MEMORY SEARCH IN EVENT CONSTRUCTION

By

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ABSTRACT OF THE DISSERTATION

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The process of event construction involves binding component parts of an event, including the objects, spatial locations, and goals, to form a coherent scene. To date, there is no mechanism for the process by which these components are populated for event construction to occur. In this dissertation, I introduced the differentiated memory search model that describes the differential search mechanisms employed when one recollects a past event and when one plans for a future event. The research explored how this model can help explain event construction processes during preschool years. Experiment 1 revealed that an open-ended memory search (directed towards future event construction) leads to more errors in the recollection of relevant components than a more directed memory search (directed towards past event construction for the same components). These results corroborate the model, and suggest that the fidelity of the components retrieved from an episodic memory depends on whether one is thinking about the past or envisioning the future. Experiment 2 presents a method by which one can facilitate access to past components and thereby, ease retrieval of relevant components from memory for a future event construction process. Altogether, the results of this dissertation indicate that there are differential memory search mechanisms that underlie construction of a past versus future scene, and further, that the representation of the underlying event structures

is temporally connected and content-specific. Further, the results of this dissertation suggest that memory processes are a precursor to future thinking abilities, and access to the underlying event structures can allow children to flexibly extract and manipulate the necessary components from memory to create the future scene.

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1 Chapter 1: Introduction

Our past is the closest proxy to our future. With knowledge of our past, we can predict with some certainty what the future might have in store, and even further, we can construct future plans using this knowledge. We can identify familiar locations if we are lost, and find our way home. We can change unhealthy habits by avoiding behaviors that have gotten us in trouble in the past. We can plan both practically and rationally for a vacation by reasoning about our prior travelling habits and tendencies. These examples illustrate the critical role of memory on future thinking. For example, when imagining a future vacation with past travel habits in mind, one has to retrieve distinct elements of past experiences while on vacation in order to make appropriate changes in future plans. This dissertation investigates the process by which memory for past experiences can inform the contents of a future scene.

Many researchers suggest that scene construction plays a central role in both memory and future thinking (Hassabis & Maguire, 2007). As early as Bartlett (1932), memory has been described as a richly recollective experience that involves the construction of distinct elements that are mediated by different regions in the brain (Hassabis et al., 2007). Similarly, future event construction involves recalling and re-combining distinct memory representations to form a coherent future scene (Addis & Schacter, 2008). Scene construction reflects the process by which scenes are built using constituent parts, including the objects, spatial locations, and contexts that comprise an event (Hassabis, Kumaran, & Maguire, 2007a; Hassabis & Maguire, 2007). The construction process has been described as relying on relational processing mechanisms (Eichenbaum & Cohen, 2001) that allow individuals to bind together distinct elements to construct a coherent scene. The process by which future events are constructed has gained attention in the last decade, but there is no process-driven account of its development during preschool years. This dissertation intends to offer such an account.

The main goal of this dissertation is to understand the mechanisms that underlie the development of future event construction. There has been little work in the developmental area that has explored the precise process by which events are constructed. I present two studies that each offer insights into scene construction during the preschool years, and specifically, the role of memory in the success of future event construction. In both studies presented in this dissertation, children are asked to construct specific components of an episode. Namely, they are asked to incrementally construct the objects (or entities), spatial contexts, and then goal contexts. These components were experienced in a past event and later, children were asked to either re-construct these components during a process of recollection or asked to construct these components to plan for an event in the future. By having children construct components learned in a single past episode either during recollection of the past event or to aid in construction of a future one, differences in event construction abilities based on whether one is thinking about the past or future could be isolated. Further, the investigation of recall and future thinking in 3- and 4-year-old children provided critical data on the early development of scene construction.

In Chapter 2, I introduce the differentiated memory search model that suggests that a distinct difference between past and future event construction is the nature of the memory search taken to extract the necessary components from the past required for event construction. Specifically, this model outlines a differential memory search process for past versus future events such that the process is more directed when thinking about the past and open-ended when thinking about the future. Further, the model predicts differences in the search process based on the components constructed (items, spatial locations, or goals). This chapter provides a process-driven account of the role of memory processes in identifying the relevant components during event construction based on time (past or future) and content unit (items, spatial locations or goals). An experiment that tests specific hypotheses derived from the model is presented.

In Chapter 3, the differentiated memory search model is extended to reflect the underlying representation of events as temporally connected, content-specific clusters in the mind. This chapter explores how connections between events within these clusters can help narrow the memory search during future event construction. I present an experiment that directs the memory search to event units temporally connected to the target event to determine whether this boosts accuracy in the memory search to identify components required for future event construction.

Altogether, this dissertation aims to present a novel theoretical framework of event construction, the differentiated memory search model, which provides a process-driven account of the manner by which children begin to construct future events using knowledge and experiences from the past. I argue that to develop a thorough understanding of future event construction, particularly its emergence in preschool years, the process must be broken down into its constituent parts or steps (i.e., incremental construction of individual components). The dissertation highlights the crucial role of memory in successful future event construction, as well as the factors that mediate performance.

2 Chapter 2: A differentiated memory search account of past and future event construction

2.1 Introduction

Adults and children think about their future, they plan and accomplish goals, they avoid or prevent unpleasant future events, and they learn from past experiences. Broadly speaking, they mentally travel backwards and forwards in time on a routine basis and imagine personal past or future episodes (Atance & O'Neill, 2001; Suddendorf & Corballis, 1997, 2007; Tulving, 2002). Many researchers argue that the past serves as a basis upon which future events are constructed. According to Schacter and Addis (2007), individuals re-combine stored information from past events to generate and construct hypothetical future events. Their hypothesis rests on the notion that the past plays an adaptive role in helping individuals plan for the future. The purpose of this investigation is to understand the factors that develop as children learn to utilize past knowledge and experiences to plan for future events. The primary aim is to determine what is being constructed when children combine discrete details from memory to help plan for future events. I propose that the construction of future events relies on children's ability to extract spatial information, entities, and goals from memory, and that each of these memory representations reflects differentiated processes in future event construction.

Researchers in memory and, more recently, in future thinking have come to a broad consensus concerning the process by which event construction unfolds: features of memory experiences are distributed across multiple memory systems (Squire, Stark, & Clark, 2004; Thompson, 2005), and are integrated during the recall process in order to generate either a past event or a possible future one (Addis & Schacter, 2008; Schacter & Addis, 2009). These memory systems differ in terms of whether they reflect memory for episodic, semantic or perceptual content. Episodic content refers to entities that are bound to specific event contexts (Henson & Gagnepain, 2010; Tulving, 1984, 2002). In contrast, semantic and perceptual content refers to entities that occur across multiple event contexts. In the process of scene construction, these discrete content units are bound together, a process commonly referred to as relational processing (Eichenbaum & Cohen, 2001). The neuroimaging literature has provided evidence for a common core network of brain regions that underlie imagining the past and imagining the future as a result of relational processing mechanisms (Addis & Schacter, 2008; Addis, Sacchetti, Ally, Budson, & Schacter, 2009; Addis, Wong, & Schacter, 2007; Hassabis, Kumaran, Vann, & Maguire, 2007b; Østby et al., 2012). Taken together, these lines of evidence suggest that people recruit the same cognitive processes involved in reconstructing memories to build novel future events.

A shared core network is plausible, because it is unclear what other information a person might rely on when constructing an event other than the episodic, semantic, and procedural knowledge that they had already required. Nevertheless, it is more difficult to think about the future than to recall the past (Addis, Muscicaro, Pan, & Schacter, 2010; De Brigard & Giovanello, 2012; D’Argembeau & Van der Linden, 2004; Johnson, Foley, Suengas, & Raye, 1988; McDonough & Gallo, 2010), e.g., individuals report fewer details in narratives reflecting possible future events (D’Argembeau & Van der Linden, 2004; Bernsten & Bohn, 2010; Gamboz, Brandimonte, & De Vito, 2010). Why might this be? If the same processes are recruited whether thinking about the past or the future, one might posit prima facie that future thinking should be just as difficult as recalling the past.

There are several proposals to explain the discrepancy between imagining the past and imagining the future, despite shared processes. One such proposal suggests that future thinking is more demanding because it requires flexible re-combination of past memory representations in addition to retrieval of the representations, while recollection of a past experience simply requires retrieval (Schacter & Addis, 2007). This account proposes that the retrieval demands are the same for both imagining the past and imagining the future. There are numerous studies that have supported this claim. For example, neuroimaging literature has found heightened activation when participants were asked to imagine the future (Abraham, Schubotz, & von Cramson, 2008; Addis et al., 2007, 2008, 2011; Botzung, Denkova, & Manning, 2008, Weiler, Suchan, & Daum, 2010). The behavioral equivalents of these neuroimaging studies have found that future event narratives contain fewer details than past event narratives as a result of the uncertainty surrounding imagination of the future (D'Argembeau & Van der Linden, 2004; Bernsten & Bohn, 2010; Gamboz, Brandimonte, & De Vito, 2010).

While greater activation and fewer details associated with future thinking may be driving the difference between imagining the past and the future, these studies do not provide a concrete mechanism regarding the process by which events are constructed. Therefore, while future thinking may require additional steps to re-combine memory representations, it is not clear as to whether the process by which these memory representations are acquired may influence future event construction.

The account proposed below provides an explanation for the role of memory processes on retrieval of memory representations for future event construction. A primary difference between memory and future thinking is that the latter requires individuals to engage in a memory search process for details from *unspecified* past events. That is, unlike recollection of a specific past event, when making future plans, individuals must perform a search for relevant information from several competing past experiences and select relevant content units that will inform the future plan. The need to engage in additional search processes can explain some of the discrepancy between past and future event construction. A useful way to explore this hypothesis is to consider the time at which future-oriented behavior emerges in childhood. Studying developmental populations can help researchers isolate factors that are essential to a fundamental future thinking mechanism (in this case, the role of search processes on event construction).

2.1.1 The provenance of future thinking

The ability to construct future events and make decisions in the present to satisfy future goals appears to mature between the ages of 3 and 4 (Atance & Meltzoff, 2005; Hudson & Fivush, 1991; Hudson & Shapiro, 1991; Hudson, Fivush, & Kuebli, 1992; Prabhakar & Hudson, 2014; Russell, Alexis, & Clayton, 2010; Scarf, Gross, Colombo, & Hayne, 2011; Suddendorf, Nielson, & van Gehlen, 2011; see Hudson, Mayhew, & Prabhakar, 2011, for a review). Children as young as 3 can form episodic memories (Bauer, 2007; Bauer & Dow, 1994; Hayne, Gross, McNamee, Fitzgibbon, & Tustin, 2011; Hayne & Imuta, 2011; Morgan & Hayne, 2011; Scarf et al., 2011) and report memories that have occurred far in the past (Fivush, Gray, & Fromhoff, 1987; Fivush & Schwarzmueller, 1998; Harley & Reese, 1999; Reese & Brown, 2000; Tustin & Hayne, 2010). In contrast, future-oriented behavior seems to emerge in a more protracted manner between the ages of 3 and 5 (Atance & O'Neill, 2001; Martin-Ordas, Atance, & Louw, 2012; Russell, Alexis, & Clayton, 2010; Scarf et al., 2011; Suddendorf et al., 2011). In many studies that explore future-oriented behavior, children are asked to choose an item they will need to satisfy a future goal or problem. These studies reveal a salient constraint: while children are able to make a choice when reflecting upon a similar past experience, they are unable to use details from the past experience in order to inform a future choice (Russell et al., 2010), particularly when the past experience occurred far in the past (Scarf et al., 2011). Hence, there exists a major disparity between recalling and reconstructing past events and thinking about future ones: young children have difficulty incorporating details from past experiences to build future events, even though they have little trouble accessing information from the past. What might explain this disparity?

There is little consensus in the literature regarding what drives the developmental changes. One reason for this could be the lack of agreement on a proper mechanism for testing future thinking development. Suddendorf et al. (2010) sought to remedy this by offering the following criteria for episodic future thinking (i.e., imagining a specific episode in the future): 1) should use single trials to ensure memory for a specific event, 2) should involve a novel problem to avoid scripted knowledge, 3) should use different temporal and spatial contexts to avoid cuing, and 4) should use problems from various domains to determine flexibility in performance. These notions put forth criteria for researchers to adhere when testing future thinking. However, they have not always proven useful in understanding underlying mechanisms. Instead, they've been able to provide a general notion of *when* future thinking (as constrained by these criteria) emerges in childhood. But, it is not yet clear why or how.

One possibility is the advent of memory processes. Suddendorf et al. (2010) found that when they imposed a delay between the target past event and the time of future planning, children, particularly younger children, were less accurate in making correct future-oriented choices, suggesting that with less access to the past, future planning suffers. In support of this notion, Atance & Sommerville (2013) found that memory for a past item predicted children's future-oriented choices. These results indicate that the development of memory processes is crucial to future thinking. However, these authors, among others (Grant & Suddendorf, 2010; Metcalf & Atance, 2013; McColgan & McCormack, 2008; Naito & Suzuki, 2011; Russell et al., 2010; Scarf et al., 2011) also note that there are other aspects that may mediate future thinking development, for example, language ability, temporal understanding, perspective-taking, relational processing and executive function. It is likely the case that a mature future thinking mechanism involves multiple factors. However, in an effort to paint a whole picture of future thinking, there are few accounts regarding the underlying mechanisms of a basic, fundamental future thinking ability. The model presented here proposes a more thorough account of the basic, most fundamental aspects of past and future thinking. To this end, event construction processes are broken down into its primary units: the components that build a past or future scene. That is, before any kind of recombination of event details can take place to construct a past or future scene, the components of the scene must be populated. This dissertation provides a model that reflects the memory search that leads to selecting items relevant for a scene. This focus on the memory search is not to say that memory processes are the most important contributor to future thinking development but instead, that memory processes play a fundamental role in event construction upon which additional factors such as relational processing and executive function ability can be added to reflect a mature, more complex future event construction process.

2.1.2 How future events are constructed: entities, space, and goals

Minimal accounts of episodic memory have isolated the basic, most fundamental components of an episode such that if these components – namely, the *what*, the *when*, and the *where* – are recalled, then one exhibits episodic-like behavior (Clayton & Dickinson, 1998). Clayton and Dickinson sought to study episodic memory in non-human animals; their model finds its origins in Tulving (1972) who described episodic memory as storing specific information about the individual in a particular time and space (i.e., event). In addition to these basic components, thinking about the future has functional purposes such that individuals engage in this process to achieve a goal. D'Argembeau and Mathy (2011) corroborated this notion and found that providing individuals with goals eased the demands of future event construction. According to these authors, future events are structured around personal goals. If this is the case, then the future event construction process should consist of basic, fundamental components (the *what*, the *when*, and the *where*) that are bound together to reflect an overall goal.

Following a minimal account, when individuals imagine a future event, the basic goal is to construct an event that incorporates the objects (the *what*), the locations of these objects in space (the *where*) and goal that binds the event together, while considering the future point in time (the *when*). Note that the main focus here is on the construction of a scene, and does not involve the agent as an actor within the scene. Therefore, while some developmental studies have asked children to shift their own perspectives when thinking about the future (Russell et al., 2010), I am simply interested in spatial relationships between objects constructed within a scene. This approach allows for the comparison of children's ability to construct details for the past versus the future without additional self-projection (i.e., shifting between perspectives) processes.

Our cognitive model of event construction suggests that past and future event construction differ based on the search process employed. In particular, the memory search process is different depending on whether one is constructing a past or future event. When all things are held equal (i.e., the constructed events are the same), the primary driving force of the difference between past and future thinking may be the nature of the memory search processes that are recruited. Consider the graphical representation of the model below. Figure 2.1 depicts a memory search as a result of recollection of a specific past episode, E_{target}. Because the memory search is directed to the past event, there are few competing representations to hinder the memory search for the relevant components. The model presented assumes that the past event is a single, novel event. However, depending on the nature of the past event, competing representations may influence the accuracy of the memory search (e.g., recalling a conversation with a friend may have more competing representations than remembering the time one went skydiving). However, if the model is considering a single, novel event, then a mature recollection process should be able to identify the event and corresponding components with relative ease in comparison to the memory search involved for future event construction (see graphical model presented in Figure 2.2). In Figure 2.2, because the single past event is not specified, a more effortful search process commences such that with each iteration of the search, the model searches through multiple components, some from the target event and others from neighboring events. With each iteration of the memory search, the model eventually isolates the relevant components for future event construction. Therefore, a critical difference between two models is the specificity of the memory search. When it is more directed (Figure 2.1), there are fewer steps required to arrive at the final model that leads to event construction. Again, it is important to note that the models presented here reflect memory search for components from a single, novel past episode in order to reflect a minimal process of event construction: either re-constructing a single past episode or using information from that single past episode for future event construction. Providing such a basic model allows for greater complexity to be introduced along multiple factors including competing past representations.

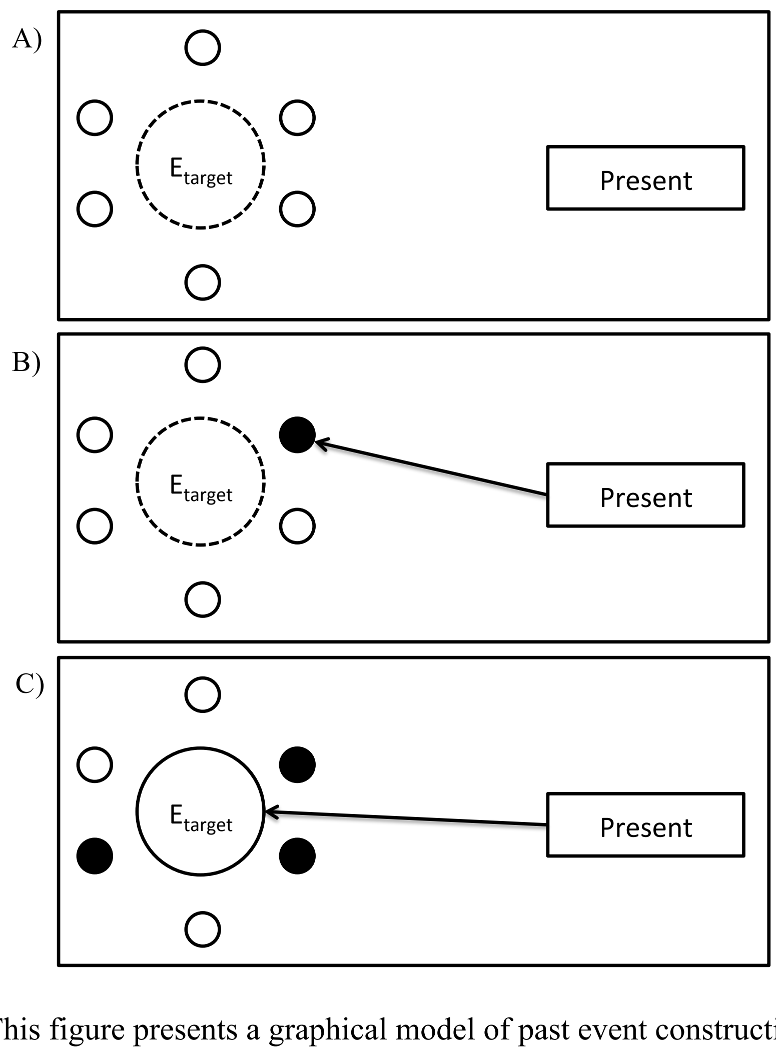

Figure 2.1. This figure presents a graphical model of past event construction. Panel A and B depicts how a directed memory search to the target event is able to isolate the components relevant to reconstructing an episode on each iteration. Panel C depicts how

once those relevant components are extracted, construction of the target event can result. Dark circles in both panels reflect activated units that are relevant for event construction.

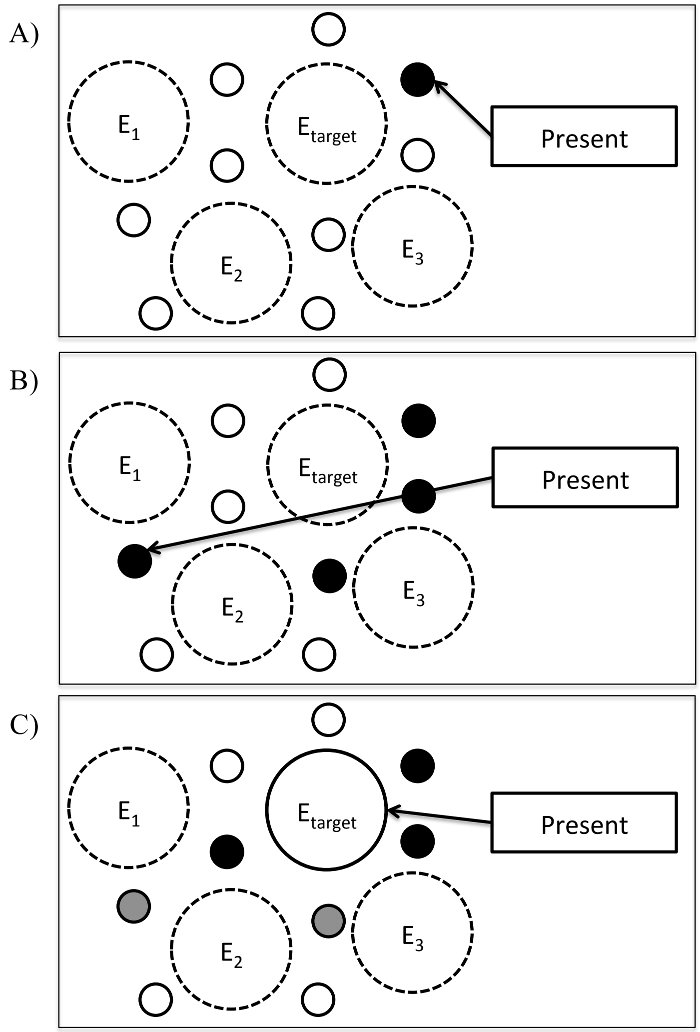

Figure 2.2. This figure presents a graphical model of future event construction. In this model, the memory search is undirected and the search progresses through multiple possible components across several past memories (Panels A and B). Therefore, with each iteration, it results in a different component, either from the target event or neighboring event, until it eventually arrives at the components required for future event construction (Panel C). The dark circles reflect activated units that are relevant for event construction and the grey circles reflect activated units that are not relevant for event construction.

This differentiated memory search model distinguishes between memory searches as a result of past or future event construction. The model further provides different explanations for the search process for individual components of an event: items (the *what*), the spatial locations (the *where*), and the goals.

Items Retrieval. In the differentiated memory search model, items refer to discrete objects that populate the scene. These refer to *what* components as described by Clayton and Dickinson's (1998) conception of episodic-like behavior. In accordance with many dual-process models of item recognition (see Yonelinas, 2002 for a review), the model posits that familiarity and recollection processes interact with one another to retrieve components of memories. When individuals do not know in which past event the target items exist, children's judgments may rely more heavily on familiarity processes that base judgments on quantitative memory strengths rather than a qualitative memory search. As familiarity is modulated by multiple competing cues (Yonelinas, 2002), thinking about the future should result in higher false alarm rates during item recognition.

Recall of Spatial Locations. Neuroimaging and neuropsychological evidence suggests that retrieval of spatial locations is closely associated with retrieval of items, suggesting that spatial context and items may be bound and reinstated together (Burgess, Quayle, & Frith, 2001; Davachi, 2006; Eichenbaum, 2004; Hassabis & Maguire, 2007; Miller et al., 2013; Polyn & Kahana, 2008; Polyn, Norman, & Kahana, 2009; Scoville & Milner, 1957). Behavioral evidence corroborates this work showing that participants envision past and future events in similar settings (D'Argembeau & Van der Linden, 2004, 2006). However, behavioral evidence in developmental populations indicates that while children by the age of 2 are able to remember multiple spatial locations over a short delay, memory for spatial representations shows greater vulnerability for forgetting over a longer period of time (Lukowski, Garcia, & Bauer, 2011; Sluzenski, Newcombe, &

Ottinger, 2004). These lines of evidence suggest an association between items and spatial locations such that access to past memory components can narrow an open-ended memory search, but it may be dependent on other factors such as age-related differences in recall ability of spatial representations (Lukowski et al., 2011; Sluzenski et al., 2004) rather than a past versus future thinking difference.

Goal Contexts. Past research indicates the central role of visual-spatial contexts in event construction, which has been supported by neuroimaging literature that suggests spatial contexts are critical to event construction, past or future (Burgess et al., 2001; Hassabis & Maguire, 2007; Hassabis et al., 2007a; O'Keefe & Nadel, 1978; Schacter & Addis, 2007), and further, that visual-spatial contexts provide a cue for past memory components (Addis et al., 2007; Eacott, Easton, & Zinkivskay, 2005; Eacott & Norman, 2004; Okuda et al., 2003; Szpunar, Watson, & McDermott, 2007). Goals may also play a central role in defining an event; the items bound to their spatial contexts (i.e., the visual-spatial contexts) may provide the elements for a targeted memory search to retrieve the goal context (or the overall purpose for the event within which they exist).

The following experiment explores the construction of these distinct components of an event – items, spatial locations, and goals – in order to isolate the memory search that results when 3- and 4-year-old children construct these components to reconstruct the past and construct the future. This age group was selected since past literature suggests that future thinking ability matures rapidly at this age (see Hudson, Mayhew & Prabhakar, 2010 for a review). Therefore, an exploration of the factors that underlie the development of future thinking during this age group can allow us to determine the factors that underlie basic, fundamental components of scene construction.

2.1.3 A novel paradigm for studying future event construction

Previous studies of future thinking have not focused on the precise process by which people pull together information from episodic memories to construct new events, and there is no psychological paradigm specifically designed to test this mechanism in preschoolers. To amend this deficit, a novel paradigm was developed using a touchscreen tablet called the "music game". The game provided children with the 3 components specified earlier – items, spatial locations, and a goal. Children were shown 3 animals (the items) in 3 houses (the spatial locations). They are told that the animals can play a song if pressed in a particular 3-step order (the goal). The 3-step order reflected a 3-step animal order. To emphasize this, children were shown animals in two different houses, and shown the same 3-step animal order with each spatial configuration. After a delay, children incrementally constructed the song.

The three tasks given to children to build the game tested various components of their memory and future thinking abilities: 1) the *item recognition* task required children to distinguish entities they had seen in the sequence from those they hadn't; 2) the *location recall* task required children to associate the items they had seen with the locations in which they had seen them; and 3) the song order recall task required children to perform the same sequence they had seen before to achieve the goal of playing a song. As outlined below, each of the three tasks could be executed within a context that focused on the past (the "past condition") or else the future (the "future condition"). The three tasks accordingly tested children's facility to identify entities, identify spatial representations, and recall goals, which correspond to the precursor abilities that are necessary for future thinking according to the differential memory search model. Let us examine each task in more depth.

Item Recognition Task. The item recognition task required children to make a two-alternative forced-choice between a target animal (entity seen in the game) and foil animal (entity not seen in the game). This task was designed to measure children's memory for entities from a specific past experience. They were given a recognition task to select the animal seen before (past condition) or the animal needed to play the game tomorrow (future condition). The model makes the prediction that thinking about the future will result in recruitment of familiarity processes that may result in higher false-alarm rates than thinking about the past, which will recruit recollection processes as a result of a more directed memory search.

Location Recall task. The location recall task requires children to place animals in one of 3 locations that they were in before when they played the song (past condition) or they should be to play the song tomorrow (future condition). Children were given this task in order to measure their ability to remember spatial locations and use this memory to visualize a future event. The differentiated memory search model predicts that children's ability to recall spatial locations of entities should be similarly taxed in the location recall task, as children are required to remember associations between the animal and its location. Associating objects with their spatial locations should be independent of considerations of past and future thinking, and should be comparably difficult for both types of event construction.

Song Order Recall Task. The song order recall task was designed to test children's memory for goals (cf. Altmann & Trafton, 2002), and it required children to specify either how they played the song before (past condition) or how they will play the song tomorrow (future condition). The locations of the animals were manipulated based on whether children had seen the animals in a single location or multiple locations in the first session. Children who had seen the animals in a single location were shown animals in those exact locations, and children who had seen animals in multiple locations were shown animals in a new set of locations not previously seen. The location was manipulated in order to determine the role of spatial locations on retrieval of contextual information (i.e., the song order). The model predicts that children who at test see a visual-spatial context that reflects the original experience (i.e., those in the single location condition) will show higher accuracies in song order recall because the visual-spatial contexts will cue a more directed memory search. In contrast, without the visual-spatial contexts, children will show deficits in song order recall, particularly when thinking about the future.

2.1.4 Predictions

Overall, the experiment presented in this paper was designed to measure children's ability to construct individual components of events, specifically, the entities (the animals), the locations (their houses), and the goal (the song order). I predicted that memory for these individual content units would differ based on varying demands of the search process, the role of visual-spatial aspects of a scene, and memory for spatial content.

The specific predictions for each content unit are described in Table 2.1 by the task that measures memory for these units. For item recognition, I predicted that the recruitment of familiarity versus recollection processes would result in differences in item recognition accuracy. A more difficult memory search (as in future event construction) should lead to recruitment of greater familiarity processes over recollection processes, leading to a higher false alarm rate in this task. For location recall, because children are required to recall specific spatial locations from the previous event, I predicted age-related differences as a result of variations in the maturity of recall processes. Finally, for song order recall, it was predicted that the demands of a memory search would be eased in the presence of visual-spatial cues. Without these cues, greater difficulties in the memory search would lead to more errors during future construction of song order.

Table 2.1. Predictions, by task, for retrieval of content units (animals, houses, song order) for future event construction in Experiment 1.

	Predictions		
Task	**Accuracy**	**Past vs. future**	**Younger vs. Older**
Item Recognition	Lower hit rate and higher false alarms	Yes; memory search for qualitative information within specified past event would increase hit rates.	--
Location Recall	Relative difficulty	--	Yes
Song Order Recall	Relative difficulty	Yes, more difficult in future without visual-spatial information	--

2.2 Method

2.2.1 Participants

Forty-eight 3-year-olds (M = 43 months; 26 Females) and forty-eight 4-year-olds (*M* = 53 months; 19 Females) participated in the study. One additional three 3-year-olds and three 4-year-olds participated but their data was excluded either because they did not meet inclusion criteria (passing session 1, see below) or they showed disinterest to continue with the study during the delay between sessions 1 and 2. Children were recruited from preschools in the Central New Jersey area. Participation was voluntary. Parents signed consent forms to allow children to participate and verbal assent was obtained from children prior to participation. Children were given a sticker of their choice as compensation for their participation.

2.2.2 Materials

A Samsung Nexus 7" tablet was used to conduct the experiment. The application for the Android tablet was developed using MIT's App Inventor tool. Participant's responses were recorded by experimenters and verified using the video record of the experimental session.

2.2.3 Procedure

The experimental session was split between two parts. In the first part, children were exposed to an experience in which they learned to press images of animals on the tablet in a particular order; when this order was satisfied, a song was triggered. The animals appeared inside houses that were positioned in a triangular formation (see Figure 2.3). The experimenter asked the child to label each animal (e.g., "horse", "cow", "pig"), and then proceeded to first verbally tell children how to play the song by pressing the animals in a particular 3-step order, and then to demonstrate it for the children. The experimenter told children "*The only way to play the song is press the animals in that order".* Following the first demonstration, half of the children were shown how to play the song once again with the animals in the same formation as previously seen (single location condition). The other half of the children was shown how to play the song once again with the animals in a new formation not previously seen (multiple location condition). Altogether, the experimenter demonstrated how to play the song two times. In the single location condition, children saw both the first and second demonstrations with animals in the same location. In the multiple location condition, children saw the each demonstration with animals in two sets of locations wherein no one animal was in the same location twice. The locations chosen for the second set was a result of a specific spatial movement pattern. The animals rotated in a clockwise manner around the triangular formation. For half the children, each animal moved just once to achieve the next configuration (Figure 2.3, Panel B shows this 1-step movement pattern). For the other half of the children, each animal moved two positions to achieve the next configuration (a 2-step movement pattern). The pattern was maintained throughout the entire experiment such that each time the animals switched locations, they moved 1 or 2 positions; this was counterbalanced between subjects.

Children were then asked to play the song the way it had been demonstrated to them. Before being allowed to imitate, all children were told one last time that the only way to play the song would be to press the animals in the correct order that had been shown to them twice. Children were given 3 attempts for imitation. The only inclusion criterion in this experiment was that children were expected to successfully imitate within these 3 attempts in order to continue to the next session. Only 1 3-year-old child was unable to successfully imitate. The other 5 children that were excluded chose not to participate in the second session of the experiment.

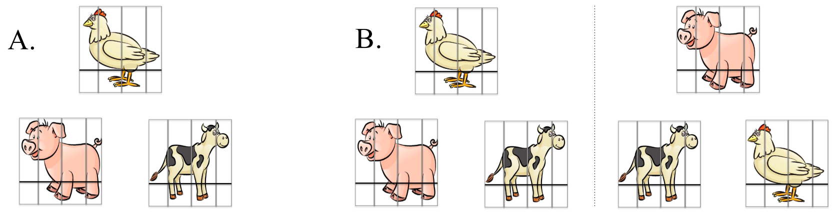

Figure 2.3. Layout of the experiment from first part of the experiment. Children were shown animals in houses positioned in a triangular formation. Half of the children were shown the animals in just one set of locations (A), while the other half saw the animals in two different sets of locations (B).

A 10-minute delay period was imposed during which children were given various unrelated distractor tasks such as assessments of children's tendency to engage in pretense, as well as tasks that measure moral reasoning abilities in preschoolers. At the end of the delay, children were asked to incrementally construct the song game either by explicitly recollecting the past event (past condition) or by planning to play the song game again in the future (future condition). All children were told that the music game is gone, and they would have to help the experimenter build the game again. Half of the children were asked, "*Can you help me get the game back together like when you played the song before?"* The other half of the children was asked, "*Can you help me get the game together so we can play the song tomorrow?"* Children were then given three tasks in the following order: *item recognition task, location recall task,* and *song order recall task*.

2.2.3.1 Item Recognition Task.

In this task, children were asked to select the animals (e.g., the items) from the song game (Figure 2.4). Children were given a two-alternative forced-choice task where on each of three trials, they were asked to select between two animals (one target and one foil) the animal they had seen before when they played the song (past condition) or the animal they will need to play the song tomorrow (future condition). On each trial, a hit (selecting target animal) received a score of 1 and a false alarm (selecting foil animal) received a score of 0.

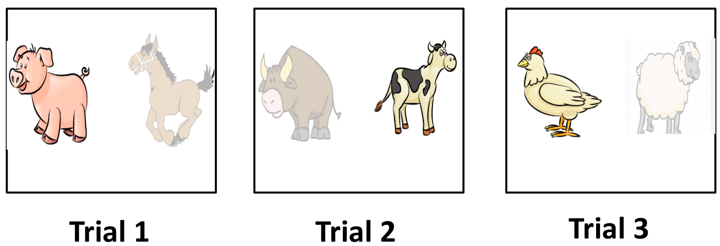

Figure 2.4. Trial-by-trial layout of the Item Recognition Task. Children were asked, on each of three trials, to select the animal they had seen before or will need tomorrow.

2.2.3.2 Location Recall Task.

In this task, children were asked to place the animals in the correct spatial locations. On each of three trials, children were shown three empty houses in the same triangular configuration as in the original experience. The target animal appeared at the center of the triangular configuration and children were asked to move the animal to its house (see Figure 2.5). All children were asked to place the target animals (i.e., those from the original experience), regardless of whether they selected the correct animal in the *item recognition task*. Children in the past condition were asked to place the animal in the house it was in when they played the song before, and children in the future condition were asked to place the animal in the house it should be in to play the song tomorrow.

For those children in the single location condition, there was only one correct location. For those children in the multiple location condition, there were two possible locations in which the animals had previously appeared. In addition, because all 3 houses were empty on each trial, it was possible for children to place multiple animals in the same house. A correct location choice was given 1 point, and an incorrect location choice was given 0 points.

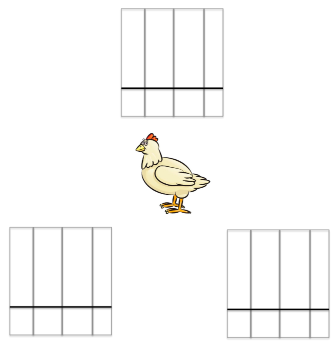

Figure 2.5. Layout of the Location Recall Task. On each of three trials, children were shown 3 empty houses and asked to place the animal either where it was before or where it should be for tomorrow.

2.2.3.3 Song Order Recall Task.

In this task, half of the children were shown the correct animals in the houses wherein they appeared in the original experience (single location condition) or they were shown animals in a new set of locations not previously seen (multiple location condition). In the latter condition, the spatial movement pattern (either the 1-step or 2-step movement pattern) reflected the same pattern used in the first session. That is, the animals either moved 1-step or 2-steps clockwise from their last location in session 1. Children in the past condition were asked how they made the song play before, and children in the future condition were asked how they will make the song play tomorrow. Children were asked to demonstrate how to play the song three times, even if they demonstrated correctly in trial 1 or 2. On each trial, if children provided the correct sequence, they were given 1 point. Incorrect 3-step sequences were given 0 points.

2.3 Results

2.3.1 Design and Coding

Children's performance was analyzed using a series of binary logistic regressions with Age (3, 4), Time (Past, Future), and Condition (Single Location, Multiple Location) as predictors of item recognition, location recall, and song order recall. A binary regression was chosen since the dependent variable, accuracy, was a binary response variable: 1 (correct response) or 0 (incorrect response). For the same reason, all planned comparisons were conducted using Mann-Whitney tests. All children were given three tasks (item recognition, location recall, song order recall) and three trials within each task.

2.3.2 Item Recognition Task Results

In this task, children were asked to select, between two animals, the animal (i.e., the item) they saw before or will need for tomorrow. A correct recognition (i.e., an animal seen in session 1) was given 1 point, and an incorrect recognition (i.e., a false alarm) was given 0 points. Initial tests found no item recognition differences based on condition (single location versus multiple location). In addition, because no differences were predicted between the single and multiple location conditions for item recognition, analyses were collapsed across this variable.

A signal detection analysis was conducted to compare sensitivity (*d'*) scores between target and foil items in the past and future conditions by 3- and 4-year-old children. Means for sensitivity (*d'*) scores from the signal detection analyses, as well as proportion of hit rates and false alarms, for each condition is given in Table 2.2. This table indicates that the predictions regarding the hit and false alarm rates were validated. The data reveal more false alarms in the future condition than the past condition, and more hits in the past condition than the future condition for both 3- and 4-year-olds.

Table 2.2. Item Recognition Task: Mean d' Scores, Proportion of Hit Rates, and Proportion of False Alarms

	3-year-olds		4-year-olds	
	M	*SE*	*M*	*SE*
Past				
d'	0.93	0.002	2.17	0.0002
Hits	0.75	0.005	0.94	0.03
False Alarms	0.25	0.05	0.06	0.03
Future				
d'	0.14	0.001	0.65	0.002
Hits	0.54	0.06	0.68	0.06
False Alarms	0.46	0.06	0.32	0.06

A binary logistic regression was conducted with age and time as predictors of item recognition (see Table 2.3).

Table 2.3. Binary Logistic Regression with age and time as predictors of item recognition.

	β	*SE* β	*z*	*p*
Age	1.73	0.58	2.98	0.003*
Time	0.93	0.36	2.58	0.01*
Age x Time	1.15	0.68	1.69	0.09
AIC: 309.39				
Nagelkereke R^2*:* 0.83				

Note: *$p < 0.05$

The results indicate that time and age were significant predictors of item recognition, while the interaction between age and time was marginally significant. These results corroborate the predictions that thinking about the past and thinking about the future recruit familiarity and recollection processes to different extents during the search process. Higher hit rates when thinking about the past suggest greater recruitment of accuracy-driven recollection processes. (The correct choice when making an item recognition judgment was the same both when thinking about the past and future.) These findings support the proposal that access to past memory representations drives differences in future event construction.

2.3.3 Location Recall Task Results

In the location recall task, children were asked to place animals from the first session in 1 of 3 locations on each trial. This made it possible for children to place multiple animals in the same location across multiple trials. (For a detailed analysis of this behavior, see Appendix A.) Individual location choices are the best arbiter of the differentiated memory search model and predictions, and so analyses focused on trial-by-trial accuracy rather than whether children placed animals in all 3 locations correctly. However, trial-by-trial accuracy was analyzed in the single and multiple locations conditions separately because accuracy was evaluated differently between these conditions. Specifically, in the single location condition, there was only 1 location in which the animal had previously been seen. In this condition, children's responses were coded as a 0 or 1 based on whether their location choice was one in which the animal was seen before (1) or not seen before (0). In the multiple location condition, there were 2 possible location choices that reflected the 2 locations in which the animal had previously been seen. In this condition, children's responses were coded based on whether they chose the location the animal as first seen or second seen (1) or the location in which the animal was yet to be seen (0). Means for each condition in the single location condition are provided in Table 2.4.

Table 2.4. Average accuracy in placing animals in location seen previously as a function of the location condition (single vs. multiple).

	Single Location		Multiple Locations	
	3-year-olds	4-year-olds	3-year-olds	4-year-olds
Past	0.67	0.83	0.75	0.67
Future	0.44	0.81	0.72	0.53

These means indicate no difference in location selection accuracy between past and future conditions; however, this was isolated to 4-year-old children. In the younger age group, children were more accurate in selecting the correct location when thinking about the past.

A binary logistic regression was computed with age and time as predictors of location recall accuracy in the single location condition. A summary of the regression model is provided in Table 2.5.

Table 2.5. Binary Logistic Regression with age and time as predictors of location recall in the single location condition.

	β	*SE β*	*z*	*p*
Age	1.64	0.54	3.06	<0.01*
Time	0.92	0.49	1.88	0.06
Age x Time	0.73	0.78	0.93	0.35
AIC: 171.20 *Nagelkereke* R^2*:* 0.54				

Note: *$p < 0.05$

Age was a significant predictor of location recall accuracy, and time was a marginally significant predictor of location recall accuracy. Planned comparisons found that while 4-year-old children showed no differences between accuracy in location selections in the past and future conditions, 3-year-old children placed the animal in the correct location more in the past condition than in the future condition; this difference was marginally significant, $z = 1.88$, $p = 0.06$, $r = 0.22$. These results partially corroborate the prediction that associating objects to their spatial locations are independent of considerations of past and future thinking. However, because younger children exhibited a marginal difference, there seems to be a slight developmental difference between past and future event construction of spatial location recall.

Accuracy in the multiple location condition is shown in Table 2.4. A binary logistic regression was run with age and time as predictors of location accuracy in the multiple location condition. The regression model is summarized in Table 2.6.

Table 2.6. Logistic Regression with Age and Time as predictors of location recall accuracy in the multiple location condition.

	β	$SE\ \beta$	z	p
Age	0.84	0.49	1.59	0.09
Time	0.14	0.54	0.27	0.79
Age * Time	0.44	0.72	0.61	0.54
AIC: 171.20				
Nagelkerke R^2: 0.21				

Note: * $p < 0.05$

The model yielded only a marginal effect of Age. Because the regression did not yield any clear findings and also resulted in a low R^2, the question remained as to whether there were any systematic behaviors in the kind of location choices children made in the multiple location condition. Therefore, the data was re-coded to reflect the number of trials, across the 3 location trials, wherein children placed animal in the first location in which the animal was previously seen, second location in which the animal was previously seen, and the location in which they had yet to see the animal in order to uncover any systematicity in children's location choices. Table 2.7 provides these counts. When considering all possible choices, results indicated that 4-year-old children chose the first location in future conditions significantly less than by chance ($p < 0.05$).

There were few differences in location recall when children were shown animals in multiple locations. Their location choices indicate no discernable pattern. However, this may be because children were unsure as to which location to place the animal – an old location or a new one. This may explain why children were no different in their choices between past and future location construction, a result that was predicted.

Table 2.7. Number of trials in which children placed animal in first location it was seen, second location it was seen, and third location yet to be seen.

	3-year-olds		4-year-olds	
	Past	Future	Past	Future
First Location	11	12	10	5
Second Location	16	14	14	14
Third Location	9	10	12	17

2.3.4 Song Order Task Results

Mean accuracies in song order recall, across all 3 trials, for each condition (age and time) are provided in Figure 2.6.

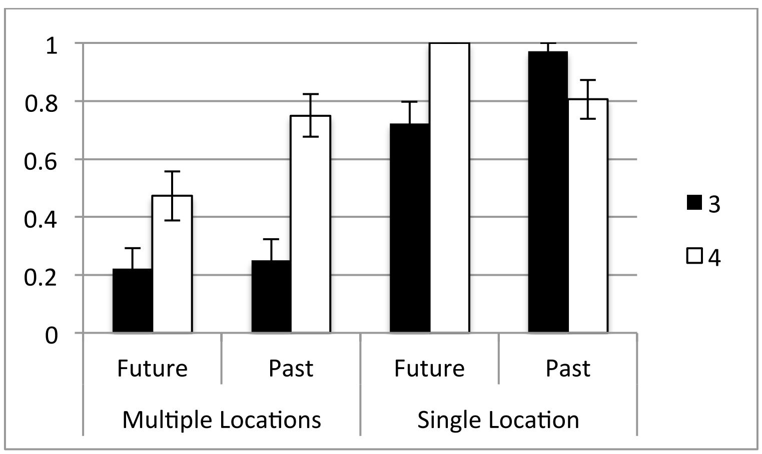

Figure 2.6. Song Order Recall: Average accuracy in selecting correct order by age, time, and condition. Bars represent the standard errors.

A binary logistic regression was computed with age, time, and condition as predictors (see Table 2.8). The results of this regression indicated that age and condition were significant predictors of song order recall.

Table 2.8. Song Order Recall: Binary Logistic Regression with age, time, and condition as predictors

	β	$SE\ \beta$	z	p
Age	1.14	0.52	2.19	0.03*
Time	0.15	0.56	0.28	0.78
Condition	2.21	0.55	4.04	<0.001*
Age * Time	1.06	0.75	1.40	0.17
Age * Condition	16.5	1087	0.02	0.99
Time * Condition	2.45	1.21	2.01	0.04*
Age * Time * Condition	20.81	1087	0.02	0.98
AIC: 272.06 *Nagelkerke* R^2: 0.99				

Note: * $p < 0.05$

The model also yielded a significant interaction between time and condition. Planned comparisons found that when children were shown animals in multiple locations in session 1 and a new set of locations in the song order recall task in session 2, they selected the correct order more in the past condition than in the future condition; this difference was marginally significant, $z = 1.85$, $p = 0.06$, $r = 0.15$. Additional tests found a significant future versus past difference in song order recall accuracy in the multiple location condition, but only with 4-year-old children, $z = 4.55$, $p < 0.001$, $r = 0.54$, but not 3-year-old children.

In the single location condition, there were no overall temporal differences. However, 3-year-old children selected the correct order more frequently in the past condition than in the future condition, $z = 2.93$, $p < 0.01$, $z = 0.34$. In contrast, 4-year-old children selected the correct order more frequently in the future condition than in the past condition, $z = 2.77$, $p < 0.01$, $z = 0.33$.

Overall, the results corroborate the prediction derived from the differentiated memory search model that when visual-spatial aspects are salient (i.e., in the single location condition), children are more accurate at selecting the goal context as these aspects trigger a directed memory search. However, there were differences within these conditions that suggest that even with visual-spatial aspects, the past still benefits from a more directed memory search than the future. Several post-hoc tests were also conducted to determine whether there were any peculiarities in children's pattern of order choices in the multiple location condition. These tests were run to determine whether children used alternative strategies in making their goal context choices and specifically, whether these strategies result in any systematic errors.

Post-hoc Analyses. In the multiple location condition, children could have selected the song order by pressing the animals based on the location in which they were seen in session 1. For example, if in session 1, children saw the experimenter play the song by pressing the animal in the *left* position, then *top* position, and then *right* position, they may have remembered the song order based on these locations rather than the animals themselves. If this were the case, then when the animals shifted locations, children may have pressed the locations that resulted in the song during the first session rather than the correct animal order, and thereby, produced an incorrect response. To assess the possibility that children utilized a location strategy, the number of times children, who responded with the incorrect song order, pressed the locations of the animals according to their first or second spatial arrangement (see Table 2.9) was counted. There were no significant differences when compared to chance (1/3).

Table 2.9. Number of trials (x) in which children, who selected the incorrect order, selected animals by location. N refers to the total number of incorrect trials

	3-year-olds		4-year-olds	
	Past	Future	Past	Future
x	12	13	3	8
N	27	28	9	19

Note: * $p < 0.01$ by Binomial Test (chance = 1/3)

I also considered whether children pressed the locations of animals from the first spatial arrangement versus the second. Examination of children's location selections revealed a recency effect for in the future condition, in which both 3- (x=12, N=28) and 4-year-old (x=8, N=19) children selected animals in the second arrangement significantly more than by chance (chance = 1/6, $p < 0.001$ by Binomial Test).

2.4 Discussion

In this chapter, differentiated memory search model is proposed to explain how individuals construct past and future events. Specifically, the model makes predictions based on the extent to which the memory search is defined. A more directed a memory search results in a better-constructed event. Further, the model has differential predictions based on the component being constructed: the items, the spatial locations, or the goals, and it is geared towards explaining the emergence of future thinking in children. The model is ideally suited to explore not only the development of future thinking ability, but also how understanding the development can inform researchers about the fundamental components of a future event construction process.

To test the predictions of the model, a novel paradigm in which children had to construct components of a previous experience, either by reflecting upon the past experience or using the past experience to plan for the future was developed. This paradigm was employed in an experiment that examined how children retrieve items (the animals), locations (their houses), and a goal (the song order) either during recollection or in order to build the task to play again tomorrow. In item recognition, results indicated that thinking about the future recruits familiarity processes, while thinking about the past recruits recollection processes. Evidence for this came from higher hit rates in the past condition, and higher false alarm rates in the future condition. For location recall, when there was only one correct choice (single location condition), the predictions were partially supported. Specifically, there was no difference between past and future in older children's ability to associate objects to their spatial locations. However, younger children showed a marginal difference. Finally, in song order recall, when visual-spatial information was provided (i.e., single location condition), participants were more accurate in their song order recall. This also corroborated the prediction that a directed memory search (in this case by the presence of visual-spatial information from the original experience) would relieve the open-ended memory search predicted during future event construction. Discussion proceeds by considering children's construction performance on each component in turn.

2.4.1 Item Recognition

The model predicted that familiarity processes would guide item recognition in the future condition, leading to a lower hit rate, while an accuracy-driven recollective search process directed toward a specific past event would lead to higher hit rates in the past condition. A signal detection analysis found greater discriminability between target and foil items in the past versus future conditions, for both age groups. Further, time was a strong predictor of item recognition. Planned comparisons found significant age differences in the past condition, but only a marginal difference in the future condition.

These results are in line with Yonelinas' (1999) dual-process model of familiarity and recollection processes in item recognition. Recruitment of familiarity processes may have led to the higher false alarm rates by both 3- and 4-year-old children in the future condition, while recruitment of recollection processes may have resulted in the age-related difference found in the past condition. That is, higher false alarm rates in the future condition may have been a result of children's difficulty in engaging in an explicit search process to *qualitatively* identify the target items from the past experience. Instead, reliance on familiarity processes based on *quantitative* memory strengths may have led to a higher rate of false alarms. In contrast, the higher hit rates in the past condition may have been a result of a search process to identify the target items from the specified past experience. It could be that verbal reference to the target event, as in the past condition, provided children with an anchor upon which a qualitative search process yielded more accurate results. When thinking about the future, this anchor was absent. Therefore, children may have had to rely on quantitative memory strengths, which would have been feebler in the future, where access to the past event was tenuous.

2.4.2 Location Recall

The differentiated search model predicts that because children have greater difficulty remembering object-to-spatial context associations (Lloyd, Doydum, & Newcombe, 2007; Sluzenski et al., 2004), there should be minimal differences between thinking about the past and future. However, due to differences in recollection abilities, there should be age-related differences. As predicted, in the single location condition, age was a significant predictor of location recall accuracy, while time was a marginally significant predictor. However, 3-year-olds children were marginally more accurate in the past than in the future condition, indicating a slightly more open-ended memory search in the future than in the past.

Another possible explanation for the marginal difference in 3-year-olds is that younger children may not have assumed that the animals stay in the same locations. However, this interpretation does not hold, as one would then expect children to have selected a new location not seen previously significantly more than by chance but this was not the case in the single or multiple location conditions. Taken together, these results suggest that deficits in recollection processes yield a developmental difference, as predicted, both in terms of general location recall abilities and in terms of a temporal distinction. More mature recollection processes in older children may have resulted in equal levels of demand in retrieval of object-to-spatial-context associations from the past and for the future.

2.4.3 Song Order Recall

The model predicted that visual-spatial context would act as a strong memory cue for retrieval of song order, both when thinking about the past and future. When the visual-spatial context at retrieval does not reflect a context previously experienced, there will be greater errors in retrieval of other contextual information, in this case, the song order. The model predicted more pronounced effects in the future than in the past. Results found that age, time, and condition differences in song order recall ability. Particularly, as predicted, when the spatial context did not reflect contexts previously seen (e.g., in the multiple location condition), children were overall less accurate in remembering the song order than when the spatial context reflected the original experience. This suggests that visual contexts act as a strong cue for contextual memory retrieval. In addition, in the multiple location condition, children were more accurate in selecting the correct order in the past than in the future suggesting that without visual cues, explicit reference to the past event increases accurate memory retrieval. This temporal difference did not hold in the single location condition where accuracies were generally higher.

In the multiple location condition, when children had to construct a future event, they were more likely to press the animals based on the locations they appeared in the second spatial configuration in session 1. This suggests two possibilities. One possibility is that when the animals shifted locations, children may not have encoded the contextualized order (based on memory for the animals), and instead, may have encoded the motor-spatial response that yielded the order in session 1. A second possibility is that children encoded both the motor-spatial response as well as the contextualized order, but a more effortful search would have retrieved the contextual order. This goes in line with research that suggests a strong role for visual-spatial contexts in memory retrieval (Addis et al., 2007; Eacott et al., 2005; Eacott & Norman, 2004; Okuda et al., 2003; Szpunar et al., 2007). When the stored visual-spatial context conflicts with that at test, as in the multiple location condition, a more effortful memory search for the contextual representation (song order) may have been avoided by relying upon a remembered or familiar motor-spatial response. Further research is required to disentangle these possibilities.

Maintaining a visual context not only had a benefit in memory for the song order, but it also facilitated memory for song order for 4-year-old children in the future condition. Children in this condition were at ceiling in specifying the correct song order. This may be evidence for a goal-directed benefit of goal-based contextual information.

Because the song order reflected a causal, future-directed sequence, thinking about the future might have provided older children with a boost in retrieval. That is, thinking about the future may, in itself, be a cue for goal-directed information from the past.

2.4.4 Conclusion

The differentiated memory search model provides an account for the role of memory in future event construction. Specifically, the model provides an explanation for how the basic, fundamental components of a scene are retrieved, and the differential search processes that underlie retrieval based on past or future event construction. While previous accounts have highlighted an important role of memory on future thinking ability (Atance & Sommerville, 2013; Buckner & Carroll, 2007; Hassabis & Maguire, 2007; Klein, Loftus, & Kihlstorm, 2002; Schacter, Addis, & Buckner, 2008; Spreng & Levine, 2006; Szpunar, 2010), these accounts do not provide a mechanistic account to explain how components are retrieved for recollection or future planning.

The results presented here provide evidence for three separate mechanisms for the retrieval of components for future thinking. This paper sought to disentangle the processes that underlie retrieval of memory components during past versus future event construction. When the past event in which the target memory components exist was salient to children, they were better able to retrieve and construct those components. However, without the exact memory indicated, children faced varying demands in memory for components required to construct the event.

During item recognition, a memory search for the correct item across multiple past events may have dropped children below an optimal threshold for recollection (Yonelinas, Aly, Wang, & Koen, 2010), and as a result, children may have recruited familiarity processes based on memory strength for target item representations. During location recall, a developmental difference was found such that retrieval of associations between objects and locations was more difficult for younger children due to recollection demands. Finally, during song order recall, visual context played a key role for contextual information retrieval. While specifying the spatial locations was difficult for younger children, all age groups were able to use highly contextualized (animals in houses seen before) information to retrieve the relevant goal-directed information. Further, thinking about the future may have a boost for goal-directed information from one's past in older children, suggesting an adaptive developmental trajectory of future thinking behavior during preschool years.

Further research is required to determine whether the differences in construction of individual components are influenced to a greater extent by encoding or retrieval processes. In addition, the extent to which semantic versus episodic content may impact the development of future event construction abilities should be assessed, as these two memory processes are representationally distinct according to the neuroimaging literature. Finally, it is possible that the future is more difficult than recollection of a past event because future event construction generally involves a greater memory search for target event items. Therefore, greater access to past memories at the retrieval stage may boost future event construction. The next chapter provides evidence for this notion.

3 Chapter 3: Access to the past facilitates future event construction

3.1 Introduction

In Chapter 2, the differentiated memory search model was introduced that described the nature of the search process that results when individuals construct past or future events. The model suggests that the primary distinction between past and future event construction is the nature of the memory search. When individuals imagine a single past event, they have direct access to the details of the past event. However, when individuals imagine a future event, they have only indirect access to the past details that inform the event; therefore, they employ a more open-ended memory search to identify the target memory representations. This open-ended memory search results in greater variability during future event construction. The experiment presented in the previous chapter found that when there were content cues at retrieval to direct the memory search to the target event details, children were more accurate in retrieving the relevant information. The outcome of this experiment suggests that memory search can be directed by factors at retrieval. However, to determine the precise factors, it is necessary to understand how the events are represented in the mind. In this chapter, it is proposed that events are clustered based on temporal and content units, and cues that direct the memory search to these units of the cluster can facilitate future event construction.

Researchers have argued that to generate a coherent past or future scene, individuals manipulate and bind together disparate details, including the objects, their spatial locations, as well as the goal and other contextual information (Hassabis & Maguire, 2007). During scene construction, relational processing mechanisms (Dusek & Eichenbaum, 1997; Eichenbaum, 2001) are recruited to maintain and bind discrete elements during the encoding of an experience. When engaging in future thinking, relational processing allows individuals to recruit distinct memory elements and bind them together to create a future event, or goal, or plan. The goal of this chapter is to understand the factors that may facilitate a more directed memory search to identify the relevant details from a past memory for future event construction. Differentiated memory search model suggests that when individuals construct a future event, the subsequent memory search for relevant components is open-ended because individuals are not directed to the exact past event within which the components exist. Subsequently, the process that identifies components and events is more taxing during future event construction than during past event construction where the search is directed to the target event. If this is the case, then easing the difficulty of the memory search for relevant past events and details should facilitate retrieval of the relevant distinct details for future event construction.

There is considerable evidence indicating that memory and future thinking are linked, both representationally and phenomenologically. Past research indicates a common core brain network that underlies memory and future thinking, and that the hippocampus plays a central role in manipulating and binding elements together for scene construction (Addis, Sacchetti, Ally, Budson, & Schacter, 2009; Addis, Wong, & Schacter, 2007; Hassabis, Kumaran, Vann, & Maguire, 2007). The strongest evidence that access to past memories is key for future event construction comes from research on patients with memory loss. In many studies, patients with bilateral hippocampal damage as well as damage to MTL regions showed deficits in access to episodic details from personal past experiences, as well as deficits in ability to imagine personal future events

(Hassabis et al., 2007a; Klein et al., 2002; Kwan et al., 2010; Maguire et al., 2006; McKenna & Gerhand, 2002; Rosenbaum et al., 2005). Many of these studies found that while patients were unable to imagine real future episodes, they were able to imagine hypothetical scenes. These results suggest a strong link between episodic memory (i.e., memory for personal experiences) and episodic future thinking (i.e., imagining real personal future events).

The underlying organization of future event construction has been investigated recently in autobiographical memory research as well (Arnold, McDermott, & Szpunar, 2011; Bernsten & Bohn, 2010; D'Argembeau & Van der Linden, 2004, 2006; Gamboz et al., Grysman, Prabhakar, Anglin, & Hudson, 2013, 2014; Spreng & Levine, 2006). In many studies, descriptions of personally relevant events (past or future) are used to cue memory for past events or future events. These studies have found that the generated events are usually causally or contextually related to the event cue (D'Argembeau & Demblon, 2012). Therefore, event generation may occur in clusters rather than as single episodic units. To understand the underlying structure of these clusters, Demblon & D'Argembeau (2014) asked participants to freely think of future events they may experience. They asked participants to rate these events based on whether they were connected along several dimensions, including causal or thematic, and found that participants generated future scenarios that followed a chronological order and had similar thematic content, suggesting that generating future events does not occur in isolation, but instead builds upon event clusters.

3.1.1 The differentiated memory search model and event clusters

The differentiated memory search to provides a developmental account of the underlying organization of future event construction as it emerges during early childhood that is consistent with findings from adult research (see Chapter 2). What is needed is research that explores the content of the underlying structures supporting the development of event construction. The present study examines the role that access to past memories plays in the development of future event construction. In particular, the proposed model builds upon the notion that events are generated in clusters and that access to details from event clusters may affect the processes by which past details are retrieved and manipulated for future event construction.

A recent account suggests events are clustered in representational space based on temporal contexts (Schapiro et al., 2013). The authors propose that components within events are clustered together based on temporal distance to one another. They provide a model wherein each aspects of an event have uniform transitional probabilities to its neighbors based on temporal proximity, thereby creating temporal community structures. The differentiated memory search model predicts a similar mechanism in the memory search for past and future event construction. Figure 3.1 shows a graphical depiction of a memory search model wherein the events are clustered by temporal proximity. In this model, temporally proximal events serve as anchors for memory searches and direct the model toward components that are relevant for future event construction.

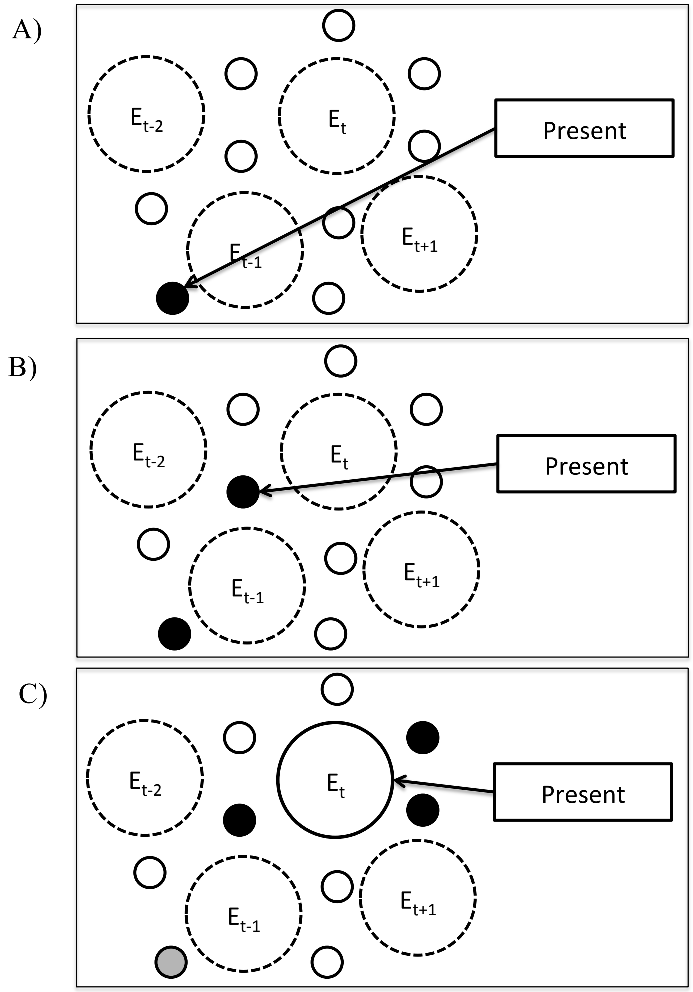

Figure 3.1. A graphical model of differentiated memory search through temporally clustered event communities. The events are part of a temporal cluster community with E_t as the target event that occurred at time t. The smaller circles indicate components of events, e.g., entities, spatial locations, and goals. The search proceeds by retrieving a neighboring event component (Panel A), then anchoring subsequent memory searches to that event component (Panel B) until a requisite number of components are retrieved to construct a future event (Panel C).

Neuroimaging literature suggests that item representations (the *what*) and contextual information (the *when* and *where*) are represented by different neural areas; specifically, item representations are subserved by the perirhinal cortex (PRc) and contextual representations are subserved by the parahippocampal cortex (PHc) each of which receive inputs from different areas in the brain (Diana, Yonelinas, & Ranganath, 2007; Eichenbaum, Yonelinas, & Ranganath, 2007; Ranganath, 2010; Suzuki and Amaral, 1994; Squire & Cave, 1991). Following this notion, the connection between units within a temporal cluster may be content-specific. That is, because item and contextual representations reflect two distinct neural processes, the event clusters may be specified by content attributes (e.g., items, spatial locations, or goal contexts) as well as temporal attributes. Therefore, the model predicts not only that access to temporally connected event information can facilitate a more directed memory search to identify components relevant for future event construction, but further, that this facilitation is domain-specific based on the modality of the component (items, spatial locations, or goal context).

To test the prediction, children were asked to recall details of a past event that was temporally connected to the target past event. The model predicted that retrieval of elements from one event would increase the likelihood that the memory search will identify the components of the temporally connected target event. In addition, it predicted that the content of the recall (items, spatial locations or goals) would result in a greater boost in retrieval of that component during future event construction.

3.1.2 A paradigm to facilitate a directed memory search

The design used was similar to that presented in Chapter 2; children were shown a song game that contained three animals in three separate houses. The children were shown that to play a song, they must press the animals in a particular 3-step order. They were taught to play the song with the animals in two different sets of spatial locations, and then were urged to imitate. In addition to this event, children were also shown a separate event, either immediately before or immediately after the song game. They were shown how to feed three different animals vegetables that were retrieved from three distinct containers. Each animal was fed one food item from one container, thereby establishing a one-to-one mapping between food item and container. Children were allowed to feed each animal after the demonstration in order to test acquisition of the association between each food item and each container. After a 10-minute delay, some children were asked to recall which food item was in each container from the previous experience, and then were asked "to plan to play the song game tomorrow" by selecting the animals, locations, and song order (prime condition). The other half of the children was given these tasks in the opposite order (no-prime condition). This design allowed us to determine whether the recall of a temporally connected event facilitated memory for the target event.

Because cognitive flexibility, the ability to flexibly switch between alternate representations, may influence future planning ability, the study included an independent measure of cognitive flexibility to test for its effect on performance on the future event construction task. The memory search required to identify the target information requires searching through multiple memory representations so it is conceivable that cognitive flexibility might play a role in navigating the temporal community structure. Further, in this study, variance contributed by verbal ability was also controlled for in order to determine whether the effects of age and prime on future thinking ability are language-dependent.

3.1.3 Predictions

It was predicted that higher accuracy rates would be found in the prime condition as this would result in a directed memory search to temporally connected information.

However, the modality of the content being recalled or retrieved for future planning (e.g., items, spatial locations, or goals) may have the greatest benefit. Therefore, because children were asked to recall objects from the temporally connected event, children should show greater cue benefits when retrieving objects from the target event than spatial locations and goals, which were not cued in the priming recall task.

3.2 Method

3.2.1 Participants

Thirty 3-year-olds (mean age 44 months; 16 females) & thirty 4-year-olds (mean age 53 months; 14 females) participated in this study. One additional 3-year-old was excluded from the study because this individual did not complete the full experiment. Children were recruited from preschools in the Central New Jersey area, and were from predominately white, middle-class backgrounds. Parents provided written consent for their children to participate, and verbal assent was obtained from children prior to participation. All children received a sticker for participation in the study.

3.2.2 Materials

A 7” Google Nexus Tablet was used to expose children to both the animal feeding and song animal game. The subsequent recall tasks and future planning tasks were all conducted on the tablet as well. The applications were programmed using MIT’s App Inventor tool. All experimental sessions were hand recorded as well as video recorded. Fidelity of the data was verified using the video record.

A verbal comprehension task was administered using materials obtained from the WPPSI-IV package and laminated cards created by our lab were used to administer the Dimensional Change Card Sort (DCCS) task that measured cognitive flexibility. These tasks were not administered on a touchscreen tablet.

3.2.3 Procedure

The experiment was divided into three phases. In the first phase, children were shown two different games, an animal feeding game and a song game, the order of which was counterbalanced between subjects. They were shown a song game and an animal feeding game. In the second phase, the WPPSI-IV was administered. In the third phase, children were asked to recall information from the animal feeding game and to set up the song game to play it the next day. After completing these tasks, the DCCS task was administered.

3.2.3.1 Phase 1: Game demonstration

Animal feeding game. In the animal feeding game, children were shown three containers, and were shown how to feed 3 animals a distinct food item from each container (Figure 3.2). Each container held one distinct food item, and each animal was fed a different item. Therefore, there was a one-to-one mapping between animal and food item, as well as food item and container. The experimenter demonstrated how to feed each animal by saying “Here is a goat. The goat loves to eat apples. You get apples from the pail.” The experimenter touched the picture of the pail on the screen, and an apple appeared directly beneath it. The apple was then moved to the animal. After the child was shown how to feed all three animals one by one, they were allowed to feed each animal in turn to demonstrate they learned the one-to-one mapping between food item and container. The experimenter said, “Here is a goat. Can you feed the goat an apple?” The child was expected to retrieve the apple from the container by pressing it. All children were able to correctly identify the container in which each food item should be retrieved when immediately tested.

Figure 3.2. In the animal feeding game, on each trial, 3 containers were shown in a row. On each trial, one of the containers was pressed to reveal a food item, which was fed to the animal. Each container contained a distinct food item that fed one of three animals shown.

Song game. The song game was similar to the multiple location condition presented in the previous chapter wherein animals were shown in two different spatial locations (Figure 3.3, Panel A). Similar to the previous experiment, children were shown how to play the 3-step song after each of two demonstrations, between which the animals switched houses, and then were given 3 attempts to correctly imitate the song. All children passed.

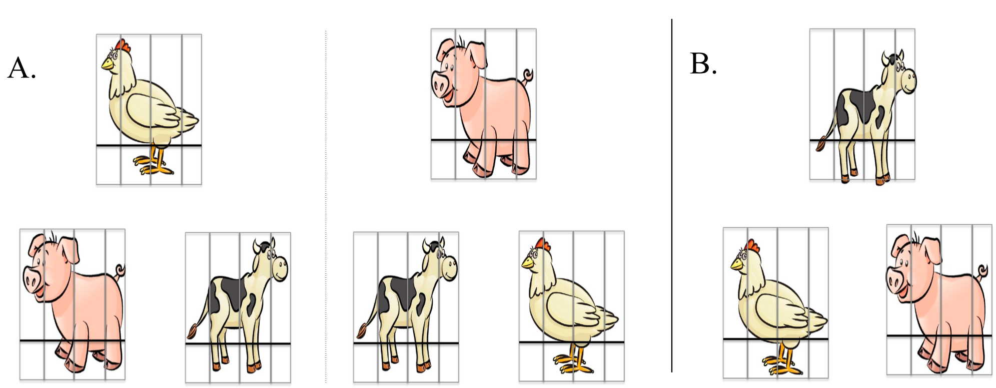

Figure 3.3. In the first session of the song game (A), children were shown animals in two

different spatial locations. In the song order recall task (B), children were shown animals in spatial locations not seen in A.

3.2.3.2 Phase 2: Administration of the WPPSI-IV

After the two games were shown to children, the touchscreen tablet was removed from view and children experienced a 10-minute delay during which they were given a task to measure verbal intelligence. The verbal comprehension subtest of the WPPSI-IV (Wechsler, 2012) included a battery of two subtests matched and standardized for each age group (3-year-olds and 4-year-olds). Three-year-olds were given a receptive vocabulary task that asks children to select a picture that represents a word read aloud by the experimenter (e.g., *Show me the butterfly*), as well as an information task that measures children's general knowledge about the world (e.g., *What color is most dirt?*). Four-year-old children were given the information task mentioned previously, as well as a similarities task that measures children's verbal concept formation and reasoning by having children describe how two words (e.g., *Mother* and *Sister*) are similar. These tasks were coded according to the manual provided by the WPPSI-IV scoring guide, and scores were standardized based on the age of each participant.

3.2.3.3 Phase 3: Recall and Future Event Construction

After the 10-minute delay, half of the children were asked to recall the food-container associations from the animal feeding game before planning to play the song in the future (Prime condition), while the other half of the children was asked to plan to play the song in the future before recalling the food-container associations (No-Prime condition).

Food-container recall task. In this task, children were asked to recall which food item was obtained from each container. Therefore, this task involved three trials wherein the tablet on which the event was experienced was out of view of the children. This was done to ensure that children had to engage in a memory search to identify the correct container without any visual memory cues. A correct response was given 1 point, and an incorrect response was coded given 0 points.

Planning for the future task. This task consisted of 3 subtasks, similar to those given in the previous chapter. Children were first given an item recognition task. In this task, children were given three trials. On each trial, children were asked to select between two animals (one target and one foil) the one they will need to play the song tomorrow (Figure 3.4). A correct response was given 1 point, and an incorrect response was given 0 points.

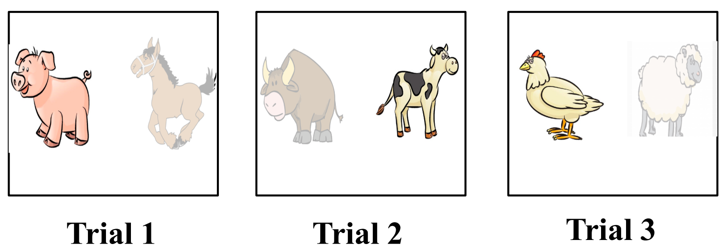

Figure 3.4. In the Item Recognition Task, children were asked, on each of three trials, to select the animal they will need to play song tomorrow.

Next, in the location recall task, children were asked to place each of the three target animals (i.e., from the previous experience), whether the subject correctly selected it or not in the item recognition task, in the location it should be in order to play the song tomorrow (Figure 3.5). This task was scored such that placing an animal in the location from demonstrations 1 or 2 was given 1 point, and a location not previously seen was given 0 points.

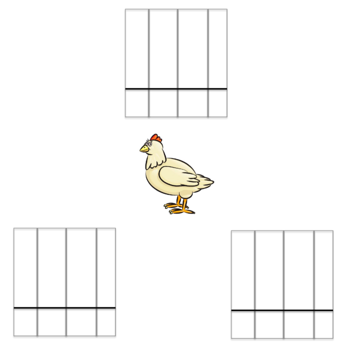

Figure 3.5. In the Location Recall Task, on each of three trials, children were shown 3 empty houses and asked to place the animal where it should be to play song tomorrow.

Finally, in the song order recall task, children were shown the animals in new locations not previously seen in demonstrations one or two, and asked to show the experimenter how they will play the song tomorrow (Figure 3.3, Panel B). Children were asked to respond three times, even if they responded correctly in the first or second attempt. A correct response was given 1 point and an incorrect response was given 0 points.

Dimensional Change Card Sort task. The DCCS task to measure cognitive flexibility (Zelazo, 2006) was administered at the end of both sessions of the future thinking game (i.e., after the food-container recall and planning for the future tasks). In the DCCS, children were asked to sort two sets of 10 cards based on two different dimensions: shape and color. Children sorted cards twice: first during a practice session and second during the experimental session. During the practice trials, children were asked to sort first by one dimension (color or shape) and then by the other. The order of the dimension was counterbalanced between-subjects and children were given 4 randomly selected cards for each dimension. For example, some children were shown green bunny cards and white boat cards, and asked to sort them into piles labeled with a white bunny or a green boat based on either matching colors or shapes. The experimenter pointed to each pile to indicate where children should sort each type of card. Within the 4 practice trials for each dimension, children were given 2 cards of each color or shape. In the practice trials, if children were incorrect, they were immediately corrected. If children did not sort more than 2 cards in a row correctly, they were excluded. However, no child failed the practice trials in this way.

After the practice trials, children were shown a new set of target cards (e.g., a yellow ball and a blue truck) which they were to sort into two different piles (e.g., with a blue ball and a yellow truck). In this experimental phase, children were first asked to sort based on the dimension last sorted in the practice trials. The children were asked to sort 5 random cards into the appropriate piles. The experimenter did not correct children during the experimental phase of the DCCS. After children sorted by the first dimension, they were asked to sort based on the other. Again, children were given 5 random cards to sort. Each set of 5 cards were randomly ordered such that they were not given the same card more than 2 times in a row. Children's responses to the second sort were recorded as pass (4 or 5 correct sorts) or fail (3 or fewer correct sorts). A pass score was given 1 point, and a fail score was given 0 points. Only the second experimental sort was scored since this allowed experimenters to measure children's ability to flexibly switch to a new sorting rule (from color to shape as in the examples earlier).

3.3 Results

3.3.1 Design and Coding.

A series of mixed effects logistic regressions controlling for verbal ability were run with Age (3 or 4) and Prime (prime or no-prime) as predictors of item recognition, location recall and song order recall accuracy. In addition to these regression models, to determine the extent to which cognitive flexibility influences future planning ability, a series of stepwise logistic regressions were computed. Planned comparisons were conducted using Mann-Whitney tests.

3.3.2 Food-to-Container Recall Results.

In this task, children were asked to recall the container that contained the three food items that were shown in session 1. Table 3.1 shows the mean accuracy in reporting the correct container by age and prime conditions.

Table 3.1. Mean accuracy in food-container recall by age and prime conditions.

	Prime	No Prime
3	0.36	0.44
4	0.53	0.60

A logistic regression with age and prime as predictors of food-container recall accuracy (*Nagelkerke* $R^2 = 0.26$) found that only age was a significant predictor of food-container recall, $\beta = 0.68$, $p < 0.05$, while prime was not a significant predictor, $\beta = 0.32$, $p = 0.29$. This indicates a developmental difference in recall performance that is not affected by when in the experimental session (i.e., before or after future planning) the recall task was given.

3.3.3 Future Planning Task Results

3.3.3.1 Item Recognition Task Results.

In this task, 3- and 4-year-old children were asked to select between two animals the one that they will need to play the song tomorrow. Half of the children were cued with recall of the animal feeding game, while the other half were not. A correct recognition of the animal needed to play song tomorrow was awarded 1 point, while an incorrect recognition (or a false alarm) was given 0 points. A signal detection analysis was conducted to compare discriminability (*d'*) scores between target and foil animal items in the prime and age conditions.

Table 3.2. Item Recognition Task: Mean d' scores, Proportion of Hits and Proportion of False Alarm Rates

	3-year-olds		4-year-olds	
	M	*SE*	*M*	*SE*
Prime				
d'	0.51	0.002	2.25	0.003
Hits	0.64	0.12	0.86	0.05
False Alarms	0.36	0.12	0.04	0.05
No-Prime				
d'	-0.12	0.002	0.85	0.002
Hits	0.47	0.13	0.73	0.12
False Alarms	0.53	0.13	0.27	0.12

Table 3.2 shows the mean d' scores, as well as mean hits and false alarm rates. The results of the signal detection analysis indicates that, as predicted, children 4-year-old children showed the overall largest discriminability between target and foil in the prime condition, and both age groups had higher discriminability scores in the prime than no-prime conditions.

A mixed effects logistic regression controlling for differences in verbal ability was conducted with age and prime as predictors of item recognition accuracy. The model (Table 3.3) after controlling for verbal ability, found that age was a significant predictor of item recognition, and prime was a marginally significant predictor of item recognition. Planned comparisons found a marginal difference between 3-year-olds ability to correctly recognize the animal in the prime condition ($M = 0.64$) versus no-prime condition ($M = 0.47$), $z = 1.69$, $p = 0.09$, $r = 0.18$. This difference between prime ($M = 0.96$) and no-prime ($M = 0.73$) was significant in 4-year-olds, $z = 2.89$, $p < 0.01$, $r = 0.30$.

Table 3.3. Mixed Effects Logistic Regression controlling for verbal ability with age and time as predictors of item recognition.

	β	*SE* β	*z*	*p*
Age	1.60	0.68	2.36	0.02*
Prime	1.04	0.57	1.83	0.07
Age x Prime	1.32	1.03	1.28	0.20
AIC: 195.00				
BIC: 210.90				
Nagelkerke R^2: 0.83				

Note: *$p < 0.05$

3.3.3.2 Location Recall Task Results.

Accuracy in placing the animals in the correct location was determined based on whether children placed the animal in the location in which it was seen in demonstration 1 or demonstration 2 (1 point) or in a location not previously seen (0 points). In the location recall task, children could have placed animals in the same location across multiple trials since on each trial they were able to place animals in any one of the 3 locations. (See Appendix A for a detailed analysis of this behavior).

Table 3.4 shows the mean accuracies by age and prime. A mixed effects logistic regression controlling for verbal ability was conducted with age and prime as predictors of location recall accuracy (see Table 3.5). This model yielded no significant predictors of location recall accuracy.

Table 3.4. Average accuracy in placing animals in location seen previously.

	3-year-olds	4-year-olds
Prime	0.64	0.87
No Prime	0.79	0.71

Planned comparisons found a significant age difference between 3-year-old (*M* = 0.64) and 4-year-old (*M* = 0.87) children's ability to select the correct location when first primed with the recall task, $z = 2.44$, $p < 0.05$, $r = 0.26$. This difference was not found when 3- and 4-year-old children were not primed with the recall task before future planning, $z = 0.23$, $p = 0.82$. Within each age group, 4-year-olds showed a marginally significant difference between selecting the correct location in the prime ($M = 0.87$) and no prime conditions ($M = 0.71$), $z = 1.80$, $p = 0.07$, $r = 0.19$. This difference was not significant with the younger age group, $z = 0.44$, $p = 0.66$. These results indicate developmental differences in children's location recall ability that was mediated by the presence of a prime. That is, while no overall prime differences were found, its presence seems to benefit 4-year-olds more so than 3-year-olds.

Table 3.5. Mixed Model Regression controlling for verbal ability with age and time as predictors of location recall.

	B	SE β	*z*	*p*
Age	0.23	0.56	0.40	0.69
Prime	0.24	0.50	0.48	0.63
Age x Prime	1.30	0.79	1.66	0.10
AIC: 212.70				
BIC: 228.60				
Nagelkerke R^2: 0.33				

In order to determine whether there were any systematic patterns in children's location choices, counts were made of the number of children who placed the animal in the location it was seen in the first demonstration, location seen in the second demonstration, or in the third location in which it was not previously seen (see Table 3.6). Results were compared to chance (1/3) using a series of Binomial tests. When primed, 3-year-old children placed animals in the second location in which they were previously seen significantly more often than by chance, $x = 22$, $N = 45$, $p < 0.05$, and in the first location significantly less often than by chance, $x = 7$, $N = 45$, $p < 0.05$. In contrast, 4-year-old children placed animals in the first location previously seen significantly more often than by chance, $x = 25$, $N = 45$, $p < 0.05$ and the third, not previously seen location, significantly less often than by chance, $x = 6$, $N = 45$, $p < 0.05$. Overall, 4-year-old children placed animals into one of the two previous locations (chance = 2/3) significantly more often than by chance in the prime condition, $x = 40$, $N = 45$, $p < 0.05$. When children were not primed, 3-year-olds were no different from chance in placing animals in the first, second, or third locations. However, 4-year-olds placed animals in the location it was first seen significantly less than by chance (chance = 1/3), $x = 8$, $N = 45$, $p < 0.05$, but were at chance in selecting the second or third locations. These results indicate that with the prime, both 3- and 4-year-old children were more likely to place an animal in a previous location.

Table 3.6. Number of trials in which children placed animal in first location it was seen, second location it was seen, and third location yet to be seen.

	3-year-olds		4-year-olds	
Trial	Prime	No Prime	Prime	No Prime
First	7	14	25	8
Second	22	17	15	21
Third	16	14	6	16

3.3.3.3 Song Order Task Results.

In this task, the animals appeared in new locations not previously seen and children were asked to show the experimenter how they would play the song tomorrow. They were awarded 1 point on each of 3 trials if they selected the correct 3-step order to play the song, or 0 points if they selected an incorrect order. Figure 3.6 provides the mean recall accuracies for 3- and 4-year-old children in the prime and no-prime conditions. This figure indicates a slight boost in order recall accuracy when children were first primed.

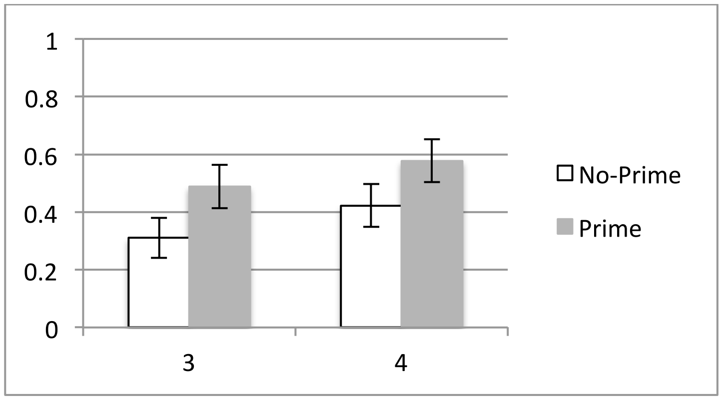

Figure 3.6. Order Memory Recall: Proportion of Correct Song Order Selections by Age and Prime conditions. Error bars show standard error.

A mixed effects logistic regression that partialed out verbal ability with age and prime as predictors of song order recall was conducted (see Table 3.7).

Table 3.7. Binomial Mixed Model Regression partialling out verbal ability with age and prime as predictors of song order recall.

	β	$SE\ \beta$	z	p
Age	0.32	0.61	0.52	0.60
Prime	0.76	0.54	1.42	0.16
Age x Prime	0.19	0.78	0.25	0.81
AIC: 245.70				
BIC: 261.60				
Nagelkerke R^2: 0.45				

The model yielded no significant predictors of song order recall when the variance contributed by verbal ability was removed. However, a planned comparison found a significant overall difference between prime (M = 0.53) and no-prime (M = 0.37), $z = 2.24$, $p < 0.05$, $r = 0.17$.

Post-hoc analyses. One possible strategy children could have employed was to select the song order based on the locations in which they appeared in the first or second demonstration rather than by the animal order. That is, children may have remembered the motor-spatial movements that led to the song in the first and second demonstration, rather than the sequence of animals that resulted in the song. If this were the case, then they would have selected an incorrect order not by pressing a random 3-step order but by repeating the 3-step motor-spatial movement that led to the song in the first session. Therefore, subjects who responded incorrectly *and* repeated the motor-spatial movements from the first session (see Table 3.8) were counted. Only three-year-old children in the no-prime condition selected the animal by location significantly more than by chance, $p < 0.05$.

Table 3.8. Number of trials (x) in which children, who selected the incorrect order, selected animals by locations according to the 1st demonstration, 2nd demonstration or in either demonstration. N refers to the total number of incorrect trials.

	3-year-olds		4-year-olds	
	Prime	No Prime	Prime	No Prime
1st demonstration	1	9	3	4
2nd demonstration	5	8	2	8
Either demonstration	6	17	5	12
N	23	31	19	26

3.3.3.4 Effect of Cognitive Flexibility on Future Planning.

Analyses examined the relative contribution of cognitive flexibility (CF) in addition to effects of age and prime condition, in each future thinking task. An initial exploration children's overall performance on the DCCS found age-related differences between 3- ($M = 0.57$) and 4-year-old ($M = 0.80$) children, $z = 3.36$, $p < 0.001$, $r = 0.25$, but no differences between the prime ($M = 0.63$) and no prime ($M = 0.73$) conditions ($z = 1.44$, $p = 0.15$), indicating no differences in performance based on condition assignment, only on developmental differences.

A series of stepwise mixed effects logistic regressions were conducted to determine the incremental influence of each factor on item recognition, location recall, and order recall. For all tasks, the stepwise regression models partialed out verbal ability in order to determine the incremental contribution of each factor in the following order: age, prime, age x prime, and cognitive flexibility. (Appendix B provides the Chi-Square test comparisons between each incremental stepwise model).

In the item recognition task, the Chi-Square comparisons found that the most informative model was one that included both age and prime condition as independent predictors of item recognition and also indicated that cognitive flexibility did not explain much of the variance.

In the location recall task, the best model based on the AIC and BIC was the first with age as the sole predictor of location recall accuracy. However, all four models did not yield any significant predictors, and yielded AIC and BIC values similar to the original model (Table 5). Therefore cognitive flexibility did not explain any additional variance in location accuracy recall.

In the song order recall task, the best model included age and prime as independent predictors. This model resulted in a Nagelkerke R^2 of 0.45, and prime as a significant predictor of order recall, $\beta = 0.85$, $p < 0.05$. However, the full model resulted in cognitive flexibility as a marginal predictor of order recall, $z = 0.70$, $p = 0.10$. A planned comparison found a difference between children's song order recall when they failed the cognitive flexibility task ($M = 0.35$) and when they passed the cognitive flexibility ($M = 0.50$), $z = 1.81$, $p < 0.07$, $r = 0.14$.

3.4 Discussion

In this chapter, the differentiated memory search model was extended to include the notion that events are clustered in a temporally connected network and activation of events nearby to the target event can direct the memory search process to the relevant information required for future event construction. The account furthers understanding of the precise mechanisms that underlie future event construction, as well as the nature of the representations that support event construction in general. To determine whether events are clustered temporally and whether content-specific units drive the memory search between units within the cluster, a new paradigm was developed that directly compared future event construction either before or after recall of items from a past event that was in temporal proximity to the target past event. If events are clustered in temporally connected content-specific networks, retrieval of the temporally proximal event should direct the memory search to retrieval of the target event and further, selective retrieval of target items during future event construction. The results also corroborate these hypotheses: children's future planning performance improved with the presence of the recall prime and item recognition showed the greatest improvements in performance. However, these results were only evident in older, but not younger, children.

In the item recognition task, children were asked to select the animal they will need to play the song tomorrow. To do this, they had to remember which animal they had seen when they previously played the song in order to correctly recognize the target animal required to play the song tomorrow. Although the presence of a prime was only a marginal predictor of item recognition, this marginal difference was driven by a large effect of the prime in the older children and marginal difference in younger children. This indicates that for older children, recalling items from a temporally connected past event helps memory of items for the future experience. One possibility for the age difference may be that older children are better able to extrapolate from the recall event to the temporally connected target event. In the previous chapter, it was suggested that when access to the past information is tenuous, then familiarity processes over recollection processes are recruited, leading to a higher false alarm rate in item recognition during future thinking. The results from this study indicate that with development of episodic memory processes, children are able to engage in a more directed memory search when the target event is anchored by a temporally connected event.

The effect of a recall prime was not as evident during location recall. However, there seem to be some discernable patterns to children's specific location choices. When children were not primed, both younger and older children were at chance in selecting a location previously seen. However, when they were primed, children in both age groups chose either the first location or second location in which the animal was previously seen significantly more than by chance. Thus, the prime may have had an effect on location choices such that children were more likely to place animals in a location previously seen.

There were no effects of cognitive flexibility on item recognition and location recall, which may not be altogether too surprising. The tasks used in this study required children to retrieve elements from a specific past episode. Cognitive flexibility may have been employed if the retrieval process required shifting through and flexibly manipulating multiple representations. However, this was not the case for items and locations. For items, even though children were shown animals in the temporally proximal event (animal feeding game) and in the target event (song game), in the item recognition task children had to make a choice only between the target animal and a novel animal. Therefore, the animals from the feeding game did not compete with the animals in the item recognition task. In the location task, while each animal was shown in two different locations in the original experience, children were not required to remember one specific location. As a result, they did not have to shift between the two spatial representations to recall the correct information. Further, there were increases in item recognition and to some extent, location recall, when the past event was anchored by a recall prime, which indicates that construction of items and spatial locations, individually, may rely greater on effortful memory searches rather than cognitive flexibility.

For song order recall, our data are mixed: the regression revealed that prime was not a significant predictor while the planned comparison yielded significant differences between the prime and no-prime conditions. Additional data would adjudicate the effect of prime, but in the absence of such data, we conclude that the data yielded an unreliable pattern of results that was nevertheless consistent with an effect of prime on song order accuracy. Our results for song order recall also indicate a marginal effect of cognitive flexibility. In this task, the items were presented bound to specific contexts. However, children had experienced two different item-to-context representations in the original event (i.e., in the first and then in the second demonstration). To play the song correctly in the future planning phase, children would have to separate the retrieved bound units (animal-to-location from the original experience) from the conflicting visual presentation at test (animal in new locations) in order to determine the correct animal order alone. To this end, multiple memory representations would need to be maintained and manipulated to extract the contextual information (i.e., song order). Therefore, it seems that success in this task may have required greater cognitive flexibility than the other tasks. Future research should directly explore the role of cognitive flexibility on tasks that recruit greater relational processing mechanisms. Further, our results indicate that the prime may help direct a memory search to contextual information (i.e., song order) when the visual spatial context does not reflect the original experience.

As predicted, item recognition showed the largest boost in the prime condition in older children. That is, the inclusion of a prime seemed to have the largest impact on item recognition. This result suggests that the temporally connected clusters are content-specific. According to Eichenbaum et al.'s (2007) Binding of Items and Contexts (BIC) model, memory representations are functionally split between subregions of the MTL such that they differ based on the information content that they process (i.e., items, spatial locations, contextual information). In line with this model, the results indicate that a prime based on retrieval of particular information content type (in this case, food items) selectively directs individuals not just to a temporally connected event, but a temporally connected content-specific representation (in this case, animal items). Further, our results also indicate that recall of temporally connected item content-type may not only facilitate retrieval of items during future event construction, but may also facilitate retrieval of contextual representations related to the items (i.e., the animal order to play the song). Therefore, the results of this study suggest that while events may be clustered in temporal context units, retrieval of adjacent units may be mediated by content-type. This notion adheres to Demblon & D'Argembeau's (2014) findings that the generation of multiple future events follows chronological order and share thematic content. Future research will need to distinguish between the role of temporal and content cues. One possibility is to vary temporal distance of the event cue to determine whether events experienced in the near past will result in greater facilitation than events experienced in the distant past. A second possible future direction is to present recall cues based on other content types (spatial locations or goals) in order to determine whether both temporal and content-based cues are required for a more targeted memory search during future event construction.

Another interesting distinction is to consider episodic versus semantic content. In this experiment, the prime was a recall task that relied more on episodic memory processes. However, a semantic prime (e.g., talking about what kinds of things one encounters on a farm) may have varying implications on memory retrieval for future event construction. The PRc has been implicated in the formation of representations with semantic content (Taylor et al., 2006). If this were the case, primes that involve semantic representations may facilitate memory search for item representations if the two are subserved by the PRc, and in contrast, primes that focus on item-to-context representations may facilitate both item recognition and memory for contexts (such as spatial locations and goals). This hypothesis should be tested in subsequent studies.

Verbal ability did not appear to play a large role in future planning in 3- and 4-year-old children since the inclusion or exclusion of the variance contributed by language did not influence whether age or prime were significant predictors. Past research indicates emerging future thinking behavior even after differences in language ability have been controlled (Hayne et al., 2011). Further, the task used in this investigation imposed minimal language demands by presenting the experiment on a touchscreen tablet, which provided a hands-on task as well as non-verbal visual cues for children to complete the task. This study, therefore, also provides a strong argument for the use of touchscreen methodologies in studying development as it may offer opportunities for non-verbal paradigms.

Overall, this study provides support to the differentiated memory search model presented in the previous chapter, suggesting that variations in the memory search distinguish between past and future event construction, and specifically, the memory search can be narrowed when individuals have a unit within an event cluster upon which to anchor the search. Further, the results of this study suggest that events may be clustered together in a temporally bound unit that is content-specific.

4 Chapter 4: General Discussion

4.1 The differentiated memory search model

In this dissertation, I introduced the differentiated memory search model, which highlights the critical role of memory in future event construction. To date, there is no account of the precise process by which components of a past event are retrieved specifically for future event construction purposes. The model provides a basic framework to determine the core factors that are involved in future event construction, particularly during development.

First, the model suggests that events are clustered in temporal, content-based units such that individual mental representations within this structure are connected both by temporal proximity and by content type (i.e., objects, spatial locations, temporal information, etc.). Therefore, the model predicts that neighboring units of the same content type that are also temporally proximal activate units within this cluster. For example, item A learned in temporal proximity to item B will have greater likelihood of cueing retrieval of item B than cueing retrieval of spatial location C, even if spatial location C occurred in temporal proximity to item A (see Figure 4.1). Figure 4.1 presents a slightly modified model from that presented in Chapter 3. In the model presented here, the content units (the individual circles) are differentiated by their outlined color (red or green). The activated unit (a green one) selectively activates like units that are in temporal proximity to it, thereby arriving at the final, fully constructed event.

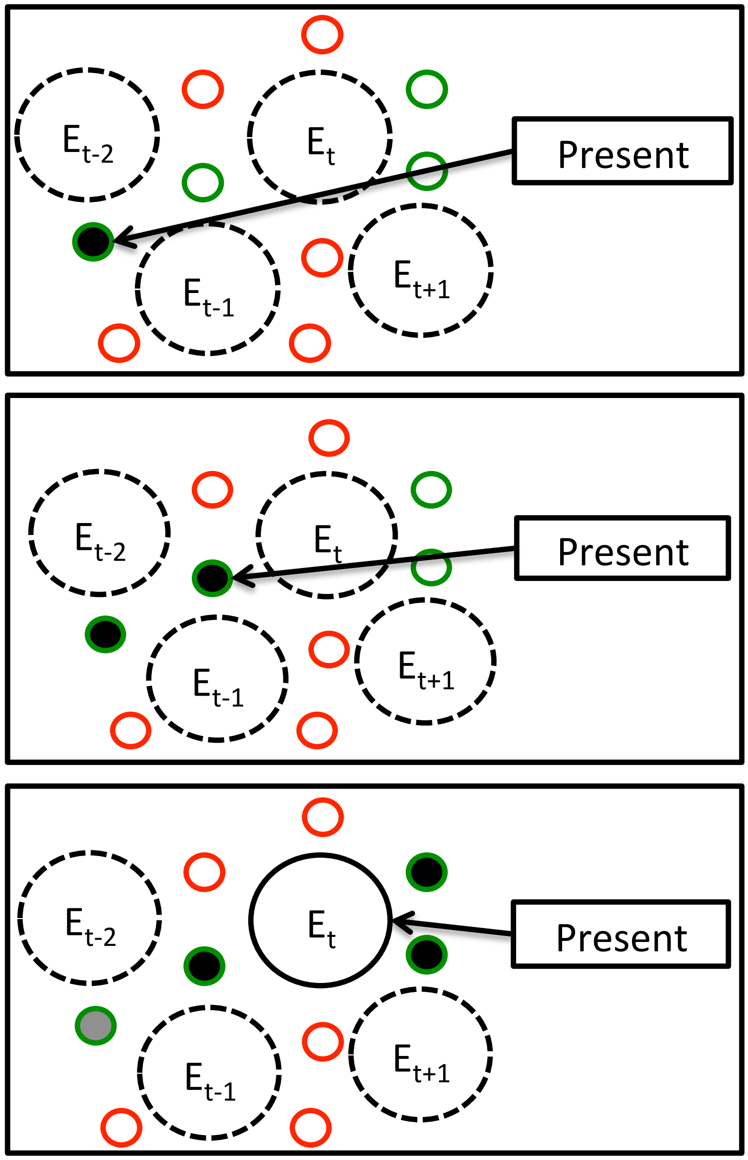

Figure 4.1. This figure depicts the differentiated memory search model accounting for both the temporal and content-specific structure that it predicts. The model is similar to that presented in Chapter 3. However, in this model, the colored circles indicate different content units such that activation of a unit of one type selectively activates units of similar types, thereby leading to all relevant components of the final event, E_t.

The differentiated memory search model also makes clear predictions about the distinction between past versus future event construction. In particular, the model presented in this dissertation focuses on memory retrieval of components from a single, novel past event. With a single, novel event, there are no competing memory representations for retrieval of information from this past event, and minimal reference to items of the past event ("Can you help me get the song together just like when you played the song before?") narrows the search easily to the relevant past information. However, without this reference, the memory search requires some input to narrow its search and a more open-ended memory search would occur, thereby resulting in greater errors in event construction.

The results of the two studies presented in this dissertation provide support for the differentiated memory search model. In the item recognition task, in both Chapters 2 and 3, children were more accurate when asked to recognize an animal they saw before versus an animal they need for tomorrow. Mechanistically, these results suggest that thinking about the past recruits greater recollection processes that are able to flexibly direct search processes toward targeted past events. This seems to be in place in children as young as 3.

In location recall, children's performance was more affected by general age-related memory differences than time or access to a past memory. Support for these results comes from several lines of research. First, past research indicates that spatial contexts are an integral part of scene construction and explain much of the similarities in neural activation between these two processes (Davachi, 2006; Hassabis & Maguire, 2007; Szpunar & McDermott, 2008). Second, developmental research suggests that bound contexts (i.e., items bound to their spatial locations) are difficult for children to recall (Lloyd et al., 2009). Therefore, corroborating these lines of evidence, the results indicate that spatial content elicits similar search processes during past and future event construction, and that age-related differences in the recall process predict performance.

Finally, for song order recall, the results provided strong evidence for the role of visual-spatial contexts in retrieving goal information. In Chapter 2, when children were shown animals in the same spatial locations as from the original experience, they were able to select the song order with higher accuracy than when the animals were in other locations not previously seen. These results could not be explained by a learned motor-spatial response (e.g., "press left animal then top animal then bottom animal to play the song"). Instead, the visual-spatial context may provide children with a directed memory search to the goal content of the past experience. In Chapter 3, the data indicated an effect of prime based on the results of the planned comparison, suggesting that the item based recall task facilitated the memory search for items during future event construction as well as contextual representations related to items. It was also the case that cognitive flexibility explained some of the variance in performance in this task. Because the animals were shown in different locations not previously seen, children would have had to shift between their retrieved representation and the conflicting one at test. It should be noted that the effect of cognitive flexibility was marginal, and further investigation of the direct effects of cognitive flexibility should be pursued.

One limitation of the studies presented here is that the two possible location choices in the multiple location condition could have provided confusion for the children in the location recall task. In fact, when looking at their location choices in Chapter 2, there were no discernable patterns of choices between the three possible location choices when children were thinking about the past or future. In this context, they may have been confused as to which location the animal actually belongs. However, when they were directed to the past event in the prime condition in Chapter 3, this confusion may have been eased with a more targeted memory search. In future explorations, it would be wise to design the location task as a location recognition task similar to some past research (Lloyd et al., 2009; Sluzenski et al., 2006) as this would allow us to determine precisely what part of the past event (the locations from the first or second demonstration) children were using to make their judgment.

A final point worth noting is that in Chapter 3, the effect of the recall prime was most evident in older children. This could reflect more general improvements in recall abilities and search abilities in 4-year-olds versus 3-year-olds, particularly since 3-year-old children's performance was trending in the right direction. The recall prime did not involve an explicit mention of the past event. Therefore, it could be the case that younger children had greater difficulty tapping into the representational cluster and identify the temporally connected relevant element.

4.2 General conclusions and future directions

This dissertation provides critical evidence for the role of memory processes in future event construction, and further, suggests that these memory processes are precursors to future thinking ability during preschool years. The differentiated memory search model provides a representational account of the memory search for items from a specific, novel past event and provides a basic framework upon which a more complicated future event construction process can be built.

One obvious future direction would be to introduce children to several competing past events to increase the demands on the memory search for both past and future event construction. This would allow us to understand the nature of a more complex event construction process that requires combining information from multiple past episodes to construct a future scene, or searching through multiple past episodes to identify the target details for recollection.

A second possibility for future explorations would be to use a similar paradigm to test differences between event constructions for a real versus imagined future event. Real events are limited in the sense that they must reflect a plausible event that could happen in the future, and also follow a general trajectory that connects one's past to the present to the future. However, imagined events do not have this constraint. They are hypothetical and can be populated by information that do not necessarily have to be from a specific past event (as presented in this dissertation). Therefore, the memory search to lead to the construction of a hypothetical event may actually benefit from the open-ended process seen as a result of imagining a real future event.

Another goal of future research will be to further understand the nature of the representational space within which events exist. Specifically, we need to understand the precise nature of the access to the event cluster. The data from the experiments presented here indicate that temporal cues are not enough to navigate through the cluster, and that content (items, locations, etc.) is an important factor in access to neighboring representations. Therefore, the nature of the content cue could predict information retrieval. For example, neuroimaging literature suggests similar pathways underlying item and semantic representations (Ranganath, 2010). This suggests that access to the underlying cluster of items may be accessed through episodic (as in this dissertation) or semantic primes. Future research should explore this possibility.

The studies presented in this dissertation require children to incrementally construct events in one particular direction: items, then spatial locations, and then goal. However, it is not necessarily the case that events are constructed in this way. In fact, given the emphasis placed on spatial locations, and the strong projections from the PHc subserving contextual representations to the PRc subserving item representations (Suzuki & Amaral, 1994), it could be the case that providing children with the spatial location task first may benefit future event construction. This notion should be tested in future studies.

Overall, the results of this dissertation provide arguments for how access to past memories can be manipulated, even when there is minimal reference to the target event at retrieval. The model we explored can be useful for pedagogical purposes: it accounts for the processes by which memory components are retrieved, and its structure reflects how events are represented. By understanding how we can access information efficiently and accurately, we can provide training tools to facilitate a more robust future thinking ability.

5 Appendices

5.1 Appendix A

In the location recall task in both experiments presented in this dissertation, children were asked to place animals in one of three empty locations on each of three trials. This meant that some children could have placed multiple animals in the same location across trials. Table 6.1 provides a list of all 27 possible combinations of location choices. Out of these 27 possible combinations, 18 reflect combinations where two animals are placed in the same location on separate trials, 3 reflect combinations where all three animals are placed in the same location on the 3 separate trials, and 6 reflect combinations where all 3 animals are placed in different locations. The locations were in a triangular position. Therefore, the locations are described as left, top or right to reflect the points of the triangle at which these locations were located.

Table 5.2 shows the number of children who repeated location choices zero times, two times, or three times in the experiment presented in Chapter 2. The table shows that the majority of children did not repeat location choices, indicating that they understood the task. However, in the future, single location condition, 3-year-old children were at chance between zero and two repeats. It is unclear whether these children understood the task. Therefore, whether children placed all 3 animals in the correct configuration as in the first session was not considered in this experiment.

In the experiment presented in Chapter 3, the majority of 3-year-olds (11 in the no prime condition and 13 in the prime condition) and 4-year-olds (13 in the no prime condition and 14 in the prime condition) did not repeat location choices (see Table 5.3). Therefore, it seems that in this experiment, most children understood the task.

Table 5.1. This table provides the possible 27 combinations of location choices that children could have made in the location recall task.

	# of Repeats	Location 1	Location 2	Location 3
1	0	Left	Top	Right
2	0	Left	Right	Top
3	0	Top	Right	Left
4	0	Top	Left	Right
5	0	Right	Top	Left
6	0	Right	Left	Top
7	2	Left	Top	Top
8	2	Left	Right	Right
9	2	Left	Left	Top
10	2	Left	Left	Right
11	2	Left	Right	Left
12	2	Left	Top	Left
13	2	Right	Top	Top
14	2	Right	Left	Left
15	2	Right	Right	Left
16	2	Right	Right	Top
17	2	Right	Top	Right
18	2	Right	Left	Right
19	2	Top	Left	Left
20	2	Top	Right	Right
21	2	Top	Top	Left
22	2	Top	Top	Right
23	2	Top	Left	Top
24	2	Top	Right	Top
25	3	Top	Top	Top
26	3	Left	Left	Left
27	3	Right	Right	Right

Table 5.2. Number of children who repeated location choices 0, 2, or 3 times in the experiment presented in Chapter 2.

	Past			Future		
Number of Repeats	Zero	Two	Three	Zero	Two	Three
3-year-olds						
Single Location	10*	1	1	5	5	2
Multiple Location	11*	1	0	7*	1	4*
4-year-olds						
Single Location	11*	1	0	12*	0	0
Multiple Location	12*	0	0	11*	0	1

Note: *, $p < 0.05$. Chance: Zero Repeats (6/27), Two Repeats (18/27), Three repeats (3/27).

Table 5.3. Number of children who repeated location choices 0, 2, or 3 times in the experiment presented in Chapter 3.

	Prime			No-Prime		
Number of Repeats	Zero	Two	Three	Zero	Two	Three
3-year-olds	13*	2	0	11*	2	2
4-year-olds	14*	0	1	13*	1	1

Note: *, $p < 0.05$. Chance: Zero Repeats (6/27), Two Repeats (18/27), Three repeats (3/27).

5.2 Appendix B

In Chapter 3, a series of stepwise mixed effects logistic regression models were computed to determine the incremental contribution of each factor in the following order: age, prime, age x prime, and cognitive flexibility. To determine the best fit, models were compared at each step using a Chi-Square test. Below are tables providing the Chi-Square test results by each task. Table 5.4 shows the Chi-Square test results for each incremental stepwise model comparison in the item recognition task. Table 5.5 shows the Chi-Square test results for each incremental stepwise model comparison in the location recall task. Table 5.6 shows the Chi-Square test results for each incremental stepwise model comparison in the order recall task.

Table 5.4. Item Recognition: Chi-Square comparisons between each incremental model of item recognition accuracy.

Model	AIC	BIC	Residual Deviance	*p*
Age	204.64	214.22	198.64	
Age + Prime	194.73	207.50	186.73	<0.001*
Age + Prime + Age x Prime	194.98	210.95	184.98	0.19
Age + Prime + Age x Prime + CF	196.50	215.66	184.50	0.49

Note: CF refers to Cognitive Flexibility; * $p < 0.05$

Table 5.5. Location Recall: Chi-Square comparisons between each incremental model of location recall accuracy.

Model	AIC	BIC	Residual Deviance	*p*
Age	212.22	221.80	206.22	
Age + Prime	213.50	226.27	205.50	0.40
Age + Prime + Age x Prime	212.66	228.62	202.66	0.09
Age + Prime + Age x Prime + CF	214.65	233.81	202.65	0.91

Note: CF refers to Cognitive Flexibility; * $p < 0.05$

Table 5.6. Order Recall: Chi-Square comparisons between each incremental model of order recall accuracy.

Model	AIC	BIC	Residual Deviance	*p*
Age	247.03	256.61	241.03	
Age + Prime	243.74	256.51	235.74	0.02
Age + Prime + Age x Prime	245.68	261.64	235.68	0.81
Age + Prime + Age x Prime + CF	244.91	264.07	232.91	0.10

Note: CF refers to Cognitive Flexibility; * $p < 0.05$

6 References

Abraham, A., Schubotz, R.I., and von Cramon, D.Y. (2008). Thinking about the future versus the past in personal and non-personal contexts. *Brain Research, 1233,* 106–119.

Addis, D. R., Pan, L., Vu, M., Laiser, N., & Schacter, D. L. (2008). Constructive episodic simulation of the future and past: Distinct subsystems of a core brain network mediate imagining and remembering. *Neuropsychologia, 47(11),* 2222-2238.

Addis, D.R., Musicaro, R., Pan, L., and Schacter, D.L. (2010). Episodic simulation of past and future events in older adults: Evidence from an experimental recombination task. *Psychology and Aging, 25,* 369–376.

Addis, D.R., Roberts, R.P., and Schacter, D.L. (2011). Age-related neural changes in remembering and imagining. *Neuropsychologia 49,* 3656–3669.

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,* 2660–2671.

Addis, D. R., & Schacter, D. L. (2008). Constructive episodic simulation: Temporal distance and detail of past and future events modulate hippocampal engagement. *Hippocampus, 18,* 227-237.

Addis, D. R., Wong, A. T., & Schacter, D. L. (2007). Age-related changes in the episodic simulation of future events. *Psychological Science, 19(1)*, 33-41.

Altmann, E. M., & Trafton, J. G. (2002). Memory for goals: An activation-based model. *Cognitive Science, 26,* 39–83.

Arnold, K. M., McDermott, K. B., & Szpunar, K. K. (2011). Imagining the near and far future: The role of location familiarity. *Memory and Cognition, 39,* 954-967.

Atance, C. M., & Meltzoff, A. N. (2005). My future self: Young children's ability to anticipate and explain future states. *Cognitive Development, 20,* 341-361.

Atance, C. M., & O'Neill, D. K. (2001). Episodic future thinking. *Trends in Cognitive Science, 5,* 533-539.

Atance, C. M., & Sommerville, J. A. (2013). Assessing the role of memory in preschoolers' performance on episodic foresight tasks. *Memory.* doi:10.1080/09658211.2013.820324

Bauer, P. J. (2007). Recall in infancy: A neurodevelopmental account. *Current Directions in Psychological Science, 16,* 142-146.

Bauer, P. J., & Dow, G. A. A. (1994). Episodic memory in 16- and 20-month-old children: Specifics are generalized, but not forgotten. *Developmental Psychology, 30,* 403-417.

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

Bernsten, D., & Bohn, A. (2010). Remembering and forecasting: The relation between autobiographical memory and episodic future thinking. *Memory & Cognition, 38,* 265-278.

Botzung, A., Denkova, E., & Manning, L. (2008). Experiencing past and future personal events: Functional neuroimaging evidence on the neural bases of mental time travel. *Brain & Cognition, 66,* 202-212.

Buckner, R. L., & Carroll, D. C. (2007). Self-projection and the brain. *Trends in Cognitive Science, 11,* 49-57.

Burgess, P. W., Quayle, A., & Frith, C. D. (2001). Brain regions involved in prospective memory as determined by positron emission tomography. *Neuropsychologia, 39*, 545-555.

Clayton, N. S & Dickinson, A. (1998). Episodic-like memory during cache recovery by scrub jays. *Nature, 395,* 272–274.

D'Argembeau, A., & Mathy, A. (2011). Tracking the construction of episodic future thoughts. *Journal of Experimental Psychology: General, 140(2)*, 258-271.

Davachi, L. (2006). Item, context and relational episodic encoding in humans. *Current Opinions in Neurobiology, 16,* 693-700.

D'Argembeau, A., & Demblon, J. (2012). On the representational systems underlying prospection: Evidence from the event-cueing paradigm. *Cognition, 125,* 160-167.

D'Argembeau, A., & Mathy, A. (2011). Tracking the construction of episodic future thoughts. *Journal of Experimental Psychology: General, 140,* 258-271.

D'Argembeau, A. & Van der Linden, M. (2004). Phenomenal characteristics associated with projecting oneself back into the past and forward into the future: Influence of valence and temporal distance. *Consciousness and Cognition, 13,* 844-858.

D'Argembeau, A., & Van der Linden, M. (2006). Individual differences in the phenomenology of mental time travel: The effect of vivid imagery and emotion regulation strategies. *Consciousness and Cognition, 15,* 342-350.

De Brigard, F., & Giovanello, K. S. (2012). Influence of outcome valence in the subjective experience of episodic past, future, and counterfactual. *Consciousness and Cognition, 21,* 1085-1096.

Demblon, J., & D'Argembeau, A. (2014). The organization of prospective thinking: Evidence of event clusters in freely generated future thoughts. *Consciousness and Cognition, 24,* 75-83.

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2007). Imaging recollection and familiarity in the medial temporal lobe: A three-component model. *Trends in Cognitive Science, 11,* 379-386.

Dusek, J., & Eichenbaum, H. (1997). The hippocampus and memory for orderly stimulus relations. *Proceedings of the National Academy of Sciences USA, 94,* 7109-7114.

Eacott, M. J., Easton, A., & Zinkivskay, A. (2005). Recollection in an episodic-like memory task in the rat. *Learning and Memory, 12,* 221–223.

Eacott, M. J., & Norman, G. (2004). Integrated memory for object, place, and context in rats: A possible model of episodic-like memory? *The Journal of Neuroscience, 24,* 1948–1953.

Eichenbaum H. (2001). The hippocampus and declarative memory: Cognitive mechanisms and neural codes. *Behavioral Brain Research, 127,* 199–207.

Eichenbaum, H. (2004). Hippocampus: Cognitive processes and neural representations that underlie declarative memory. *Neuron, 44,* 109-120.

Eichenbaum, H., & Cohen, N. J. (2001). *From Conditioning to Conscious Recollection.* Oxford: Oxford University Press.

Eichenbaum, H., Yonelinas, A. P. & Ranganath, C. (2007). The medial temporal lobe and recognition memory. *Annual Review of Neuroscience, 30,* 123–152.

Fivush, R., Gray, J., & Fromhoff, F. (1987). Two-year-olds talk about the past. *Cognitive Development, 2,* 393–409

Fivush, R., & Schwarzmueller, A. (1998). Children remember childhood: Implications for childhood amnesia. *Applied Cognitive Psychology, 12,* 455–473.

Gamboz, N., Brandimonte, M. A., & De Vito, S. (2010). The role of past in the simulation of autobiographical future episodes. *Experimental Psychology, 57(6),* 419-428.

Grysman, A., Prabhakar, J., Anglin, S. M., & Hudson, J. A. (2013). The time travelling self: Comparing self and other in narratives of past and future events. *Consciousness* *and Cognition, 22(3),* 742-755.

Grysman, A., Prabhakar, J., Anglin, S. M., & Hudson, J. A. (2014). Self-enhancement and the life script in future thinking across the lifespan. *Memory*.

Harley, K., & Reese, E. (1999). Origins of autobiographical memory. *Developmental Psychology, 35,* 1338–1348.

Hassabis, D., Kumaran, D., & Maguire, E. A. (2007a). Using imagination to understand the neural basis of episodic memory. *The Journal of Neuroscience, 27(52),* 14365-14374.

Hassabis, D., Kumaran, D., Vann, S. D., & Maguire, E. A. (2007b). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences USA, 104,* 1726-1731.

Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in Cognitive Science, 11,* 299-306.

Hayne, H., & Imuta, K. (2011). Episodic memory in 3- and 4-year-old children. *Developmental Psychobiology, 53,* 317-322.

Hayne, H., Gross, J., McNamee, S., Fitzgibbon, O., & Tustin, K. (2011). Episodic memory and episodic foresight in 3- and 5-year-old. *Cognitive Development, 26,* 343-355.

Henson, R. N., & Gagnepain, P. (2010). Predictive, interactive multiple memory systems. *Hippocampus, 20,* 1315-1326.

Hudson, J. A., Mayhew, E. M., & Prabhakar, J. (2011). The development of episodic foresight: Emerging concepts and methods. *Advances in Child Development and Behavior, 40,* 95-137.

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.*

Johnson, M. K., Foley, M. A., Suengas, A. G., & Raye, C. L. (1988). Phenomenal characteristics of memories for perceived and imagined autobiographical events. *Journals of Experimental Psychology: General, 117,* 371-376.

Kant, I. (1998). *Critique of pure reason* (P. Guyer & A. W. Wood, Eds. Trans.). Cambridge, UK: Cambridge University Press (Original work published 1781).

Klein, S. B., Loftus, J., & Kihlstorm, 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,* 353-379.

Kwan, D., Carson, N., Addis, D. R., & Rosenbaum, R. S. (2010). Deficits in past remembering extend to future imagining in a case of developmental amnesia. *Neuropsychologia, 48,* 3179-3186.

Lukowski, A. F., Lechuga-Garcia, M. T., & Bauer, P. J. (2010). Memory for events and locations obtained in the context of elicited imitation: Evidence for differential retention in the second year of life. *Infant Behavior and Development, 34,* 55-62.

Lloyd, M. E., Doydum, A. O., & Newcombe, N. S. (2007). Memory binding in early childhood: Evidence for a retrieval deficit. *Child Development, 80(5),* 1321-1328.

Maguire, E. A., Nannery, R. & Spiers, H. J. (2006). Navigation around London by a taxi driver with bilateral hippocampal lesions. *Brain, 129*, 2894–2907.

Martin-Ordas, G., Atance, C. M., & Louw, A. (2010). The role of episodic and semantic memory in episodic foresight. *Learning and Motivation, 43,* 209-219.

McDonough, I. M., & Gallo, D. A. (2010). Separating past and future autobiographical events in memory: Evidence for a reality monitoring asymmetry. *Memory and Cognition, 38,* 3-12.

McKenna, P., & Gerhand, S. (2002). Preserved semantic learning in an amnesic patient. *Cortex, 38,* 37-58.

Miller, J. F. et al. (2013). Neural activity in human hippocampal formation reveals the spatial context of retrieved memories. *Science, 342,* 1111-1114.

Morgan, K., & Hayne, H. (2011). Age-related changes in visual recognition memory during infancy and early childhood. *Developmental Psychobiology, 53,* 157–165.

O'Keefe, J., & Nadel, L. (1978). *The hippocampus as a cognitive map.* London: Oxford University Press.

Okuda, J. et al. (2003). Thinking of the future and past: The roles of the frontal pole and the medial temporal lobes. *Neuroimage, 19,* 1369-1380.

Østby, Y. et al. (2012). Mental time travel and default-mode network functional connectivity in the developing brain. *Proceedings of the National Academy of Sciences, 109,* 16800-16804.

Polyn, S. M., & Kahana, M. J. (2008). Memory search and the neural representation of context. *Trends in Cognitive Science, 12,* 24-30.

Polyn, S. M., Norman, K. A., & Kahana, M. J. (2009). Task context and organization in free recall. *Neuropsychologia, 47,* 2158-2163.

Ranganath, C. (2010). A unified framework for the functional organization of the medial temporal lobes and the phenomenology of episodic memory. *Hippocampus, 20,* 1263-1290.

Reese, E., & Brown, N. (2000). Reminiscing and recounting in the preschool years. *Applied Cognitive Psychology, 14,* 1–17.

Rosenbaum, R. S., Köhler, 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,* 989-1021.

Russell, J., Alexis, D., & Clayton, N. S. (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,* 56-71.

Scarf, D., Gross, J., Colombo, M., & Hayne, H. (2011). To have and to hold: Episodic memory in 3- and 4-year-old children. *Developmental Psychology, 55(2),* 125–132.

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 B, 362,* 773-786.

Schacter, D. L., Addis, D. R., & Buckner, R. L. Episodic Simulation of Future Events. *Annals of New York Academy of Science, 1124,* 39-60.

Schapiro, A. C., Rogers, T. T., Cordova, N. I., Turk-Browne, N. B., & Botvinick, M. M. (2013). Neural representations of events arise from temporal community structure. *Nature Neuroscience, 16(4),* 486-492.

Scoville, W. B. & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology & Neurosurgery: Psychiatry, 20,* 11–21.

Sluzenski, J., Newcombe, N., & Ottinger, W. (2004). Changes in reality monitoring and episodic memory in early childhood. *Developmental Science, 7(2),* 225-245.

Spreng, R. N., & Levine, B. (2006). The temporal distribution of past and future autobiographical events across the lifespan. *Memory and Cognition, 34,* 1644–1651.

Squire, L. R., & Cave, C. B. (1991). The hippocampus, memory, and space. *Hippocampus, 1(3),* 269-271.

Squire, L. R., Stark, C. E. L., & Clark, R. E. (2004). The medial temporal lobe. *Annual Review of Neuroscience, 27,* 279-306.

Suddendorf, T, & Corballis, M. C. (1997). Mental time travel and the evolution of the human mind. *Genetic, Social, and General Psychology Monographs, 123,* 133-167.

Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: what is mental time travel, and is it unique to humans? *Behavioral Brain Sciences, 30,* 299-351.

Suddendorf, T., Nielson, M., & von Gehlen, R. (2010). Children's capacity to remember a novel problem and to secure its future solution. *Developmental Science, 14(1),* 26-33.

Suzuki W. A., Amaral D. G. (1994). Perirhinal and parahippocampal cortices of the macaque monkey: Cortical afferents. *Journal of Comparative Neurology,* 350:497–533.

Szpunar, K. K. (2010). Episodic future thought: An emerging concept. *Perspectives in Psychological Science, 5,* 142-162.

Szpunar, K. K., & McDermott, K. B. (2008). Episodic future thought and its relation to remembering: Evidence from ratings of subjective experience. *Consciousness and Cognition, 17,* 330-334.

Szpunar, K. K., Watson, J. M., & McDermott, K. B. (2007). Neural substrates of envisioning the future. *Proceedings of the National Academy of Sciences, 104,* 642-647.

Taylor K. I., Moss H. E., Stamatakis E. A., Tyler L. K. (2006). Binding cross-modal object features in perirhinal cortex. *Proceedings of the National Academy of Sciences USA, 103,* 8239–8244.

Thompson, R. F. (2005). In search of memory traces. *Annual Review of Psychology, 56,* 1-23.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381-403). New York: Academic Press.

Tulving, E. (1984). Précis of elements of episodic memory. *The Behavioral and Brain Sciences, 7,* 223-268.

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology, 53,* 1-25.

Tustin, K., & Hayne, H. (2010). Defining the boundary: Age-related changes in childhood amnesia. *Developmental Psychology, 46(5),* 1049 – 1061.

Weiler, J. A., Suchan, B., & Daum, I. (2010). When the future becomes the past: differences in brain activation patterns of episodic memory and episodic future thinking. *Behavioral Brain Research, 212,* 196-203.

Yonelinas, A. P. (1999). The contribution of recollection and familiarity to recognition and source memory judgments: A formal dual-process model and an analysis of receiver operating characteristics. *Journal of Experimental Psychology: Learning, Memory & Cognition, 25(6),* 1415-1434.

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.

Yonelinas, A. P., Aly, M., Wang, W. C., Koen, J. D. (2010). Recollection and familiarity: Examining controversial assumptions and new directions. *Hippocampus, 20(11),* 1178-1194.

Zelazo, P. D. (2006). The dimensional change card sort: A method of assessing executive function in children. *Nature Protocols, 1,* 297-301.