way to evaluate the skills potentially involving self-projection in this population, without a reliance on verbal responding for the dependent variable (Hanson, 2013). This is especially true because some of the traits characterized as symptomatic of ASD, such as repetitive behaviour and a lack of behavioural flexibility (DSMV, 2013), may be related to deficits in future thinking (Hanson & Atance, 2014). If a deficiency in episodic future thinking exists, properly understanding it could open up therapeutic opportunities for cultivating goal directed behaviour and self-regulation in this population. The failed tasks in the described test battery debatably require more creativity than the others which involved either ordering or describing routines. The mixed results that have been shown in previous studies of episodic memory and episodic future thinking may be evidence of the fact that performance on various tests are influenced by task demands. As there have been relatively few studies to date, is difficult to determine what has played a role in delivering mixed results, but it may be important to evaluate these abilities through a behavioural rather than verbal response. Ultimately, it is a challenge to evaluate at memory and planning in Autism Spectrum Disorders. It is difficult to tell whether or not memory impairments, and therefore planning abilities, are a downstream consequence of deficits in social functioning, perception abilities or cognitive processing, (Boucher and Bowler, 2011). However, childhood ASD provides us with a unique opportunity to investigate episodic future thinking in a population where episodic memory and self-projection (ToM) deficits have been clearly established, leading to a more comprehensive understanding of how these abilities are related.

In order to look at episodic future thinking within an ASD population, we conducted the modified spoon test previously described in Chapter 3. This is, as far as I can tell, the first example of a spoon test methodology used in this clinical population. The use of this test, which controls for associative learning, could enable us to further explore the nature of the memory deficit seen in ASD. Associative memory is independent from episodic memory, but also an important component of the memory system (Howard Eichenbaum, 2004). These memory types can work together to aid retrieval and learning processes (Rumbaugh et al., 2012). Understanding how children with ASD rely on different forms of memory could aid in the development of additional support needs curricula and intervention development programs.

In addition to a non-verbal test of episodic thinking, we also included a recently developed test designed to assess perspective tracking (Rubio-Fernandez & Geurts, 2013). It is well-documented that children with ASD perform poorly on tests designed to assess theory of mind (ToM). As perspective tracking is one component of this skill, we wanted to see whether or not this ability, which may be required for episodic thought, is also impaired in this population. As explained previously, this is relevant to discussions linking memory and future thinking to a potential third ability, such as self-projection (Buckner & Carroll, 2007) and theory of mind (Saxe, Moran, Scholz, & Gabrieli, 2006). This is a more speculative part of the study, which is only being used to provide data in the case that the ASD sample do show some variation in performance, which they might very well not. Equally, there is good reason to think that the group will fail on a ToM task, but by using a component of this ability we hope to take an exploratory look at performance. This pared-down methodology is similar to some theory of mind tasks previously used in children (Sally Anne: Happé, 1994) but places decreased demands on executive functions through explicit instructions designed to aid the participant in following the line of sight of the character. This is conducted as a Sally Anne task, but with the insertion of explicit instructions and visual aids to prevent the participant from losing track of the protagonist he/she is being asked about. This test might fall short of testing an explicit theory of mind, but may still require self-projection. Given that ASD is known to be characterized by differences in executive function (Goldberg et al., 2005), it is possible that this group will perform better on this task than they would on a typical Sally Anne task. Additionally, it has been shown that high functioning adults with ASD are capable of performing visual perspective tracking tasks (Zwickel, White, Coniston, Senju, & Frith, 2011). In this experiment eye tracking methods showed that adults could follow the actions of a triangle that served as a protagonist in a series of short computer animated videos. However, as it does require taking another person's point of view, it might still be failed by this group. This possibility is reflected in the mixed results to date that have been found in studies of visual perspective taking in autism (for review: Pearson, Ropar, & Hamilton, 2013). This review highlights describes perspective tracking as a fundamental component part of wider social interaction, then goes on to describe several studies assessing both the ability to understand that different people have different lines of sight (VPT1) and that the same item viewed by people in different places looks different (VPT2). Across both domains, individuals with autism either passed or failed depending on how the task was setup. However, most consistently deficits were seen in VPT2, while VPT1 remained intact. This difference may be related to self-projection, because VPT2 may possess elements of egocentric projection in a way that VPT1 does not. While the findings to date have been mixed, this potential relationship makes perspective tracking an attractive component to assess in this population and the task we have chosen to use in this population employs elements of both forms of visual perspective tracking.

We propose to conduct a spoon test methodology in children with Autism Spectrum Disorders in order to provide an evaluation of episodic future thinking in this population that is independent of verbal ability. Additionally, we would like to compare this to a test of perspective tracking that can be used to potentially assess the relationship between episodic thought and self-projection. This is in keeping with the rest of this thesis, which has sought to test and evaluate episodic future thinking and its relationship to other cognitive abilities. It is important to note that we would only see these differences if there is individual variation within the test group. This is an important caveat, because while we are interested in looking at the relationship between these tasks, it is possible that children with ASD will fail both the spoon test and perspective tracking tasks. I would argue that this would be an important finding regardless, but the only way we will be able to look at the relationships is if some children can complete the task. This is likely, as Autism Spectrum Disorders present with high individual variation (Volkmar & McPartland, 2014). This is a clinical feature of the disorder and will be an important consideration to keep in mind when evaluating the findings of this study. If episodic memory and episodic future thinking are related to the clinical presentation of autism, then we would predict that performance on the spoon test will be impaired in a population with ASD as compared to a control group. This spoon test is designed, like all spoon tests, to engage both episodic memory and episodic future thinking in order to pass. Additionally, we would expect that if these abilities are related to one another and to perspective tracking, then we would see similarly diminished performance within individuals across the tasks. If this is symptomatic of the disorder, then ability should be inversely correlated with the presence of autistic traits.

Methods

Participants

We tested 30 children with a confirmed diagnosis of Autism Spectrum Disorder between the ages of 4 and 13 (M = 9 years, 2 months; range = 4,2-13,6). A diagnosis was confirmed via the Fife ASCA process, which is a multi-institutional evaluation of ASD characteristics in individuals. An average diagnosis takes four months to receive and involves evaluations by parents, teachers (if applicable) and developmental psychologists. This report was supplemented by the Autism Spectrum Screening Questionnaire (ASSQ), which parents completed prior to the experiment. This questionnaire is a 27-item checklist, which has been proven to reliably correlate with formal diagnoses of ASD (Ehlers, Gillberg, & Wing, 1999). Every individual in the test group received a score over 25, indicating a high presence of autistic traits. Four children did not complete the training phase due to fussiness, however three of these children knew both which box was on the table and which token to use on the test box in the knowledge probes run after the choice phase (see below) and so we included them in the analysis. Children were recruited through support groups, primary schools and online advertisements. Each individual was tested separately in one session lasting no more than one hour. This was held in either the St Andrews Baby and Child Lab or their primary school. As in Chapter 3, testing occurred in one large room that was partitioned in half by a divider to create two separate testing areas. During the session, all children completed the British Picture Vocabulary Scale (BPVS-III) in order to assess their receptive vocabulary. This has shown to be an effective measure of verbal ability as it closely correlates with Verbal IQ (Bell, Lassiter, Matthews, & Hutchinson, 2001; Hodapp & Gerken, 1999). The control group was taken from a previous dataset (Chapter 3) and raw receptive vocabulary scores were matched in this sample (M = 6 years, 3 months;

range = 4,0-7,11). This was the only control measure used because it was the only additional test both groups mutually completed. We first matched the BPVS scores exactly and if there were multiple children with the same score we took the one with the closest chronological age to that of the child they were being matched to. The control group was screened for special education needs and did not report any. Table 4.1 shows the age, receptive vocabulary scores and sex breakdown of both groups.

	Control: Mean	Control: SD	Test Group: Mean	Test Group: SD
Age (months)	74.8	14.6	117.6	28.6
Receptive Vocabulary	115	27.5	115	27.5
	Control: Male	Control: Female	Test Group: Male	Test Group: Female
Sex	18	12	27	3

Table 4.1: Descriptive statistics for participants

Spoon Test (as described in Chapter 3)

After completing the training phase of the experiment, children were ushered into another room to complete a test of receptive vocabulary, as in Chapter 3. At this point, children were asked which token they would like to choose to take with them back to the other room (choice phase). This part of the experiment all remained the same as in the previous chapter. At the end of this session, the perspective tracking test was conducted (approximately 5 minutes).

Perspective Tracking Task

Materials

Lego Duplo girl, two small Lego containers (1.25” X 1”) painted red and blue and a small set of clay bananas (as shown in Figure 4.1).

Figure 4.1: Perspective task testing materials

Procedure

This was a recently developed perspective tracking test (Rubio-Fernández & Geurts, 2012). Children were invited to sit and play at a table containing several toys. A familiar air was employed throughout the course of this experiment in order to put children at ease and make them feel as though they were not being tested. The experimenter then informed participants that the Lego girl liked bananas and had one for breakfast every morning. They were told that "she already had a banana so she wants to put the rest of them back in the fridge." After this, the experimenter put the bananas in one of the small containers (this was counterbalanced between participants) and then told the participant that the girl wants to go for a walk. In keeping with the experiment by Rubio-Fernández and Geurts, this was the point at which several deviations from the original Sally Anne experiment were introduced, so as to better encourage perspective tracking. The experimenter kept the girl on the table at all times and drew attention to her point of view through direct questioning. After moving the girl away from the “fridges” the experiment asked “Can the girl see me from where she is?” Regardless of the participant’s response, the experimenter then confirmed “She surely can’t see me from over there.” At this point, the experimenter would make eye contact with the child with an expression suggesting connivance and move the bananas from one fridge to the other. They then confirmed that the child understood with more questioning, “She hasn’t seen what I did, has she?”, and “No, she hasn’t seen what happened!”, regardless of how the child responded. The character was then turned around and moved back between the two fridges. At this point, instead of questioning the participant directly, they were simply encouraged to play with the girl and act out what happens, “Would you like to play with the girl now? What happens next?” This was done so that children would not have to interact directly with the experimenter, removing the necessity for social interaction from the task design. If the child did not do anything they were further prompted, “You can take the girl yourself if you want… what is she going to do now?”. This constituted the end of the experiment. Children were taken out of the testing area and given a toy regardless of performance.

Results

Cohort comparisons

In order to determine whether or not children with autism performed differently than the control group, we compared the performance between these two groups on all tasks except perspective tracking. These results are shown below in Table 4.2, which includes descriptive statistics from the different elements of the experiment for both groups, and statistical comparisons between them. The control group was significantly more likely to choose the correct token compared to the group with ASD. Similarly, the control group was more likely to spontaneously use the correct token than the group with ASD. However, as both groups were equally likely to use the token on the box without being prompted, therefore this difference can be explained by more children in the control group choosing the correct token.

Task	ASD Group	Control Group	Comparison: p-value (test)
Training phase (average trials, SD)	22.60 (10.10)	24.93 (15.46)	.49 (t-test, t = .692)
Token Choice (percent correct)	43%*	80%*	.004 ($X^2 = 11.01$)
Memory question: Box colour (percent correct)	80%	93%	.13 ($X^2 = 2.52$)
Memory question: Token use (percent correct)	97%	97%	1.0 ($X^2 = 0.00$)
Spontaneous Use (percent used)	67%	70%	.78 ($X^2 = 0.98$)
Spontaneous Use (percent used correctly)	37%*	70%*	.018 ($X^2 = 7.68$)

Table 4.2: Test vs. control group performance in tasks, * indicates significant difference (p = <.05)

The token choice performance for both groups can be seen graphically in Figure 4.2. Overall performance in the group of children with a confirmed diagnosis of ASD was not shown to be different from chance (binomial, test prop = .33, observed = .43, p = .285), while the control group chose the correct token at above chance levels (binomial, test prop = .33, observed = .80, p = .001).

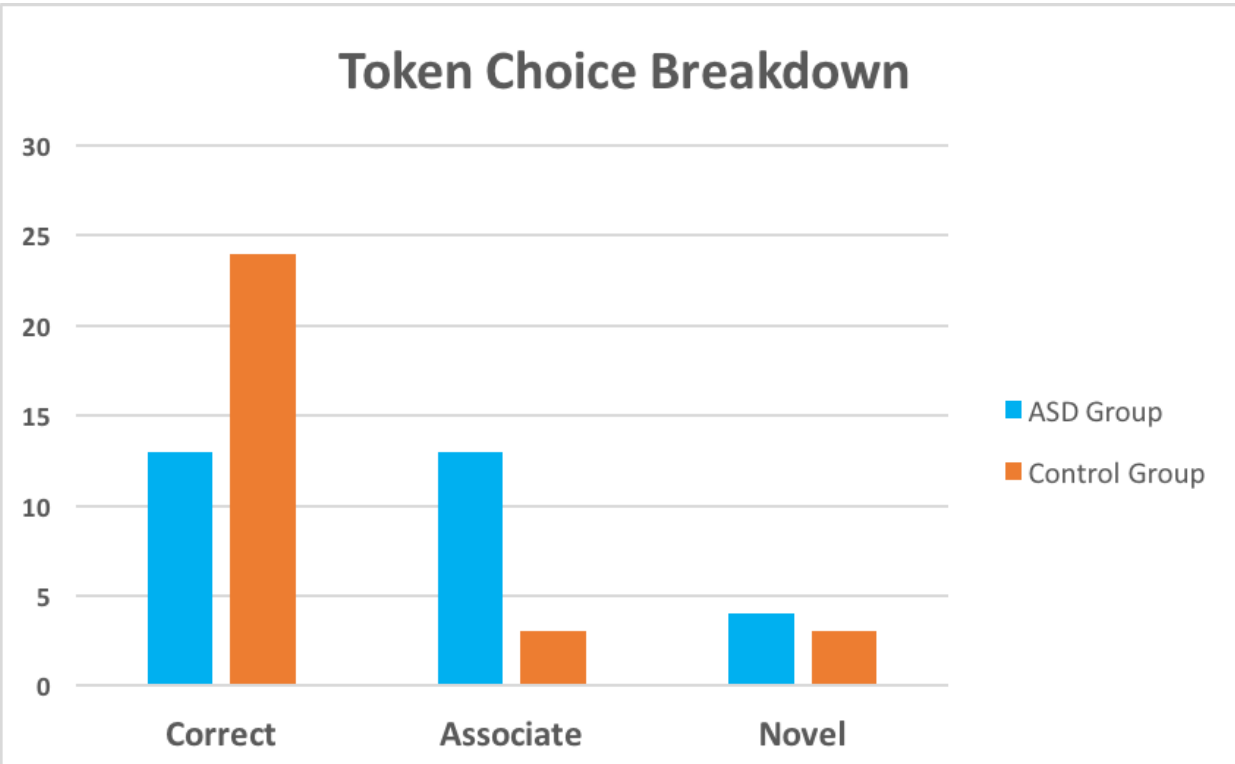


Figure 4.2: Choice distribution for the test and control groups.

We were also interested in whether or not children who selected the correct token did so in order to use it on the accessible box. In order to receive a pass designation, they had to either verbalize their reasoning at the time of choice or use the token on their own when they went back to the original room. Children in the control group who chose the correct token were more likely to use it than children who chose the incorrect token (X^2 (1, N = 30) = 10.80, p = .001). Children who chose the correct token in the test group were not significantly more likely to use it on the box, but they trended in that direction (X^2 (1, N = 30) = 3.33, p = .068). The groups similarly used the tokens when they made a correct choice (p = 1.00, two-tailed Fisher's exact test). This is shown below in Figure 4.3, which illustrates the difference in spontaneous use between children who did and did not choose the correct token in both groups.

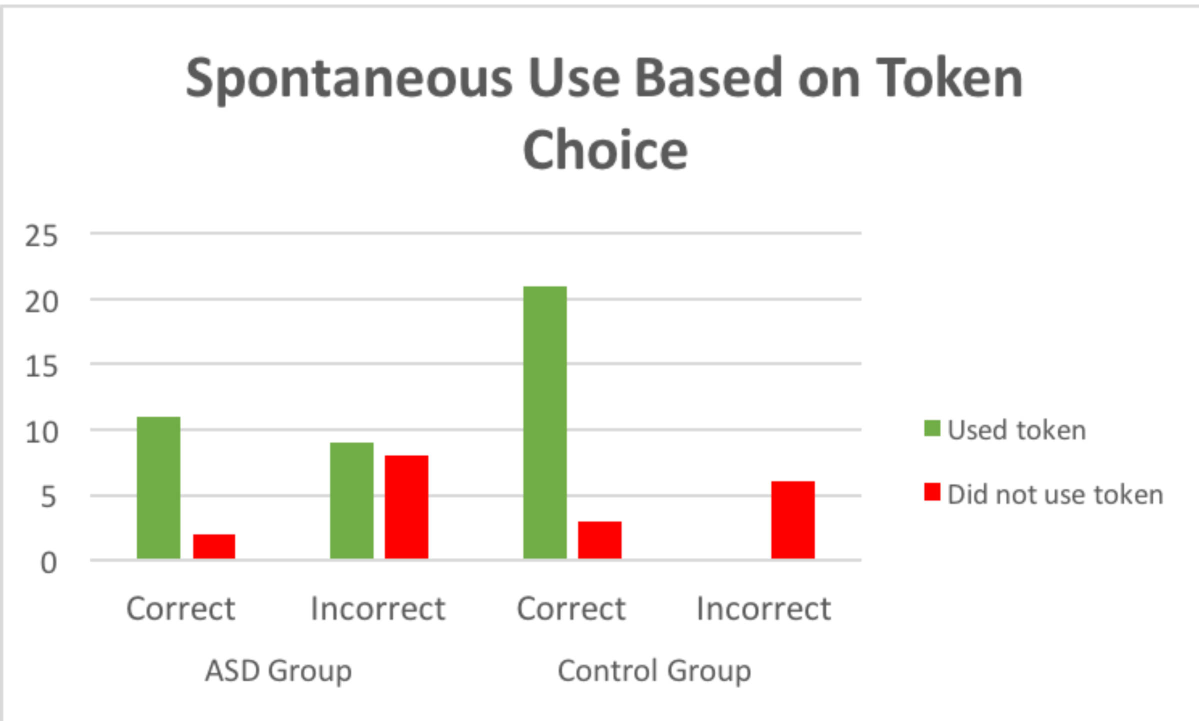


Figure 4.3: Children who spontaneously used the token in relation to whether or not they selected the correct token.

Individual differences

Despite the fact that the ASD group did not perform differently from chance as a group, we were interested to see if there was any relationship between choosing the correct token and the other variables we measured. We found that children who chose the correct token had higher receptive vocabulary scores, were more likely to pass the perspective tracking task and know the colour of the box on the table in the other room (see Table 4.3 for descriptive and test statistics). However, they were not, on average, older than children who chose an incorrect token and did not have higher scores on the Autism Spectrum Screening Questionnaire.

Measure	Pass	Fail	Comparison: p-value (test)
Age (average months)	122 (SD = 28.7)	114 (SD = 28.9)	.44 (point-biserial correlation)
ASSQ (average score)	27.46 (SD = 7.9)	32.9 (SD = 9.8)	.11 (point-biserial correlation)
BPVS-III (average score)	127 (SD = 25.3)	105 (SD = 25.9)	.028* (point-biserial correlation)
Perspective-tracking (% pass)	100% (13/13)	56% (10/17)	.008* ($X^2 = 10.8$)
Box colour memory question (% pass)	100% (13/13)	65% (11/17)	.017* ($X^2 = 9.7$)

Table 4.3: Pass vs. fail token choice performance in relation to other variables, * indicates significant difference (p = <.05)

We also ran a hierarchical multiple regression analysis on this data to determine whether or not chronological age, verbal ability and object choice could explain perspective tracking. Vocabulary scores were shown to significantly account for 14.9% of the observed relationship and this model increased in predictive value to 21.2% when object choice was added. These relationships can be seen below in Table 4.4.

	Perspective-tracking (R^2, p)
Model 1: Age	.012, .193
Model 2: add Raw BPVS	.149, .004
Model 3: add Object Choice	.212, .001

Table 4.4: Hierarchical regression data looking at the influence of Model 1: age, Model 2: age and receptive vocabulary and Model 3: age, receptive vocabulary and object choice on predicted performance

Discussion

In this experiment we looked at performance on a behavioural test of episodic memory and future thinking in a group of children with Autism Spectrum Disorders and found a difference in their ability to pass the task compared to typically developing children from a previous dataset. Unlike a group of children matched for verbal IQ, children with ASD did not pass the task at above chance levels. Importantly, both the control group and the group with ASD did equally well on the memory question and knowledge probe measures, demonstrating that the failure by children with ASD cannot be explained by an inability to remember the critical information about which box is available. A memory of the encoding event, though necessary for successful planning in this experiment, does not seem to be sufficient. As in Chapter 3, both groups were equally likely to spontaneously use the token on the box in the other room, even though the group with ASD was more likely to use the wrong token. This is a good indicator that motivation for task success was equal in both groups, but demonstrates that motivation is also necessary but not sufficient for planning. This study adds to a small body of literature providing evidence of diminished episodic future thinking in a population with ASD (Lind, Williams, et al., 2014). This group differences may be related to deficits in a wider ability, such as mental simulation or self-projection. It is possible that this reflective of the fact that individuals with autism may have deficits in representational processes and therefore are unable to fully mentally simulate alternate temporal and spatial perspectives.

While we found group performance to be diminished overall, there was some individual variation in performance. Children in the test group who chose the correct token were more likely to provide correct answers to the memory questions. This may support the idea that episodic memory and episodic future thinking may hang together in this population. It is likely that some children with ASD chose the correct token by chance. However, we found that children who selected the correct token were more likely than the others to answer the memory question correctly, to correctly identify where the Duplo girl would search, and had higher receptive vocabulary. These findings and the relationships between variables make it seem more likely that some children within this group displayed evidence of episodic future thinking. One further strength of this result is that it comes from a test that is not part of children's daily routine. This is an important component, because it is less likely children were able to complete this task by chance, since it is something that they were previously unfamiliar with. This therefore requires a flexible form of future thinking that is separate from communicating and acting upon routine behaviour. As individuals with ASD are known to be oriented towards routines, (Rumsey, Rapoport, & Sceery, 1985), this may be an important component to stress in future studies of episodic future thinking in populations with ASD.

These findings are difficult to align with previous discussions of how memory and future thinking may be related. While individual differences point towards a relationship between memory and future thinking capabilities in successful children, children in the test group performed better on the memory question than the token choice or spontaneous use conditions. Children with ASD performed comparably on the token choice task as 4-year-olds in the study described in Chapter 3. However, performance on the memory questions was notably different than that shown in younger age groups in the previous chapter. The group with ASD was more likely to answer memory questions correctly. This provides further evidence for some dissociable components between episodic memory and episodic future thinking. It should be noted, however, that this population is a unique subset and that developmental findings here may not be reflective of typical cognitive development. Not only is there a significant amount of individual variation in the ASD phenotype, but the rationale for choosing this population had to do with a previously demonstration weakness in episodic memory. We found that this group did surprisingly well on our measure of memory, but this is one small test and should be interpreted cautiously.

The perspective tracking test used in this experiment was conducted with several modifications, in keeping with a previous study by Rubio-Fernandez and Geurtz (Rubio-Fernandez & Geurts, 2013). This task was used because, while theory of mind is a notable deficit in autism, perspective tracking is a component part of this ability. By keeping the doll in sight, using specific language prompts and not introducing a second character, the earlier study provided evidence that 80% of three-year-old children could pass this test. It is thought that perspective tracking is a fundamental component part of a more general theory of mind ability. This is in line with previous research highlighting perspective shifting as an important element of social cognition (Zwickel et al., 2011). This skill could be encompassed by a more general ability like self-projection, which could contribute to deficits in both ToM and mental time travel. However, while individuals who display evidence of one tend to also have functional indicators of the others, we did not find diminished group performance across all tasks in this experiment. Token choice performance was diminished, but perspective tracking and memory questions were not as compared to a control group. This is difficult to interpret, but could be a promising area for future research with a larger cohort and more tests of each skill. Also, while deficits in our tasks were not shown to correlate with a general presence of ASD traits as judged by the ASSQ, it is important to note that our diagnostic measures were provided by the participant's parents using a rough scoring procedure. These individuals were not trained to recognize autistic characteristics. Individual variability in judgement could have contributed to the lack of relationship we saw between diagnostic measures and task performance. Regardless, this finding emphasizes that Autism Spectrum Disorders are widely varied in presentation and it is important to note that this heterogeneity may contribute to differences between individuals that impact how they learn and relate to others (Seltzer et al., 2003).

It is important to note that the control group and ASD group underwent the exact same experimental procedure until the time of the perspective taking task, which was an additional test for the experimental group. However, the physical location of testing was different between children. The control group was split between either the Edinburgh Zoo or the Dundee Science Centre, while the ASD population was tested either in their school or privately in the St Andrews Baby and Child Lab. Conditions across all of these locations were standardized. The room was kept quiet and the two locations for encoding and choice were divided by a screened partition. This is an important feature, because it has been shown that spatial disruption, in the form of switching rooms, can make tasks more difficult for children (Suddendorf et al., 2011). The relative similarity between these testing conditions lends credence to the differences seen between groups, but ideally both cohorts would have been tested in exactly the same location.

This study adds to a small body of literature examining episodic memory, episodic future thinking and theory of mind in a population with Autism Spectrum Disorder. We found a significant difference between episodic future thinking skills as compared to a control group. These group differences did not extend to tests of memory and perspective taking. We also found a relationship between the token choice task, memory questions, spontaneous use measure and perspective tracking task within individuals. These findings will hopefully provide a springboard for future research on these abilities within this population. Disentangling the strengths and weaknesses of individuals with ASD will hopefully contribute to more tailored educational plans and improve future treatment options and teaching strategies for this group. Similarities within individuals on these tasks provide further evidence of a common mechanism underlying episodic memory, episodic future thinking and perspective tracking, while some differences in group performance emphasize the presence of dissociable components within these abilities.

<u>Chapter 5</u> - General Discussion

Over the past few decades, we have reoriented the definition of what it means to remember. From the early conceptions of episodic memory as a system of storage and retrieval (Tulving, 1972), we have moved to an understanding of past and future representations as being intimately linked (Schacter et al., 2012). Despite this transition, the relationship between episodic memory and episodic future thinking is still not well understood (Zheng et al., 2014). Over the course of several experiments, this thesis has provided evidence of both similarities and differences between these abilities and come to understand them as related but separable. This is a timely distinction, as the debate over the nature of this relationship continues in both the philosophical (Michaelian, 2016) and psychological literature (Suddendorf & Corballis, 2007). While "continuists" argue that these abilities are instances of a single general capacity for mental time travel, "discontinuists" maintain that these are two distinct capacities (Perrin, 2016). The results shown here provide evidence that the reality is somewhere in between these two broad schools of thought. In each of these experiments we independently tested memory and future thinking and found correlations between these abilities, but also differences in performance. In each study, performance was diminished on the test of episodic future thinking as compared to the test of episodic memory. This could reflect unique challenges in the constructive aspect of prospective thought (Atance, 2015).

In Study 1 we looked at the relationship between verbal and behavioural tests of mental time travel in order to determine whether or not these methodologies are testing the same cognitive processes. Using a modified interview protocol designed for children, we found a correlation between verbal methods in the future tense and performance on a spoon test called the Smiley

Face Task. This finding demonstrated the importance of determining what behavioural methodology is testing, but also provided support for the continued usage of these methods in non-verbal populations. This is relevant to the comparative literature, where there is an ongoing debate about whether or not non-human animals possess the ability to employ mental time travel (Redshaw, 2014; Suddendorf & Corballis, 2007, 2010; Tulving, 2005). While this phenomenological experience is an essential part of human cognition, many other species are able to complete seemingly comparable preparatory actions (Raby & Clayton, 2009). Chimpanzees can remember the location of various food sources and act accordingly to obtain said food, through planned routes and specific tool transport (Boesch & Boesch, 1984; Janmaat, Polansky, Ban, & Boesch, 2014). Western scrub-jays cache food for the future and can remember which type they stored where (Raby, Alexis, Dickinson, & Clayton, 2007). Laboratory rats have even been trained to obtain food using a series of lever presses and show evidence of not only remembering how to do this but anticipating upcoming meals (Wilson & Crystal, 2012). This scientific evidence joins a vast number of preparatory behaviours seen in the wild, like food storage, nest building and tool use (Zentall, 2005). However, some argue that these behaviours are not distinguishable from meeting a current state of need (Suddendorf & Corballis, 1997). The Bischof-Köhler hypothesis says that animals are incapable of distinguishing another mental state from their current one and are therefore unable to perform mental time travel (Roberts, 2002). Preparatory actions in animals are argued to be evidence of simpler mechanisms (Shettleworth, 2010). While these "unconscious" and "innate" actions produce seemingly complex behaviour, Shettleworth claims it is unnecessary to attribute higher processes to these deeds. So are animals "stuck in time"? This ongoing debate rages between comparative researchers and the wider scientific community (Redshaw, 2014; Roberts, 2002;

Suddendorf & Corballis, 2007), and begs the question: how do we prove the existence of episodic memory in animals? The answer may lie in the refined development of behavioural techniques, which is what we went on to improve upon in Study 2.

This modified interview technique used episodic features in order to evaluate scene creation in the past, present and future tenses. We found a relationship between all three, and argue that this provides evidence of a link between episodic memory, imagining and episodic future thinking. However, performance in the present and future tenses was diminished as compared to performance in the past tense. Only the latter tense dictates that subjects describe something that has been previously experienced. This important difference may indicate that it is not necessarily the prospective element of future thinking that is difficult, but the general necessity to create something new. These findings provide an important comparison point for analyzing the effects of temporal change. This study offers evidence that the change in time is less important than the creative aspect, by demonstrating equally diminished performance in present imagination and future thought.

Study 2 worked to improve the current behavioural testing protocol, by controlling for associative learning. We found differences in performance between this new protocol and previously run versions of item-choice tasks (Scarf et al., 2014), particularly in the four-year-old age group. While initially it was possible that this was due to differences in complexity and therefore diminished memory performance, several follow-up studies showed that this was not the case. In many studies it is possible to pass an item-choice test by choosing the item that has been previously rewarded (Atance, 2015). We showed that when two items are present that have been useful, four-year-olds performed at chance. In the exact same experimental design, when only one of these is present during the choice phase, they are above chance performance. This difference persists, despite the location of memory questions and whether or not four-year-olds can remember the encoding phase. This is one of the first spoon-tests to use comparable behavioural methods to those used in the animal literature, as we looked at spontaneous use of the target object instead of prompted behaviour. We saw severely diminished performance on this condition that would have led us to assume an absence of future oriented thought in many members of this age group. This lends credence to the idea that there is a significant challenge in "proving" the existence of mental time travel for comparative research (Osvath, Martin-Ordas, & Osvath, 2014). However, this new task is designed to address the concerns that memory tasks can be solved by simpler mechanisms and may prove to be a promising method for future use.

Study 3 takes this newly developed technique and uses it to look at the relationship between episodic memory and episodic future thinking in a population where verbal instruction may affect performance. In Autism Spectrum Disorders diminished performance on tasks of episodic memory and theory of mind have previously been demonstrated (Happé & Frith, 1995; Shalom, 2003). In order to look at the relationship between memory and planning we wanted to determine whether or not episodic future thinking was also impaired. We found correlations between all of these abilities, lending credence to the idea that diminished self-projection may play a role in the autism phenotype. This is the first study of its kind in a population with autism, in that we removed elements of the social nature of research, which arguably makes it a more fair test of these abilities (Crane et al., 2013). This is one of the largest studies of episodic thought in autism and adds to a very small body of research looking at the relationship between these skills in a population with ASD (Lind, Bowler, et al., 2014). We noted diminished performance in the test group with autism as compared to a control group on our spoon test designed to evaluate episodic future thinking, making this an important area for future research. It is also possible that mental time travel improvement may be an area for therapeutic technique development, as has been the case in several other patient populations (Daniel, Stanton, & Epstein, 2013; MacLeod et al., 2005).

Future Research

In order to further evaluate future thinking and better understand the nature of the overlap between planning and memory, it is important to develop a task that isolates this ability. Over the course of this thesis I have isolated various components of this ability that I think are important, including controlling for associative learning, employing tests that exploit flexible planning instead of routine behaviour and providing participants with unprompted chances to demonstrate this ability. I would argue that these developments are an improvement, but that further dissociation needs to occur. Thus far, task completion in all behavioural evaluations of future thinking require multiple skills including, but not limited to, episodic memory. A participant has to remember the problem at hand before securing a future solution. While I have focused on this skill because this particular relationship (between memory and planning) has been the one most debated and evaluated in the literature, there are also several other skills that could impact future thinking ability.

In order to succeed in behavioural assessments, participants need to be able to efficiently focus on the problem at hand, employing executive function skills (Picard, Cousin, Guillery-Girard, Eustache, & Piolino, 2012). These skills support a wide range of tasks and include set shifting, error correction/detection, attention, planning and inhibitory control (Carlson, 2005; Welsh, Pennington, & Groisser, 1991; Zelazo, Carlson, & Kesek, 2008) In order to be focused, flexible, and disciplined, we must rely on this set of cognitive abilities (Diamond & Lee, 2011). Executive function has been shown to both develop and decline across the lifespan, following an inverted U-shaped curve with large changes happening in the early years (Zelazo, Craik, & Booth, 2004). In preschool-aged children, these changes could have an important impact on social and learning abilities (Carlson, 2005), particularly because executive function has also been shown to correlate with other key developmental milestones like theory of mind and prospective memory (Ford, Driscoll, Shum, & Macaulay, 2012; Hughes, 1998). In keeping with the theories about the relationship between mental time travel and these other abilities, it makes sense that executive function has been shown to impact episodic memory capability in aging (Troyer, Graves, & Cullum, 1994). Fifty-one subjects were tested on episodic memory and executive function and it was shown that age was no longer a predictor of episodic recall, when factoring in executive functioning. The authors therefore concluded that age-related differences in memory may be mediated by decline in executive function. It has also been shown that in middle childhood executive functions contribute to memory performance (Blankenship & Bell, 2015). Specifically, episodic memory capabilities were shown to correlate with three separate components of executive function: inhibitory control, working memory and cognitive flexibility in a sample of 9- to 12-year olds. Episodic future thinking has similarly been shown to be related to executive functions (D'Argembeau, Ortoleva, Jumentier, & Van der Linden, 2010). In particular, this study showed a significant correlation between executive processes and measures of episodic detail and autobiographical specificity in future scene generation in 100 young adults.

However, a recent developmental study on executive function (and theory of mind) in relation to episodic future thinking did not demonstrate the same correlation in children between the ages of three and five years (Hanson, Atance, & Paluck, 2014). Hanson et al. examined five abilities (working memory, generativity, inhibition, cognitive flexibility and planning) and their relationship to episodic future thinking through a set of five previously used tests of future thinking. Only one test, known as the Picture Book task, remained correlated with a composite score for executive function after controlling for age and verbal ability. The authors note that this particular task contains choosing between several options, where an incorrect option is often semantically associated with the question, and therefore may involve inhibitory control in a way that other tests of episodic future thinking do not. Therefore, they interpret their results as a lack of association between executive functioning and future thinking. However, methodological differences could also contribute to whether or not the study provides evidence of a relationship between these abilities. For example, in the study proposing an overlap, D'Argembeau et al. used a verbal measure of episodicity (D'Argembeau et al., 2010). Whereas in this later study by Hanson, Atance and Paluck, they used tests without rich verbal scene generation (Hanson et al., 2014). Perhaps asking participants to verbally report a scene required them to use more elements of executive function, like working memory so that they did not repeat themselves and extended task attention in order to fully describe the entire event (Kopelman et al., 1989).

It is arguable that something like executive function could be ascribed to the reason that the same children tend to pass tasks of episodic memory, episodic thinking and even perspective tracking as tested in Chapter 4. However, this link does not consistently appear across all methodologies and does not appear to fully explain the overlap between episodic memory and episodic future thinking. It is therefore unlikely that this third skill drives the relationship between these abilities across all age groups. It may, however, play a role in the developmental relationship because it may impact a child's ability to complete complicated tasks. This means that it important to control for this in future studies with children. Isolating episodic future thinking may prove difficult, but this ability is strongly related to performance in the classroom (Atance & O'Neill, 2001), social functioning (Anderson et al., 2012) and even the presence of negative clinical outcomes, including mental illness (MacLeod et al., 2005) and obesity (Daniel et al., 2013). This is an incredibly important skill, and if this work has done nothing else, I hope that it has given credence to that point.

Summary of Aims

The aims of this thesis were to look at the relationship between episodic memory and episodic future thinking throughout development, validate and develop better methods of testing these abilities and determine whether or not mental time travel is impaired throughout development in autism. We noted performance improvements across all tasks between the ages of three and six. We also used several methods to independently test these abilities and found consistently diminished performance in tasks evaluating episodic future thinking as compared to episodic memory. A new behavioural method controlling for associative learning was developed and tested, showing important differences in performance and highlighting the necessity for similar controls in future studies. Finally, we saw diminished episodic future thinking abilities in children with autism spectrum disorder, regardless of age. This was shown to correlate with perspective tracking performance, providing evidence of a relationship that extends past mental time travel to encompass a broader ability like self-projection. Future research will be needed to further understand what independently defines these abilities, but these studies provide evidence that episodic future thinking and episodic memory are related but have some dissociable components.

Past, Present and Future walk into a bar.

It was tense.

The End

Works Cited

Addis, D. R., Cheng, T., Roberts, R. P., & Schacter, D. L. (2011). Hippocampal contributions to the episodic simulation of specific and general future events. *Hippocampus*, *21*(10), 1045–1052. http://doi.org/10.1002/hipo.20870

Addis, D. R., Pan, L., Vu, M. A., Laiser, N., & Schacter, D. L. (2009). Constructive episodic simulation of the future and the past: Distinct subsystems of a core brain network mediate imagining and remembering. *Neuropsychologia*, *47*(11), 2222–2238. http://doi.org/10.1016/j.neuropsychologia.2008.10.026

Addis, D. R., Sacchetti, D. C., Ally, B. A., Budson, A. E., & Schacter, D. L. (2009). Episodic simulation of future events is impaired in mild Alzheimer's disease. *Neuropsychologia*, *47*(12), 2660–2671. http://doi.org/10.1016/j.neuropsychologia.2009.05.018

Addis, D. R., Wong, A. T., & Schacter, D. L. (2008). Age-related changes in the episodic simulation of future events. *Psychological Science*, *19*(1), 33–41. http://doi.org/10.1111/j.1467-9280.2008.02043.x

Anderson, R. J., & Dewhurst, S. A. (2009). Remembering the past and imagining the future: differences in event specificity of spontaneously generated thought. *Memory (Hove, England)*, *17*(4), 367–373. http://doi.org/10.1080/09658210902751669

Anderson, R. J., Dewhurst, S. a., & Nash, R. a. (2012). Shared cognitive processes underlying past and future thinking: The impact of imagery and concurrent task demands on event specificity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(2), 356–365. http://doi.org/10.1037/a0025451

Association, A. P. (2013). *DSM 5. American Journal of Psychiatry*. http://doi.org/10.1176/appi.books.9780890425596.744053

Astur, R. S., Taylor, L. B., Mamelak, A. N., Philpott, L., & Sutherland, R. J. (2002). Humans with hippocampus damage display severe spatial memory impairments in a virtual Morris water task. *Behavioural Brain Research*, *132*, 77–84. Retrieved from www.elsevier.com/locate/bbr

Atance, C. M. (2015). Young Children's Thinking About the Future. *Child Development Perspectives*, *9*(3), 178–182. http://doi.org/10.1111/cdep.12128

Atance, C. M., & Jackson, L. K. (2009). The development and coherence of future-oriented behaviors during the preschool years. *Journal of Experimental Child Psychology*, *102*(4), 379–91. http://doi.org/10.1016/j.jecp.2009.01.001

Atance, C. M., Louw, A., & Clayton, N. S. (2015). Thinking ahead about where something is needed: New insights about episodic foresight in preschoolers. *Journal of Experimental Child Psychology*, *129*, 98–109. http://doi.org/10.1016/j.jecp.2014.09.001

Atance, C. M., & Meltzoff, A. N. (2005). My future self: Young children's ability to anticipate and explain future states. *Cognitive Development*, *20*(3), 341–361. http://doi.org/10.1016/j.cogdev.2005.05.001

Atance, C. M., Metcalf, J. L., Martin-Ordas, G., & Walker, C. L. (2014). Young children's causal explanations are biased by post-action associative information. *Developmental Psychology*, *50*(12), 2675–85. http://doi.org/10.1037/a0038186

Atance, C. M., & O'Neill, D. K. (2001). Episodic future thinking. *Trends in Cognitive Sciences*. http://doi.org/10.1016/S1364-6613(00)01804-0

Atance, C. M., & O'Neill, D. K. (2005). The emergence of episodic future thinking in humans. *Learning and Motivation*, *36*(2 SPEC. ISS.), 126–144. http://doi.org/10.1016/j.lmot.2005.02.003

Atance, C. M., & Sommerville, J. a. (2014). Assessing the role of memory in preschoolers' performance on episodic foresight tasks. *Memory (Hove, England)*, *22*(1), 118–28. http://doi.org/10.1080/09658211.2013.820324

Baddeley, A. D. (1990). *Human memory: theory and practice*. Allyn & Bacon.

Baddeley, A. D., & Hitch, G. (1993). The recency effect: implicit learning with explicit retrieval? *Memory & Cognition*, *21*(2), 146–155. http://doi.org/10.3758/BF03202726

Baron-Cohen, S. (1995). *Understanding Other Minds: Perspectives From Autism*. *Neurology* (Vol. 45). Oxford University Press. http://doi.org/10.1212/WNL.45.1.210-b

Baron-Cohen, S. (2001). Theory of mind and autism: A review. In L. M. Glidden (Ed.), *International review of research in mental retardation: Autism* (xiii). Academic Press.

Baron-Cohen, S., & Goodhart, F. (1994). The "seeing-leads-to-knowing" deficit in autism: The Pratt and Bryant probe. *British Journal of Developmental Psychology*, *12*(3), 397–401. http://doi.org/10.1111/j.2044-835X.1994.tb00642.x

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind" ? *Cognition*, *21*(1), 37–46. http://doi.org/10.1016/0010-0277(85)90022-8

Baron-Cohen, S., Ring, H., Moriarty, J., Schmitz, B., Costa, D., & Ell, P. (1994). Recognition of mental state terms. Clinical findings in children with autism and a functional neuroimaging study of normal adults. *British Journal of Psychiatry*, *165*(NOV.), 640–649. http://doi.org/10.1192/bjp.165.5.640

Beck, S. R., Apperly, I. A., Chappell, J., Guthrie, C., & Cutting, N. (2011). Making tools isn't child's play. *Cognition*, *119*(2), 301–306. http://doi.org/10.1016/j.cognition.2011.01.003

Bell, N. L., Lassiter, K. S., Matthews, T. D., & Hutchinson, M. B. (2001). Comparison of the Peabody Picture Vocabulary Test - Third edition and Wechsler Adult Intelligence Scale -

Third edition with University students. *Journal of Clinical Psychology*, *57*(3), 417–422. http://doi.org/10.1002/jclp.1024

Bennetto, L., Pennington, B. F., & Rogers, S. J. (1996). Intact and impaired memory functions in autism. *Child Development*, *67*(4), 1816–1835. http://doi.org/10.1111/j.1467-8624.1996.tb01830.x

Blankenship, T. L., & Bell, M. A. (2015). Frontotemporal Coherence and Executive Functions Contribute to Episodic Memory During Middle Childhood. *Developmental Neuropsychology*, *40*(7–8), 430–444. http://doi.org/10.1080/87565641.2016.1153099

Blumer, D. (1969). Book Review: Deranged Memory: A Psychonomic Study of the Amnesic Syndrome. *Psychosomatic Medicine*, *31*(3), 279–280. Retrieved from http://journals.lww.com/psychosomaticmedicine/Citation/1969/05000/Deranged_Memory__A_Psychonomic_Study_of_the.14.aspx

Boesch, C., & Boesch, H. (1984). Mental map in wild chimpanzees: An analysis of hammer transports for nut cracking. *Primates*, *25*(2), 160–170. http://doi.org/10.1007/BF02382388

Boucher, J. (2012). Putting theory of mind in its place: psychological explanations of the socio-emotional-communicative impairments in autistic spectrum disorder. *Autism : The International Journal of Research and Practice*, *3*(3), 219–233. http://doi.org/10.1177/1362361311430403

Buckner, R. L., & Carroll, D. C. (2007). Self-projection and the brain. *Trends in Cognitive Sciences*, *11*(2), 49–57. http://doi.org/10.1016/j.tics.2006.11.004

Burgess, N., Maguire, E. A., & O'Keefe, J. (2002). The Human Hippocampus and Spatial and Episodic Memory. *Neuron*, *35*(4), 625–641. http://doi.org/10.1016/S0896-6273(02)00830-9

Busby, J., & Suddendorf, T. (2005). Recalling yesterday and predicting tomorrow. *Cognitive*

Development, *20*(3), 362–372. http://doi.org/10.1016/j.cogdev.2005.05.002

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology*, *28*, 595–616. http://doi.org/10.1207/s15326942dn2802

Case, R. (1991). Stages in the development of the young child's first sense of self. *Developmental Review*, *11*(3), 210–230. http://doi.org/10.1016/0273-2297(91)90010-L

Cheke, L. G., & Clayton, N. S. (2010, November). Mental time travel in animals. *Wiley Interdisciplinary Reviews: Cognitive Science*. John Wiley & Sons, Inc. http://doi.org/10.1002/wcs.59

Clayton, N. S., Bussey, T. J., & Dickinson, A. (2003). Can animals recall the past and plan for the future? *Nature Reviews. Neuroscience*, *4*(8), 685–91. http://doi.org/10.1038/nrn1180

Clayton, N. S., & Dickinson, A. (1998). Episodic-like memory during cache recovery by scrub jays. *Nature*, *395*(6699), 272–274. http://doi.org/10.1038/26216

Cleveland, E. S., & Reese, E. (2008). Children remember early childhood: Long-term recall across the offset of childhood amnesia. *Applied Cognitive Psychology*, *22*(1), 127–142. http://doi.org/10.1002/acp.1359

Coughlin, C., Lyons, K. E., & Ghetti, S. (2014). Remembering the past to envision the future in middle childhood: Developmental linkages between prospection and episodic memory. *Cognitive Development*, *30*, 96–110. http://doi.org/10.1016/j.cogdev.2014.02.001

Crane, L., & Goddard, L. (2008). Episodic and semantic autobiographical memory in adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *38*(3), 498–506. http://doi.org/10.1007/s10803-007-0420-2

Crane, L., Lind, S. E., & Bowler, D. M. (2013). Remembering the past and imagining the future in autism spectrum disorder. *Memory (Hove, England)*, *21*(2), 157–66. http://doi.org/10.1080/09658211.2012.712976

Crovitz, H. F., & Sciffman, H. (1974). Frequency of episodic memories as a function of their age. *Bulletin of the Psychonomic Society*, *4*(5B), 517–518. http://doi.org/10.3758/BF03334277

Cuevas, K., Rajan, V., Morasch, K. C., & Bell, M. A. (2015). Episodic memory and future thinking during early childhood: Linking the past and future. *Developmental Psychobiology*. http://doi.org/10.1002/dev.21307

D'Argembeau, A., Ortoleva, C., Jumentier, S., & Van der Linden, M. (2010). Component processes underlying future thinking. *Memory & Cognition*, *38*(6), 809–19. http://doi.org/10.3758/MC.38.6.809

Daniel, T. O., Stanton, C. M., & Epstein, L. H. (2013). The future is now: Comparing the effect of episodic future thinking on impulsivity in lean and obese individuals. *Appetite*, *71*, 120–125. http://doi.org/10.1016/j.appet.2013.07.010

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science 959-*, *333*(6045), 959–964. http://doi.org/10.1126/science.1204529

Ehlers, S., Gillberg, C., & Wing, L. (1999). A Screening Questionnaire for Asperger Syndrome and Other High-Functioning Autism Spectrum Disorders in School Age Children. *Journal of Autism and Developmental Disorders*, *29*(2), 129–141. http://doi.org/10.1023/A:1023040610384

Eichenbaum, H. (2004). Hippocampus: Cognitive processes and neural representations that underlie declarative memory. *Neuron*. http://doi.org/10.1016/j.neuron.2004.08.028

Eichenbaum, H., Yonelinas, A. P., & Ranganath, C. (2007). The medial temporal lobe and recognition memory. *Annual Review of Neuroscience*, *30*, 123–52. http://doi.org/10.1146/annurev.neuro.30.051606.094328

Flick, U. (2000). Episodic Interviewing. *Qualitative Researching with Text, Image and Sound: A Practical Handbook for Social Research*, (November), 75–92. http://doi.org/10.4135/9781849209731

Ford, R. M., Driscoll, T., Shum, D., & Macaulay, C. E. (2012). Executive and theory-of-mind contributions to event-based prospective memory in children: exploring the self-projection hypothesis. *Journal of Experimental Child Psychology*, *111*(3), 468–89. http://doi.org/10.1016/j.jecp.2011.10.006

Friedman, W. J. (2005). Developmental and cognitive perspectives on humans' sense of the times of past and future events. *Learning and Motivation*, *36*(2), 145–158. http://doi.org/10.1016/j.lmot.2005.02.005

Garfield, J. L., Peterson, C. C., Perry, T., Currie, G., Davies, M., Sterelny, K., … Peterson, C. (2001). Social Cognition, Language Acquisition and The Development of the Theory of Mind. *Mind & Language*, *16*(5), 494–541. http://doi.org/10.1111/1468-0017.00180

Gerlach, K. D., Dornblaser, D. W., & Schacter, D. L. (2014). Adaptive constructive processes and memory accuracy: consequences of counterfactual simulations in young and older adults. *Memory*, *22*(1), 145–62. http://doi.org/10.1080/09658211.2013.779381

Gilbert, D. T., & Wilson, T. D. (2007). Prospection: experiencing the future. *Science (New York, N.Y.)*, *317*(5843), 1351–4. http://doi.org/10.1126/science.1144161

Giovagnoli, A. R., Franceschetti, S., Reati, F., Parente, A., MacCagnano, C., Villani, F., & Spreafico, R. (2011). Theory of mind in frontal and temporal lobe epilepsy: Cognitive and neural aspects. *Epilepsia*, *52*(11), 1995–2002. http://doi.org/10.1111/j.1528-1167.2011.03215.x

Goldberg, M. C., Mostofsky, S. H., Cutting, L. E., Mahone, E. M., Astor, B. C., Denckla, M. B., & Landa, R. J. (2005). Subtle executive impairment in children with autism and children with ADHD. *Journal of Autism and Developmental Disorders*, *35*(3), 279–293. http://doi.org/10.1007/s10803-005-3291-4

Gregory, C. (2002). Theory of mind in patients with frontal variant frontotemporal dementia and Alzheimer's disease: theoretical and practical implications. *Brain*, *125*(4), 752–764. http://doi.org/10.1093/brain/awf079

Griffiths, D., Dickinson, A., & Clayton, N. (1999). Episodic memory: What can animals remember about their past? *Trends in Cognitive Sciences*. http://doi.org/10.1016/S1364-6613(98)01272-8

Habermas, T., Diel, V., & Welzer, H. (2013). Lifespan trends of autobiographical remembering: Episodicity and search for meaning. *Consciousness and Cognition*, *22*(3), 1061–1073. http://doi.org/10.1016/j.concog.2013.07.010

Hanson, L. K. (2013). Episodic Foresight in Typically-Developing Children and Children with Autism Spectrum Disorder. Université d'Ottawa / University of Ottawa. Retrieved from http://www.ruor.uottawa.ca/handle/10393/26094

Hanson, L. K., & Atance, C. M. (2014). Brief report: episodic foresight in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *44*(3), 674–84. http://doi.org/10.1007/s10803-013-1896-6

Hanson, L. K., Atance, C. M., & Paluck, S. W. (2014). Is thinking about the future related to theory of mind and executive function? Not in preschoolers. *Journal of Experimental Child*

Psychology, *128*, 120–37. http://doi.org/10.1016/j.jecp.2014.07.006

Happé, F. (1994). An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. *Journal of Autism and Developmental Disorders*, *24*(2), 129–154. http://doi.org/10.1007/BF02172093

Happé, F., & Frith, U. (1995). Theory of mind in autism. In *Learning and cognition in autism* (pp. 177–197).

Harner, L. (1975). Yesterday and tomorrow: Development of early understanding of the terms. *Developmental Psychology*, *11*(6), 864–865. http://doi.org/10.1037/0012-1649.11.6.864

Harner, L. (1976). Children's understanding of linguistic reference to past and future. *Journal of Psycholinguistic Research*, *5*(1), 65–84. http://doi.org/10.1007/BF01067949

Hassabis, D., Kumaran, D., & Maguire, E. A. (2007). Using imagination to understand the neural basis of episodic memory. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *27*(52), 14365–74. http://doi.org/10.1523/JNEUROSCI.4549-07.2007

Hassabis, D., Kumaran, D., Vann, S. D., & Maguire, E. A. (2007). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(5), 1726–31. http://doi.org/10.1073/pnas.0610561104

Hayne, H., Gross, J., McNamee, S., Fitzgibbon, O., & Tustin, K. (2011). Episodic memory and episodic foresight in 3- and 5-year-old children. *Cognitive Development*, *26*(4), 343–355. http://doi.org/10.1016/j.cogdev.2011.09.006

Hayne, H., & Imuta, K. (2011). Episodic memory in 3- and 4-year-old children. *Developmental Psychobiology*, *53*(3), 317–322. http://doi.org/10.1002/dev.20527

Hermelin, B., & O'Connor, N. (1970). *Psychological experiments with autistic children* (vi).

Hodapp, A. F., & Gerken, K. C. (1999). Correlations between scores for Peabody Picture Vocabulary Test-III and the Wechsler Intelligence Scale for Children-III. *Psychological Reports*, *84*(3), 1139–1142. http://doi.org/10.2466/pr0.1999.84.3c.1139

Hopfield, J. J. (2010). Neurodynamics of mental exploration. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(4), 1648–1653. http://doi.org/10.1073/pnas.0913991107

Hudson, J. A. (2006). The Development of Future Time Concepts Through Mother-Child Conversation. *Merrill-Palmer Quarterly*, *52*(1), 70–95. http://doi.org/10.1353/mpq.2006.0005

Hudson, J. A., Mayhew, E. M. Y., & Prabhakar, J. (2011). *The Development of Episodic Foresight. Emerging Concepts and Methods. Advances in Child Development and Behavior* (Vol. 40). http://doi.org/10.1016/B978-0-12-386491-8.00003-7

Hudson, J. A., Shapiro, L. R., McCabe, A., & Peterson, C. (1991). From knowing to telling: The development of children's scripts, stories, and personal narratives. In *Developing narrative structure*. (pp. 89–136). Lawrence Erlbaum Associates, Inc.

Hughes, C. (1998). Executive function in preschoolers: Links with theory of mind and verbal ability. *British Journal of Developmental Psychology*, *16*(2), 233–253. http://doi.org/10.1111/j.2044-835X.1998.tb00921.x

Intraub, H., Gottesman, C. V., Willey, E. V., & Zuk, I. J. (1996). Boundary Extension for Briefly Glimpsed Photographs: Do Common Perceptual Processes Result in Unexpected Memory Distortions? *Journal of Memory and Language*, *35*(2), 118–134. http://doi.org/10.1006/jmla.1996.0007

Intraub, H., & Richardson, M. (1989). Wide-angle memories of close-up scenes. *Journal of*

Experimental Psychology. Learning, Memory, and Cognition, *15*(2), 179–87. http://doi.org/10.1037/0278-7393.15.2.179

Irish, M., Addis, D. R., Hodges, J. R., & Piguet, O. (2012). Exploring the content and quality of episodic future simulations in semantic dementia. *Neuropsychologia*, *50*(14), 3488–95. http://doi.org/10.1016/j.neuropsychologia.2012.09.012

Jackson, L. K., & Atance, C. M. (2008). Future thinking in children with autism spectrum disorders: A pilot study. *Journal on Devolopmental Disabilities*, *14*(3), 40–45.

Janmaat, K. R. L., Polansky, L., Ban, S. D., & Boesch, C. (2014). Wild chimpanzees plan their breakfast time, type, and location. *Proceedings of the National Academy of Sciences*, *111*(46), 16343–16348. http://doi.org/10.1073/pnas.1407524111

Kapur, N., & Brooks, D. J. (1999). Temporally-specific retrograde amnesia in two cases of discrete bilateral hippocampal pathology. *Hippocampus*, *9*(3), 247–254. http://doi.org/10.1002/(SICI)1098-1063(1999)9:3<247::AID-HIPO5>3.0.CO;2-W

Kemper, S. J., Rash, S., Kynette, D., & Norman, S. (1990). Telling stories: The structure of adults' narratives. *European Journal of Cognitive Psychology*, *2*(3), 205–228. http://doi.org/10.1080/09541449008406205

Klein, S. B., Loftus, J., & Kihlstrom, J. F. (2002). Memory and Temporal Experience: the Effects of Episodic Memory Loss on an Amnesic Patient's Ability to Remember the Past and Imagine the Future. *Social Cognition*, *20*(5), 353–379. http://doi.org/10.1521/soco.20.5.353.21125

Klein, S. B., Robertson, T. E., & Delton, A. W. (2010). Facing the future: memory as an evolved system for planning future acts. *Memory & Cognition*, *38*(1), 13–22. http://doi.org/10.3758/MC.38.1.13

Kopelman, M. D. (1994). The Autobiographical Memory Interview (AMI) in organic and psychogenic amnesia. *Memory*, *2*(0965–8211), 211–235. http://doi.org/10.1080/09658219408258945

Kopelman, M. D. (1995). The Korsakoff syndrome. *British Journal of Psychiatry*, *166*(FEB.), 154–173. http://doi.org/10.1192/bjp.166.2.154

Kopelman, M. D., Wilson, B. A., & Baddeley, A. D. (1989). The autobiographical memory interview: a new assessment of autobiographical and personal semantic memory in amnesic patients. *Journal of Clinical and Experimental Neuropsychology*, *11*(5), 724–744. http://doi.org/10.1080/01688638908400928

Larsen, S. F. (1992). Personal context in autobiographical and narrative memories. *Theoretical Perspectives on Autobiographical Memory*., 53–71. Retrieved from http://philpapers.org/rec/LARPCI-2

Leekam, S., Baron-Cohen, S., Perrett, D., Milders, M., & Brown, S. (1997). Eye-direction detection: a dissociation between geometric and joint attention skills in autism. *British Journal of Developmental Psychology*, *15*(1), 77–95. http://doi.org/10.1111/j.2044-835X.1997.tb00726.x

Leslie, A. M., & Frith, U. (1988). Autistic children's understanding of seeing, knowing and believing. *British Journal of Developmental Psychology*, *6*(4), 315–324. http://doi.org/10.1111/j.2044-835X.1988.tb01104.x

Levine, B. (2004). Autobiographical memory and the self in time: Brain lesion effects, functional neuroanatomy, and lifespan development. *Brain and Cognition*. http://doi.org/10.1016/S0278-2626(03)00280-X

Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: dissociating episodic from semantic retrieval. *Psychology and Aging*, *17*(4), 677–689. http://doi.org/10.1037/0882-7974.17.4.677

Lind, S. E., & Bowler, D. M. (2010). Episodic memory and episodic future thinking in adults with autism. *Journal of Abnormal Psychology*, *119*(4), 896–905. http://doi.org/10.1037/a0020631

Lind, S. E., Bowler, D. M., & Raber, J. (2014). Spatial navigation, episodic memory, episodic future thinking, and theory of mind in children with autism spectrum disorder: evidence for impairments in mental simulation? *Frontiers in Psychology*, *5*, 1411. http://doi.org/10.3389/fpsyg.2014.01411

Lind, S. E., Williams, D. M., Bowler, D. M., & Peel, A. (2014). Episodic memory and episodic future thinking impairments in high-functioning autism spectrum disorder: an underlying difficulty with scene construction or self-projection? *Neuropsychology*, *28*(1), 55–67. http://doi.org/10.1037/neu0000005

Loftus, E. F., Korf, N. L., & Schooler, J. W. (1989). Misguided memories: Sincere distortions of reality. In *Credibility Assessment* (Vol. 47, pp. 155–173).

MacLeod, A. K., Tata, P., Tyrer, P., Schmidt, U., Davidson, K., & Thompson, S. (2005). Hopelessness and positive and negative future thinking in parasuicide. *The British Journal of Clinical Psychology / the British Psychological Society*, *44*(2005), 495–504. http://doi.org/10.1348/014466505X35704

Maguire, E. A., Frith, C. D., Burgess, N., Donnett, J. G., & O'Keefe, J. (1998). Knowing where things are parahippocampal involvement in encoding object locations in virtual large-scale space. *Journal of Cognitive Neuroscience*, *10*(1), 61–76. http://doi.org/10.1162/089892998563789

Maguire, E. A., & Mullally, S. L. (2013). The hippocampus: A manifesto for change. *Journal of Experimental Psychology: General*, *142*(4), 1180–1189. http://doi.org/10.1037/a0033650

Martin-Ordas, G., Atance, C. M., & Louw, A. (2012). The role of episodic and semantic memory in episodic foresight. *Learning and Motivation*, *43*(4), 209–219. http://doi.org/10.1016/j.lmot.2012.05.011

Martinelli, P., Anssens, A., Sperduti, M., & Piolino, P. (2013). The influence of normal aging and Alzheimer's disease in autobiographical memory highly related to the self. *Neuropsychology*, *27*(1), 69–78. http://doi.org/10.1037/a0030453

Maylor, E. A., Moulson, J. M., Muncer, A.-M., & Taylor, L. A. (2002). Does performance on theory of mind tasks decline in old age? *British Journal of Psychology (London, England : 1953)*, *93*(4), 465–485. http://doi.org/10.1348/000712602761381358

McCandliss, B. D., Cohen, L., & Dehaene, S. (2003). The visual word form area: Expertise for reading in the fusiform gyrus. *Trends in Cognitive Sciences*. http://doi.org/10.1016/S1364-6613(03)00134-7

McColgan, K. L., & McCormack, T. (2008). Searching and planning: Young children's reasoning about past and future event sequences. *Child Development*, *79*(5), 1477–1497. http://doi.org/10.1111/j.1467-8624.2008.01200.x

McCormack, T., & Atance, C. M. (2011). Planning in young children: A review and synthesis. *Developmental Review*, *31*(1), 1–31. http://doi.org/10.1016/j.dr.2011.02.002

Mccormack, T., & Hoerl, C. (1999). Memory and temporal perspective: The role of temporal frameworks in memory development. *Developmental Review*, *19*(1), 154–182. http://doi.org/10.1006/drev.1998.0476

Michaelian, K. (2016). Against discontinuism : Mental time travel and our knowledge of past and future events. In *Seeing the Future: Theoretical Perspectives on Future-Oriented Mental Time Travel* (pp. 1–37).

Monacelli, A. M., Cushman, L. A., Kavcic, V., & Duffy, C. J. (2003). Spatial disorientation in Alzheimer's disease: the remembrance of things passed. *Neurology*, *61*(11), 1491–7. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14663030

Morris, R. (1984). Developments of a water-maze procedure for studying spatial learning in the rat. *Journal of Neuroscience Methods*, *11*(1), 47–60. http://doi.org/10.1016/0165-0270(84)90007-4

Mulcahy, N. J., & Call, J. (2006). Apes save tools for future use. *Science (New York, N.Y.)*, *312*(5776), 1038–40. http://doi.org/10.1126/science.1125456

Mullally, S. L., Hassabis, D., & Maguire, E. A. (2012). Scene construction in amnesia: an fMRI study. *The Journal of Neuroscience*, *32*(16), 5646–5653. http://doi.org/10.1523/JNEUROSCI.5522-11.2012

Mullally, S. L., Intraub, H., & Maguire, E. A. (2012). Attenuated boundary extension produces a paradoxical memory advantage in amnesic patients. *Current Biology*, *22*(4), 261–268. http://doi.org/10.1016/j.cub.2012.01.001

Mullally, S. L., & Maguire, E. A. (2013). Memory, Imagination, and Predicting the Future: A Common Brain Mechanism? *The Neuroscientist : A Review Journal Bringing Neurobiology, Neurology and Psychiatry*, *20*(3), 220–234. http://doi.org/10.1177/1073858413495091

Mullally, S. L., & Maguire, E. A. (2014). Counterfactual thinking in patients with amnesia. *Hippocampus*, *24*(11), 1261–1266. http://doi.org/10.1002/hipo.22323

Munakata, Y., Herd, S. A., Chatham, C. H., Depue, B. E., Banich, M. T., & O'Reilly, R. C.

(2011). A unified framework for inhibitory control. *Trends in Cognitive Sciences*. http://doi.org/10.1016/j.tics.2011.07.011

Myles-Worsley, M., Cromer, C. C., & Dodd, D. H. (1986). Children's preschool script reconstruction: Reliance on general knowledge as memory fades. *Developmental Psychology*, *22*(1), 22–30. http://doi.org/10.1037/0012-1649.22.1.22

Nielsen, J. M. (1958). *Memory and amnesia*. San Lucas Press.

Okuda, J., Fujii, T., Ohtake, H., Tsukiura, T., Tanji, K., Suzuki, K., … Yamadori, A. (2003). Thinking of the future and past: The roles of the frontal pole and the medial temporal lobes. *NeuroImage*, *19*(4), 1369–1380. http://doi.org/10.1016/S1053-8119(03)00179-4

Osvath, M., Martin-Ordas, G., & Osvath, M. (2014). The future of future-oriented cognition in non-humans: theory and the empirical case of the great apes. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1655), 20130486. http://doi.org/10.1098/rstb.2013.0486

Osvath, M., & Osvath, H. (2008). Chimpanzee (Pan troglodytes) and orangutan (Pongo abelii) forethought: Self-control and pre-experience in the face of future tool use. *Animal Cognition*, *11*(4), 661–674. http://doi.org/10.1007/s10071-008-0157-0

Osvath, M., & Persson, T. (2013). Great apes can defer exchange: A replication with different results suggesting future oriented behavior. *Frontiers in Psychology*, *4*(OCT). http://doi.org/10.3389/fpsyg.2013.00698

Payne, G., Taylor, R., Hayne, H., & Scarf, D. (2014). Mental time travel for self and other in three-and four-year-old children. *Memory*, *8211*(November), 37–41. http://doi.org/10.1080/09658211.2014.921310

Pearson, A., Ropar, D., & Hamilton, A. F. (2013). A review of visual perspective taking in autism spectrum disorder. *Frontiers in Human Neuroscience*, *7*(October), 652. http://doi.org/10.3389/fnhum.2013.00652

Perner, J., Frith, U., Leslie, A. M., & Leekam, S. R. (1989). Exploration of the autistic child's theory of mind: knowledge, belief, and communication. *Child Development*, *60*(3), 688–700. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2737018

Perrin, D. (2016). Asymmetries in subjective time. In *Seeing the Future: Theoretical Perspectives on Future-Oriented Mental Time Travel* (pp. 39–61).

Picard, L., Cousin, S., Guillery-Girard, B., Eustache, F., & Piolino, P. (2012). How Do the Different Components of Episodic Memory Develop? Role of Executive Functions and Short-Term Feature-Binding Abilities. *Child Development*, *83*(3), 1037–1050. http://doi.org/10.1111/j.1467-8624.2012.01736.x

Prabhakar, J., & Hudson, J. A. (2014). The development of future thinking: young children's ability to construct event sequences to achieve future goals. *Journal of Experimental Child Psychology*, *127*, 95–109. http://doi.org/10.1016/j.jecp.2014.02.004

Pratt, C., & Bryant, P. (1990). Young Children Understand That Looking Leads to Knowing (So Long as They Are Looking into a Single Barrel). *Child Development*, *61*(4), 973–982. http://doi.org/10.1111/j.1467-8624.1990.tb02835.x

Raby, C. R., Alexis, D. M., Dickinson, A., & Clayton, N. S. (2007). Planning for the future by western scrub-jays. *Nature*, *445*(7130), 919–21. http://doi.org/10.1038/nature05575

Raby, C. R., & Clayton, N. S. (2009). Prospective cognition in animals. *Behavioural Processes*, *80*(3), 314–24. http://doi.org/10.1016/j.beproc.2008.12.005

Race, E., Keane, M. M., & Verfaellie, M. (2011). Medial Temporal Lobe Damage Causes Deficits in Episodic Memory and Episodic Future Thinking Not Attributable to Deficits in

Narrative Construction. *Journal of Neuroscience*, *31*(28), 10262–10269. http://doi.org/10.1523/JNEUROSCI.1145-11.2011

Rajendran, G., & Mitchell, P. (2007). Cognitive theories of autism. *Developmental Review*, *27*(2), 224–260. http://doi.org/10.1016/j.dr.2007.02.001

Ranganath, C. (2010). A unified framework for the functional organization of the medial temporal lobes and the phenomenology of episodic memory. *Hippocampus*, *20*(11), 1263–1290. http://doi.org/10.1002/hipo.20852

Redshaw, J. (2014). Does metarepresentation make human mental time travel unique? *Wiley Interdisciplinary Reviews: Cognitive Science*, *5*(5), 519–531. http://doi.org/10.1002/wcs.1308

Redshaw, J., & Suddendorf, T. (2013). Foresight beyond the very next event: four-year-olds can link past and deferred future episodes. *Frontiers in Psychology*, *4*, 404. http://doi.org/10.3389/fpsyg.2013.00404

Reese, E., Yan, C., Jack, F., & Hayne, H. (2010). Emerging identities: Narrative and self from early childhood to early adolescence. *Narrative Development in Adolescence*, 23–43. http://doi.org/10.1007/978-0-387-89825-4

Rendell, P. G., Bailey, P. E., Henry, J. D., Phillips, L. H., Gaskin, S., & Kliegel, M. (2012). Older Adults Have Greater Difficulty Imagining Future Rather Than Atemporal Experiences. *Psychology and Aging*, *27*(4), 1089–1098. http://doi.org/10.1037/a0029748

Renninger, K. A., & Wozniak, R. H. (1985). Effect of interest on attentional shift, recognition, and recall in young children. *Developmental Psychology*. American Psychological Association. http://doi.org/10.1037/0012-1649.21.4.624

Reyna, V. F., & Brainerd, C. J. (1998). Fuzzy-trace theory and false memory: new frontiers.

Journal of Experimental Child Psychology, *71*(2), 194–209. http://doi.org/10.1111/1467-8721.00192

Roberts, W. A. (2002). Are animals stuck in time? *Psychological Bulletin*, *128*(3), 473–489. http://doi.org/10.1037/0033-2909.128.3.473

Roberts, W. A., & Feeney, M. C. (2009). The comparative study of mental time travel. *Trends in Cognitive Sciences*, *13*(6), 271–277. http://doi.org/10.1016/j.tics.2009.03.003

Rosenbaum, R. S., Kohler, S., Schacter, D. L., Moscovitch, M., Westmacott, R., Black, S. E., … Tulving, E. (2005). The case of K.C.: Contributions of a memory-impaired person to memory theory. *Neuropsychologia*, *43*(7), 989–1021. http://doi.org/10.1016/j.neuropsychologia.2004.10.007

Rubio-Fernandez, P., & Geurts, B. (2013). How to Pass the False-Belief Task Before Your Fourth Birthday. *Psychological Science*, *24*(1), 27–33. http://doi.org/10.1177/0956797612447819

Rumbaugh, D. M., King, J. E., Beran, M. J., Washburn, D. A., Gould, K., Kornell, N., … Maia, T. V. (2012). Associative Memory and Learning. In *Encyclopedia of the Sciences of Learning* (pp. 340–342). Boston, MA: Springer US. http://doi.org/10.1007/978-1-4419-1428-6_375

Rumsey, J. M., Rapoport, J. L., & Sceery, W. R. (1985). Autistic children as adults: psychiatric, social, and behavioral outcomes. *Journal of the American Academy of Child Psychiatry*, *24*(4), 465–73. http://doi.org/10.1016/S0002-7138(09)60566-5

Russell, J., Alexis, D., & Clayton, N. (2010). Episodic future thinking in 3- to 5-year-old children: The ability to think of what will be needed from a different point of view. *Cognition*, *114*(1), 56–71. http://doi.org/10.1016/j.cognition.2009.08.013

Russell, J., & Jarrold, C. (1999). Memory for actions in children with autism: self versus other. *Cognitive Neuropsychiatry*, *4*(4), 303–31. http://doi.org/10.1080/135468099395855

Saxe, R., Moran, J. M., Scholz, J., & Gabrieli, J. (2006). Overlapping and non-overlapping brain regions for theory of mind and self reflection in individual subjects. *Social Cognitive and Affective Neuroscience*, *1*(3), 229–234. http://doi.org/10.1093/scan/nsl034

Scarf, D., Gross, J., Colombo, M., & Hayne, H. (2013). To have and to hold: Episodic memory in 3- and 4-year-old children. *Developmental Psychobiology*, *55*(2), 125–132. http://doi.org/10.1002/dev.21004

Scarf, D., Smith, C., & Stuart, M. (2014). A spoon full of studies helps the comparison go down: A comparative analysis of Tulving's spoon test. *Frontiers in Psychology*. http://doi.org/10.3389/fpsyg.2014.00893

Schacter, D. L., & Addis, D. R. (2007). The cognitive neuroscience of constructive memory: remembering the past and imagining the future. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *362*(1481), 773–86. http://doi.org/10.1098/rstb.2007.2087

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2007). Remembering the past to imagine the future: the prospective brain. *Nature Reviews Neuroscience*, *8*(9), 657–661. http://doi.org/10.1038/nrn2213

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2008). Episodic Simulation of Future Events: Concepts, Data, and Applications. *Annals of the New York Academy of Sciences*, *1124*(1), 39–60. http://doi.org/10.1196/annals.1440.001

Schacter, D. L., Addis, D. R., Hassabis, D., Martin, V. C., Spreng, R. N., & Szpunar, K. K. (2012). The Future of Memory: Remembering, Imagining, and the Brain. *Neuron*.

http://doi.org/10.1016/j.neuron.2012.11.001

Schacter, D. L., Gaesser, B., & Addis, D. R. (2013). Remembering the past and imagining the future in the elderly. *Gerontology*.

Schnider, A. (2008). *The Confabulating Mind: How The Brain Creates Reality*. *The British Journal of Psychiatry* (Vol. 194). http://doi.org/10.1192/bjp.bp.108.053439

Seamon, J. G., Schlegel, S. E., Hiester, P. M., Landau, S. M., & Blumenthal, B. F. (2002). Misremembering pictured objects: People of all ages demonstrate the boundary extension illusion. *American Journal of Psychology*, *115*(2), 151–167. http://doi.org/10.2307/1423432

Seltzer, M. M., Krauss, M. W., Shattuck, P. T., Orsmond, G., Swe, A., & Lord, C. (2003). The Symptoms of Autism Spectrum Disorders in Adolescence and Adulthood. *Journal of Autism and Developmental Disorders*, *33*(6), 565–581. http://doi.org/10.1023/B:JADD.0000005995.02453.0b

Shalom, D. Ben. (2003). Memory in autism: review and synthesis. *Cortex*, *39*(4–5), 1129–1138. http://doi.org/10.1016/S0010-9452(08)70881-5

Shettleworth, S. J. (2010). Clever animals and killjoy explanations in comparative psychology. *Trends in Cognitive Sciences*, *14*(11), 477–481. http://doi.org/10.1016/j.tics.2010.07.002

Spreng, R. N., & Grady, C. L. (2010). Patterns of brain activity supporting autobiographical memory, prospection, and theory of mind, and their relationship to the default mode network. *Journal of Cognitive Neuroscience*, *22*(6), 1112–1123. http://doi.org/10.1162/jocn.2009.21282

Spreng, R. N., Mar, R. a., & Kim, A. S. N. (2009). The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: a quantitative meta-analysis. *Journal of Cognitive Neuroscience*, *21*(3), 489–510.

http://doi.org/10.1162/jocn.2008.21029

Squire, L. R., & Zola, S. M. (1998). Episodic memory, semantic memory, and amnesia. *Hippocampus*, *8*(3), 205–211. http://doi.org/10.1002/(SICI)1098-1063(1998)8:3<205::AID-HIPO3>3.0.CO;2-I

Suddendorf, T., & Busby, J. (2005). Making decisions with the future in mind: Developmental and comparative identification of mental time travel. *Learning and Motivation*, *36*(2), 110–125. http://doi.org/10.1016/j.lmot.2005.02.010

Suddendorf, T., & Corballis, M. C. (1997). Mental time travel and the evolution of the human mind. *Genetic Social and General Psychology Monographs*, *123*(2), 133–167. Retrieved from http://uq.summon.serialssolutions.com/link/0/eLvHCXMwTV27CsJAEDwEwcYmoNf6AxfulXvUwWAhCGKh5e49yqCY_8fLEdFyuoUZhil2dgk5-Ow0xmBykNgFhJJog_NCB23A5nog6cfon5sPDVmlcUduw_HWn9jyDIA9OydYLLkclcpJdtnZ6BX6pI3IygI4LTh4mWROqcgRvcSSgpXVwUSLwK0ELvZkC_PO-DjVblmkZJ0LwYnOpk

Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: What is mental time travel, and is it unique to humans? *The Behavioral and Brain Sciences*, *30*(3), 299-313–51. http://doi.org/10.1017/S0140525X07001975

Suddendorf, T., & Corballis, M. C. (2010). Behavioural evidence for mental time travel in nonhuman animals. *Behavioural Brain Research*, *215*(2), 292–298. http://doi.org/10.1016/j.bbr.2009.11.044

Suddendorf, T., Nielsen, M., & Von Gehlen, R. (2011). Children’s capacity to remember a novel problem and to secure its future solution. *Developmental Science*, *14*(1), 26–33.

http://doi.org/10.1111/j.1467-7687.2010.00950.x

Summerfield, J. J., Hassabis, D., & Maguire, E. A. (2010). Differential engagement of brain regions within a "core" network during scene construction. *Neuropsychologia*, *48*(5), 1501–1509. http://doi.org/10.1016/j.neuropsychologia.2010.01.022

Swettenham, J. G., Baron-Cohen, S., Gomez, J. C., & Walsh, S. (1996). What's inside someone's head? Conceiving of the mind as a camera helps children with autism acquire an alternative to a theory of mind. *Cognitive Neuropsychiatry*, *1*(1), 73–88. http://doi.org/10.1080/135468096396712

Szpunar, K. K., Addis, D. R., McLelland, V. C., & Schacter, D. L. (2013). Memories of the future: new insights into the adaptive value of episodic memory. *Frontiers in Behavioral Neuroscience*, *7*, 47. http://doi.org/10.3389/fnbeh.2013.00047

Szpunar, K. K., Watson, J. M., & McDermott, K. B. (2007). Neural substrates of envisioning the future. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(2), 642–647. http://doi.org/10.1073/pnas.0610082104

Tager-Flusberg, H. (2007). Evaluating the theory-of-mind hypothesis of autism. *Current Directions in Psychological Science*, *16*(6), 311–315. http://doi.org/10.1111/j.1467-8721.2007.00527.x

Talland, G. A. (1965). *Deranged memory; a psychonomic study of the amnesic syndrome*. Academic Press.

Terrett, G., Rendell, P. G., Raponi-Saunders, S., Henry, J. D., Bailey, P. E., & Altgassen, M. (2013). Episodic Future Thinking in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *43*(11), 2558–2568. http://doi.org/10.1007/s10803-013-1806-y

Troyer, A. K., Graves, R. E., & Cullum, C. M. (1994). Executive functioning as a mediator of the relationship between age and episodic memory in healthy aging. *Aging, Neuropsychology, and Cognition*, *1*(1), 45–53. http://doi.org/10.1080/09289919408251449

Tulving, E. (1972). Episodic and Semantic Memory. In *Organization Memory* (pp. 381–402). Academic Press. Retrieved from http://www.rotman-baycrest.on.ca/index.php?module=publicationmodule&action=view&id=3042

Tulving, E. (2002). Episodic Memory: From Mind to Brain. *Annual Review of Psychology*, *53*(1), 1–25. http://doi.org/10.1146/annurev.psych.53.100901.135114

Tulving, E. (2005). Episodic Memory and Autonoesis: Uniquely Human? In *The Missing Link in Cognition: Origins of self-reflective consciousness*. http://doi.org/10.1093/acprof:oso/9780195161564.003.0001

Tulving, E., Schacter, D. L., McLachlan, D. R., & Moscovitch, M. (1988). Priming of semantic autobiographical knowledge: A case study of retrograde amnesia. *Brain and Cognition*, *8*(1), 3–20. http://doi.org/10.1016/0278-2626(88)90035-8

Volkmar, F. R., & McPartland, J. C. (2014). From Kanner to DSM-5: autism as an evolving diagnostic concept. *Annual Review of Clinical Psychology*, *10*, 193–212. http://doi.org/10.1146/annurev-clinpsy-032813-153710

Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology*, *7*(2), 131–149. http://doi.org/10.1080/87565649109540483

Wilson, A. G., & Crystal, J. D. (2012). Prospective memory in the rat. *Animal Cognition*, *15*(3), 349–58. http://doi.org/10.1007/s10071-011-0459-5

Wing, L., Gould, J., Yeates, S. R., & Brierly, L. M. (1977). Symbolic Play in Severely Mentally

Retarded and in Autistic Children. *Journal of Child Psychology and Psychiatry*, *18*(2), 167–178. http://doi.org/10.1111/j.1469-7610.1977.tb00426.x

Yirmiya, N., Solomonica-levi, D., & Shulman, C. (1993). The Ability to Manipulate Behavior and to Understand Manipulation of Beliefs: A Comparison of Individuals With Autism, Mental Retardation, and Normal Development, *32*(1), 62–69.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, *46*(3), 441–517. http://doi.org/10.1006/jmla.2002.2864

Zelazo, P. D., Carlson, S. M., & Kesek, A. (2008). The development of executive function in childhood. In *Handbook of Developmental Cognitive Neuroscience* (pp. 553–574). http://doi.org/10.1017/CBO9781107415324.004

Zelazo, P. D., Craik, F. I. M., & Booth, L. (2004). Executive function across the life span. *Acta Psychologica*, *115*(2–3), 167–83. http://doi.org/10.1016/j.actpsy.2003.12.005

Zentall, T. R. (2005). Animals may not be stuck in time. *Learning and Motivation*, *36*(2), 208–225. http://doi.org/10.1016/j.lmot.2005.03.001

Zheng, H., Luo, J., & Yu, R. (2014). From memory to prospection: what are the overlapping and the distinct components between remembering and imagining? *Frontiers in Psychology*, *5*, 856. http://doi.org/10.3389/fpsyg.2014.00856

Zwickel, J., White, S. J., Coniston, D., Senju, A., & Frith, U. (2011). Exploring the building blocks of social cognition: spontaneous agency perception and visual perspective taking in autism. *Social Cognitive and Affective Neuroscience*, *6*(5), 564–571. http://doi.org/10.1093/scan/nsq088

Supplemental Information

Interview Quality Rating Rubric

Structure:
Sense of space

0- Barely mentions it
1- Some spatial structure
2- Mostly spatially coherent

Sense of time

0- Barely mentions it
1- Some temporal structure
2- Mostly temporally coherent (plausible sequence of events)

Sense of self

0- No personal content
1- Some personal content (a description from their perspective or any reference to how they thought or felt)
2- Clear sense that this is a personal narrative

Content:
Meaning/logic

0- Messy, hard to comprehend
1- Sort of understandable
2- Perfectly clear

Vividness

0- Details are listed
1- Isolated pockets of vividness
2- Vividly paints a picture

Cued vs. Un-cued Description Content for Each Tense

Each detail that factored into the description content scores were judged as either cued, if they followed from a specific prompt, and as spontaneous if they were generated in response to an open-ended question. This did not play into the scoring system, but was evaluated to ensure that children were answering equally across all conditions. There was not a significant relationship between proportion of cued details and tense (one-way ANOVA, $p = .210$).

	Past	Present	Future
DC/Cued:	4.42	4.70	4.26
SD	1.33	1.08	1.72