Event-related potential study of intentional and incidental retrieval of item and source memory during early childhood

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Abstract

The event related potential (ERP) technique is a useful methodology for studying neural changes underlying memory development in childhood. However, systematic comparisons of differences in memory tasks and retrieval demands are lacking. To address this gap, the present study explored the effects of memory task (i.e., item versus source) and retrieval paradigm (i.e., intentional versus incidental) on 4- to 5-year-old children's memory performance and associated electrophysiological responses. Children were familiarized with items in a play-like setting and then asked to retrieve item or source memory details while their brain activity was recorded (intentional retrieval) or while they passively viewed images of the items with no explicit task (incidental retrieval). Memory assessments for the incidental groups followed ERP recording. Analyses of the ERP data suggested that the brain's response during intentional retrieval of source information differed from the other three conditions. These results are discussed within a two-component framework of memory development (e.g., Shing et al., 2010), and implications for future methodological decisions are presented.

Keywords: Event related potentials, Item memory, Source memory, Intentional retrieval, Incidental retrieval.

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Research on memory development is of interest to both basic and applied researchers, as this information is critical for understanding mechanisms of memory and learning, in home, school, and/or therapeutic settings. Memory ability shows striking improvement during childhood (see Schneider, 2015 for review). However, memory is not a monolithic entity. Previous research has shown that improvements in different types of memory may vary depending on the age of the child (e.g., Riggins, 2014). These differences are likely due to differences in underlying neural processes needed to complete differ types of memory tasks (e.g., Shing et al, 2010; Raj & Bell, 2010). In order to gain insight into the neural mechanisms associated with these improvements, several studies have begun to examine the neural underpinnings of memory in childhood using the event related potential (ERP) technique (e.g., Cycowicz, 2002). ERPs are a particularly useful methodology for studying neural changes underlying memory improvement during childhood, as they offer a relatively non-intrusive way of measuring electrical neural activity in a comfortable environment (DeBoer, Scott, & Nelson, 2007). However, to date, studies have varied on 1) the type of material that is to be retrieved (e.g., individual items versus contextual/source details), and 2) the type of retrieval processes in which children are engaged (e.g., intentional versus incidental). In this paper we systematically these features. Knowing how these manipulations influence brain response may not only provide key insight in to differences in memory processes during early childhood but also inform the design of future studies that seek to investigate memory development in early childhood.

In this introduction we review literature on children's memory development, discuss differences in the types of tasks used and the retrieval processes that underlie these tasks. We then summarize findings from previous developmental ERP memory studies and address how these findings may have been influenced by the type of information retrieved and the degree to which retrieval processes were engaged. This review lays the groundwork for the current investigation that systemically examined differences in memory behavior and ERP responses during early childhood as a function of information type and retrieval demands.

Heterogeneous nature of memory development

Early childhood (3-6 years) is a period of rapid developmental change in memory abilities (e.g., Riggins, 2014). These changes are reflected in a wide variety of memory tasks, including both item and source memory tasks. In short, item memory tasks require discriminating items that have been previously experienced from items that are new. Source memory tasks require not only recognition that an item has been previously experienced, but also accurate judgment of a contextual detail associated with the initial encounter, such as who was present or where the encounter took place. Children show improvements on both types of tasks in early childhood. However, these developmental changes have been shown to follow different developmental trajectories, with item memory showing earlier, yet more consistent, change over time and source memory showing pronounced change during early childhood and continued improvement through adolescence (Bauer, Doydum, Pathman, Larkina, Güler, & Burch, 2012; Drummey & Newcombe, 2002; Lloyd, Doydum, & Newcombe, 2009; Ghetti, Lyons, Lazzarin & Cornoldi, 2008; Newcombe, Balcomb, Ferrara, Hansen, & Koski, 2014; Oakes, Ross-Sheehy, & Luck, 2006; Riggins, 2014; Sluzenski, Newcombe & Kovacs, 2006; Sluzenski, Newcombe, & Ottenger, 2004).

For example, Riggins (2014) examined 4- to 10-year-old children's item and source memory abilities in a longitudinal study. Children participated in a trivia game where they learned novel facts from either an experimenter or a puppet. At test, children were tested for both memory of the facts (item memory) and memory for who taught them the facts (source memory). Whereas children's item memory showed a steady increase between 4 to 10 years, their memory for source showed accelerated rates of changes between 5 to 7 years of age (see Drummey & Newcombe, 2002 for similar results in a cross-sectional study). Increases in children's source memory ability are argued to be related to improvements in memory binding or the ability to form an association between multiple pieces of to-be-remembered information (Oakes et al., 2006; Sluzenski et al., 2006). Moreover, these improvements in binding are thought to be primarily driven by memory retrieval processes (as opposed to encoding processes, as one study found age-related differences only when a longer delay or increased cognitive load was imposed, see Lloyd et al., 2009 for elaboration)

Item vs. Source memory tasks

Item and source memory tasks are thought to require different memory processes (e.g., Shing, Werkle-Bergner, Li, & Lindenberger, 2008). For example, Shing and colleagues (2010) proposed that memory is dependent on interactions between two components: associative and strategic (see also Moscovitch, 1992; Prull, Gabrielli, & Bunge, 2000). The associative component consists of the basic binding mechanisms that integrate different features of an episode into a coherent whole (Zimmer, Mecklinger, & Lindenberger, 2006). The strategic component refers to cognitive control processes that aid and regulate memory function during both encoding and retrieval (Craik & Lockhart, 1972; Pavio, 1972) and includes specifying, verifying, monitoring, and evaluating relevant information at retrieval. Consistent with this proposal, adult ERP research has shown that different neural processes are involved during item and source memory tasks (see Rugg & Curran, 2007 for review). Specifically item memory tasks have been shown to elicit a mid-frontal old/new effect, whereas tasks involving retrieval of source memory elicit a left parietal effect (Rugg, Schloerscheidt, Doyle, Cox, & Patching, 1996).

Research suggests that the changes observed in item and source memory during early childhood are due to changes in both these associative and strategic components and their neural substrates (e.g., Raj & Bell, 2010). Although associative and strategic processes play a role in both item and source memory tasks, the strategic component has been found to be particularly important in source memory tasks. Functionally, associative and strategic components follow different developmental trajectories, and these trajectories mirror those observed in the development of item and source memory abilities. Specifically, the associative component is thought to develop earlier, being mature by middle childhood, whereas the strategic component continues to develop into adolescence (Shing & Lindenberger, 2011). In other words, the differential contribution of these processes may explain differential performance on item and source memory (Shing et al., 2008). Because it is challenging to isolate associative and strategic processes in behavioral tasks, examining different components in the ERP response may allow a glimpse into associative and strategic memory components on item and source memory tasks.

Incidental vs. Intentional retrieval

In addition to *what* is retrieved, memories also differ in *how* they are retrieved. Specifically, memories (for either item or source) can be retrieved intentionally (i.e., when actively trying to remember the information), but also incidentally (i.e., when passively going through day to day activities, not trying to bring a past episode to mind, Bernsten, 2010). It is speculated that memories retrieved incidentally reflect associative memory processes, but that memories retrieved intentionally are influenced by both associative and strategic processes (Hall, Gjedde, & Kupers, 2008). Studies in adults have explored intentional and incidental retrieval using a variety of methods including ERP (Bennington & Polich, 1999; Curran, 1998; Nelson, Thomas, De Hann, & Wewerka, 1998; Polich, 1987), fMRI (Kompus, Eichele, Hugdahl, & Nyberg., 2011) and PET (Hall et al., 2008). For example, Curran (1999) tasked participants with completing either a recognition memory task or a lexical decision task. In both tasks, words and non-words were repeated. Participants were instructed to respond to either if the word was real (e.g., lexical decision task) or if the word had been presented before (e.g., memory task). The brain response to initial and repeated stimuli was compared for words that were intentionally processed during the recognition task and incidentally processed during the lexical decision task. Collectively, these studies report differences between initial and repeated presentations (i.e., memory effects) in primary memory areas (i.e., medial temporal lobe) during both intentional and incidental retrieval. These results suggest basic memory processes are capable of facilitating retrieval with and without strategic retrieval attempts.

However, minor differences between these retrieval conditions have also been reported. For example, Nelson, and colleagues (1998) reported overall amplitude for the P300 was greater for intentional retrieval compared to incidental retrieval (cf. Curran, 1999). Results from other methods with higher spatial resolution (i.e., fMRI) have shown differential activation patterns for intentional versus incidental retrieval. Specifically, dorsolateral prefrontal cortex (DLPFC) activation was only found with intentional retrieval and certain posterior brain regions had decreased activation with incidental retrieval.

To our knowledge, no study to date has examined how incidental and intentional retrieval vary as a function of memory task type (i.e., item versus source). This represents a significant gap in the literature, particularly because if passive retrieval does not involve the strategic process, and source memory tasks rely on the strategic process more than item memory tasks, source memory retrieval may not be entirely captured with passive retrieval. Early childhood is likely an ideal period to studies these effects, as differences are known to exist between item and source memory abilities may make it easier to observe potential difference in associative and strategic processes.

Neural bases of memory during early childhood

Many studies have explored memory development during early childhood, however relatively few have explored the neural correlates. Studies that do exist have primarily used ERPs and explored two components of interest: the Negative component (Nc) and positive slow wave (PSW). The Nc is an early component occurring approximately 200-500ms post stimulus onset that has been shown to be related to attentional processes in infancy and is thought to be modulated by attention memory (e.g., Carver, Bauer, & Nelson, 2000; Nelson, 1998; Richards, 2005; Riggins, Miller, Bauer, Georgieff, & Nelson, 2009). The PSW is a later component occurring approximately 800-1500ms post stimulus onset that is thought to be related to context or memory updating (e.g., Carver et al., 2000; Nelson, 1998; Snyder, Webb, & Nelson, 2002) and retrieval of contextual details (e.g., Riggins, Miller, Bauer, Georgieff, & Nelson, 2009; Riggins, Rollins, & Graham, 2013).

However, these previous developmental ERP studies utilized a variety of tasks and retrieval paradigms, which has led to inconsistent/mixed ERP findings. For example, Marshall and colleagues (2002) asked children to engage in intentional retrieval during an item memory task. Specifically, children viewed pictures of everyday items and later distinguished between items they had seen before and item that were new. In contrast, Riggins and colleagues (2013) asked children to recall the source of previously learned information and measured their brain response during incidental retrieval (also see Riggins & Rollins, 2015). Specifically, in their study children were familiarized to novel toys in one of two different locations after which ERPs were recorded while the children passive viewed picture of the toys. Following ERP recording, the children sorted both the old toys and new toys into the rooms where they were originally encountered.

These investigations reported memory effects in both Nc and PSW, however the pattern and location of effects varied across studies, despite the fact that similar age groups were used (i.e., 4- to 5-yaer-old children). For example, in Marshall et al., 2002 amplitude to old items was greater than amplitude to new items, whereas in Riggins et al., 2013; 2015 this pattern was reversed. In addition, the spatial locations over which these effects were found also differed between studies (i.e., right hemisphere versus bilateral temporal leads). Although the reason for these differences across studies is unclear, methodological differences, specifically whether children were given item or source memory tasks and whether memory retrieval was intentional or incidental may play a role, as these manipulations may tap into memory processes in different ways Exploring the impact these manipulations have on the brain response will provide insight into differing memory processing during early childhood and provide important information for the design of future studies.

Present Study

The present study had two main goals. First, to compare differences in the ERP correlates of item memory and source memory tasks during early childhood and second, to determine if the ERP correlates for item and source memory tasks differed during intentional compared to incidental memory retrieval. To accomplish these goals, 4- to 5-year-old children came to the lab and were familiarized with age appropriate items. During retrieval, children were tested on either memory for the items or memory for the location in which they encountered the items (i.e., source). Half the children in each group gave verbal responses to the task while brain activity was recorded, and half passively viewed the items while brain activity was recorded and completed the overt memory tasks after brain recording. Since item and source memory place different reliance on associative and strategic processes, and strategic processes are less prominent during incidental retrieval (Hall et al., 2008), it was expected that the ERP correlates during an intentional source memory task would be different than the other three conditions.

Methods

Participants

This report includes data from 83, 4- to 5-year-old children[1] recruited from a University database that provided both useable behavioral and ERP data. Children in this age were selected to (1) be similar in age to children used in previous studies of memory development with ERPs (i.e., Marshall et al 2002; Riggins et al, 2013; Riggins & Rollins, 2015) and (2) capture a time in which associative processes are thought to be relatively well developed while strategic processes are still developing. An additional 31 children came into the lab but did not provide usable ERP data (i.e., refused to wear the EEG cap, had too much movement related artifact, or provided too few useable trials in the required conditions). The numbers of excluded children for each condition were as follows: Intentional Item memory task, 5; Incidental Item memory task, 3; Intentional Source memory task, 14; Incidental Source memory task, 9. The children in the Intentional retrieval conditions had more movement related artifact *and* the children in the Source conditions had fewer trials behaviorally; combined, this lead to a higher exclusion rate

[1] One child in the Incidental Source condition was 6-years old. This child participated in the study two days after their sixth birth.

for children who completed the Intentional Source memory task compared to the other groups. We return to this point later in the Discussion, as it has implications for future research. Children were screened to ensure they were not born more than three weeks before their due date and no children were diagnosed with any developmental delays or disabilities. Children were from middle to upper class families, and predominately Caucasian. Children's ages ranged from 4.05 to 6.03 years with a mean age of 4.97 years (sd = .65). A summary of participant demographics for every group is presented in Table 1. Participant ages were compared with a 2-way ANOVA, with Memory Task (Item, Source) and Retrieval Group (Intentional, Incidental) both as between subjects factors. There were no significant differences between children in the Intentional and Incidental retrieval groups $F(1,79) = 0$, $p = .99$. However, the children who completed the Item memory task were, on average, 6 months older than the children who completed the Source memory task $F(1,79) = 4.98$, $p = .03$[2].

Stimuli

Stimuli consisted of a total of 108 child-friendly store-bought items (e.g., fire hat, bug net, plastic pail). These items were randomly assigned to 3 sets of 36 items. Digital photographs were taken of each item to use during ERP recording. The items were randomly assigned into the sets, and which set served as the Old items was randomly assigned for each child.

Procedure

The University Institutional Review Board approved all procedures prior to data collection. Parents or guardians provided informed consent for all children. After the study was

[2] ERP analyses were re-run controlling for child's age. All differences between Item and Source memory remained. For example, the Condition x Group x Study interaction remained $F(1,78) = 6.96$, $p = .01$, $\eta^2 = .08$. Therefore, differences between these two conditions were not driven by differences in age.

complete, children received a small gift for participating and a certificate with a picture of their brain waves.

Data collection for the Item memory task was completed first with one set of children, followed by data collection for the Source memory task with a separate group of children." Within each task, children were randomly assigned to either the Intentional or Incidental retrieval group. A summary of task instructions for each group is presented in Table 2.

Item Memory Task. During the encoding portion of the study, children were familiarized to 36 age-appropriate items (e.g., a cowboy hat) in a play-like setting. Each item was verbally labeled, "This is my X", and handed to the child with opportunity for open play, "How would you play with my X". To ensure encoding, children were required to, at minimum, make contact with each item before moving on to the next item. Children were not told there would be a later memory test on the items.

The retrieval portion of the task began approximately 25 minutes after the conclusion of the encoding portion. This delay was used to ensure accurate performance was not solely driven by working memory and due to practical limitations of preparation for EEG recording. Approximately 10 minutes of the delay consisted of a snack break and the remaining 15 minutes were spent applying the EEG cap. Children's head circumferences were measured and fit with appropriately sized stretchy Lycra caps. EEG data were continuously recorded from a Biosemi Active 2 system with 64 active Ag-AgCl scalp electrodes at a sampling rate of 512 Hz referenced to CMS/DRL. Two vertical and two horizontal electrooculogram (EOG) channels were also obtained for later blink correction. During recording of brain activity, all children viewed 72 digital color photographs at eye level on a neutral computer screen with a black background. The photographs consisted of the 36 previously experienced items and 36 comparable but novel items. All photographs were presented in a random order using E-prime software for 1000ms. After the photograph, a blank screen was presented for 500ms followed by a "?" which remained on the screen until the children responded. Children were instructed to not respond until the question mark appeared to minimize movement during the recording window.

The children in the Intentional retrieval group completed the Item memory task while their brain activity was recorded. Children were instructed to respond "yes" if the photograph had been of an item they had played with before and "no" if the photograph had been of a new item, after the image left the screen (see Table 2). Children gave all answers verbally. Children in the Incidental retrieval group viewed the photographs passively with no explicit task while their brain activity was recorded. The photographs progressed automatically with an inter-stimulus interval ranging from 750-1750 ms, a time determined to be comparable to the amount of time it took the children in the Intentional retrieval group to give their responses. After viewing and recording, the cap was removed. Children in the Incidental retrieval group then returned to the setting where they originally encountered the items. Both the old items and new items were mixed together in a large bin and children were told to sort the items to the play room or a new toy bin. Although behavioral measures of memory occurred after a longer delay for the Incidental than the Intentional children, the delay was the same at the point of EEG recording. Variables of interest for both Intentional and Incidental retrieval include old items that the children accurately identified as old (max = 36) and new items that the children accurately identified as new (max = 36).

Source Memory Task. The Source memory task was designed to be as similar as possible to the Item memory task except the memory question was in regards to the source as opposed to item. In order to generate two different possible sources, during the encoding portion, children were familiarized to two sets of 36 items, in two different rooms that were associated with two different female experimenters. The experimenter served as the source memory component at test. The labeling and interactions with the items during encoding were consistent across experimenters and the same as in the Item memory task.

The delay period and EEG collection procedure were the same as in the item memory task. While brain activity was recorded children viewed 108 digital color photographs of the items (36 from each experimenter and 36 new). The photos were displayed for 1000 ms with a 500 ms blank screen before the response screen. Instead of making an old/new item distinction, children in the source memory task completed an exclusion paradigm. While their brain activity was recorded, children in the Intentional retrieval condition were told to response "yes" if the item was in the room of experimenter A and "no" to items that were either new *or* belonged to experimenter B. This task required the children to retrieve not only if they had experienced the item before, but the source (i.e., who) they experienced it with. Children in the Incidental retrieval group again viewed the image with no explicit instruction while EEG was recorded. After EEG recording the cap was removed and the children in the Incidental group again viewed the photographs this time completing the exclusion task. Variables of interest for both Intentional and Incidental retrieval included old items that the children accurately identified the source (max = 36) and new items that the children accurately identified as new (max = 36). All other methodological details were identical to those in the Item memory task.

EEG Data Processing and Analysis

All EEG data were processed using Brain Electrical Source Analysis (BESA) software (MEGIS Software GmbH, Gräfelfing, Germany). Data were re-referenced to an average reference, bad channels were interpolated up to a maximum of 8 channels, and all data were hand-edited to remove movement related artifacts. The Ille, Berg, and Sherg (2002) algorithm was used to correct eye-blinks. High-pass filters of .1 Hz and low-pass filters of 40 Hz were applied. As recommended by previous developmental ERP research, a minimum of 10 trials per condition were required in order for participants to be included in analyses (DeBoer Scott, & Nelcson, 2005; 2007). There was a maximum of 36 potential trials for both old and new items in all four conditions. Mean trial numbers (standard deviation, range) for new and old items by Retrieval Group and Memory Task were as follows: Intentional Item memory task: Old 22 (6, 11-32), New 24 (6, 11-33); Incidental Item memory task: Old 21 (6, 10-35), New 22 (7, 10-32); Intentional Source memory task: Old 16 (3, 11-23), New 19 (7, 10-31); Incidental Source memory task: Old 17 (5, 10-26), New 22 (7, 12-32). The trial numbers for the groups were compared using a 2-way ANOVA with 2 Memory Task (Item, Source) and 2 Retrieval Group (Intentional, Incidental) both as between subjects factors. There was a main effect of Memory Task, with the children in the Item condition having more old trials included than children in Source condition $F(1,79) = 19.83$, $p < .001$. This was not surprising given their task was easier. The current analysis examined mean amplitudes across time windows, which are relatively unaffected by differences in trial numbers across groups and conditions (Luck, 2005).

Data Analysis

Behavioral Analysis Behavioral results were analyzed using d’, a measure of memory sensitivity, using a 2-way ANOVA with 2 Memory Task (Item, Source) and 2 Retrieval Group (Intentional, Incidental) both as between subjects factors. Significant effects were followed-up with separate analyses for hits and correct rejections to determine the source of the difference (see Lloyd et al., 2009 for rationale).

ERP Analysis Mean amplitudes for the Nc (250-450ms) and PSW (800-1100ms) were used to explore differences in memory effects between memory tasks and retrieval groups. Time windows were selected based on previous research exploring memory effects in this age group. Data were analyzed using an omnibus ANOVA with 2 Memory Task (Item, Source) and 2 Retrieval Group (Intentional, Incidental) as between subjects factors and 2 Item Type (Old/Source correct, New), 3 Sagittal Plane (left, midline, right), and 3 Coronal Plane (frontal, central, parietal) as within subjects factors. The following leads were included in analyses: F5, Fz, F6, C5, Cz, C6, P5, Pz, P6. When appropriate, the Greenhouse Geisser procedure was used to correct for violations of sphericity. Reported findings include those with a main effect of Group or interaction with Item Type. When interactions were observed, follow-up analyses were conducted by Task and then by Retrieval Group.

Results

Behavioral Results

A summary of all behavioral results can be seen in Table 3. Analysis of the behavioral performance revealed a main effect of Memory Task, such that children who completed the Item memory task had significantly higher d' scores than children who completed the Source memory task, $F(1,79) = 111.43$, $p <.001$, $\eta^2 = .59$[3]. Follow-up analyses revealed that the children who completed the Item Memory tasks were better at both identifying old items as old, $F(1,79) = 142.19$, $p <.001$, $\eta^2 = .64$, and correctly rejecting new items, $F(1,79) = 11.88$, $p < .001$, $\eta^2 = .13$, compared to children who completed the Source Memory task. There were no main effects of Retrieval Group or interactions between Retrieval Group and Memory Task.

[3] ERP analyses were re-run controlling for ability to discriminate old from new items (d'). Difference between Item and Source memory remained. For example, the Condition x Group x Study interaction remained $F(1,78) = 5.26$, $p = .025$, $\eta^2 = .06$. Therefore, differences between these two conditions were not driven by differences in performance on respective memory tasks.

ERP Results

Grand average ERPs for all four groups are presented in Figure 1.

Nc (250-450ms). Analysis of the Nc revealed interactions between Retrieval Group x Coronal Plane, $F(2,158) = 4.80$, $p = .02$, $\eta^2 = .06$, and Memory Task x Item Type x Sagittal Plane, $F(2,158) = 3.18$, $p = .05$, $\eta^2 = .04$. Follow-up analyses of the 2-way interaction indicated that children in the Intentional retrieval group had overall greater Nc amplitude in the Frontal and Central leads, $F(1,79) = 5.06, 16.06$, $ps < .03$, η^2s= .06 - .17, compared to children in the Incidental retrieval conditions. There was no difference in amplitude between groups at parietal leads. Follow-up analyses of the 3-way interaction indicated that for children in the Source Memory tasks, there was a main effect of item type at the midline leads, with greater negative amplitude to New items ($M = -5.27$ µV) compared to Old items ($M = -4.11$ µV) , $F(1,36) = 5.31$, $p = .03$, $\eta^2 = .08$. There were no significant effects of item type at the lateral leads. This effect was not apparent for children who completed the Item memory tasks.

PSW (800-1100ms) Analysis of PSW revealed a Memory Task x Retrieval Group x Item Type interaction, $F(1,79) = 6.523$, $p= .01$, $\eta^2 = .08$, and a Retrieval Group x Item Type x Coronal Plane x Sagittal Plane interaction, $F(3, 316) = 4.19$, $p = .01$, $\eta^2 = .05$. Although the 5-way interaction did not reach conventional levels of significance, $p = .22$, the overlap between/within these interactions suggests complex interactions as a function of all 5 factors. Thus, we chose to examine all interactions as a function of Memory Task in order to fully capture the memory effects occurring for each of the two different tasks. A summary of the main findings are displayed in Figure 2.

Follow-up analyses for the Item Memory Task revealed an Item Type x Coronal Plane interaction, $F(2,86) = 3.33$, $p = .07$, eta = .072, with amplitude differences in the frontal leads, such that amplitude to New items (*M* = -1.03 µV) was greater than amplitude to Old items (*M* = -2.18 µV), $F(1,43) = 3.83$, $p = .07$, $\eta^2 = .08$. See Figure 2A. There were no significant effects of Item Type in the central or parietal leads for these children.

Follow-up analyses for the Source Memory Task revealed an Item Type x Retrieval Group x Coronal Plane x Sagittal Plane interaction, F(4,144) = 3.51, $p = .02$, eta = .09. These data were then split by Retrieval Group. Within the Intentional retrieval group, across the central leads amplitude to New items (*M* = 2.59 µV) was greater than amplitude to Old items (*M* = -0.88 µV), $F(1,19) = 6.44$, $p = .03$, $\eta^2 = .25$. See Figure 2B. The same pattern was found in the left parietal lead, $F(1,19) = 7.17$, $p = .02$, $\eta^2 = .27$, amplitude to New items (*M* = 2.25 µV) was greater than amplitude to Old items (*M* = -1.06 µV). See Figure 2C. Within the Incidental retrieval group, similar to the children who completed the Item memory tasks, in the frontal leads, mean amplitude to New items (*M* = 0.60 µV) was greater than amplitude to Old items (*M* = -1.11 µV), $F(1, 17) = 5.84$, $p = .03$, $\eta^2 = .26$. No effects of Condition were found in the central or parietal leads.

Discussion

The goals of the present study were to examine effects of Incidental and Intentional retrieval during Item and Source memory tasks on ERP memory effects in early childhood. Findings revealed that although memory effects were observed in both the Nc and PSW for both Item and Source memory and for both Intentional and Incidental retrieval, differences were apparent in these effects. Specifically, memory effects were present in the Nc for all children who completed the Source memory task regardless of retrieval condition. This may appear to suggest that the Nc is modulated by what is retrieved (i.e., item information versus source information); however it may also be influenced by task difficulty as children preformed more poorly on the source memory task compared to the item memory task. Given the Nc is thought to be related to attentional processes, the latter is more likely. In addition, in the PSW, memory effects differed between Item and Source memory tasks and Intentional and Incidental retrieval conditions. Specifically, for all children who completed the Item memory tasks *and* those in the Incidental retrieval condition of the Source memory task, PSW amplitude was greater in the frontal leads for new items than old/source correct items. In contrast, the PSW effect for children who completed Intentional retrieval during the Source memory tasks showed an effect more posterior and left lateralized, a finding similar to the left parietal effect found in adults (Rugg et al, 1996). Taken together, these findings suggest significant differences between ERP memory effects generated during Intentional retrieval of Source memory and the other 3 conditions (i.e., Intentional retrieval of Item memory and Incidental retrieval of Item and Source memory).

Behaviorally, children performed better on the Item memory than the Source memory task, but this finding is not surprising given the increased number of to-be-remembered stimuli and the vast body of research showing source memory abilities are still developing during this age range (Drummey & Newcombe, 2002; Ghetti et al., 2008; Lloyd et al., 2009; Oakes et al., 2006; Riggins, 2014; Sluzenski et al., 2006; Sluzenski et al., 2004). More surprising however, was that, although there were no differences in behavior between children who participated in the two Source memory tasks, there were differences in the ERP response. Although the Incidental and Intentional retrieval groups were equally able to distinguish both source correct items from new items and source correct items from source incorrect items, their ERP responses suggest different processes were at play during intentional and incidental retrieval of these source details. One possible explanation is a difference in the strategic component, specifically the strategic component may have been more involved during intentional than incidental retrieval (Hall et al., 2008). Given that source memory requires the strategic component more than item memory, this would also explain why no differences between Intentional and Incidental retrieval were observed for children who completed the Item memory task.

Together, these findings suggest that different processes may be involved in item and source memory retrieval during early childhood, and that these processes may be differentially assessed by paradigms requiring either intentional or incidental retrieval. Incidental retrieval paradigms may be capturing processes involved in item memory retrieval, whereas intentional paradigms may be required to entirely capture strategic processes that play a larger role in retrieval of contextual details.

Overall, the present findings are consistent with those of past studies. First, consistent with previous ERP work comparing intentional and incidental retrieval in adults, memory effects were present for both conditions, but overall ERP amplitude was greater for intentional retrieval (Nelson et al., 1998). Second, analysis of the Nc for children who completed the Source memory task revealed greater negative amplitude for new items compared to old items consistent with the findings of Riggins, and colleagues (2013), which used a similar paradigm. This suggests that differing amounts of attention may be directed towards items in which contextual details such as who or where are recognized. Third, similar to the incidental paradigms used in Riggins, and colleagues (2015), children who completed the Incidental Source memory paradigm showed greater amplitude for new items than old items in the frontal leads.

However, findings in the present study also differ from previous studies. First, in children who used Intentional retrieval on the Source memory tasks, greater amplitude was found for new compared to old items in central and left parietal leads, which is dissimilar from previous studies using incidental source memory tasks (e.g., Riggins et al., 2013; 2015). However, this is not very surprising given the differences in retrieval demands. Second, although findings at frontal leads for children who completed Incidental retrieval were similar to Riggins et al., (2015), no significant effects were found in the parietal leads in this study, which is dissimilar from Riggins et al., 2013 (although the general pattern was consistent , see Figure 2C). This may be due to differences in delays between encoding and test (30 min versus 1 week) or the content or difficulty of the source judgement (person vs location), however, future research is needed to examine these hypotheses. Third, the direction of effects in the present study (specifically those in the Intentional Item memory condition) differed from those found in Marshall et al., (2002) who also used an intentional item memory task. In the present study, PSW response to new items was greater than the response to old items, whereas, in Marshall et al., (2002) the response to old items was greater than new items. However, it should be noted that other differences also exist between the present work and Marshall et al., including delay (25 mins v. 5 mins) and encoding experience (rich v. shallow). Future research should explore these differences. However, combined with the results of past studies, the present results suggest that item and source memory rely on different processes and these processes are not equally detected with both intentional and incidental retrieval.

There is a large body of literature suggesting that children are able to perform well on item memory tasks before source memory tasks (e.g., Drummey & Newcombe, 2002). Shing et al., (2010) suggested that one potential reason for this difference may be that the strategic processes necessary for source memory retrieval develops later than the associative processes capable of accomplishing item memory. Given that incidental retrieval only captures the associative processes, whereas intentional retrieval captures both associative and strategic processes (Hall et al., 2008), our data provide support for this proposal (i.e., one contributing factor in the delayed development of source memory abilities may be the developmental trajectory of source memory, as the ERP response of intentional source memory retrieval may reflect different processes than incidental retrieval).

There are many additional questions that would be important to address in future studies. First, strategic abilities are thought to emerge early in life yet are also known to continue to develop through adolescence. In addition, efficient use of memory strategies are typically not observed in children younger than 6 years of age (Shing et al., 2010). Thus, future research should extend these questions to a wider age range, including both younger and older age groups. Second, only one age group was analyzed in this study. Results of Riggins et al., (2015), suggest that the neural response to incidental memory retrieval shows significant changes from 3- to 6-years of age. Future research should also explore if similar patterns of change are observed during intentional memory tasks that fully capture the strategic process.

Although the results of this study suggest that intentional retrieval is necessary to fully capture strategic memory processes, the results also suggest there are benefits of incidental retrieval. Of the 31 children excluded from analysis, 19 were in the intentional condition (5 Item memory, 14 Source memory) and 12 were in the incidental condition (3 Item memory, 9 Source memory). More children were lost in the intentional condition and this difference became larger with the more difficult (i.e., Source memory) task. When giving responses verbally, children had a difficult time remaining still (i.e., they were inclined to nod their responses along with giving them verbally) compared to children in the incidental conclusion. Incidental paradigms are also beneficial in that they are available to a wider population (e.g., younger children and infants) given they require minimal tasks demands during ERP recoding.

To summarize, this study explored incidental and intentional retrieval of item and source memory in early childhood. Findings suggest that item and source memory may rely on different underlying processes and that these processes may be differentially measured by both incidental and intentional retrieval. Although these findings shed light on previous differences in early childhood memory ERP research, future research is still needed to address other methodological variations and explore potential developmental changes. Incidental paradigms lead to less data loss and are applicable to a greater variety of populations, whereas intentional paradigms are better able to capture strategic processes and retrieval of contextual details. Future studies exploring ERP memory effects should weigh the pros and cons of each type of retrieval and the specific questions they hope to address when selecting which type of paradigm to use.

Notes

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Tables

Table 1

Participant Demographics

	N	Age in years M(sd)	Gender
Item Memory Task			
Intentional Retrieval	23	5.13 (.63)	11 Male
Incidental Retrieval	22	5.08 (.61)	7 Male
Source Memory Task			
Intentional Retrieval	20	4.76 (.67)	12 Male
Incidental Retrieval	18	4.82 (.62)	6 Male

Table 2

Task instructions for each of the four groups

	Item Memory	Source Memory
Active	Responded “yes” to toys they had played with and “no” to new toys ***while*** brain activity was recorded	Responded “yes” to toys that belonged to researcher A and “no” to new toys and toys that belonged to researcher B ***while*** brain activity was recorded (i.e,. exclusion paradigm)
Passive	Viewed the toys with no explicit task during ERP recording. After recording, responded “yes” to toys they had played with and “no” to new toys	Viewed the toys with no explicit task during ERP recording. After recording, responded “yes” to toys that belonged to researcher A and “no” to new toys and toys that belonged to researcher B

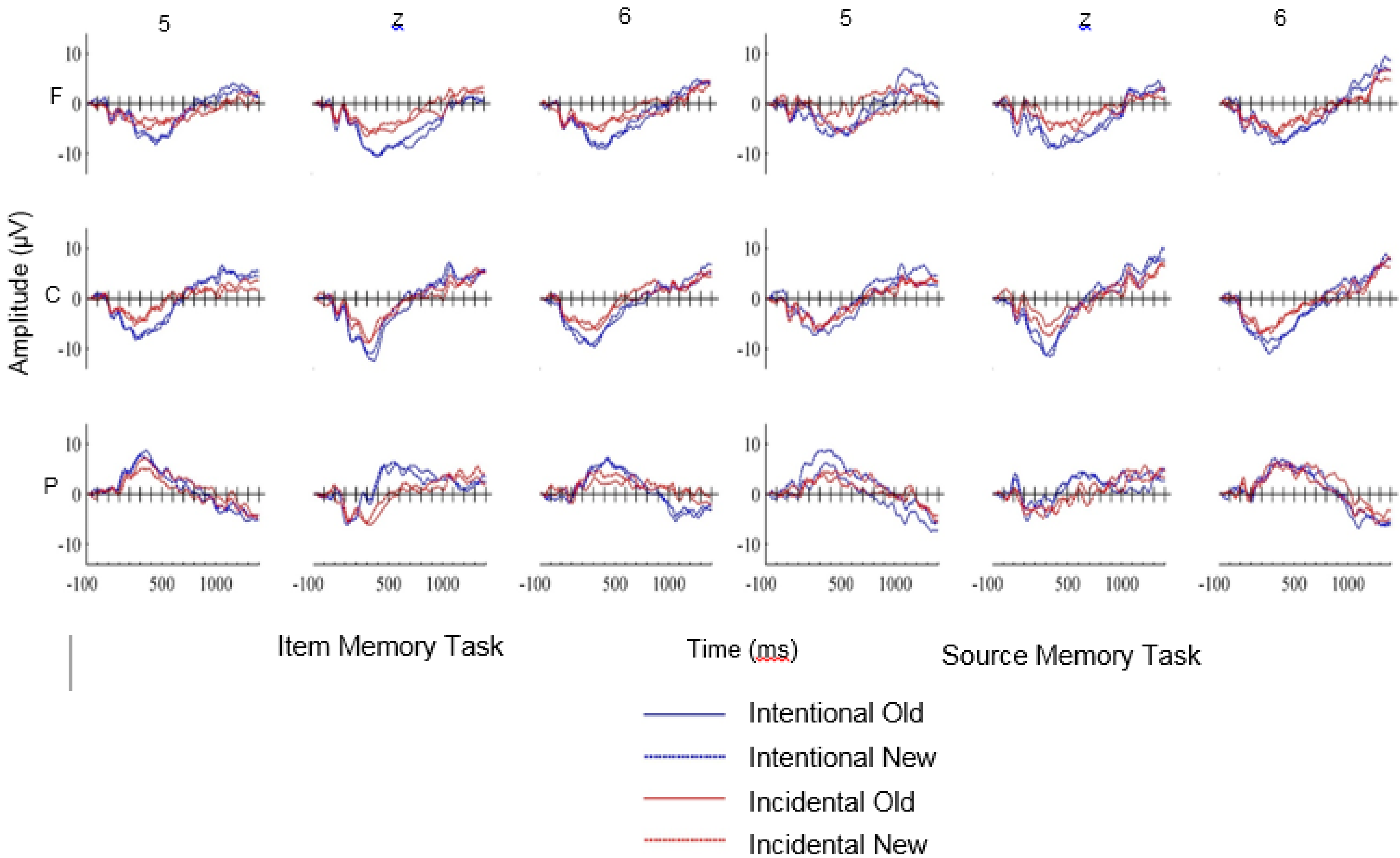
Table 3

Behavioral task performance for all groups

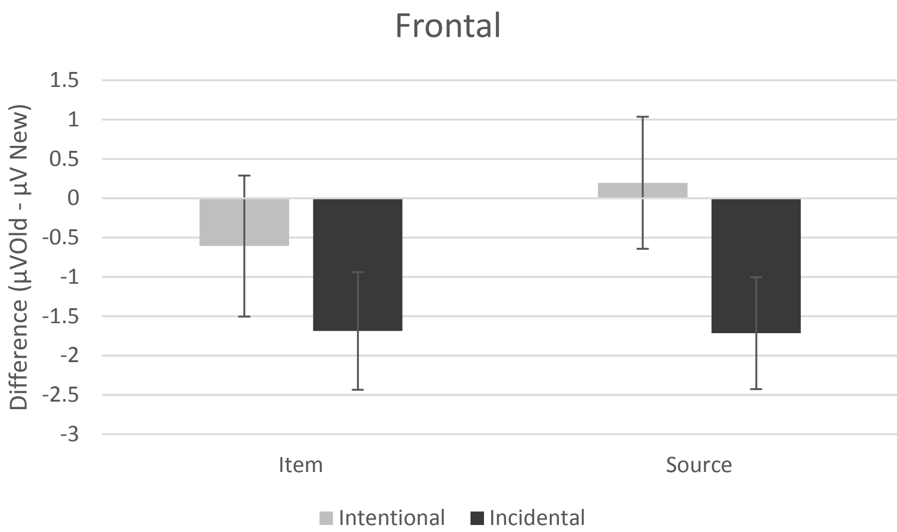
			Old Items v. New Items
	% Old	% CR	d'
Item Memory Task	.95 (.04)	.99 (.03)	3.83 (.44)
Intentional Retrieval	.94 (.05)	.99 (.03)	3.7 (.53)
Incidental Retrieval	.97 (.03)	.99 (.03)	3.96 (.28)
Source Memory Task	.71 (.13)	.90 (.17)	2.22 (.91)
Intentional Retrieval	.72 (.10)	.92 (.15)	2.34 (.71)
Incidental Retrieval	.70 (.16)	.87 (.20)	2.08 (1.1)

Note: For the Item Memory Task old represents Hits whereas for the Source Memory Task Old represents Source Correct

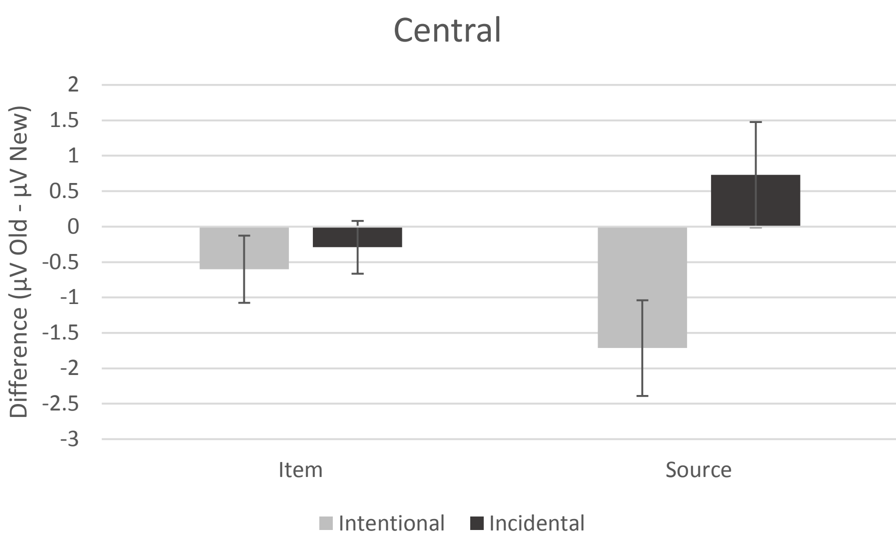
Figures


5
z
6
5
z
6
F
C
P
Amplitude (μV)
10
0
-10
-100
500
1000
Item Memory Task
Time (ms)
Source Memory Task
Intentional Old
Intentional New
Incidental Old
Incidental New

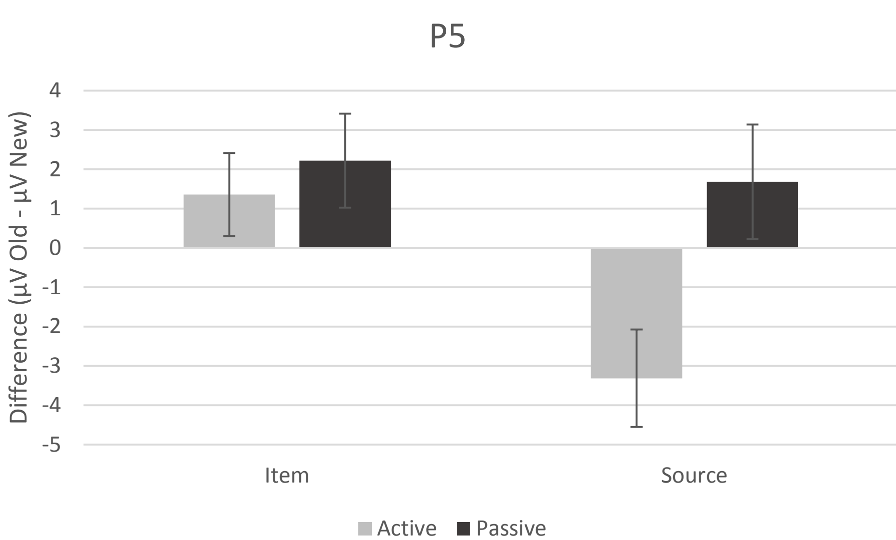
A.


Frontal
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Difference (µVOld - µV New)
Item
Source
Intentional
Incidental

B.


Central
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Difference (µV Old - µV New)
Item
Source
Intentional
Incidental

C.


P5
4
3
2
1
0
-1
-2
-3
-4
-5
Difference (µV Old - µV New)
Item
Source
Active
Passive

Captions

Figure 1. ERP responses to all four conditions.

Figure 2. PSW (800-1100ms) differential amplitude (µV Old - µV New) for each of the four conditions A. averaged across frontal leads (F6, Fz, F5) B. averaged across central leads (C6, Cz, C5) C. at the left parietal lead (P5).