The Neuroscience of Memory Development: Implications for Adults Recalling Childhood Experiences in the Courtroom

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Preface

Adults frequently provide compelling, detailed accounts of early childhood experiences in the courtroom. Judges and jurors are asked to decide guilt or innocence based solely on these decades old memories using "common-sense" notions about memory. These notions are not in agreement with findings from neuroscientific and behavioural studies of memory development. Without expert guidance, it is difficult to see how judges and jurors can properly adjudicate the weight of memory evidence in cases involving adult recollections of childhood experiences.

Introduction

Memory often serves as the key or only evidence in the courtroom. Whether the witness is a child or an adult, all memory-based evidence is reconstructive. This is because memories are not veridical records of experience but are fragmented remnants of what happened in the past, pieced together in a "sensible" manner according to the rememberer's current worldview[1,2]. The reliability of memories may be questionable in general, but several additional issues should be considered when forensic evidence comes from adults recalling childhood experiences. These issues are the focus of this article.

First, memories that are formed during childhood are different from memories formed during adolescence and adulthood in terms of both longevity and content. These differences have important consequences for what judges and jurors should expect to hear from complainants when they testify about childhood experiences, especially the amount and type of details being remembered[3] (Box 1). Second, to be remembered in adulthood, childhood memories must have been retained for considerable periods of time. However, during that time memories can change or even disappear due to a process known as reconsolidation [6-7].

Many of these memory facts are not known by judges and jurors who must then rely on their own 'common sense' views of memory and memory development when evaluating the reliability of memory-based evidence. These views can be at odds[8-12] with what has been revealed by the scientific study of memory and its development. For example, many jurors and legal professionals (e.g., judges, lawyers, police) in North America[8] and Europe (e.g., Sweden[13] and Norway[14]) are naïve when it comes to understanding how memories are formed, how they become distorted over time, and how stress and emotion affect remembering[15-16]. Jurors are similarly naïve when it comes to understanding whether children can remember events that happen only once, events that are traumatic, or which factors can affect the accuracy of memories across childhood (e.g., suggestibility, repeated questioning)[17]. Indeed, these naïve but 'common sense' beliefs directly impact the verdicts jurors render in court[18] (Box 2).

The purpose of this article is to debunk these naïve beliefs by reviewing recent scientific advances from behavioural and neuroscientific studies concerning the development declarative memory during childhood. I also discuss factors that can influence the long-term retention of childhood memories and the effects of stress on memory. Finally, I consider the implications of these findings for courtroom cases that involve evidence based on memories of childhood experiences.

Development of declarative memory

Declarative memory, also known as explicit memory, is memory of facts and experiences. When experiences are encoded with respect to the self, memory is considered autobiographical; that is, they are not just memories of events that happened, they are memories of events that happened to 'me'. It is this form of declarative memory that we are dealing with in the courtroom; namely, adults remembering experiences that happened to them when they were children. In this section, I discuss the recent behavioral and neurobiological data concerning the development of autobiographical declarative memory from infancy through childhood.

Findings from behavioral studies

There is considerable evidence that most if not all memories from very early childhood (i.e., 18 to 24 months of age; *infantile amnesia*) are effectively lost, or are certainly not available to conscious recall[1,19]. Research from studies in humans and nonhuman animals has shown that forgetting occurs more rapidly in younger members of the species[20-23]. This increased sensitivity of early memories to forgetting extends into the preschool years[24].

Therefore, it is not surprising that studies in adults show that very few events from early childhood are remembered, even events that occurred somewhat later in childhood (i.e., before the age of five to seven years; *childhood amnesia*) (see Figure 1).

Several phenomena that underpin the absence of autobiographical memories of early childhood experiences have emerged from behavioural studies. Before these findings are described, it is important to note that autobiographical memory has an episodic component (the who, what, where, and when of an event, including the personal experience of the event) and a semantic component (factual information that is independent of the specific event in which that information was acquired, including the meaning of the event)[1, 26, 27]. To illustrate, I know not only that grapefruits are bitter (semantic knowledge (or semantic memory)) but also remember the first time I tasted the bitterness of a grapefruit (episodic memory). Episodic and semantic components develop in parallel throughout childhood and adolescence[1, 26-28]. For example, younger children's narrative recall of a recent event is sparser, containing fewer (particularly peripheral) details about the experience, than older children's recall of a recent event[1,28], suggesting that fewer details are stored in episodic memory in younger than older children. Accordingly, although young children are frequently correct in the basic facts of what happened (e.g., we went on a trip to the museum), their narratives do not contain many of the additional details (e.g., it was a warm and sunny day, I was wearing my favorite dress, we learned what a curator was) as older children's.

Parallel developments also occur in the semantic components of children's autobiographical[1, 27-29]. One way to study these developmental changes in the organization of semantic knowledge is by asking children to make similarity judgments among concepts or objects. Using multidimensional scaling analyses to calculate relational (or associative, that is, semantic) distances between these concepts, one can map how these distances change across age. When 4-year-olds and 9-year-olds rated the same set of concepts for their similarity, different scaling solutions were obtained (Figure 2)[29], indicating that older children's knowledge base is organized differently (i.e., concepts are interrelated in a qualitatively different manner) than younger children's in ways that can have direct behavioural consequences. For example, semantic distances between concepts for younger children predict confusions among those concepts for children of that age but not for older children. Indeed, these distances have been used to predict susceptibility to memory illusions (e.g., spontaneous false memories)[30-32] and to anticipate age-based changes in children's vulnerability to suggestion[29]. Interestingly, younger children (4- to 7-year-olds) generate fewer spontaneous false memories than older children (9- to 12-year-olds) and adults [28, 30-32]. That is, when asked to remember a list of associatively related terms (e.g., *nap, doze, pillow, bed, dream, … snore*) younger children (e.g., 7-year-olds) remember fewer presented words than older children and adults, and are less likely to falsely remember the non-presented but associated word *sleep* [28, 30-32]. This is thought to be because their knowledge base — or the semantic component of memory — is not as well developed as that of older children and adults. This does not mean that spontaneous false memories do not occur in young children; they do, especially when age sensitive materials are used[30-32].

That age-appropriate materials increase false memory rates in children is critical when we consider what adults are remembering about their childhood experiences. If one is truly recalling an event from childhood, then the language and concepts being used in that memory should correspond to the person's knowledge base at the time of the event, and not to what they surmise to have been the case given their current adult worldview. For example, the concept of disgust does not usually develop until approximately the age of 5[33], so memories involving this concept cannot have been encoded before that age. Indeed, there is evidence that the concepts and words used to retrieve true early memories are age-appropriate to the memories themselves[34].

A second, related, phenomenon that underpins childhood amnesia is that young children have considerable difficulty binding the different aspects of an event together into an integrated memory trace[26]. Binding refers both to the integration of features encoded from the environment into a cohesive trace and the subsequent integration of this trace with information that is already stored in memory. Binding captures both semantic relations (e.g., integrating elements such as bird with wings, feathers, flight) and episodic relations (e.g., location where one was when seeing an eagle capture a salmon). There is some evidence that children are better at binding features of an event when those events are personally significant[35]. Nevertheless, the development of binding ability across childhood into adolescence facilitates encoding, storage, and retrieval processes. Interestingly, these processes involve the hippocampus and the prefrontal cortex, areas that undergo structural and functional changes at this time[36-38] (see below).

What this behavioral evidence shows is that improvements that occur during childhood in the ability to encode, store, and retrieve information are associated with an increased ability to bind information into coherent memories. This ability to identify relations between features helps to shape the child's emerging knowledge base (including knowledge about the self) and enables the extraction of abstract (semantic) knowledge from episodic experiences. As the ability to link newly encoded information into relational structures develops — along with the ability to integrate these structures with memories already in storage — more stable and better-integrated memories are stored, ones that not only contain more information but also may be better preserved over time.

In addition, there is a third phenomenon associated with the fragility of early memories, namely, that their episodic components frequently deteriorate more rapidly than the meaning or core components[39]. What this means is that although the central features of experiences (e.g., that I went to a museum when I was young) are preserved in memory, additional (perhaps more peripheral) details of those experiences (e.g., what time of day the visit happened, what I was wearing, who I was with) are not. It is this waning of episodic detail that can undermine the integrity and longevity of early memories, something that frequently leaves the adult rememberer with only vague (and decontextualized) recollections of the past[4, 39] (Box 1).

A fourth phenomenon that underpins poor recollection of childhood memories is that information that has been stored only becomes stable and better integrated within important knowledge structures after several other cognitive changes have emerged. For example, the emergence of the cognitive self at around 18 to 24 months[40-41] provides a structure within which memories can be embedded, a development that leads to more stable, hence potentially longer-lasting, memories[40-44]. Developments in language[34, 44-47] (e.g., development of pronoun use) and the sharing of our past experiences with others[45] (e.g., parents) also contribute to the restructuring and enhanced retention of children's memories for recent experiences[44-47]. There is some debate regarding whether this restructuring of memories in childhood by adult conversation partners changes the contents of children's memories or simply provides a culturally appropriate linguistic framework for talking about autobiographical experiences. Regardless, what is clear is that children's conversations with parents about their autobiographical experiences, does increase the longevity of memories for these events[46-47].

Importantly, a common sense notion holds that emotional or traumatic events from our childhoods are remembered better than more neutral events. However, studies have consistently shown that adults' earliest memories are not ones that are highly emotional or traumatic, but rather, are often devoid of emotional content[4, 39]. This finding is not unexpected given that infants and young children do not have the level of semantic knowledge needed to encode the meaning (in adult terms) of an event; any meaning given to events is constructed later, when the fragments are retrieved. In fact, when the details of a previously experienced event (e.g., a visit to a fire station) are known and can be compared to what is later recalled, young children's (5- and 6-year-olds) subsequent recall rarely includes verbatim, emotional, temporal, or introspective information[39]. Even specific questioning about the event does not elicit these details from young children, whereas older (9- and 10-year-olds) children's reports do contain such information[39]. Thus, when adults provide detailed narratives (for example, in the courtroom; Box 1) for events experienced in early childhood, these narratives are unlikely to be based on memories alone and are likely to have been 'filtered' through the lens of the person's current worldview.

Findings from neurobiological studies

Of course, these behavioural changes in children's memory development do not occur in isolation but rather, happen in tandem with, and to some extent are mediated by, important neurobiological changes. Developmental neuroscientists have documented these changes using an ever-growing toolkit with which to study brain development. These include structural MRI, diffusion tensor imaging to study changes in brain structure, and EEG, ERP and functional MRI to study changes in regional activity and functional connectivity. Studies using these tools have shown that changes in brain structure and function occur throughout childhood and adolescence. In terms of structure, cortical thinning (resulting in part from synaptic pruning) appears earlier in the primary sensory cortices than in the association cortices and the prefrontal cortex[48-49], whereas white matter volume increases during development, mainly as a result of increases in myelination and axon diameter[49-50].

Findings from EEG/ERP studies suggest that early (e.g., the latter part of the first postnatal year) changes in structural and functional connectivity changes in the MTL and the PFC are associated with increases in the speed of information processing and in the longevity of memory traces[51]. These changes in memory longevity (i.e., consolidation) involve maturation of MTL structures (e.g., hippocampus, parahippocampus, entorhinal and perirhinal cortices, and the dentate gyrus) into the latter part of the first postnatal year[19]. These areas of the MTL continue to develop during the first few years of life[52-54] and, together with changes in the dorsolateral (dl) PFC[53, 55-57] serve to bind distributed representations into integrated memory traces.

Neuroimaging studies have examined the brain areas (mainly the MTL and PFC) involved in memory formation and retrieval in individuals aged 8-24. These include studies of both the automatic (memory processes that may not be under conscious control; e.g., feature sampling) and strategic (memory processes that are under conscious control; e.g., semantic clustering of to-be-remembered information) aspects of memory (both at encoding and retrieval) and studies of changes in children's knowledge base[56-63]. Results have shown that dlPFC regions that mediate the encoding of detailed episodic representations of experiences may have a protracted period of development than the MTL[52, 56-63 (but see 64-66)], so that memory formation early in childhood depends more on MTL contributions[26, 36, 38, 67-68]. Speculation is that early reliance on the MTL may lead to sparser representations in memory, but as development proceeds, contributions from the PFC facilitates the encoding of more detail, especially detail that involves semantic processing[56, 66, 69], but also storing greater contextual and source information[60]. These findings are consistent with the behavioral data showing that younger children have a qualitatively and quantitatively different knowledge base with more limited semantic processing than older children[26-27]. Continued development of the hippocampus in middle childhood and adolescence also influences encoding and retrieval[66-67]. Indeed, a recent fMRI study examining activation of brain regions during memory retrieval in 8- and 12-year-olds and adults found that age-related increases in semantic memory errors were related to changes in the pattern of engagement of the left anterior MTL, left posterior parietal cortex, and the left ventrolateral prefrontal cortex (vlPFC)[70].

Memory results in the accumulation of both abstract knowledge (the semantic component of autobiographical memory) and contextual or source details of individual experiences (the episodic component of autobiographical memory). Neuroimaging studies have found that memory formation is associated with activation in brain regions that are known to be content sensitive. For example, a recent study[58] showed that the formation of memory for scenes was associated with activation of cortical areas responsible for the visual perception of scenes (i.e., parahippocampal place area[71]). Memory for natural scenes improves during childhood and adolescence through to adulthood[72] , and these improvements correlate with changes in the activity of cortical areas specialized for processing scenes[73] during the encoding and subsequent representation of complex scenes.

Other studies[61] have examined the influence of changes in knowledge base and memory[61]. Here, children (8.5 to 11.5 years of age) and adults participated in an encoding task that compared the encoding of noun-color pairings that either were matched with one's world knowledge (e.g., seeing the word tomato printed on a red background) or were mismatched (e.g., seeing the word tomato printed on a blue background). While being scanned, participants viewed word-color combinations and were asked if these combinations occurred in nature. Later, outside the scanner, participants were given a recognition test. Behavioral studies have routinely demonstrated that when the noun-color pairings match, participants remember more of these items than when they mismatch. In this study[61] adults remembered more than children, but all participants exhibited the congruency effect (i.e., better recognition for congruent than incongruent pairings). Neuroimaging data revealed that during the encoding phase, adults showed activity in regions known to be associated with semantic/conceptual processing (e.g., left PFC, parietal and occipito-temporal cortices), whereas children showed activity in regions that are involved earlier in the processing sequence (e.g., the right occipital cortex). That is, in adults encoding relied more on neural substrates involved in semantic processing, whereas in children encoding relied more on neural substrates involved in perceptual processing. Thus, consistent with the behavioral data, children's knowledge base is less well developed than that of adults, perhaps relying more on perceptual-level than semantic-level processing. As development proceeds, this perceptual to semantic shift depends on the ability to abstract knowledge from individually experienced episodes[64] and this shift not only facilitates better correct recollection of information, it also begets more semantic errors (false memories) in adulthood than childhood.

In addition, increases in the functional connectivity of the PFC with regions in the MTL [38, 57] may also contribute to the emergence of cognitive control (e.g., strategies for encoding, monitoring retrieval contents)[38] over memories. In terms of encoding, increased cognitive control lets children selectively attend to and store relevant versus irrelevant information, something that leads to better integrated and more detailed memories for experiences[57]. For example, positive correlations between age (8- to 14-year-olds) and level of recruitment of left dlPFC have been obtained during encoding of complex scenes, which in turn resulted in increased memory for the contents of these scenes[63]. In terms of retrieval, increased cognitive control lets children selectively remember and rehearse relevant information and selectively suppress or omit irrelevant information. For example, when examining retrieval of memories in children (8- to 12-year-olds) and adults, differences in activation patterns in several PFC areas (left dlPFC, rostrolateral PFC, and vlPFC) were related to age[70], suggesting developmental improvements in discriminating relevant from irrelevant information in memory and better, more flexible use of semantic retrieval cues[74]. Of course, additional changes in the MTL (e.g., changes in cortical thickness, hippocampal volume)[64] also contribute to these developments in memory. Indeed, there is evidence that age-related increases in the functional specialization of the hippocampus and the posterior parahippocampal gyrus may have an important role in the increasing ability to construct detailed memories with age[58, 60]. For example, in an fMRI study, 14-year-olds and adults showed similar activity profiles in the anterior region of the hippocampus when encoding source information, whereas 8- to 11-year-olds activity patterns were less differentiated[60]. Moreover, during retrieval of episodic information, activity in the anterior but not the posterior hippocampus was increased in adults, whereas children exhibited the reverse pattern[67].

Together, these neurobiological developments have a myriad of important consequences for how children encode, store, and retrieve their autobiographical experiences. Children become better at using selective attention to encode relevant information and engage in elaboration of information with information already stored in their knowledge base in order to better integrate autobiographical information in memory. In addition, retrieval becomes more strategic (e.g., discriminating relevant from irrelevant memory contents, better use of semantic cues) and the contents of what is being retrieved are more likely to be filtered by monitoring processes, as children get older. Many of these developments are contingent on changes in the PFC[75] Indeed, the development of strategic retrieval is associated with increased activation in the left vlPFC, whereas developmental improvements in estimating the accuracy of what has been retrieved are associated with increased activation of the dlPFC[70].

Given the intricate interconnections between of the PFC and the MTL, it is perhaps not surprising that the MTL also has a role in these improvements in retrieval[67].

Together, the neurobiological evidence shows that several structural and functional changes are associated with the development of encoding, storage, and retrieval abilities. These changes begin very early in life and continue through adolescence, and are both qualitative and quantitative in nature. In addition, changes in encoding (e.g., increased binding), consolidation (e.g., greater longevity), and retrieval (e.g., strategic monitoring) processes contribute to an increased ability to interpret and remember experiences and to retain them over longer and longer retention intervals.

Reconsolidation and long-term retention

It is not just the nature of early memory development that is important when adjudicating memory evidence about childhood events in the courtroom, but also how well such traces are maintained over the ensuing decades. Because our memories are used not just to remember a past and interpret our present but also to plan for and anticipate our future, our memory system needs to be dynamic and responsive to changes that occur with experience[1,2]. Reconsolidation is one process that allows memories to remain relevant, by updating them with current information[76]. When traces are reactivated during their retrieval, they re-enter a labile state and must stabilize again (reconsolidation) if they are to persist[6, 7]. It is during this reconsolidation process that memories are updated by new information through strengthening, weakening, changing, or even erasing what was already stored in memory. Because we do not consciously register these reconsolidation processes, memories can be distorted or eliminated without our awareness.

Of course, it is obvious to most people that memories can be forgotten and that there are ways in which people can forestall such forgetting (e.g., through reinstatement and rehearsal, conversing with others about our experiences). There is a considerable body of evidence showing that children's ability to use forestalling strategies increases with age[27, 77-80]. However, these strategies themselves can have memory distorting consequences, ones that may lead to the blending of the current contents of one's experiences (including suggestions or elaborations of information that occur during conversations with others, material extracted from newspapers, magazines, television, or social media) with information retrieved from memory[28, 81]. Because the contents of our current experiences can blend with what has been reactivated in memory, and these altered contents get reconsolidated in memory, attempts to forestall forgetting can have detrimental effects when trying to accurately recollect autobiographical events in the courtroom. Indeed, the neuroscience underlying reconsolidation shows just how insidious these memory distortion processes can be, with the changes that arise as a result of reconsolidation not being privy to conscious inspection (e.g., occurring at a neurochemical level)[6, 7]. Thus, our rememberer will be blissfully unaware of these transformational processes and will never know whether what they are remembering actually happened, is some distortion of what occurred, or something that never happened at all.

Effects of stress and trauma on memory

There is another ‘common sense’ belief about memories of stressful and traumatic experiences, namely, that they are protected from being lost or distorted, being preserved outside of the experiencer’s conscious awareness (e.g., repressed) until a cue (e.g., a newspaper article, a TV program) suddenly brings them back into conscious awareness[1, 28] (see Box 2). Indeed, stress and trauma can have either a positive (memory enhancing) or a negative (memory impairing) effect: extreme levels of stress impair memory, whereas moderate levels can strengthen memory[82]. Although hormones released during stress (e.g., epinephrine, cortisol) modulate consolidation and memory strength, this does not mean that these memories are immune to forgetting, distortion, or even possible erasure[82]. In addition, stress impairs retrieval, particularly of autobiographical memories[82], and stress during reconsolidation can also lead to systematic distortions[6, 7].

Importantly, key changes in the systems that modulate stress take place during childhood. For example, the hippocampus and the amygdala change from early childhood through adolescence in terms of increased volume and increased connectivity between the amygdala and the hippocampus[50]. There are also prolonged effects of stress (e.g., child maltreatment) on the developing brain that can involve alterations in the neural structures that underpin memory, including the hippocampus, amygdala and the medial PFC. Long-term stress has particularly deleterious effects on structures (e.g., hippocampus, basolateral nucleus of the amygdala) rich in glucocorticoid receptors[83]. One consequence of long-term stress is poorer consolidation of emotional information, including through inhibition of neurogenesis, at least in rodents[84-87], primates[88], and possibly humans[89-90]. Although the role of adult neurogenesis in memory consolidation in humans is hotly debated[89-90], there is evidence[91] that in adult humans, new neurons are added each day to the hippocampus at a rate commensurate with that found in nonhuman animal studies. The role these new hippocampal neurons play in human memory is yet to be fully explored, although there is speculation that neurogenesis reduces interference between overlapping memories formed at different points in time[91-92]. Regardless, there is evidence that the inhibition of neurogenesis leads to poorer storage (and hence retention) of stressful memories in nonhuman animals[84-88, 93]. Some of these negative effects of early life stress in human[94-95] and nonhuman[96] animals can be ameliorated by modifying the environment (e.g., by removing the stressor, social enrichment), but this effect depends not only on the timing of these changes but also on the timing, duration, intensity, and frequency of exposure to stressors during development. Overall, then, the fact that an event was stressful or traumatic is not a good predictor of a child's (or an adult's) subsequent memory for that event.

Implications for the Courtroom

Evidence in legal cases involving historic childhood experiences consists of complainant's narrative recall of decades old memories. These narratives are often remarkable not just for their detail but also the inclusion of concepts and knowledge (e.g., temporal information) that someone so young (e.g., 2 to 5 years of age) could not possibly have understood at the time of the event (Box 1). If this knowledge was not available at that time, then how could such information have been encoded? When an adult reconstructs an event from childhood, their current motivations and world knowledge (e.g., schemas) may fill in any 'gaps' in the memory. Thus, schema-driven reconstructive processes can lead to the creation of partially or entirely false memories. Although aspects of such memories can be based on things that actually occurred (e.g., people and places involved in these alleged events do exist), it is difficult to know which aspects of memory evidence are 'true' and which are 'false' because there is no litmus test for the veracity of what has been remembered[97].

In these cases, judges and jurors may have to use "common sense" to evaluate the reliability of the memory-based evidence. As I hope this article has demonstrated, the scientific study of memory does not support the 'common sense' notions (see Box 2) that many judges and jurors use in judicial cases in which adult recollections of childhood experiences serve as the only evidence. First, cognitive and neurobiological changes during development affect how information is encoded, stored, and retrieved, and thereby constrain the content and durability of these memories. Second, memories can change during the storage of new information through the process of reconsolidation. Third, because memories are used to understand the world around us, what is extracted from stored experiences is abstract knowledge (semantic memory), often at the expense of the specific episodic details about that experience. Thus, when we try to remember a specific childhood experience, the memory is often fragmentary and decontextualized, and meaning-based (semantic) reconstructive processes 'fill in the gaps' so that our narrative about these events appears sensible.

It is important that judges and jurors know that the contents of narratives about childhood events should be gauged with respect to the age of the person at the time the event was encoded[24, 34]. Younger children's (5- to 6-year-olds) narratives rarely include emotional, temporal, introspective, or verbatim information even when the children are directly questioned about these aspects of an event they had experienced[34, 39]. Thus, if testimony about events that occurred early in childhood contains such elements, one should be skeptical about the veracity of that information and not assume that this level of detail increases the credibility of the complainant's narrative. The important questions are: which parts of the narrative reflect things that probably did happen (if any); and how can we discriminate those facts from distortions that may have arisen through reconstructive remembering processes?

Importantly, processes like reconsolidation occur outside of consciousness, and a rememberer will often not be aware that their memories have been transformed. This means that when judging the veracity of the narrative, it will not be useful to look for signs of deception (or assess levels of confidence). It is also important for jurors and judges to know that experiences that are encoded, stored, or retrieved during times of stress are not more likely to be remembered. Indeed, stress can actually impair the encoding and storage of autobiographical experiences and reduce the ability to retrieve specific episodic information during subsequent recall attempts.

These scientific findings stand in stark contrast to judges' and jurors' beliefs about memory and its development (see Box 2). This gap needs to be closed so that decisions about guilt or innocence in the courtroom reflect the scientific 'truths' about memory and not simply 'common sense' beliefs of judges and jurors. This knowledge should help jurors and others to evaluate memory-based evidence properly and does not usurp, but rather aids the judges' and jury's primary role of deciding the guilt or innocence of the defendant. Legal policy, procedures and practice need to change such that a memory expert's evidence is given its proper weight when a defendant's guilt or innocence is being determined primarily or solely on the basis of adults remembering childhood experiences.

Box 1. Adults' courtroom evidence of alleged memories of childhood events

When asked to recall early childhood memories, adult narratives are frequently very sparse: "I remember sitting in the kitchen sink with a toy army man, not really sure how I reached the sink, but I remember that there was music", or "I remember sitting in my parents' bedroom, observing my mother as she did some house cleaning. There is nothing else to the memory, but I remember having a very different perspective of the room at the time"[4 (p. 572)].

However, in the courtroom, such narratives surprisingly contain considerably more detail. An example is provided by early events being recalled by a complainant who alleged sexual abuse when she was three years old (all reports have been anonymised): "I was upstairs and I was playing in the spare room, and I was a bit upset. I was wearing my favorite pink dress and I remember him coming up to me … and he just picks me up and he just sat me on his lap and gave me a really big squeeze. He was wearing jeans and a t-shirt and would just sit there with his legs straight down in front of him. When he picked me up he would sit me facing the same way, he just pulled me really close in to him … he had his arms around my waist. I remember feeling uncomfortable." A similar level of detail was provided by another complainant when remembering an abusive event from the same age period: "I was in the house alone with him a lot of the time and he would take me into his room … he had a green solid pressed-wood headboard and blue flannel sheets on his bed. He would just lie there on top of the sheets, just sitting up on the bed with big feather pillows behind his head and just lie me next to him, to his right … and then I remember him, he was rubbing himself with his right hand, and then he would say 'why don't you feel it too?' I remember looking at him and then he would take my left hand and he would make me completely grab it and pleasure him. I remember thinking, 'this is disgusting'." Not only are these complainants' narratives unusually rich in detail, they also contain concepts that are not normally available to children so young (e.g., handedness, disgust). Moreover, oftentimes these unusually detailed memories also include verbatim conversations, conversations that most of us could rarely, if ever, remember some decades later.

This is not to say that adults who have experienced trauma in childhood cannot remember these events, particularly if those events are still viewed by the person as salient, life-changing experiences[5]. However, like all memories, recollection of traumatic experiences is reconstructive, subject to forgetting, and prone to error[3]. For example, adults who recalled documented childhood sexual abuse experienced some 12 to 21 years earlier were able to accurately recollect core features of these experiences. However, these narratives were sparse on peripheral information and contained reconstructive errors[5].

Box 2. Science and belief about memory: Comparing what memory experts know with the common sense views of law enforcement professionals, judges, and jurors.

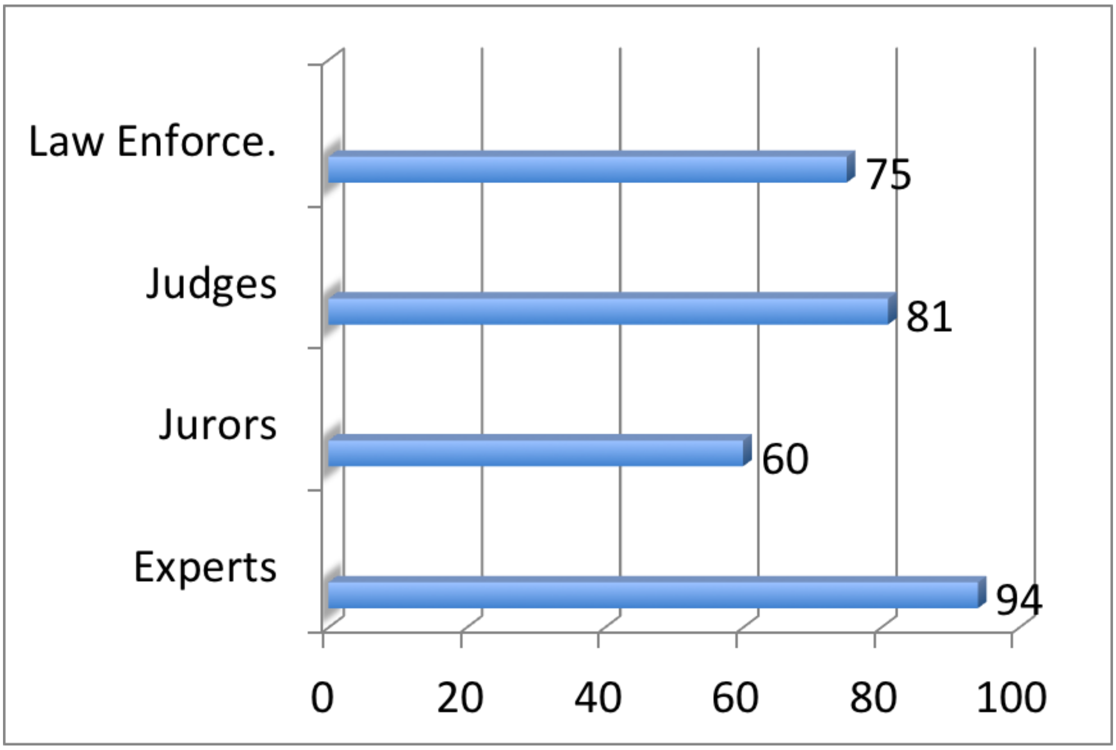
Recent court decisions in the United States (e.g., *State v. Coley*; 32 S.W.3d 831; Tenn. 2000) and in the United Kingdom (*R v. S*; *R v. W;* 2006 EWCA Crim. 1404, Royal Courts of Justice, London, p. 9) have suggested that, " it is difficult to see how … expert evidence can properly be tendered to establish a justifiable criticism of an adult witness who says that she suffered abuse throughout her childhood, which must have begun at too early an age for her to remember the first occasion [and who provided] highly specific details of abuse at such an early age. … the jury should consider their own experiences, searching their recollections for their earliest memories, and analysing what they could actually remember, and how far back their memories went. They did not require, and would not have been assisted by the evidence of an expert." That is, "Eyewitness testimony has no scientific or technical underpinnings which would be outside the common understanding of the jury; therefore, expert testimony is not necessary to help jurors 'understand' the eyewitness' testimony" (*State v. Coley,* pp. 833-834).

In an effort to understand whether 'common sense' views of memory are consistent with what the scientific study of memory has revealed, a number of researchers[8-17] have posed questions about how memory operates to various legal professionals (lawyers, law enforcement officers, judges) as well as members of the general public who are eligible for jury service. As it turns out, the common sense view of memory is frequently inconsistent with the findings from memory research. For example, whereas potential jurors believe that memory acts like a video recorder accurately registering a person's experiences, and that once recorded, such memories cannot be altered[16], there is a wealth of evidence showing that memory is reconstructive and fallible[28].

Of particular relevance here, are studies that examine 'common sense' beliefs about early childhood memories. For example, when 111 jurors (people summoned for jury duty), 42 judges (with an average of 11.2 years on the bench), and 52 law enforcement personnel (detectives, police officers, with an average of 13 years experience) were asked a series of questions about memory, ones that had been asked earlier of memory experts, the findings showed that there was a serious deficiency in their understanding of how memory operates[8]. As illustrated in the following figures, relative to experts, those serving as law professionals and those evaluating memory evidence in court have only limited knowledge of issues concerning the memory issues relevant to how adults remember childhood experiences.

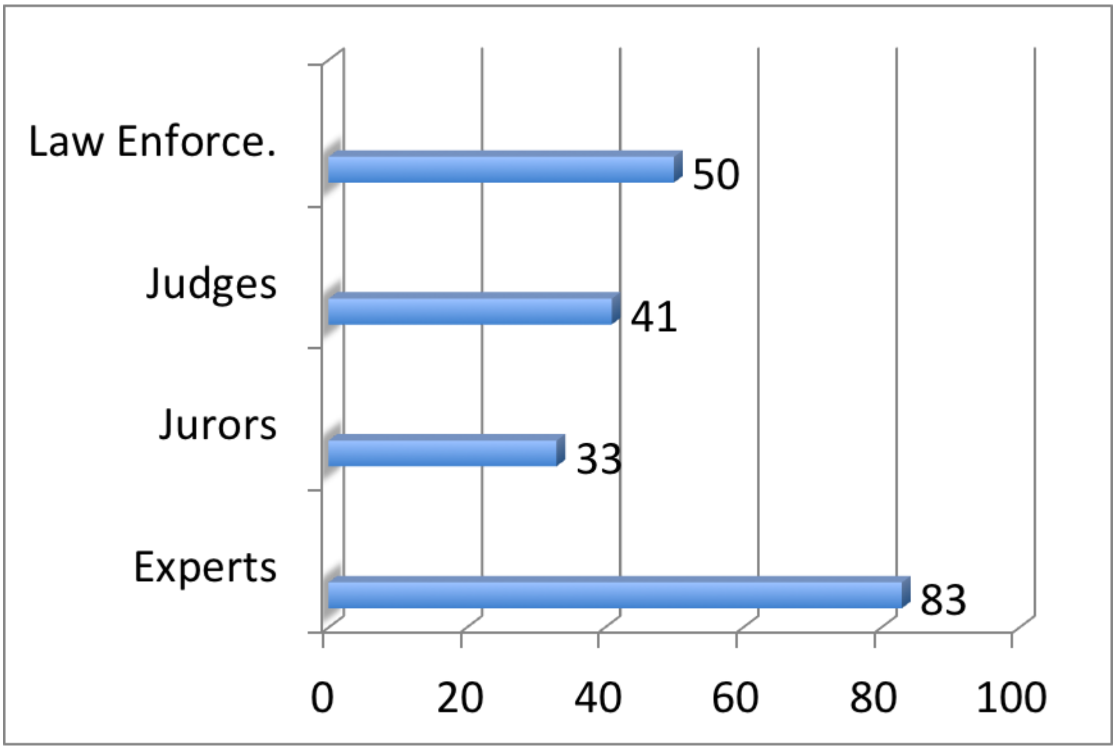
Effects of Post-event Information

"Eyewitness testimony about an event often reflects not only what they saw but also information they obtained later on." [This statement is correct. The figure depicts percentage agreement rates with the 'post-event information' statement. All three non-expert groups agreement rates were significantly lower than those of experts.]



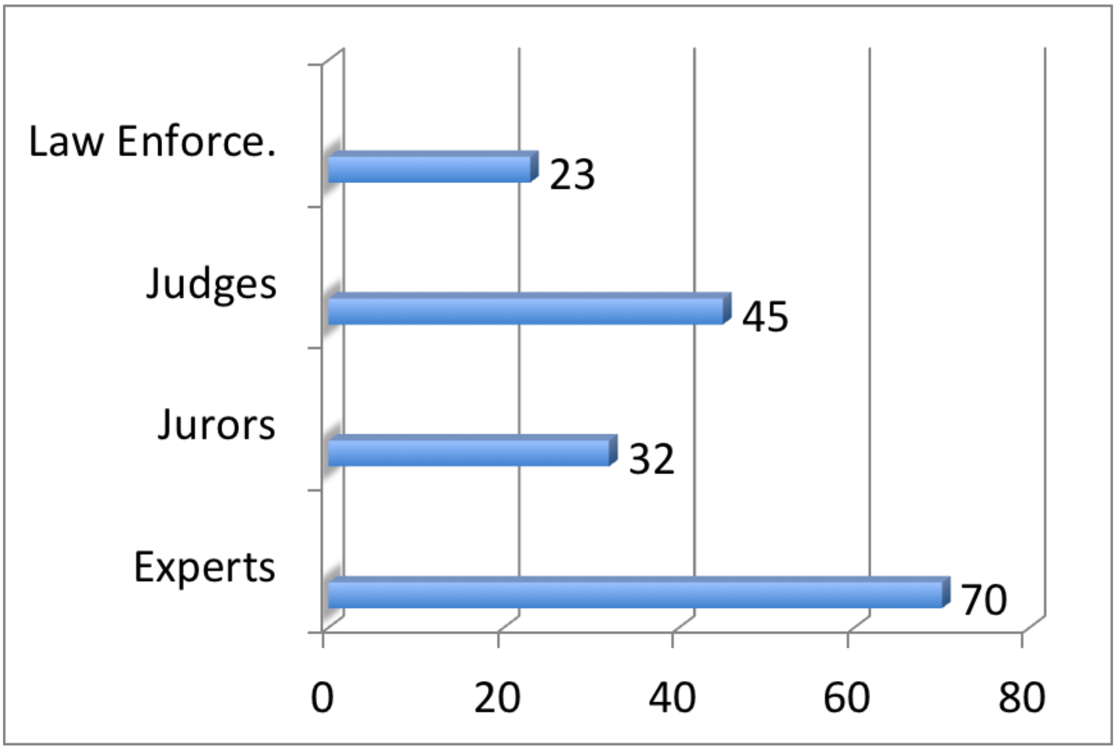
Forgetting Rate

"The rate of memory loss for an event is greatest right after the event and then levels off over time." [This statement is correct. The figure depicts percentage agreement rates with the 'forgetting rate' statement. All three non-expert groups agreement rates were significantly lower than those of experts.]



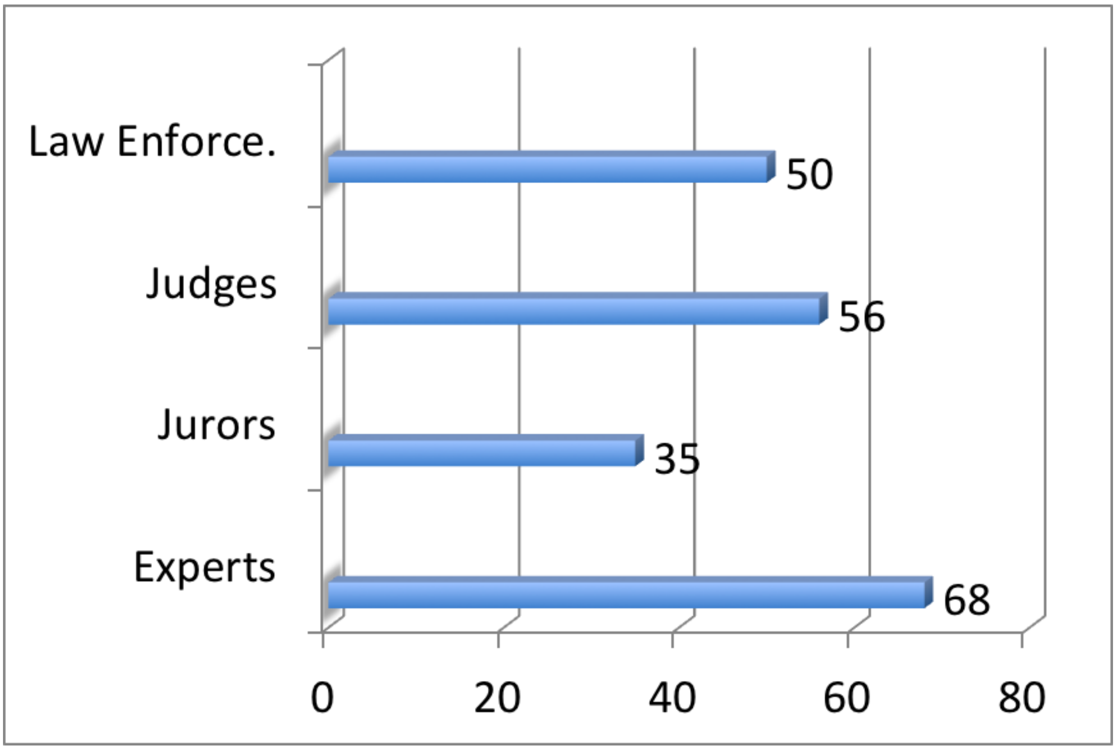
Child Witness Accuracy

"Young children are less accurate as witnesses than are adults." [This statement is correct. The figure depicts percentage agreement rates with the 'child witness accuracy' statement. All three non-expert groups agreement rates were significantly lower than those of experts.]



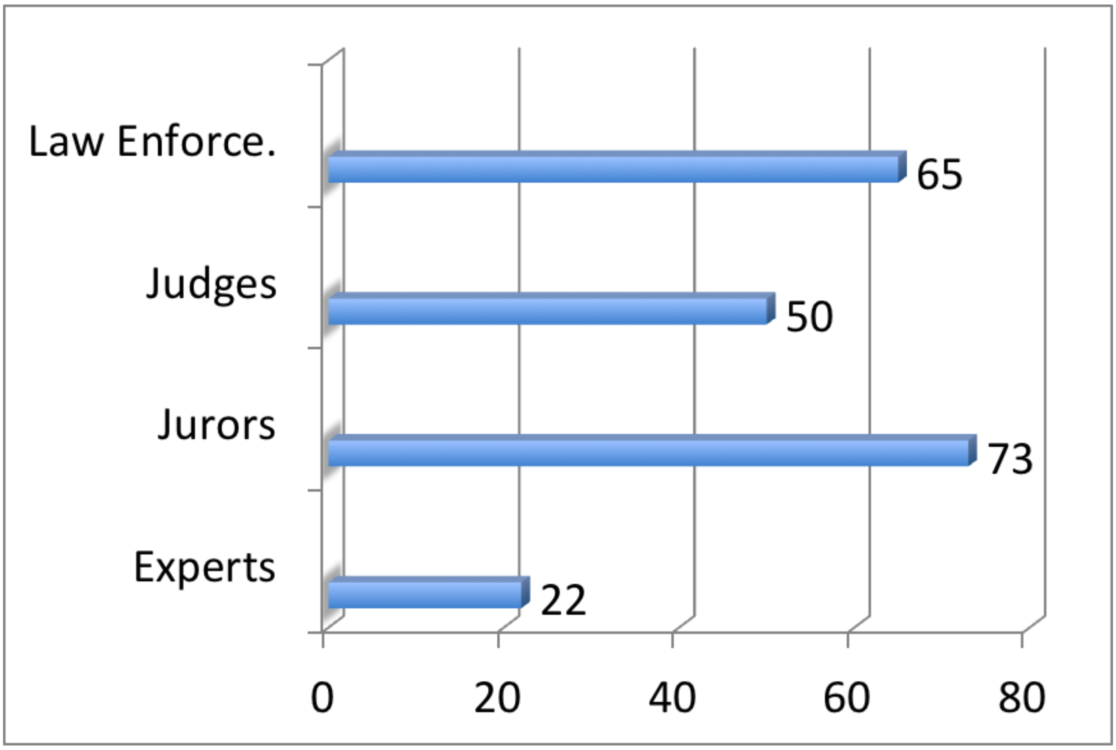
False Childhood Memories

"Memories people recover from their own childhood are often false or distorted in some way." [This statement is correct. The figure depicts percentage agreement rates with the 'false childhood memories' statement. Two of the three non-expert groups (with the exception of judges) agreement rates were significantly lower than those of experts.]



Long-term Repression

"Traumatic experiences can be repressed for many years and then recovered." [This statement is incorrect. The figure depicts percentage agreement rates with the 'long-term repression' statement. All three non-expert groups agreement rates were significantly higher than those of experts.]



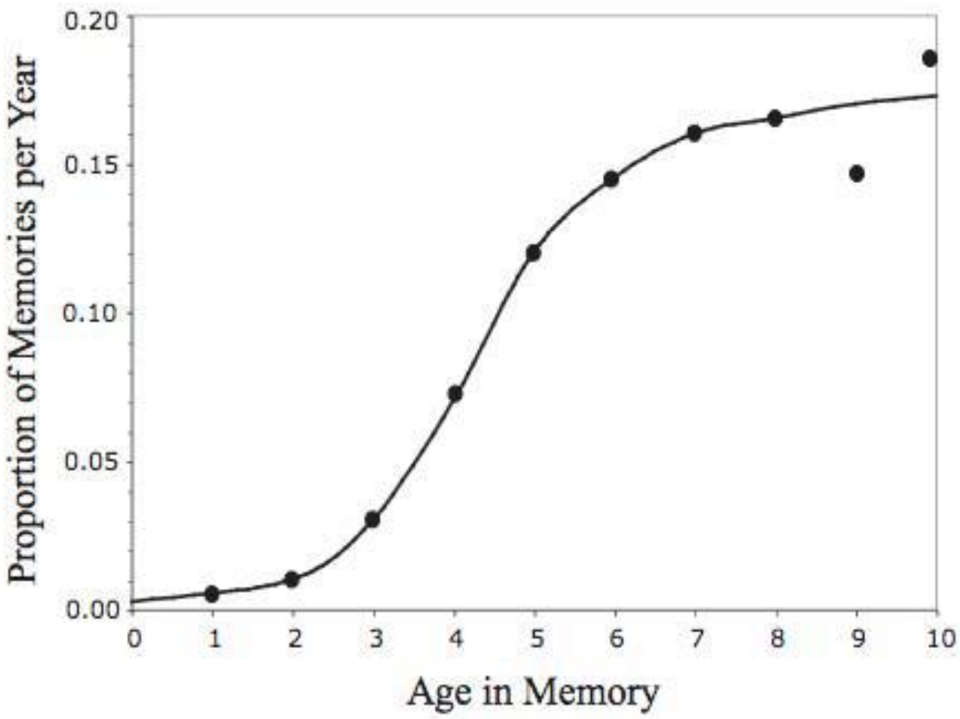


Figure 1: A composite distribution of adult recall of 11,000 childhood memories (adapted from D. C. Rubin[24]). Points along the distribution (Y-axis) represent the proportion of memories retrieved by adults, memories that were stored at different ages across their childhoods (X-axis). What these data show is a summary across several studies of autobiographical recall of childhood events by adults using different recall techniques[24]. What the results show is that people have very little memory for autobiographical experiences that occurred before the age of two, few memories for events that occurred between two and three years of age, and that the number of memories of events occurring later increases with the person's age at the event. Importantly, it is not until around the age of seven that we begin to see mature levels of autobiographical remembering. These data are consistent with the growing consensus[25] that experiences occurring at or after the age of seven or eight can be reliably remembered in adulthood. It is perhaps prudent, then, that legal proceeding where memories of such events constitute the main or only evidence heed the advice in a report by the British Psychological Society[25] that states, first, "In general the accuracy of memories dating below the age of 7 years cannot be established in the absence of independent corroborating evidence"; and second, "These findings lead to the conclusion that by approximately 9 to 10 years of age children have autobiographical memories that are adult in nature".

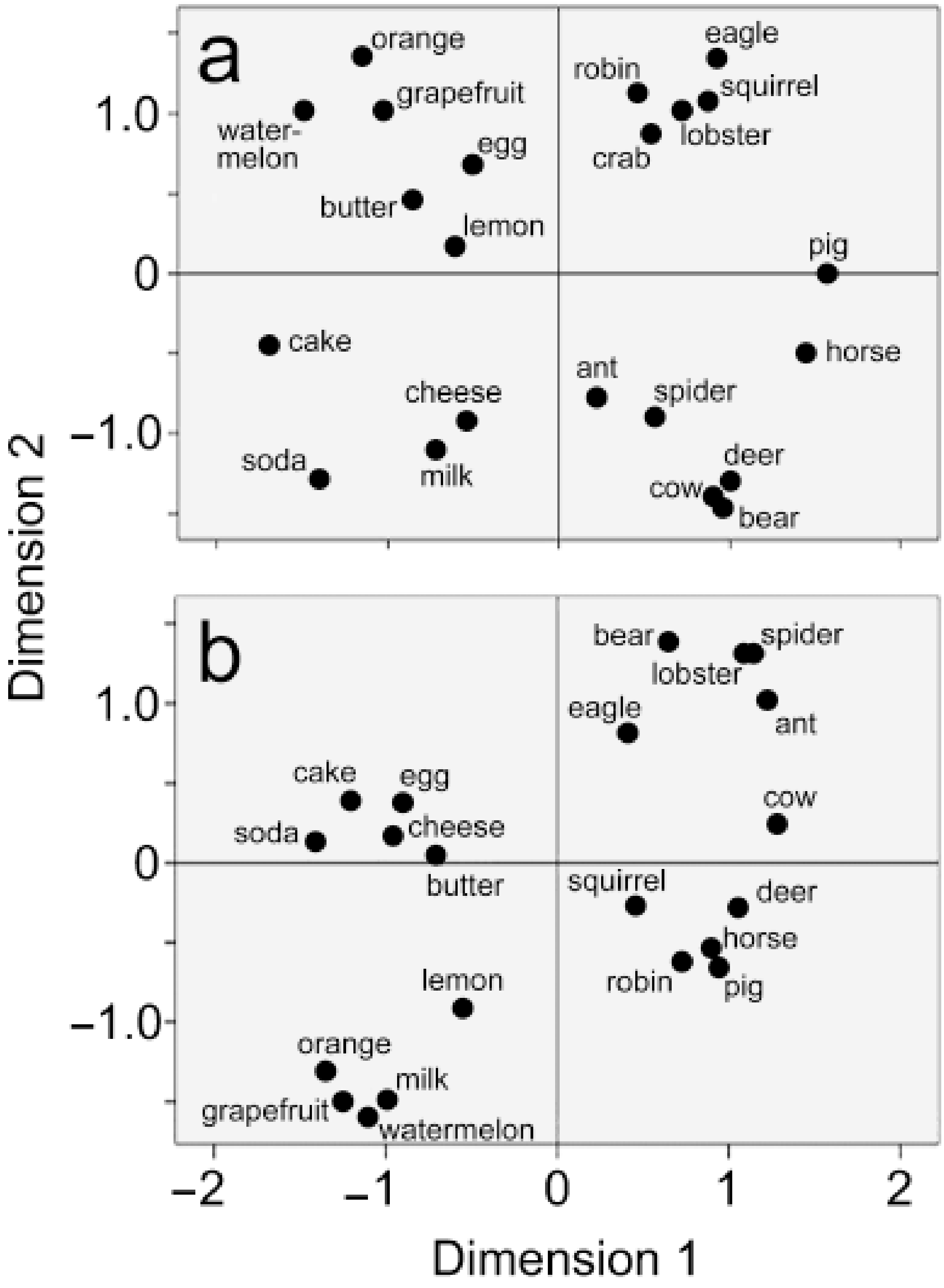


Figure 2: Differences in (a) younger and (b) older children's knowledge base using nonmetric multidimensional scaling solutions derived from INDSCAL models of children's similarity ratings (adapted from Ceci et al.[29]). These solutions show Euclidean distances between concepts for 4-year-olds and 9-year-olds and illustrate changes with age in how concepts are interrelated in semantic memory (knowledge base). These differences in how concepts are clustered in memory predict the types of memory confusions experienced by children of different ages. Indeed, Euclidean distance was a strong predictor of children's confusions. Specifically, children were more likely to exhibit age-appropriate memory confusions between items actually presented and distractor items on a memory test for concepts more

closely clustered in semantic space (e.g., crab-lobster for 4-year-olds but spider-lobster for 9-year-olds) than those less densely clustered. These results not only illustrate how representations of concepts change in children's knowledge base across age but also how these changes affect memory performance, particularly, memory confusions.

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