RUNNING HEAD: DEVELOPMENT OF MEMORY FUTURES

Securing the Future by Remembering the Past: But just when does this Past and Future Begin to Develop?

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Klein (2013) suggests that at least one evolutionary pressure that led to the emergence of associative memory is the need for organisms to anticipate and plan for the future. That is, we remember the past in the service of securing our future survival, something that has considerable fitness relevance. In fact, those who can use the past to more effectively anticipate the future must surely enjoy increased opportunities for reproductive success.

The current zeitgeist in memory research is sympathetic with Klein's (2013) view, particularly among those who dabble in what is known as "adaptive memory" (see articles in Howe & Otgaar, in press and chapters in Schwartz, Howe, Toglia, & Otgaar, 2014). Although most agree that memory for the past is a harbinger for understanding the present and anticipating the future in adult humans, there is less consensus concerning whether memory behaves in a similar fashion in nonhuman animals as well as younger humans (i.e., infants and toddlers). Klein (2013, pp. xxx-xxx) argues that, "all organisms capable of memory are, of necessity, oriented toward the future … Species-specific differences in future-orientation trade on complexity and temporal scope of anticipatory and planning abilities, not on their presence or absence."

Although organisms endowed with associative memory may be able to use the past to anticipate the future, the question posed in this article is one about when this episodic foresight or future thinking[1] emerges in an organism's ontogeny. Specifically, when has an organism stored enough of its past to anticipate its future? That is, if future orientation is not present at birth, requiring some accumulation of experience, then at what point has sufficient experience been stored in memory to anticipate the future. Moreover, it is not simply a matter of the quantity of what has been stored, but more obviously, the domain of that experience. That is, surely one cannot anticipate where to find food if one's stored experiences have not involved previous food-related experiences including attempts to locate food in the past.[2] Thus, like other adaptive behaviors, the episodic foresight component of memory functioning may require certain developmental experiences to occur before it begins to function (i.e., the expression of an adaptation may be *experience expectant* or *experience dependent*; e.g., see Howe, 2011). Specifically, the expression of a fitness-relevant memory system may not occur until there have been sufficient encounters with and knowledge of the situations relevant to current and future need states.[3]

Although to qualify as an adaptation a behavior must emerge at some point during an organism's life, this does not mean that adaptations need to be present early in life. Indeed, many adaptive behaviors emerge long after birth (e.g., bipedal locomotion at around 12 months, language usually at 18-24 months, secondary sex characteristics during puberty; see Buss, Haselton, Shackelford, Bleske, & Wakefield, 1998; Confer et al., 2010). In terms of episodic foresight, it is reasonable to assume that this adaptive component of memory might emerge even later in some of today's (Western) cultures, given the rather extended periods of infancy and childhood that many humans experience (see Gopnik, 2009).

To answer this ontological question, I will restrict my comments to the human developmental literature. Although some of the paradigms used to examine this question in humans (i.e., those involving nonverbal responses) have also been used to examine this same question in nonhuman animals (e.g., Martin-Ordas, Atance, & Call, in press; Schwartz, Colon, Sanchez, Rodriguez, & Evans, 2002), I will simply consider the developmental trajectory of episodic foresight in young children. However, before considering the episodic foresight literature proper, it is important to note that even very young infants are capable of anticipating future events. For example, 3- (e.g., Adler & Haith, 2003; Adler, Haith, Arehart, & Lanthier, 2008) and 4-month-olds (e.g., von Hofsten, Kochukhova, & Rosander, 2007) can visually track an object that becomes occluded and anticipate where it should reappear. This anticipatory behavior is not just based on pre-occlusion visual tracking skills or other low-level visual processing mechanisms, but involves something more cognitive; that is, the infant tracks the objects in their 'mind's eye' even when those objects disappear behind the occluder (von Hofsten et al., 2007). Indeed, infants not only exhibit surprise if the occluded object does not reappear in the anticipated position, but they are similarly surprised if there are changes in the object's appearance (e.g., height, color) or its identity when it finally does reappear. This research shows that temporal information plays an important role very early in life and that even very young infants anticipate future outcomes based (perhaps) on memory for how objects have behaved in the past. Together, these studies on an infant's grasp of object permanence (its continued existence behind the occluder), its physical properties (height, color, identity), and trajectory (where it should reappear) not only provide valuable information about early expectant (visual) behaviors, but also about what might be the precursors to later future thinking.

Although perhaps a precursor to the future planning aspects of associative memory, these results do not demonstrate the sort of episodic foresight that Klein (2013) is referring to.[4] To date, such studies have only been conducted with preschool-age children (3- to 5-year-olds). Here, there are at least two ways in which young children's future planning has been examined—prospective memory and episodic foresight. In prospective memory studies, children are asked to remember to do something in the future (e.g., bring an item for show-and-tell, check the oven in 20 minutes, return a book to a friend next time you see them; see Aberle & Kliegel, 2010; Atance & Jackson, 2009). Although some of these studies have reported age differences favoring older children, other studies have failed to find age differences even among the youngest preschool children (for a review, see Kvavilashvili, Kyle, & Messer, 2008). Of course, prospective memory tasks may not involve planning *per se* as they may simply tap children's ability to remember the instruction to do something later.

More direct tests of children's episodic foresight have been conducted using both nonverbal (e.g., Metcalf & Atance, 2011) and verbal (e.g., Atance & Sommerville, in press; Hayne, Gross, McNamee, Fitzgibbon, & Tustin, 2011; Richmond & Pan, 2013; Scarf, Gross, Colombi, & Hayne, 2013) tests. Like the research on prospective memory, developmental differences in episodic foresight can appear and disappear depending on the procedure implemented to examine children's future planning abilities. For example, in a typical verbal version of this paradigm, children might be asked to talk about an event that happened in the past (e.g., earlier that day, yesterday, or events more distant in the past) and then about an event that might happen in the future (e.g., later the same day, tomorrow, or even further into the future). Here, 3-year-olds often provide less information in their narratives than 4- and 5-year-olds for both retrospective and prospective memories, suggesting a developmental shift in episodic memory (remembering the past) and episodic foresight (anticipating the future) between the ages of 3 and 4 years (see Busby & Suddendorf, 2005).

However, developmental changes have not always been found. For example, when the task is made easier for younger children (e.g., by providing a visual timeline so they can physically track both the past and the future), differences in the performance of 3- to 5-year-olds virtually disappear (Hayne et al., 2011). Similarly, in a nonverbal task (remembering to save marbles for a future task), there were no differences in the amount saved among 3- to 5-year-olds (Metcalf & Atance, 2011).[5]

Still other studies have shown important developmental changes in children's episodic foresight. Atance and Sommerville (in press) examined episodic foresight in 3-, 4-, and 5-year-olds. Here, children were given a problem in one room and, following a delay, were taken to a second room where they could select an item to solve the earlier presented problem. Children were also asked questions about the original problem to see whether they correctly remembered what it was in order to determine the relationship between retrospective episodic memory and prospective problem solving. The results showed that children's ability to select the correct item to secure the solution to the problem increased with age, but this relation was mediated by memory for the original problem. That is, using regression analyses, memory for the past, not age, predicted correct item selection. Thus, the ability to remember the past (i.e., the problem in this case) is a major predictor of episodic foresight. That both episodic memory and episodic foresight develop in tandem is consistent with neuroscientific evidence demonstrating that both of these processes rely on the activation of many of the same neural regions (e.g., Addis, Pan, Vu, Laiser, & Schacter, 2009).

Scarf et al. (2013) also examined episodic memory for the problem and used a delay between problem presentation and item selection. They showed that despite being able to form episodic memories for the problem, when the delay between the problem and solution selection was longer than 15 minutes, 3-year-olds did not retain the relevant problem information over the delay. In contrast, 4-year-olds could retain this information as long as one week. These results add to the growing consensus that memory for the original problem is key to episodic foresight and that as children develop they are better able to retain that information over longer and longer intervals. Indeed, these findings are in line with a wealth of evidence showing that improvement in children's ability to store information in memory (i.e., consolidation) is critical to the development of episodic memory (Bauer, 2009). What Scarf et al. (2013) have added is that these changes in retention of past experiences are also critical to the development of episodic foresight.

Finally, Richmond and Pan (2013) have demonstrated that like the changes that occur in children's ability to consolidate information in storage, advances in children's ability to bind elements of the past into a more integrated, relational associative network is also predictive of their performance on episodic foresight tasks. Although surely binding together past experiences into more integrated traces is also related to changes in children's executive function (e.g., inhibition, working memory; see Suddendorf & Corballis, 2007), memory for the past is necessary for anticipating future outcomes. That is, remembering previous relevant experiences (in these cases, the earlier presented problem) is necessary for successful episodic foresight.

So, although associative memory may have evolved to afford organisms that possess it with the fitness-relevant consequence of being able to anticipate the future through remembering the past, such benefits may not be available to humans (or nonhuman animals) immediately upon birth. This is a critical insight that needs to be factored into any theory about the evolution of memory, regardless of which direction we believe is best to study the fitness-relevant role of an adaptive memory system.

Indeed, what the research reviewed here suggests is that there exists a specific developmental trajectory for this adaptive advantage, one that unfolds as a consequence of the development of episodic memory more generally. Although there exist early precursors to episodic foresight (e.g., visual anticipation), ones that involve an immature form of episodic memory (e.g., one that has recently coded the properties of objects and their trajectory through space), research has shown that for humans, at least, true future planning of the sort Klein (2013) envisages may not emerge until three years of age (but see Footnote 5). As this aspect of memory emerges, there are at least four proximate mechanisms that have been identified that need to be in place for the mature functioning of episodic foresight: (1) development of storage and retention processes (i.e., consolidation; e.g. Scarf et al., 2013), ones that depend on neurological maturation (e.g., Bauer, 2009); (2) development of retrieval skills so the past that is available in storage is also accessible (e.g., Atance & Sommerville, in press); (3) age-related changes in binding so that past experiences become better integrated in associative networks (e.g., Richmond & Pan, 2013), again something that depends on neurological maturation (e.g., Townsend, Richmond, Vogel-Farley, & Thomas, 2010); and (4) age-related improvements in executive processing (e.g., response inhibition, working memory; see Suddendorf & Corballis, 2007). Together these behavioral and neurobiological developments determine the emergence of both episodic memory for the past and episodic foresight used to plan for the future. Indeed, it is because humans are animals that rely on the accumulated knowledge of our past experiences in order to imagine and plan for our future, childhood tends to be a much more protracted period than that of other animal species (also see Gopnik, 2009).

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Footnotes

[1]For the purposes of this article, these two terms will be used interchangeably.

[2]This question has to do with the development of an organism's knowledge base, something that has been studied extensively in human development (e.g., Ceci, Fitneva, & Williams, 2010). Because of length constraints, and because of the seeming obviousness of the proposition that domain relevant experience may be necessary for anticipating similar events in the future, there will be no additional discussion of this topic in this article (but see discussion in Howe, 2011; Howe & Otgaar, 2013).

[3] Of course, because these critical developmental experiences can differ between individuals within and across cultures, fitness-relevant aspects of memory may not emerge at the same time in all children. Although, as Klein (2013) opines, we may all eventually exhibit episodic foresight, the developmental course of the emergence of this adaptive memory effect may vary considerably (also see Howe & Otgaar, 2013).

[4]Both Klein (2013) and Tulving (2005) suggest that episodic memory (remembering the past) and episodic foresight (anticipating the future) are accompanied by autonoetic awareness (a feeling that one is reliving the past or mentally travelling into the future, respectively). Of course, such a requirement rules out nonverbal organisms (nonhuman animals and preverbal humans) because there is no way for them to report their conscious experiences when remembering the past or planning for the future. Although I will not pursue this issue in depth here, it is important to point out that (1) autonoetic awareness may be a simple epiphenomenal component that arises in adult humans when remembering the past or anticipating the future, not a necessary one, and (2) children not only fulfill all of the other requirements associated with possessing episodic memory and foresight, but, whether epiphenomenal or not,

even 3-year-olds provide first person accounts of past experiences and future planning (e.g., Hayne, Gross, McNamee, Fitzgibbon, & Tustin, 2011), consistent with the autonoetic requirement.

[5] Despite the availability of nonverbal procedures, researchers have not tested episodic foresight in children younger than three years of age. Because of this, we do not know whether children younger than three years of age evince future planning. Future research is well advised to adapt these procedures for use in younger children, much in the same way nonverbal procedures have been used to examine future-oriented behavior in nonhuman animals (Martin-Ordas et al., in press; Schwartz et al., 2002).