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RUNNING HEAD: THE 'ME' IN MEMORY

The me in memory: The role of the self in autobiographical memory development

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Abstract

This paper tests the hypothesis that self development plays a role in the offset of childhood amnesia; assessing the importance of both the capacity to anchor a memory to the self-concept, and the strength of the self-concept as an anchor. We demonstrate for the first time that the volume of 3- to 6-year-old’s specific autobiographical memories is predicted by both the volume of their self-knowledge, and their capacity for self-source monitoring within self-referencing paradigms (*N* =186). Moreover, there is a bidirectional relationship between self and memory, such that autobiographical memory mediates the link between self-source monitoring and self-knowledge. These predictive relationships suggests that the self memory system is active in early childhood.

Keywords: Autobiographical memory, self memory system, childhood amnesia

“Episodic memory differs from other forms of memory in that its operations require a self. It is the self that engages in the mental activity that is referred to as mental time travel: there can be no travel without a traveler”

Tulving, 2005, pp.14-15

The above quotation makes clear that there is a close connection between self and memory; without the meta-representative self, we have no sense of connection to the past or future, no access to our own autobiography. The ‘me’ inherent in memory was recognized early (Hulme, 1739/2003; James, 1890; Locke, 1690/1995), and the relationship between self and memory continues to guide modern theories of autobiographical processing. For example, Conway’s influential self-memory system (SMS) describes how the information that we encode and retrieve is dynamically driven by the goals of the ‘working self’ (Conway, 2005; Conway & Pleydell-Pearce, 2000). Drawing from an existing knowledge base containing both episodic and semantic self-knowledge, the working self aims to maintain a coherent sense of identity, and to ensure that short term self-relevant goals (e.g. to pay a bill) are met. In this model, the self-concept therefore both drives the capture of, and is maintained by, incoming episodic information (see Rathbone, Moulin, & Conway, 2008). It follows from this bidirectional relationship that the developmental onset and growth of autobiographical memory and the conceptual self will be closely linked. However, very little empirical work has explored the relationship between these systems across childhood. The current research addresses this gap in our understanding, examining the association between 3 to 6-year-old children’s self-source monitoring, self-knowledge and autobiographical memories, in an effort to elucidate the offset of childhood amnesia.

Early autobiographical memory

It has been established for more than a century that autobiographical memory development is associated with a period of amnesia; we remember no personal events preceding our 2nd or 3rd birthday, and relatively few from early childhood (Henri & Henri, 1898; Pillemer & White, 1989; Tustin & Hayne, 2010). Although the cause of infant and childhood amnesia is yet to be established (Bauer, 2015), prevailing theories focus on the idea that early amnesia may be offset by developments in social, cognitive and linguistic domains which qualitatively change the manner in which episodic memories are encoded and retrieved, and open the possibility of autobiographical retention (e.g. Bauer, 2015; Fivush, 2011; Hayne, 2004; Howe & Courage, 1993, 1997, 2004; Howe, Courage & Edison, 2003; Johnson, Hashtroudi & Lindsay, 1993; Nelson & Fivush, 2004; Perner & Ruffman, 1995; Welch-Ross, 1995a). Of current relevance, Howe and Courage (1993, 1997, 2004; Howe et al., 2003) take the logical standpoint that the development of an objective concept of self is a minimal requirement for the encoding and retrieval of an event which one remembers experiencing.

The mirror mark test of self-recognition provides the first evidence of an idea of ‘me’. In the mark test, children are surreptitiously marked in a visually inaccessible area of the face before being shown their reflection in a mirror. By the age of two years, children typically connect the mirror self-representation with their body in the real world, as demonstrated by their reaching to their face to explore the unexpected mark (Courage, Edison, & Howe, 2004). Drawing attention to the parallel emergence of mirror self-recognition and the earliest autobiographical memories, Howe and Courage (1993, 1997, 2004; Howe, Courage & Edison, 2003) suggest that until self-representation is present, children cannot explicitly reflect on experiences as belonging to the self. As a result, they cannot store self-referent memories of early life events. The idea that the salience of self may influence the strength of a memory can also be found in literature describing the ‘reminiscence bump’ in adolescence/early adulthood, thought to be tied to the defining role of this period in constructing personal identity (Conway, Wang, Hanyu, & Haque, 2005; Rathbone et al., 2008; Rubin, Weltzler & Nebes, 1986).

There is some direct evidence to support a relationship between the emergence of self and autobiographical memory. Howe et al. (2003) tested a cohort of 15- to 23-month-old children on the mirror mark test, and involved them in hiding a toy. Up to 12 months later, those who were self-recognizers at the time of the hiding event were more likely to remember the location of the hidden toy. Likewise, Harley and Reese (1999) report a positive association between 19-month-olds’ self-recognition and their ability to sequence actions in a deferred imitation task spanning one week. They also found that both mirror self-recognition and maternal reminiscing style predicted children’s ability to provide specific details of past life events.

These studies support Howe’s contention that the offset of infantile amnesia may be connected to the development of the self-concept. However, they do not directly assess children’s ability to ‘tag’ memories as their own. The development of self-source monitoring offers a potentially valuable source of evidence here. Traditionally, measuring this ability requires children to specify the source of their action memories as imagined, witnessed or performed (Foley & Johnson, 1985; Welch-Ross, 1995b), or to identify the source of semantic knowledge (e.g. how did you find out X?) (Drumney & Newcombe, 2002; Perner & Ruffman, 1995). Although self-actions are implicated in such paradigms, the role of the self is typically not considered. A notable exception comes from the overlapping developmental literature on the subject-performed task (SPT) effect (see for example, Ross, Anderson & Campbell, 2011a Study 1). Typically-developing children as young as three years show better memory for action phrases which they have enacted, relative to action phrases they have encoded passively. This research implies that *personally experiencing* an event makes it more memorable for children, and is keeping with Howe and colleagues' idea that autonoetic experiences lead to stronger or distinct memory traces.

Indeed, a number of theorists have highlighted the importance of binding a memory to source information in order for it to be re-experienced in an autonoetic manner (Bauer, 2015; Hayne, 2004; Johnson et al., 1993; Newcombe, Drummey, Fox, Lie, & Ottinger-Alberts, 2000; Perner & Ruffman, 1995; Raj & Bell, 2010). According to these accounts, memories encoded with contextual information pertaining to the subjective experience of the event (emotions, smells, sounds) are qualitatively richer than memories encoded without this information, which might be considered semantic. In this model, encoding agentive experience is viewed as necessary to enrich the memory trace, creating a memory that is resistant to forgetting (Bauer, 2015; Hayne, 2004; see also Prudhomme (2005) for evidence linking this to mirror self-recognition). Meta-cognitively reflecting on this information to identify the source of the memory as being experienced by 'me' is also viewed as important (Johnson et al., 1993; Newcombe et al., 2000; Perner & Ruffman, 1995; Raj & Bell, 2010; Welch-Ross, 1995a). Meta-cognitive reflection distinguishes the state of 'remembering' as distinct from the subjective state of 'knowing' (Tulving, 2005), and is by definition necessary for autobiographical recall. First emerging between the ages of 3 and 4 years (Pillow, 1989) and increasing across childhood (Piolino, Hisland, Ruffeveille, Matuszewski, Jambaqué, & Eustache, 2007); Welch-Ross (1995a) argues that it is the remember-know distinction that allows children to enter into dialogues with others about personally experienced events (rehearsing and elaborating the memory), and allows remembered events to be stored as belonging to the self. The available evidence suggests that both autonoetic source monitoring capacity and binding of specific details within an event develop gradually across early childhood (see Raj & Bell, 2010 for review). However, developments in self-specific source monitoring in childhood have not been empirically related to developments in autobiographical memory. This evidence is necessary to support Howe and Courage’s (1993, 1997, 2004; Howe et al., 2003) theory that tagging an event as self-referent is key to the offset of childhood amnesia. Accordingly, linking the development of self-specific source monitoring to autobiographical memory is a key aim of the current paper. Our second key aim is to link age-related change in the self-concept to age-related change in autobiographical memoryin early childhood. Using mirror self-recognition to test Howe and colleagues’ theory limits the period of qualitative change to the period of 18 to 24 months. However, amnesia persists beyond infancy, as reflected in the slow growth of memories for events in early childhood (Hayne, Gross, McNamee, Fitzgibbon, Tustin, 2011; Nuttall, Valentino, Comas, McNeill, & Stey, 2014; Tustin & Hayne, 2010). Howe and colleagues argue that the gradual offset of childhood amnesia is related to gradual development in the self-concept, strengthening the anchor to which memories are attached. However, this critical aspect of their theory remains untested.

Early self-reference effects

The self-concept may act as an effective anchor for memories by offering a psychologically rich network of knowledge in which to embed incoming information. This supportive role of the self in memory is exemplified by the ‘self-reference effect’ (SRE). This describes a mnemonic advantage for information encoded with reference to self (Rogers, Kuiper, & Kirker, 1977). Well-established in adults (see Symons & Johnson, 1997 for meta-analysis), the SRE is typically measured by asking participants to process whether psychological trait words (friendly, clever, honest) are self-descriptive. When compared to trait words processed in reference to another person (*“Is Trump clever?”*), or non-socially (*“Is this word in upper or lower case?”*), memory for self-processed trait words is superior. The SRE is thought to arise from organization and elaboration of the trait word within a rich body of existing semantic and autobiographical self-knowledge (Klein, 2012; Symons &

Johnson, 1997). The SRE may also arise from preferential encoding (Cunningham & Turk, 2017; Turk, Cunningham & Macrae, 2008), since self-relevant cues in the environment are likely to capture attention (Bargh, 1982; Brédart, Delchambre, & Laureys, 2006). These attentional, elaborative and organisational explanations of the SRE are entirely consistent with the multi-faceted role of self described in Conway's SMS (Conway, 2005; Conway & Pleydell-Pearce, 2000).

Although children can show an SRE on the traditional trait paradigm, reported developmental patterns are mixed (Bennett & Sani, 2008; Halpin, Puff, Mason & Marston, 1984; Pullyblank, Bisanz, Scott, & Champion, 1985), perhaps because the trait task is developmentally challenging (Cunningham, Brebner, Quinn & Turk, 2014). Using more age-appropriate measures of self-referencing, children as young as three years have been found to show a memory advantage for stimuli linked with the self (Cunningham, Vergunst, Macrae & Turk 2013; Cunningham, et al., 2014; Ross et al., 2011a; Sui & Zhu, 2005). Although the SRE has rarely been related to the childhood amnesia debate (see Ross et al., 2011a), the finding that young children can benefit from the SRE provides indirect support for Howe and Courage's (1993, 1997, 2004; Howe et al., 2003) theory that the self is active in strengthening event memories in early childhood.

Exploring the emerging SRE in more depth, Cunningham et al. (2014, Exp's 1 and 2) adapted the traditional paradigm for use with children by substituting the trait adjective for a picture of a toy or household object, which the child was asked to assess for desirability to themselves (when pictured with own face) or another child (when pictured with another face). Cunningham et al. found that 4- to 6-year-olds had a robust SRE, remembering more of the items shown with their own face than those presented with the other child. Interestingly, this effect emerged regardless of whether conscious evaluation was required during encoding; when the task was modified such that the identity of the face was incidental to the task (by asking the child to report the locus of the object rather than its desirability), Cunningham et al. (Exp. 3) found that images presented with the self were still better remembered. This ‘incidental’ SRE (see Turk, Cunningham, & Macrae, 2008) was similar in magnitude to the ‘evaluative’ SRE, and was age-invariant. Critical to autobiographical processing, 4- to 6-year-old children in Cunningham et al.’s (2014) study also showed a self-bias in source memory for incidentally and evaluatively self-relevant items. This is important because a) source memory elevates recognition scores to fulfill the criteria for episodic recall, demonstrating conscious self-processing, and b) the children’s source-bias implies that they have entered the SMS system, in which self-relevant events have mnemonic priority.

Source-monitoring within the SRE paradigm therefore allows one to determine if an episodic memory has been tagged as self-referent, and if this tagging has any mnemonic benefit. Moreover, unlike the mirror mark test of self-recognition, the SRE paradigm is not limited to a binary perspective on the quality of memories before and after the onset of mirror self-recognition at two years. Rather, the capacity for binding an event to self across various levels of self-processing (for example, incidental, evaluative) can be employed to probe the potentially complex role of self-development in the critical period of amnesia recession. This allows elucidation of Howe and Courage (1993, 1997, 2004; Howe et al., 2003) and Welch-Ross’s (1995a) suggestions that the offset of infantile amnesia is not sudden, but recedes gradually across childhood as the self-concept grows in size and complexity (Eder, 1989, 1990; Harter, 1999; Montmayer & Eisen, 1977; Wang, 2004).

The current inquiry

We aim to examine, for the first time, the relationship between the autobiographical memory system and theself-conceptin early childhood (three to six- years). We assess the quantity of detail provided in children’s autobiographical event memories, and relate this to source memory for self- and other-referenced stimuli in the SRE paradigm, and for self- and other-performed actions in the SPT. Source monitoring in incidental, evaluative and physical self-reference paradigms is included since each aspect of these memories is necessary to form mature autobiographical memory; one must autonoetically remember experiencing the event (SPT task), attend to the role of self (incidental SRE) and integrate the event with extant self-knowledge (evaluative SRE). Alongside these memory measures, we assess self-knowledge by asking children to respond to the standard “Who am I?” test (Montmayer & Eisen, 1977; Wang, 2004). Using this methodology, the current paper provides the first comprehensive test of the relationship between the self and memory described by Howe and Courage (1993, 1997, 2004; Howe et al., 2003); assessing the importance of both the capacity to anchor a memory to the self-concept (as measured by source-monitoring), and the strength of the self-concept as an anchor (as measured by self-description).

Following extant research, we expect to replicate the finding that self-performed actions and self-referenced stimuli are better remembered by young children than stimuli linked with others (Cunningham et al., 2014; Ross et al., 2011a). We also expect source-monitoring capacity (Drumney & Newcombe, 2002; Foley & Johnson, 1985; Welch-Ross, 1995b), the quantity of specific autobiographical details of past events (Hayne et al., 2011; Nuttall et al., 2014; Tustin & Hayne, 2010) and the quantity of self-descriptive detail to increase with age (Eder, 1989, 1990; Harter, 1999; Montmayer & Eisen, 1977; Wang, 2004). Crucially, we assess for the first time [to our knowledge] whether these age-related changes are predictive of one another, even when controlling for vocabulary and memory capacity. It is important to control for vocabulary given that the amount of detail provided in children’s self-descriptions and autobiographical reports may vary with linguistic capacity. Controlling for general memory capacity is important to support Howe and Courage’s (1993, 1997, 2004; Howe et al., 2003) claim that the offset of childhood amnesia is self-specific.

Specifically, we hypothesize that source monitoring in SPT and SRE tasks, alongside the volume of children's self-descriptions, will be predictive of the volume of autobiographical event details If the former relationship is self-specific, and not a consequence of general memory processes, then self-source monitoring within the SPT and SRE paradigms should be a better predictor of autobiographical memory than other-source monitoring (where the child identifies another person as the source of their knowledge). This predictive model would provide clear evidence for the idea that tagging a memory as one's own improves its memorability, due to the supportive nature of the self-concept in motivating the capture of and organizing the storage of self-referent information. Moreover, recognizing the bidirectional nature of self and memory, we hypothesize that children's self-knowledge will be predicted by the volume of their autobiographical event narratives. This predictive relationship would provide evidence for the idea that the autobiographical memory base (described by Conway's SMS) is responsible for maintaining and growing an idea of 'me'.

Method

Participants

A total of 186 three to six year old children were recruited (*M* = 56.99 months, range = 36 - 85 months; 54% female). All children had English as a first language, and were pupils at local nurseries or schools of medium to low socio-economic status. The children were tested with the written consent of a parent or guardian, and their own assent, and the research was approved by Abertay and Dundee University's Psychology Ethics Committees.

Procedure and materials

The children were tested individually over three sessions on five tasks measuring: autobiographical memory, self-description, memory for self-performed action, self-relevant action, and receptive vocabulary. Testing was carried out in the child's place of education, with each child completing one session per week for three consecutive weeks. At the end of each session, the child was thanked, given a sticker and taken back to class.

Session 1

SPT. During the first session, the children completed a subject-performed action task (the SPT) adapted from Ross et al. (2011a). Participants were introduced to a fictional character called a “wug”. Across a series of 24 picture cards revealed in turn, the Wug was depicted performing everyday actions. The experimenter and participant acted out alternate actions modeled by the wug, with the order of the actions counterbalanced across experimenter and participant. After a delay in which participants completed the NIH Toolbox vocabulary Task (see below), they were then asked to free recall the actions, and identify the source of each (i.e., indicate whether they were performed by self or the experimenter). To provide a self-source score, the proportion of hits for self actions was calculated (i.e., number of self items correctly attributed to being conducted by self/12 = total number of self actions). The equivalent score was calculated for other-source. To correct for guessing, the proportion of false alarms was calculated for self and other actions (number of other actions incorrectly identified as self or other/12) and subtracted from raw scores to give a final, corrected score for self-source (proportion self hits – proportion self false alarms) and other-source (proportion other hits – proportion other false alarms).

NIH Toolbox Vocabulary Task (see Akshoomoff et al, 2014). This task was performed on a touchscreen laptop provided by the experimenter. Within each trial a set of four pictures was presented onscreen simultaneously with a spoken word that described one of the pictures. Participants were then asked to select the picture that best matched the spoken word by touching the appropriate picture on the laptop screen. Participants were given as much time as required to complete each trial. Due to the lack of reading or literacy requirement this task was deemed suitable for children of all ages and abilities. This is a computer adapted task whereby the difficulty of each successive item presented is based on the current estimate of the participant's ability level, as estimated by their responses to the previously administered items on the test. Items were administered to match each participant's ability with item difficulty. Each participant was exposed to 25 trials and the task lasted on average approximately 5 minutes. The children received an age corrected score with a normative mean of 100 and standard deviation of 15.

At the end of Session 1 each participant's photograph was taken for use in the subsequent testing session. This picture was used to cue self-reference in the SRE task, which replicated the methods of Cunningham et al. (2014).

Session 2

SRE task. Before seeing the child for a second time, the experimenter cropped the photograph taken in Session 1 using picture editing software, creating a 250 x 250 pixel (72 dpi) image of the child's face on a transparent background. This picture was used to cue self-referencing. Facial photographs of age-matched controls who were unknown to the participants, were modified in the same way to create gender and age-matched other-referent cues named "Sam" as a unisex name. On arrival, the child sat at a table facing a 15" laptop with a touchscreen. The experimenter sat beside the child, in front of the laptop. The experiment was run using EPrime experimental software, and consisted of an encoding task followed by an unexpected recognition memory test.

In the encoding phase a face was presented on a white background in the centre of the touch-screen monitor for 2,000 ms. In half of the trials, this was the child's own face ("self-referent" trials). The other half comprised "other-referent" trials, in which the face of the unknown, same-sex child was presented. Self-referent and other-referent trials were presented in an order randomized by the software. During the trial, 500 ms after the onset of the face, an object was shown in a box to the left or right of the face. Objects (e.g., toothbrush, broccoli), and were presented as 250 X 250 pixel (72 dpi) color photographic images on a white background. The presented objects were taken from a total of 72 for the 3-4 year old children, and 108 for the 5-6 year old children (with age-appropriate stimuli set lengths determined by pilot testing). The objects were split into three equal lists. For each child, one of the three lists was presented in self-referent trials, one was presented in other-referent trials, and the third was reserved to be used as foils in the subsequent recognition memory test. The use of these lists was counterbalanced across participants.

Two versions of this task were used: ‘evaluative’ and ‘incidental’ versions, following Cunningham et al. (2014). In the evaluative version of the SRE task, the children’s task was to evaluate the object with reference to the faces. Specifically, they were asked, “Would you [Sam] really, like this object, or would you [Sam] not like it?” The two images (i.e., face and object) remained onscreen together for 1,500 ms, then a 100-ms blank interstimulus interval preceded presentation of two yellow circle “buttons” depicting a smiley and neutral face, respectively. The children were asked to touch either the smiley face or neutral face button to indicate the outcome of their evaluation. Following the child’s response, the faces disappeared and a blank 1,000 ms interval preceded presentation of the next trial. Before beginning the experimental trials, each child was given three practice trials (two self-referent and one other-referent trial) to ensure that they recognized their own face, understood the task instructions, and were able to evaluate their own and the other-referent’s likely feelings toward the objects. All the children recognized themselves and were able to follow the task instructions. After the practice trials, the children were encouraged to keep attending to the items onscreen to avoid missing any objects, and were asked not to talk during the task. After completing the experimental trials, the children were praised for their concentration before being introduced to the memory task.

The stimuli and procedure for the incidental version of the cognitive SRE task exactly followed that of the evaluative version, with the exception that instead of being asked to evaluate each object with reference to self or the other-referent, the children were asked simply to report on which side of the screen the object had been presented. This involved presenting two yellow circles as response buttons, with no neutral or smiley faces. The size, color, brightness, and position of these “left” and “right” buttons were exactly matched with the face response buttons presented in the evaluative version. All the children recognized themselves and were able to follow the task instructions. Since piloting indicated that the evaluative and incidental SRE tasks interfered with one another if given on a within subjects basis, children completed EITHER the evaluative or incidental version (random assignment).

In the memory phase, children completed a one-step source memory test, with participants being asked to respond to each picture with one of the following answers: “New picture”, “Shown with me” or “Shown with Sam”. The children were told they could guess if they were not sure of their answer. The child responded by pressing the appropriate key on the keyboard. Keys were annotated with “New” “Me” “Sam” Once the child had made their response the object disappeared and a 1,000ms inter-trial interval preceded presentation of the next object. Following Cunningham et al (2014), the self-source score was calculated by subtracting the proportion of “self” false alarm rate (New items incorrectly identified as “Shown with me”/total number of new items) from the proportion of self-referent items correctly identified as “Shown with me”. Likewise, the other-referent source score was scored by subtracting “other” false alarm rate (New items incorrectly identified as shown with Sam/ total number of new items) from items correctly identified as shown with the other-referent. This correction method ensures that the data analyzed focuses on accurate source plus recognition data i.e. data which fulfils the criteria for episodic recall. This data is corrected for guessing by subtracting data from foils, for which there is no accurate memory.

Children also make source confusions i.e. identifying old items with the wrong source. These may represent familiarity rather than recall and are not included in the calculations here.

Session 3

During the final testing session participants were interviewed about their early memories and self-knowledge following a procedure used by Wang (2004), and their responses recorded on a Dictaphone and subsequently transcribed. The experimenter told the child that they had some questions to ask and would record their responses. The child was assured there was no right or wrong answer and just to respond with whatever they could think of.

Autobiographical memory. To elicit autobiographical event narratives, the experimenter asked the children “What can you remember about your first day of school/nursery?”, and “What can you remember about your last birthday?”. These events were chosen because they objectively happened to all of the children in the past and are culturally considered memorable. Following each response the experimenter used standard prompts such as “What else can you remember?” and “Is there anything else?” until the child indicated by speech or gesture they had finished.

Propositions, as described by Fivush, Haden, and Adam (1995; see also Wang, 2004) as subject-verb propositions, were used as the coding unit with each new proposition counting as a new unit (e.g., “I dance” was one unit; “I dance and swim” was two units). The propositions that made up children’s memory reports were coded as either *specific* if they referred to a memory that occurred at a particular point in time (e.g., I had a Spiderman birthday cake) or *general* for memories that referred to events that took place on multiple occasions or happened regularly (e.g., I had a birthday cake; Wang, 2004). Following Wang (2004) specific memories were given a score of 1, and general memories a score of 0, to preserve a focus on autobiographical rather than semantic information. The total number of specific memory propositions provided were summed across memory reports to create an overall score. This coding method is designed to provide a meaningful measure of both volume and specificity of autobiographical reports.

Self-description. Next the experimenter used an open-ended question to elicit the child’s self-description. The experimenter told the child “I wonder if you can tell me some things all about you, some things that would describe {child’s name] to me?” The experimenter prompted the child after each response with “What else could I write about you?” until the child indicated by speech or gesture that they had finished. Interviews were transcribed verbatim onto paper at a later date (Wang, 2004). Responses referring to qualities, opinions or traits were coded as abstract (e.g., “I love to cycle”); responses referring to physical traits or facts (e.g., “I have glasses”; “I live on a farm”) were coded as concrete self-descriptions (Wang, 2004). Since the volume of abstract responses was relatively low, analyses were based on total self-description scores, created by summing the number of abstract and concrete details provided.

The autobiographical memory and self-description tasks were completed in this fixed order to replicate Wang (2004), and since piloting indicated that the autobiographical memory task was a more effective conversation opener than the free self-description task. Inter-rater reliability for coding within the autobiographical memory task (specific versus general) and self-description task (abstract versus concrete) was established by having the data coded by two independent raters (authors 1 and 3), and yielded a robust Cohen’s kappa score (k = .971 overall, k = .929 specific versus general, k = .993, concrete versus abstract). Raters were blind to any details of the child’s age or performance when coding autobiographical reports and self-descriptions.

Results

The first section below (a) describes checks that our data yielded predicted patterns regarding self v. other-referent encoding, and age. Thus the sample was split by median age to create two equal age groups (N = 93 each) for comparison in between subjects analyses (Younger age group 36 – 55 months; older age group 56 – 85 months). The two age groups were combined for the main results section (b), in which age by months was included as a co-variate for detailed analysis regarding our key theoretical predictions.

(a) Referent and age patterns

Effects of Self v. Other-referent encoding

Table 1 shows performance in the SRE and SPT tasks. Recall accuracy was highest on the SRE tasks, which were supported by forced choice picture prompts, and particularly high when encoding required evaluation of the to-be remembered item (as would expected from this deeper processing). There was a bias for accurate self-source memory across all tasks, which was similar for younger and older children.

Table 1: SPT and SRE performance, overall and split by median age

Task	Proportion of accurate responses		
	Overall	Younger	Older
	Corrected M (Raw M), SE	*Corrected M (Raw M), SE*	*Corrected M (Raw M), SE*
SPT self-source	*.090 (.114), .008*	*.046 (.076), .011*	*.134 (.15), .011*
SPT other-source	*.064 (.077), .007*	*.020 (.038), .010*	*.109(.118), .010*
Incidental SRE self-source	*.226 (.417), .028*	*.136 (.475), .038*	*.316 (.453), .040*
Incidental SRE other-source	*.150 (.289), .024*	*.096 (.286), .033*	*.205 (.291), .035*
Evaluative SRE self-source	*.375(.60), .027*	*.164 (.537), .039*	*.589 (.671), .039*
Evaluative SRE other-source	*.271 (.417), .024*	*.083 (.305), .033*	*.458 (.528), .034*

The SPT scores were analyzed using a 2 (Referent: self, other) x 2 (Age Group: younger, older) mixed ANOVA. Both main effects were found to be significant with source memory increasing with age $F(1, 182) = 56.10$, $p < .001$, partial $\eta^2 = .24$; and more self-actions attributed to the correct source relative to other-actions, $F(1, 177) = 8.55$, $p = .004$, partial $\eta^2 = .05$. There was no interaction between Referent and Age Group [$F(1, 182) = .01$, $p = .94$, partial $\eta^2 = .00$.

The two SRE scores were submitted to a combined analysis, using a 2 (Referent: self, other) X 2 (SRE Task: evaluative, incidental) x 2 (Age group: younger, older) mixed ANOVA. All three main effects were found to be significant, with source memory being better in the evaluative SRE task ($M = .32$, SE= .02) relative to the incidental SRE task ($M = .19$, SE = .02), $F(1, 176) = .18.02$, $p < .001$, partial $\eta^2 = .09$; increasing with age $F(1, 176) = 74.02$, $p < .001$, partial $\eta^2 = .30$ ($M = .12$, SE = .02 and $M = .39$, SE = .02 respectively); and being better for self-referent items ($M = .30$, SE = .02) relative to other-referent items ($M = .21$, SE = .02), $F(1, 176) = 25.59$, $p < .001$, partial $\eta^2 = .13$. There was no evidence of any interactions: Referent x SRE Task interaction $F(1, 176) = .64$, $p = .42$, partial $\eta^2 = .00$; Referent x Age Group interaction $F(1, 176) = 3.07$, $p = .08$, partial $\eta^2 = .02$; Referent x SRE Task x Age Group interaction $F(1, 176) = .70$, $p = .79$, partial $\eta^2 = .00$.

Self-knowledge and autobiographical memory in younger and older children

The quantity of information about autobiographical events was highly variable across both age groups, but on average older children provided a higher volume of specific details than younger children (see Table 2). Likewise for self-descriptions, although the volume of self-description was variable in both age groups, older children tended to provide a higher volume of self-descriptive information.

Table 2: Self-reported autobiographical memory and self-description volume, split by median age

Self-report	Volume	
	Younger	Older
Specific autobiographical detail	M =2.76, SD =2.96, *Range* = 0-12	M =4.51, SD =3.50, *Range* = 0-14
Total self-knowledge	M =1.14, SD =1.49, *Range* = 0-7	M =2.72, SD =2.44, *Range* = 0-12

The volume of specific autobiographical detail was analyzed using a univariate ANOVA with age as a between subjects factor (Age group: younger, older). This analysis confirmed a main effect of age, with older children producing more specific details than younger children, $F(1, 168) = 12.48$, $p < .001$, partial $\eta^2 = .07$.

Self-description scores were also analyzed a univariate ANOVA with age as a between subjects factor (Age group: younger, older). A main effect of age was found, with older children producing more self-descriptive details than younger children, $F(1, 184) = 28.54$, $p < .001$, partial $\eta^2 = .13$.

In sum, these initial analyses confirm that the expected memory advantage for self-referenced items emerged in our sample, as did the predicted age effect in source-monitoring, volume of autobiographical details recalled and self-descriptions produced by older children.

(b) Relationship between SRE source scores, self-knowledge and autobiographical memory

The theoretical predictions of the current inquiry were tested by analyzing all of the key measures as continuous variables (age, SRE self- and other-score, SPT self- and other-score, autobiographical score, self-description scores). Given that there were no SRE task interactions, we collapsed across incidental and evaluative SRE scores so that all children could be included in a single analysis.

To assess the relation between tasks, correlations were calculated between specific autobiographical memory score, SPT self- and other-scores, SRE self- and other-scores, total self-descriptions, age in months and vocabulary score (receptive vocabulary M = 102.08, SD = 11.98, Range =67.25-127.96). As shown in Table 3, these analyses indicated that specific autobiographical memories correlated moderately with self-descriptions ($p < .001$), self-source scores (SPT self $p < .001$, SRE self $p < .001$) and age ($p < .001$), and weakly with other-source scores (SPT other $p = .012$, SRE other $p = .009$). Total self-description scores correlated weakly with self- (SPT $p < .001$, SRE $p = .001$) and other-source (SPT $p = .002$, SRE *p* =.001) scores and moderately with age (*p* <.001). Source scores also consistently correlated within and across tasks, and with age (*p* <.001 for all). Vocabulary scores were unrelated to the majority of measures, correlating only with age in months (*p* =.005) and self-source scores in the SRE task (*p* =.001). This pattern confirms a general age related improvement in source-monitoring, which is associated with age-related growth in both autobiographical memory and self-description. Since 27 correlations were run, the Benjamini Hochberg false-discovery rate procedure was run to assess Type 1 error; the only previously significant relationship to lose significance was between autobiographical memory and SPT other-source.

Table 3. *Summary of correlations for SRE source scores, self-knowledge and autobiographical memory tasks, including relations to age and receptive vocabulary.*

	Self-Description	SPT self-source	SPT other-source	SRE self-source	SRE other-source	Age	Vocab
Autobiographical memory	.421**	.313**	.193* †	.322**	.199**	.343**	.090
Self-description	–	.281**	.229**	.244**	.248**	.362**	.042
SPT self-source		–	.417**	.317**	.354**	.482**	.133
SPT other-source			–	.363**	.364**	.453**	.143
SRE self-source				–	.678**	.610**	.257**
SRE other-source					–	.562**	.121
Age						–	210**

** p <.001, * p <.05 † non-significant when corrected for false detection rate.

Given these broad relations across tasks, a linear multiple regression was performed to assess the best predictors of autobiographical memory from this group. This analysis tested our theoretical predictions that the ability to tag (as measured by self-source monitoring) and store memories as part of the self-concept (as measured by self-description) may account for age-related change in autobiographical memory. Age in months and vocabulary were entered in the first step of the analysis, followed by measures of other-referenced memory abilities (i.e., other-performed items in the SPT paradigm, other-referenced items in the SRE paradigm) in step 2. Having controlled for the contribution of age, vocabulary and general memory capacity in this way, we then entered our self specific measures (i.e., self-performed items in the SPT paradigm, self-referenced items in the SRE paradigm, and self-descriptions) in step 3.

At step 1, the model was significant ($R^2 = .118$, F (2,169) = 11.169, $p < .001$), accounting for 11.8% of the variance in autobiographical scores. Age (β = .086, p <.001) but not vocabulary (β = .006, p =.754) was an independently significant predictor. This confirms age-related change in autobiographical memory. At step 2, the model remained significant ($R^2 = .120$, F (4,169) = 5.601, $p < .001$), accounting for a similar proportion of variance at 12%. Age (β = .081, p =.001) continued to have predictive value superior to that of both vocabulary (β = .006, p =.787) and other-referencing (SPT other source: β = 1.421, p =.596; SRE other source: β = .016, p =.989). At step 3, where the self specific variables were entered, the predictive value of the model more than doubled to 26.5% ($R^2 = .265$, F (7,169) = 8.347, $p < .001$). Moreover, age dropped out as an independent predictor (β = .025, p =.323). Instead, each of the self specific variables made independent predictions: SPT self-source: β = 4.913 p =.042; SRE self-source: β = 2.452, p =.018; self-description β = .503, p <.001). Vocabulary (β =-.002, p =.930) and other specific variables remained insignificant (SPT other source: β =-1.304 , p =.610; SRE other source: β =-1.731 , p =.147). Regression lines for step 3 are displayed in Figure 1. These results imply the self-knowledge and self-source monitoring account for a significant proportion of the age-related change in autobiographical memory between 3 and 6 years. These analyses also confirm that the strongest relationship between autobiographical memory and source monitoring is self-specific, and not domain general.

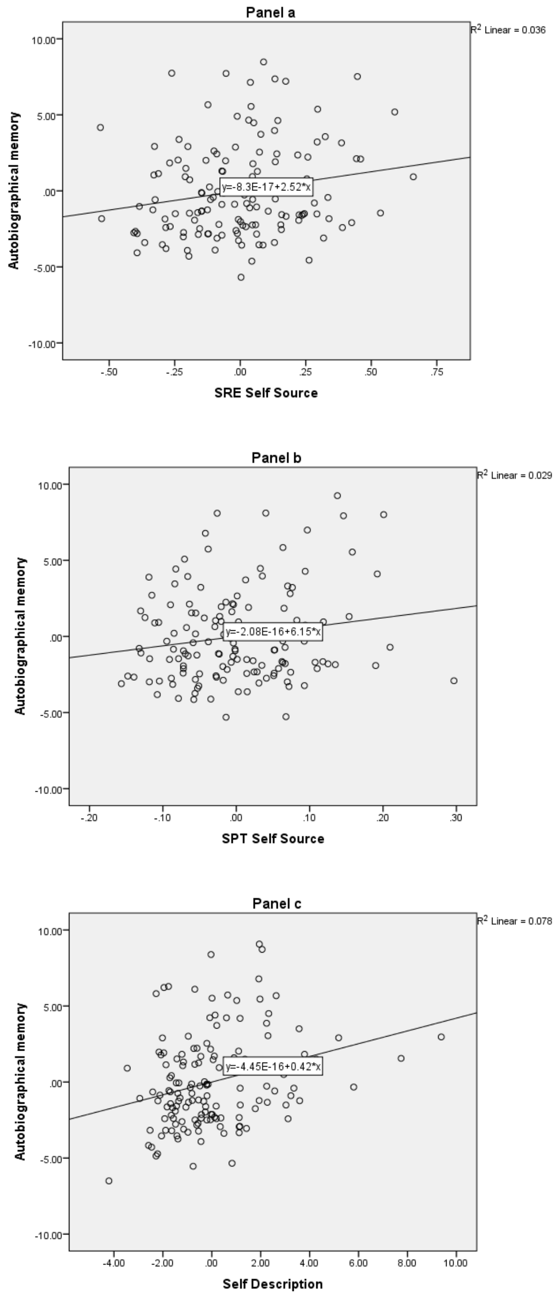

Figure 1: Regression lines between autobiographical memory and SRE self source (panel a), SPT self source (panel b) and self-description (panel c).

To explore the potentially bidirectional relationship between autobiographical memory and self-knowledge predicted by Conway’s SMS model, we then ran a regression analysis to predict self-description scores. As before, age and vocabulary were entered in step 1, other specific variables in step 2, and self specific variables (including SPT self source, SRE self-source and autobiographical memory) in step 3. At step 1, the model was significant

(R^2 = .121, F (2,169) = 11.521, p < .001), accounting for 12.1% of the variance in self-knowledge. Age (β = .058, p <.001) but not vocabulary (β = -.005, p =.688) was an independently significant predictor. This confirms age-related change in self-knowledge. At step 2, the model remained significant (R^2 = .132, F (4,169) = 6.259, p < .001), accounting for a similar proportion of variance at 13.2%. Age (β = .047, p =.003) continued to have predictive value superior to that of both vocabulary (β = -.005, p =.688) and other-referencing (SPT other source: β = 2.157, p =.214; SRE other source: β = .312, p =.663). At step 3, where the self specific variables were entered, the predictive value of the model rose to 23.6% (R^2 = .236, F (7,169) = 7.157, p < .001). Again, age dropped out as an independent predictor (β = .030, p =.068). In this instance, autobiographical memory emerged as the only significant predictor (β = .222, p <.001). Self-source scores (SPT self-source: β = .802, p =.619; SRE self-source: β = -.441, p =.539), vocabulary (β =-.005, p =.674) and other specific variables (SPT other source: β =1.713 , p =.312; SRE other source: β =.535, p =.501) did not make a significant contribution. These analyses suggest that autobiographical memory is a powerful predictor of age-related change in self-knowledge.

Together, the above analyses suggest that self-source memory and self-knowledge predict autobiographical memories, and that autobiographical memories predict self-knowledge. This implies that the positive relations between self-knowledge and self-source monitoring reported in Table 3 may be mediated by a common link with autobiographical memory. To test this theory, we ran Haye's PROCESS mediation analyses, using self-knowledge as the outcome variable, self-source score as the independent variable, and autobiographical memory as the mediator, fitting the data to model 4. For both SPT (b = 2.26, *BCa CI* [1.15, 3.80], Z = 2.24, p = .001) and SRE tasks (b = .840, *BCa CI* [.453, 1.39], Z = 3.33 , p =.001) there was a significant indirect effect of self-source monitoring on self-knowledge through autobiographical memory. The theoretical outcome of these key regression and mediation analyses is displayed in Figure 2; depicting a cyclical relation between autobiographical memory and self-knowledge, which the capacity to self-source monitor feeds into.

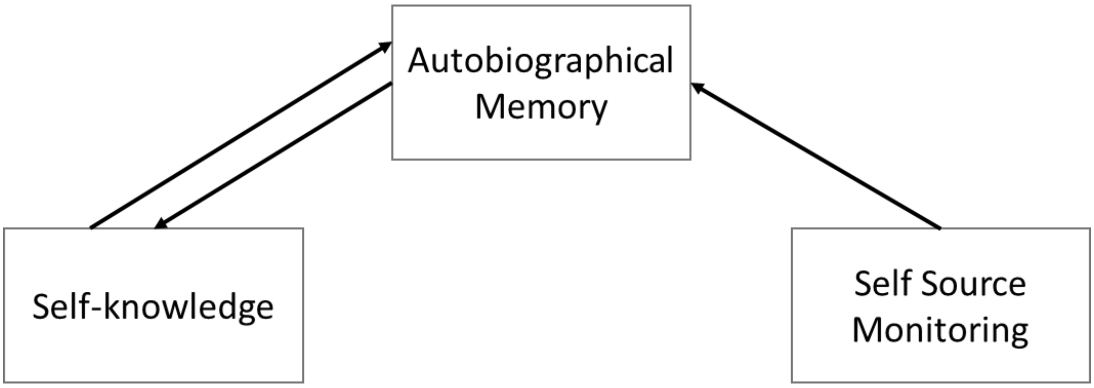

Figure 2: The predictive relations between self source monitoring, autobiographical memory and self-knowledge

Discussion

The current inquiry examined the relationship between autobiographical memory, source memory for self- and other-referenced stimuli, and self-knowledge in children. Consistent with previous research, source monitoring ability increased with age across early childhood (Drumney & Newcombe, 2002; Foley & Johnson, 1985; Welch-Ross, 1995b), as did autobiographical memory (Hayne et al., 2011; Nuttall et al., 2014; Tustin & Hayne, 2010), and self-descriptive details (Eder, 1989, 1990; Harter, 1999; Montmayer & Eisen, 1977). We also found the expected age-invariant memory advantage for both actions and objects encoded in a self-referent context (see Cunningham et al., 2014). Extending extant research, we identified for the first time predictive relationships between self and memory. We hypothesized that source memory for self-referenced actions and objects would predict the volume of children’s autobiographical memory as a result of increased self-specific binding at encoding, and our analyses confirmed this relationship. We also hypothesized that self-description details would predict autobiographical memory because growing self-knowledge provides a framework in long-term memory. Again, this relationship was supported. Finally, we found evidence to support the hypothesis that the relation between autobiographical memory and self-knowledge is bidirectional, as described in Conway's SMS model (Conway, 2005; Conway & Pleydell-Pearce, 2000).

This pattern of results provides support for Howe and Courage's (1993, 1997, 2004; Howe et al., 2003) theory, which postulates that the self-concept might be viewed as a cognitive anchor around which episodic memories can be organized and elaborated, entering the autobiographical system. Our results suggest that as the self-concept develops across 3- to 6 years, the special mnemonic properties associated with self-reference may facilitate the capacity to encode memories as part of a personal narrative. As the self-concept expands, as indexed here by the volume of self-descriptions, so too does the likelihood that more specific autobiographical details will be recalled. This is an important step in providing empirical evidence to support the hypothesis that growth in autobiographical memory is functionally related to the development of the self. Guided by Conway's SMS theory, the role of self in memory is well-evidenced in adults (Conway, 2005; Conway & Pleydell-Pearce, 2000; Rathbone et al., 2008), and the mutual emergence of these systems in two-year-old children has some support (Howe et al., 2003). However, the co-development of self and autobiographical memory systems across early childhood has remained purely speculative, so our results are of considerable theoretical significance.

By contributing the advancement in knowledge outlined above, the current study provides proof of concept for the idea that the SRE paradigm might be usefully adapted to elucidate autobiographical memory development (as proposed by Ross et al., 2011a). Adding to extant developmental demonstrations of the cognitive SRE in childhood (Bennet & Sani, 2008; Halpin et al., 1984; Pullyblank et al., 1985; Ross et al., 2011a; Sui & Zhu, 2005) our findings support the concrete SRE paradigm adapted by Cunningham et al. (2014) and confirm an age-invariant early self-referential bias on memory. Although the SRE observed here was likely primarily attention driven (Cunningham et al., 2014), the self-processing it engendered was deep enough to predict autobiographical retention. Our adaptation of the SPT task (Ross et al., 2011a Study 1) was similarly successful in demonstrating a robust, low level memory advantage for events linked with self at encoding, which was associated with autobiographical recall. These findings confirm that the capacity for self-processing has a significant impact on the memorability of events within early childhood, despite the nascent nature of the self-concept. Of course, the level of self-reference present in each of the memory tasks described is open to debate; perhaps the SPT functions as a simple depth of processing effect, and the SRE on the basis of familiarity. However, it is indubitable that the depth of processing and familiarity effects arising from being a physically embodied self are unique, thus whether conscious or not, the effects are self-specific. Moreover, in each of the tasks the children were asked to explicitly tag the event as 'self-referent', making it difficult to argue that conscious self-reference did not play a role (see Ross et al, 2011).

The current results clearly speak to Howe and Courage's (1993, 1997, 2004; Howe et al., 2003) theory of childhood amnesia, and are highly consistent with SMS theory (Conway, 2005; Conway & Pleydell-Pearce, 2000; Rathbone et al., 2008). As displayed in Figure 2, self-source memory can be viewed as a proxy for the working self in action, leading to autobiographical memory, which itself draws from and feeds the self-knowledge system. Our results are also broadly consistent with competing theories of the childhood amnesia. The relationship that we observe between self-source memory and autobiographical memory, together with the bias for self-referent memories, supports the idea that remembering the experience of an event adds a depth of processing which supports autobiographical recall (Welch-Ross, 1995a). Our findings are also consistent with the idea that binding a memory to source information, and the ability to retain specific details of the event, are skills supportive of autobiographical recall (Bauer, 2015;; Hayne, 2004; Johnson et al., 1993; Newcombe et al., 2000; Perner & Ruffman, 1995; Raj & Bell, 2010).

However, since we do not measure the distinction between remembering and knowing directly, and the children do make some source errors (implying knowledge rather than recall), we cannot claim to provide uncomplicated evidence of the role of metacognitive remembering. Moreover, although there were domain general relationships between source monitoring and the level of specific detail recounted for early life events, self- source memory emerged across two tasks (SPT and SRE) to be independently predictive of autobiographical memory. These results might be viewed as supporting an emphasis on self-source binding skills (Johnson et al., 1993; Newcombe et al., 2000; Perner & Ruffman, 1995; Raj & Bell, 2010) over general binding ability (Bauer, 2015; Hayne, 2004). Finally, we cannot fully assess the role of language in the offset of infantile amnesia using the current design. An individual's expressive vocabulary or verbosity may contribute to the strength of the relationship between self-knowledge and autobiographical memory, since both capacities were measured through verbal self-report. Thus, although we do not find evidence that receptive vocabulary is related to memory development, the contribution of expressive vocabulary may nonetheless be important (see Nelson & Fivush, 2004; Welsch-Ross, 1995a). One way to test the contribution might be to elicit a non self-referent semantic control narrative. However, finding a topic which is neither self-referent nor informed by autobiographical memory may be challenging.

The finding that the self may play a 'special' role in memory is in accord with a growing body of neuroscience literature which implies that self-referencing in memory across a number of diverse paradigms is associated with increased activation in the medial prefrontal cortex (mPFC) relative to when non-self items are processed (e.g. Kelley, Macrae, Wyland, Caglar, Inati, & Heatherton, 2002;; Pfeifer, Lieberman, & Dapretto, 2007; Pfeifer & Peake, 2012; Ray et al., 2009). The tendency for the self to automatically trigger attentional responses has also been captured neuropsychologically (e.g., Brédart et al., 2006; Gray, Ambady, Lowenthal, & Deldin, 2004; Sui, Zhu, & Han, 2006). Further, it is clear that source monitoring and binding abilities may be dependent on maturation of specific brain regions (see Raj & Bell, 2010 for review). However, as the vast majority of brain imaging work is done with older adults and children, there is a need for further investigation of the neural developmental of the SMS in early childhood.

Importantly, if the self does have a special role in memory in childhood, as supported by the current study, then it has significant real-world implications. Firstly, there are educational implications whereby self-referential methods could be embedded in educational practices to aid memory for material without recourse to expensive resources or additional time pressures on staff. For example, Cunningham and colleagues have demonstrated how SREs can be usefully applied to support the processing and retention of maths and literacy curricula (Cunningham, Scott, Hutchison, Ross & Martin, 2018; Turk, Gillespie-Smith, Krigolson, Havard, Conway & Cunningham, 2015).

A second key application of this work is in clinical intervention. Self-processing systems have been implicated in a number of conditions (see Klein, 2012). Of particular relevance to early development, self-processing issues may be an important element of autism. Studies of children (Gillespie-Smith, Ballantyne, Branigan, Turk, Cunningham, 2018; Henderson et al., 2009) and adults (Grisdale, Lind, Eacott & Williams, 2014; Lombardo, Barnes, Wheelwright & Baron-Cohen, 2007; Toichi et al., 2002) with autism suggest there may be unusual SRE patterns, which may be symptomatic of disruptions in the SMS (see Lind & Bowler, 2009). Interestingly, brain imaging studies suggest that adolescents with and without ASD show divergent patterns of neural activation when engaged in self-processing (Pfeifer, Merchant, Colich, Hernandez, Rudie & Dapretto, 2013). Crucially, understanding any divergent pattern in self-referential processing is only possible once we have a greater understanding of typical development of self-referential processing. A clear picture of self-processing development is therefore vital in order to develop successful strategies and interventions for children with developmental disorders associated with disruptions in the self-concept and/or autobiographical memory.

Finally, it is important to establish whether the integrated development the self-construct and autobiographical memory established here is replicable cross-culturally. Adult studies suggest that the self plays a reduced role in memory in non-individualistic cultures (Sparks, Cunningham, & Kritikos, 2016; Turk, Walford & Itagaki, 2016; Zhu & Zhang, 2002). However, there is a lack of developmental work exploring when this cultural difference emerges. Wang (2004) finds that 4- to 8-year-olds’ self-descriptions qualitatively differ cross-culturally, with Chinese children emphasizing their relations to other people, in contrast to American children’s focus on personal attributes and psychological traits. American children also tended to provide more detailed and specific autobiographical memory reports referencing themselves and their personal preferences. Drawing these findings together, Wang (2003) suggests that an autonomous perspective on self may be more supportive of autonoetic recall than more collectivistic perspectives. This idea is in keeping with Nelson and Fivush’s (2004) socio-cultural theory, suggesting that children’s social context might scaffold the development of autobiographical memory. However, infantile and childhood amnesia and early adulthood reminiscence bumps are universal; implying that although the quality of self and memory may vary cross-culturally, the SMS may be invariant (Conway et al., 2005).

Conclusion

Contributing to broader gap in the literature concerning the functional development of self beyond mirror self-recognition (Ross, 2017; Ross et al., 2011a; Ross, Anderson and

Campbell, 2011b; Ross, Yilmaz, Dale, Cassidy, Yildirim & Zeedyk, 2017), the current study presents novel empirical evidence of a relationship between autobiographical memory and the self-concept. Pioneering the empirical application of a robust source-based SRE in 3- to 6-year-old children (Cunningham et al., 2014; Ross et al., 2011a), we demonstrate for the first time that the volume and specificity of children’s’ autobiographical memories is predicted by both the volume of their self-knowledge, and their capacity for self-source monitoring within both physical and cognitive SRE paradigms. Drawing from the long theorized relationship between self and memory (Hulme, 1739/2003; James, 1890; Locke, 1690/1995), these results elucidate the emergence of Conway’s (2000, 2005) SMS and provide support for the theory that childhood amnesia may be offset by the ability to explicitly process event memories in relation to the self (Howe & Courage 1993, 1997, 2004; Howe et al., 2003).

Since the SREs we measure function at various levels (physical, incidental, evaluative), which may draw on different aspects of self-consciousness, future studies should address how the role of self in memory develops (see Hutchison, Ross & Cunningham, in prep; Welch-Ross, 1995a). It is also important to assess how this aspect of autobiographical development interacts with other important drivers of infantile and childhood amnesia including linguistic and socio-cultural contexts (Fivush, 2011; Nelson & Fivush, 2004; Wang, 2004), domain general binding abilities (Bauer, 2015; Hayne, 2004; Johnson et al, 1993; Newcombe et al., 2000; Perner & Ruffman, 1995; Raj & Bell, 2010), and cortical maturation (Brédart et al.,2006; Gray et al., 2004; Kelley et al., 2002; Pfeifer et al., 2007; Pfeifer & Peake, 2012; Raj & Bell, 2010; Ray et al., 2009; Sui et al., 2006).

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