DEVELOPMENTAL ASPECTS OF ERRORLESS LEARNING AND THE GENERATION EFFECT

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Abstract

Purpose: This study examined the role of the developmental decrease in interference and increase in semantic knowledge/fluency on the effectiveness of Errorless (EL) versus Errorful (EF) learning in children. The first goal of this study was to compare EL to EF learning in children ages 8 to 16 and to determine whether differences in EL versus EF learning are related to age. The second goal was to examine the degree to which the generation of items based on semantic definitions improves the benefit of EL learning and whether this benefit increases with age. The third goal of the study was to explore the relationship between the ability to inhibit irrelevant responses and performance in EF learning conditions in children. The fourth goal of the study was to examine the relationship between verbal and category fluency and memory performance when participants generated their own responses.

Method: Sixty children ages 8 to 16 were tested over two sessions. In the first session, measures assessing intellectual functioning, verbal fluency and inhibition were administered, and in the second session, children learned lists of words under five different conditions (Errorless-Experimenter Provided, Errorless-Subject Generated, Errorful- Experimenter provided, Errorful-Subject Generated, and a Baseline condition). Children's memory for each list was tested under immediate free recall and cued recall.

Results: EL learning was superior to EF learning for cued but not for free recall. However, this advantage was not related to age. No significant effect of word generation was found. For free recall, the EL-EP condition was superior to both the baseline and EL-SG conditions, and for cued recall, the EL-EP condition was superior to both the EF-SG and EF-EP conditions. Contrary to expectations, there were no significant correlations between the verbal and category fluency measures and performance in the self-generation conditions in the total sample.

Similarly, in the total sample, there were no significant correlations between the inhibition measures and the EF learning conditions. However, for the third age group (ages 14-16), a significant positive correlation was found between learning in the EF-SG free recall condition and category fluency and between EF-SG free and cued recall and inhibition. EF-EP free and cued recall was also related to Inhibition/Switching for the second age group (ages 11-13).

Conclusion: The results of this study suggest that EL learning may be superior to EF learning under certain cued recall conditions. The failure to find an effect of self-generation supports the notion that self-generation effect may be dependent on the nature of the initial encoding and retrieval demands. Implications for future research and understanding children's memory are discussed in the context of developmental theories of memory and executive functioning, and transfer-appropriate processing.

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Developmental Aspects of Errorless Learning and the Generation Effect

Factors influencing children's ability to learn, process and acquire information have long been a subject of investigation. Theories of cognitive development (e.g., Piaget, 2000) have attempted to understand different factors that can influence children's ability to acquire, integrate and remember information. This understanding allows for insights into developing strategies to optimize learning and in understanding how deficiencies in certain abilities can influence learning. One area of cognitive development that has been extensively researched is that of memory, as it is an essential ability in the acquisition of knowledge. The developmental changes in declarative and nondeclarative memory, processing speed, executive functions, strategy use and metacognition have been implicated in improvements in children's ability to recall information across development (Schneider, 2015).

Given the known developmental changes and processes associated with memory, including inhibition, metamemory and strategy use, it would follow that the use of certain instructional techniques or strategies would show variable effectiveness across the lifespan. Although a number of studies have examined the effectiveness of memory strategies in the aging population as well as in individuals with memory impairments (Clare et al., 2000; Evans et al., 2000; Kessels, & Haan, 2003), few studies have examined these techniques in children or addressed the usefulness of these techniques (Haslam, Bazen-Peters & Wright, 2012; Landis et al., 2006; Pauly-Takacs, Moulin, & Estlin, 2012).

The rehabilitation literature has repeatedly utilized and demonstrated the effectiveness of Errorless (EL) learning (i.e., a teaching technique that prevents individuals from making errors during the acquisition of new information) as a strategy to facilitate memory performance in adults with memory impairments (Evans et al., 2000; Lubinksy, Rich, & Anderson, 2009). The effectiveness of EL learning as compared to EF learning has been attributed to deficits in declarative memory and/or executive functioning, which are areas that also change across childhood. Although EL learning has also been shown to be more effective than EF learning in pediatric brain injury patients, no research to date has compared EL and EF learning in typically developing children.

The purpose of this study was to investigate the effectiveness of EL learning as compared to EF learning in typically developing children. The first goal of this study was to examine the effectiveness of EL learning as compared to EF learning and whether any differences are related to age. The second goal was to determine if there is a benefit of self-generation under the EL learning condition and whether this benefit is related to age. The third goal of this study was to examine the relationship between susceptibility to interference and performance under the EF learning conditions. The fourth goal of the study was to examine if there is a relationship between verbal and category fluency and memory performance when participants generated their own responses.

The findings of this study will be important in understanding the degree to which EL and EF learning are beneficial to different age groups and the factors that may be related to their effectiveness. This will allow educators to be more aware of factors influencing children's ability to acquire information as well as create interventions to support children who may have deficits in memory and cognitive processes that can impact their ability to acquire new information, such as children with executive functioning and semantic knowledge deficits.

This paper will provide an overview of the cognitive developmental theories relating to memory development, followed by a discussion of some of the abilities that would, empirically and theoretically, be related to EL and EF learning in children, including the development of semantic knowledge and the resistance to interference. Following this overview, a review of the literature on the use of EL learning in children and adults with and without memory impairments will be discussed to provide the rationale for the predicted effectiveness of EL learning as compared to EF learning across childhood in typically developing children.

Literature Review

Memory Development

Many processes and skills can influence children's ability to attend to, encode, and retrieve information from memory. Recently, research in memory development has focused on identifying the underlying abilities and mechanisms of developmental changes in memory (Schneider & Pressley, 2013). It has been consistently reported that declarative memory shows improvements between 6 and 12 years of age. This improvement in memory has been attributed to changes in basic memory span, the development of metamemory, and use of memory strategies, as well as increases in semantic and domain knowledge and processing speed.

Basic memory span or memory capacity refers to the amount of information an individual can hold in mind in an active available state, as well as his or her ability to manipulate the information (Schneider & Pressley, 2013). The assumption of a limited capacity suggests that one can recall only a few pieces of information at any given time. Whereas short-term memory involves only the storage and reproduction of information, working memory also includes the ability to manipulate or transform information (Schneider, 2015). Developmental changes have been found in memory span for sentences, with increases observed until late adolescence (Schneider, Knopf, & Sodian, 2009).

Evidence obtained from memory research across development (Schneider, 2015) suggested that the acquisition and use of control processes and memory strategies, such as rehearsal and chunking might explain the difference in short-term memory capacity. Memory strategies can be defined as mental or behavioural activities that support learning and that are effortful, conscious and controllable (Schneider & Pressley, 2013). Strategies can be executed either at the time of encoding (i.e., at the time of learning) or during retrieval (i.e., when information is accessed in long-term memory). Children's development of their metamemory (i.e., their knowledge regarding the functioning and contents of their memory) would also influence their use of strategies (Bjorklund, Dukes, & Brown, 2009). Further, young children's representations of knowledge are different from the representations of older children, adolescents and adults, and therefore, younger children cannot utilize their knowledge in the use of strategies in the same way that older children can (Schneider, 2015). Further, children's knowledge base (i.e., long-term representations of world knowledge) is organized in a semantic network that changes with age and experience. Developmental changes in the network affect the number of available items and their accessibility. In addition to an increase in the number of items or concepts in the knowledge base expanding with age and experience, the number and strength of conceptual associations between items also increases (Bjorklund, 1987; Schneider & Bjorklund, 2003). This richness of the knowledge base can influence the speed and accuracy of memory processes, leading to more efficient processing and therefore greater availability of mental resources to retrieve items or facilitate strategy use (Schneider & Bjorklund, 2003). Further, the increase in processing speed across childhood has been implicated in the development of short-term memory capacity (Kail & Salthouse, 1994). The results from these studies that found age-related changes in processing speed is consistent with theories that attribute changes in cognitive development to changes in general information processing capacity (e.g., Baddeley & Hitch, 1974; Case, 1995). A number of these theories have been influential in understanding children`s cognitive and memory development.

Neo-Piagetian theories (e.g., Case, 1995; Fischer, 1980; Pascual-Leone, & Baillargeon 1994) view age-related developmental changes as related to differences in information processing capacity. Their common postulates are that the general stages of development should be defined in terms of an upper limit at which children of a given age or cognitive level can function and that working memory or attentional capacity plays a strong role in determining the upper limit (Schneider & Pressley, 2013).

One of the first influential neo-Piagetian theories of cognitive development is Pascual-Leone's theory of constructive operators (Pascual-Leone & Johnson, 2011). According to his theory, developmental stages reflect the "endogenous growth of maturationally driven mental attention mechanisms" (Pascual-Leone, 2000, p. 843). He proposed that the "central computing space" or "mental space" (M-Space) is a quantitatively specifiable parameter that can be used to explain many of the cognitive changes described by Piaget. A child's cognitive capacity is represented by M, which is the maximum number of schemata that a person can activate, coordinate, or both activate and coordinate simultaneously. The concept of M-space can also be referred to as working memory. Pascual-Leone hypothesized that there is a linear increase in this mental capacity from 3 to 16 years of age.

In Pascual-Leone's model, (Pascual-Leone & Baillargeon 1994; Pascual-Leone & Johnson 1999, 2011), working memory is not a unitary system, but corresponds to a set of highly activated schemes that relate to performance on a given task. When children process information, a larger set of schemes are activated, most of them automatically and these schemes represent the "activation field." Depending on the situation and task demands, certain schemes in this field are inhibited, whereas others are more strongly activated, defining the "field of mental attention." Pascual-Leone posited that three mechanisms contribute to the selection and activation of schemes in this field. These include: (1) M-space; (2) An inhibition mechanism that lowers the weight of task-irrelevant but highly activated schemes; and (3) Executive schemes responsible for performance control (i.e., for planning and monitoring and for distribution of resources). Recent work by De Ribaupierre, Fagot, and Lecerf (2011) supported the importance of inhibition and processing speed for working memory development using an experimental design that included children, young adults and older adults. The same structural equation model accounted for working memory performance in all three age groups, and indicated that age differences in working memory are driven by age differences in processing speed and inhibition. This finding is consistent with both neo-Piagetian (e.g., Case, 1995; Fischer, 1980) and information processing accounts of cognitive development (Kail & Salthouse, 1994; Pascual-Leone & Baillargeon 1994; Pascual-Leone & Johnson 1999, 2011), which suggest that in addition to the development of storage systems (e.g., short-term memory and long-term memory), the development of mental processes plays a role in cognitive and memory development. One of the processes proposed to play a role in the development of memory is resistance to interference (i.e., the capacity to inhibit irrelevant information; Dempster, 1992).

Interference Theory

Interference theory has been referred to as an association theory, which suggests that an association bond or functional connection between two or more elements may compete with one another, and one association can inhibit or suppress the activation of another. There have been changes to interference theory over the years, with the concept widening to include proactive sources (i.e., when previously learned information hinders subsequent learning; Dempster, 1992). The concept of interference has received attention from developmental psychologists. For example, resistance to interference has been used to explain developmental differences in memory phenomena (Dempster, 1992; 1993). Bjorklund and Harnishfeger (1990) have argued that neurologically based changes in the efficiency of inhibitory processing contribute to increased working memory efficiency. Also, Brainerd and Reyna (1989) have suggested that young children's recall is more susceptible to output interference (i.e., when the act of retrieval interferes with recall of information) than is older children's.

The Frontal Lobes and their Role in the Development of Resistance to Interference

One of the reasons that children's susceptibility to interference decreases throughout childhood and into adolescence is the development of the frontal lobes, which constitute the anterior portion of the cerebral cortex, bounded by the central sulcus and the lateral sulcus (Figure 1). It has a very rich system of connections and feedback loops both with lower levels of the brain and with all other parts of the cortex. Pathways carrying information about the external environment from the posterior cortex and information from internal states originating in the limbic system also converge in the frontal lobes. One of the functional areas of the frontal lobes is the prefrontal cortex, which has been associated with executive functions, such as planning, inhibition, as well as attention, and emotional regulation. All prefrontal connections are reciprocal in that structures projecting fibers to the prefrontal cortex are the recipients of fibers from it (Fuster, 1991).

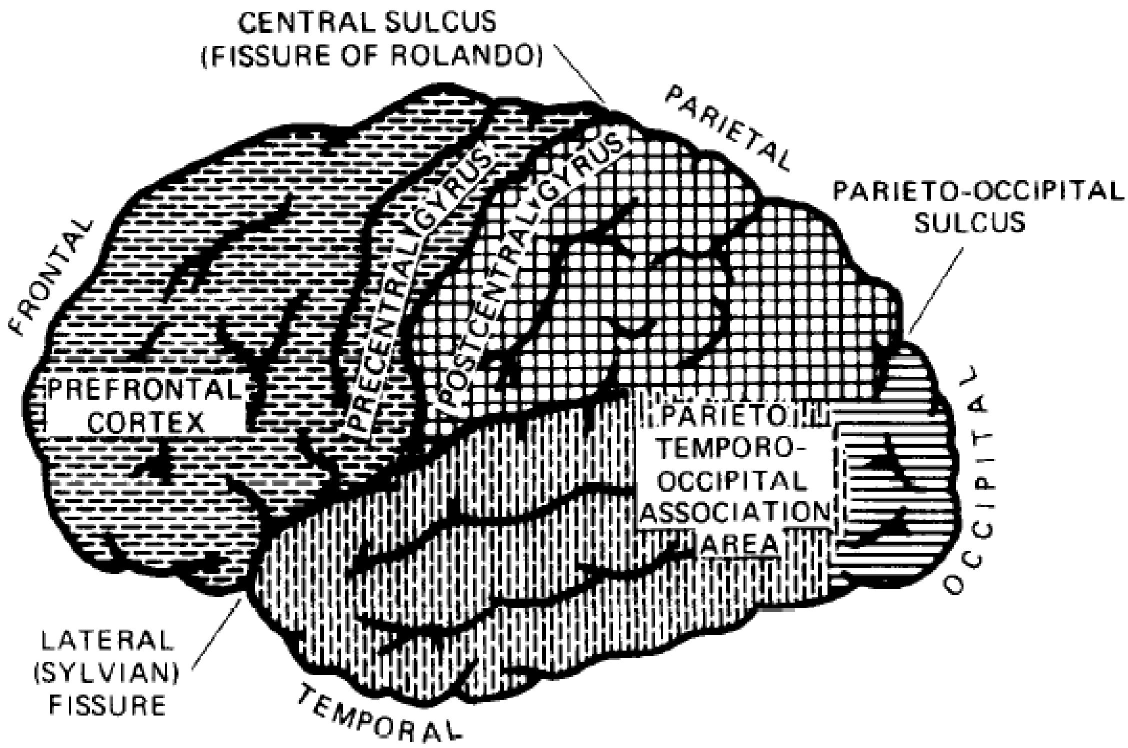

Figure 1. The Lobes and Landmark Structures of the Cerebral Cortex

From Lezak (1983, 2004).

The brain area comprising the frontal lobes is the last to develop, with its size increasing significantly from birth to the second year of life, followed by a less pronounced growth spurt from about 4 years to 7 years of age. After this time, there is a slow increase in size of the frontal lobes until young adulthood. Much of the increase is due to an increase in size and complexity of the nerve cells (Reinis & Goldman, 1980), as well as further myelination until the early teenage years. The development of myelin is important, as myelinated axons propagate impulses more rapidly and with less energy, and are less susceptible to abnormal transmission from fiber to fiber than unmyelinated axons (Reinis & Goldman, 1980).

Frontal lobe lesions have been associated with impairments in the ability to control interference from both external and internal sources, due to the inability to effectively inhibit or suppress stimuli or associations that are not relevant to the task at hand. Tasks that were suggested to be sensitive to interference include ones with multiple trials, in which previously correct responses are no longer appropriate, stimuli that resemble one another but not all of which are appropriate at the moment, secondary tasks or distractor activities or the presentation of a delay prior to responding (Dempster, 1992; 1993).

Inhibition refers to an 'active suppression process' such as the removal of task-irrelevant information from working memory (Harnishfeger, 1995). Baddeley's (2000) working memory model includes inhibitory control and cognitive flexibility (e.g., multitasking, shifting between tasks). A central idea in cognitive developmental theories is that young children have more difficulty than older children and adults ignoring task-irrelevant stimuli in their environments, as well as keeping task-irrelevant thoughts out of working memory. In addition, developmental changes in strategic processing in memory have been attributed to parallel maturation of the frontal lobes and executive functions. From early childhood through to adolescence, typically developing children increase their ability to hold and organize information (working memory) and are less susceptible to the effects of interference when learning new information. The interference account suggests that young children are less able to inhibit irrelevant information from working memory, which means less capacity available to store new information or to execute cognitive processes. Significant improvements in inhibition occur between the ages of 5 and 8, and several studies found continued improvement in middle adulthood. Best, Miller, and Jones (2009) reported continued improvement on tests of response inhibition that are used to assess one`s ability to suppress responses that are inappropriate in a particular context (e.g., the stop-signal task and Eriksen Flankers task) until age 15 and on a Stroop-like task until age 21.

Studies investigating the development of various prefrontal functions, including inhibition and verbal fluency, have revealed an improvement in these abilities into childhood and adolescence (Brocki & Bohlin, 2004; Kail, 2002; Welsh, Pennington, & Groisser, 1991; Williams, Ponesse, Schachar, & Logan, 1999). Kail (2002) conducted a meta-analysis showing that age and number of stimuli were the only two variables consistently related to recall and interference scores. Whereas recall increased from age 4 to 9, interference declined across the same age range, indicating that the ability to inhibit irrelevant information increases systematically during childhood and may contribute to the increase observed in memory over that time.

Williams, Ponesse, Schacter, & Logan (1999) investigated the developmental change in inhibitory control using the stop-signal procedure in individuals age 6 to 81. Inhibition in the stop-signal procedure is the ability to stop a planned ongoing response or thought, and is the analogue of a situation that requires an individual to stop a planned or pre-potent response. This study revealed that both the ability to inhibit pre-potent responses and the ability to execute them improved throughout childhood and then diminished throughout adulthood.

A study by Welsh, Pennington, & Groisser (1991) that assessed other executive functioning abilities, including verbal fluency, further supports the developmental course of prefrontal functions. They tested 110 subjects between the ages of 3 and 28 on a number of executive functioning tasks, including a visual search task, a verbal fluency task and a motor planning task. Motor sequencing, verbal fluency efficiency and complex planning on the 4-disk

Tower of Hanoi appeared to continue to develop into adulthood, as 12-year-olds were significantly less skilled than the adults.

Another study by Brocki and Bohlin (2004) investigated the development of executive functions in 92 children, ages 6 to 13, using measures drawn from developmentally relevant conceptualizations of executive or prefrontal functions and included a go/no-go task, a verbal fluency task, a Continuous Performance Task (CPT), a Stroop-like task, a hand movements task and a digit span task. A factor analysis revealed three factors: Disinhibition (two types of CPT impulsivity: inattentive impulsivity, and go/no-go impulsive errors), Speed/Arousal (CPT ReactionTime, RT, go/no-go RT, inattentive errors/omissions, on CPT and go/no go), and Working Memory/Fluency (verbal fluency, hand movements, digit span, Stroop-like task, time reproduction). On the Disinhibition dimension (mainly withholding a response), the most apparent developmental advances occurred at ages 7.6 to 9.5 and 9.6 to 11.5 with little further improvement in the oldest age group (11.6-13 years old). On the speed of processing/Arousal Factor, there was a major gain in development between the first age group (6-7.5 years) and the second group (7.6-9.5). On Working Memory/Fluency, significant improvements were observed at two points in development, the first around age 8 with one further improvement around age 12 years. This developmental increase on Working Memory/Fluency reflects a protracted course of development observed on verbal fluency tasks (both semantic and phonetic). Given that verbal fluency tasks require the organized search of the individual's semantic network (Welsh et al., 1991), the interplay of prefrontal functioning (e.g., organizational strategies) and the degree to which children have acquired semantic knowledge, can influence their memory development.

Semantic Knowledge and Memory Development

The development of a richer semantic network has been implicated in the increase in memory ability. Throughout development, the number of items in a child's knowledge base expands, as do the number and strength of associations between related items (Bjorklund, 1987). Bjorkund et al. (1990, 2009) propose that knowledge should be conceptualized in terms of information contained in a modified network model of semantic memory. Each item in semantic memory can be defined as a node that is connected to other nodes. Each node is connected to other conceptually associated items, as well as with the features that characterize it. Throughout development, the number of nodes as well as the strength of connections among them changes. In addition, the number of features associated with an item increases as children gain additional everyday experiences. This semantic network consists of concepts or nodes that are linked together in long-term memory. It is believed that older children and adults have an increasingly elaborated knowledge base, which refers to knowledge that is highly organized with many strong connections among items. Therefore, the activation of items in any one domain would facilitate the activation of related items. Bjorkund et al. (1990, 2009) suggested that the primary effect of an elaborated knowledge base on memory is the increase in the speed of processing for domain-specific information.

Both age and individual differences in children's knowledge base have been shown to be important in children's ability to recall information. An increased knowledge base can affect how children process information, and older children generally know more about what they are asked to remember than younger children. The impact of children's knowledge base on strategy use and memory ability has been demonstrated in a number of studies (Bjorklund et al. 1990; Ghatala, 1984; Schneider, Bjorklund, & Valsiner, 2003). For example, older children and adults recalled more words than younger children when participants encoded the words using semantic cues (e.g., when the word “apple” is presented, participants may be asked “is this a fruit?”). However, recall was comparable across 7- and 11-year olds when words were judged in terms of their sounds. A few developmental studies have shown significant relationships between semantic knowledge and memory (Hasselhorn 1992; Schneider, Schlagmuller & Vise, 1998). One reason proposed for the positive effects of conceptual knowledge on memory is that semantic relations between highly associated items are activated with relatively little mental effort and therefore would facilitate retrieval. For example, Bjorklund and Jacobs (1985) proposed that semantic organization initially seen in recall by young schoolchildren is mediated by the relatively automatic activation of well-established semantic memory relations, rather than a deliberately imposed strategy.

Generation Effect

A memory advantage that may be facilitated by the richness of semantic and knowledge structures is the Generation Effect. The Generation Effect refers to the idea that information is better recalled if it is generated by the individual as opposed to being read. Craik’s (2002) levels of processing account of memory suggests that remembering is related to the type of analysis performed at the time of encoding and that deeper levels of processing are associated with higher levels of remembering. In his theory, more deeply processed memory traces are more easily integrated in one’s pre-existing, organized knowledge structures, which serve as useful frameworks for reconstructive retrieval processes. Therefore, older children with more elaborate knowledge structures and semantic networks will likely benefit more from semantic processing of information than younger children who have simpler knowledge structures. Levels of Processing theory suggests that memories are strengthened by elaboration or processing information on the basis of its meaning. Therefore, the generation effect may only be obtained when study stimuli have pre-existing semantic and/or lexical representations.

In addition to the Levels of Processing theory, other hypotheses have been proposed to explain the Generation Effect (Taconnat & Isingrini, 2004). The Semantic hypothesis suggests that the generation effect is due to the increase in the number of activated semantic characteristics specific to the item produced. A multifactor explanation of the generation effect has been proposed, whereby generation increases the processing of information about item-specific properties of the target and improves encoding of the characteristics shared by the cue word and the target word, as well as the encoding of relationships between the items in the list. McFarland, Duncan, and Bruno (1983) suggested that if generating items from semantic memory involved similar mnemonic strategies to generating items from episodic memory, then the effectiveness of the generation effect should improve with age. According to the authors, and consistent with the effort hypothesis, it may also be that the added difficulty in stimulus generation would involve additional mental operations and that active retrieval, especially those observed in free recall, would involve strategic memory searches that become more sophisticated as children develop. They examined the Generation Effect in 60 children in each of Grades 2, 3, 5 and 7. For the subject-generated condition, participants were presented with a category name followed by the initial consonant cluster of the correct response and were required to generate a response (e.g., *Tool-N*___). During the experimenter-generated trials, participants were presented with both words, with the second word underlined. Generation of items enhanced free recall for all age groups, with the effect increasing in magnitude across the grade levels. Similarly, a generation effect was obtained on a recognition test obtained for the youngest children as well as for the older children. However, performance was at ceiling in both groups, so no conclusions could be made about a potential interaction between generation and age group.

The Effort Hypothesis is a third hypothesis proposed to explain the Generation Effect. According to this hypothesis, the Generation Effect would be the consequence of the degree of cognitive effort used at the time of learning. Fiedler, Lachnit, Fay, and Krug (1992) explained the Generation Effect as the consequence of greater mobilization of processing resources. According to Fiedler et al. (1992), the generation of items increases the individual's interest in the task and makes them more active than they would be in a more passive, reading condition.

Transfer-Appropriate Processing is the fourth theory used to explain the Generation Effect. According to this theory, memory improves when the same types of processes are used at encoding and retrieval. For example, De Winstanley et al. (1996, 1997) showed that when the processes used in encoding and recall are the same, the recall of information requires fewer processing resources, whereas if they are different, greater resources are required. Therefore, the Generation Effect can be due to the re-creation of the same cognitive procedures at testing that were used during the study stage (Taconnat & Isingrini, 2004).

To assess the possible source of the benefit of self-generation on memory, Rosner, Elman, and Shimamura (2013) assessed the generation effect in 24 healthy individuals ages 18 to 32. Participants were shown related word pairs in the form of a cue word and word fragment (e.g., Quarrel_F_ght) and asked to complete the second word in the pair, which was compared to trials in which participants just read related pairs. At test, old/new recognition memory for the second word in each pair was assessed with confidence ratings (high vs. low). Participants were scanned during both study and test phases to identify the neural substrates underlying the generation effect. Significant prefrontal activity confirmed the role of executive control processes important for establishing long-term memories. Generation also increased activity in posterior regions involved in verbal processing, object analysis and visuospatial imagery. Therefore, depending on the task at hand, active generation may promote increases in attention, cognitive effort, item distinctiveness, semantic processing and conceptual processing. These studies suggest that all four hypotheses/theories proposed may play a role in the benefit of generating items during learning.

In addition to the studies described above, suggesting relationships between inhibition, semantic knowledge and memory, studies examining memory rehabilitation techniques in the aging population and in children with memory and cognitive deficits have shed some light on the relationship between cognitive and memory variables and learning (Baddeley & Wilson, 1994; Clare et al., 2000; Haslam, Gilroy, Black & Beesley, 2006; Lubinsky, et al., 2009; Pauly-Takacs, et al., 2012). More specifically, the impact of making errors during learning (Errorful Learning) as opposed to the reduction of errors during learning (Errorless Learning) leads to the question of which variables influence the effectiveness of Errorless Learning.

Errorless (EL) Learning

Errorless (EL) learning refers to a teaching technique that prevents individuals from making errors during the acquisition of new information. This approach involves encoding new information without making errors in the learning process. During learning, individuals are given the correct information by the examiner. In contrast, during Errorful (EF) learning, individuals are encouraged to guess during the encoding phase, which ensures that they make errors prior to arriving at the correct response during this phase. The EL learning technique has been especially important as an intervention strategy in individuals with memory impairment, as it has been found to be more effective than trial and error, or EF learning. For example, Squires, Hunkin, and Parkin (1997) compared EL and EF methods in the acquisition of novel associations in a group of adults with memory impairments. There was an EL learning advantage under immediate retention conditions as well as on delayed testing. Clare et al. (2000) provided individually tailored interventions, based on EL learning principles, to six participants with early dementia of the Alzheimer's type to target a specific everyday memory problem, such as face-name associations. Participants demonstrated significant improvements on the memory tasks following training based on EL learning. These results suggest that EL learning can be more effective than EF learning in individuals who have weak or poorly developed memory.

EL learning was more recently investigated in the pediatric population to address memory and learning difficulties. Pauly-Takacs et al. (2012) reported the application of the EL learning technique to a verbal learning task in a 15-year old brain tumour survivor, with profound episodic memory difficulties and deficits in executive functions, including inhibition, task switching and planning and organizing behavior. The patient and 10 age-matched control participants were required to learn words under either EF or EL learning conditions over three trials, and their memory was tested after each trial, using letter cues. A final free-recall test was given following completion of all three trials after a short delay. For both the patient and the controls, learning was better under the EL condition using cues, but no benefit was found under free recall. The controls reached ceiling by the second trial for the EL condition and by the third trial for the EF condition. However, the patient's performance in the EF condition was significantly weaker than in the EL condition. This beneficial effect of EL learning was maintained for a delayed cued recall test, which suggested that learning for this patient was more efficient under EL conditions, but was dependent on cues provided.

Baddeley and Wilson (1994) suggested that EL learning is superior to EF learning because individuals with amnesia cannot use explicit memory effectively and must rely on their intact implicit memory. They suggested that implicit memory is particularly sensitive to the effect of interference from errors, since responses based on implicit memory depend on emitting the most prepotent response and does not allow for error correction in the way that explicit memory does. In contrast, other researchers have proposed that the advantage of EL learning is due to residual or weaker explicit memory capacities and not to implicit memory (Hunkin, Squires, Parkin, & Tidys, 1998; Page, Wilson, Shiel, Carter, & Norris, 2006; Tailby & Haslam, 2003).

A more recent study (Lubinsky et al., 2009) found evidence that the benefit of EL learning is due to intact implicit memory in older adults and in patients with amnestic mild cognitive impairment. In this study, EL learning led to greater priming of target words (i.e., a higher probability of completing a studied word stem with a target word than the probability of completing a nonstudied word stem with a predesignated word) than did EF learning. In addition, participants with memory impairments showed greater priming relative to the healthy older adults for their prior errors, providing support for implicit memory's contributing to the benefit of EL learning.

Anderson and Craik (2006) used a process dissociation procedure (i.e., a procedure that allows the determination of the degree to which performance on a memory or cognitive task is mediated by conscious or controlled versus automatic processes) to explore the independent contributions of explicit and implicit memory processes to EL learning in healthy younger (mean age of 21) and older adults (mean age of 75). They found that estimates of explicit recollection were reduced in the older group relative to their younger participants whereas estimates of implicit memory did not differ between the two groups. Further, in younger adults, EL learning was associated with a reduction in recollection, which was attributed to a possible lack of active encoding strategies in this group. It was suggested that the requirement to guess the target information leads to deeper levels of processing, and therefore generating a semantic associate in the EF condition increased recollection only for the younger adults, and not for the older adults who may have relied more on automatic, familiarity-based processes during EF learning. In their study, EL learning was less beneficial than EF learning when correctly recalling highly probable items (i.e., typical word pairs, such as Knee_Bone). However, for the older adults, EL learning was more beneficial when recalling less probable items (i.e., atypical word pairs, such as Knee_Bend). As older individuals have reduced recollection, they would be less adept at using recollection to suppress incorrect responses. Therefore, it was suggested that EL learning may be effective for individuals with explicit memory deficits and may not be ideal for individuals with intact explicit memory, as this method may underutilize self-initiated elaborative processes, such as active strategy use.

Although EL learning has been found to be beneficial among individuals with memory impairments and older individuals with compromised explicit memory, its decreased and variable level of effectiveness in individuals with intact explicit memory and in children (Anderson & Craik, 2006; Landis et al., 2006; Pauly-Takacs, et al., 2012) suggests that the effectiveness of this learning method may not be generalizable across all populations. Further, if it is hypothesized that errors produced during EF learning interfere with elicitation of the correct response, then the ability to inhibit irrelevant responses, which are also compromised with aging and also develop throughout childhood and adolescence, would influence the degree to which errors would be detrimental to learning. A number of investigations have considered the possibility that other cognitive abilities, more specifically executive functions and metacognition, which vary across age groups, may contribute to the effectiveness of EL learning.

Souchay and Isingrini (2004) examined metacognitive control in younger and older adults and its relation to memory performance and executive functioning. They found that younger adults (age range 20-31) were better at adjusting their strategies at encoding (i.e., study time and rehearsal) to task demands than older adults (age range 60-98). Another major finding of this study was that age-related decline in metamemory control (e.g., study time and task difficulty adjustment) appeared to be largely the result of executive-frontal limitations associated with aging. Further, Page et al. (2006) found an advantage for EL over EF learning for both severely and moderately memory-impaired participants on a word-stem completion task. When given a recognition task for target items, both groups could recognize target items only in the absence of lures derived from the participants' prior errors. In this study, source memory, which relies on the integrity of prefrontal cortex (Craik, Morris, Morris, & Loewen, 1990), was significantly impaired in the severely memory impaired group and only weakly present in the moderately impaired group.

Haslam et al. (2006) proposed that the cognitive representations that mediate between stimulus and response are predominantly formed through Hebbian learning; this refers to associative learning that occurs due to simultaneous neural activation leading to increases in synaptic strength. Given that the Hebbian approach allows learning in situations where there is no feedback, the system performs poorly in EF learning situations. They proposed that because human cognition is able to use feedback to address problems with Hebbian learning, there are a number of cognitive abilities needed for feedback modulation that allow filtering out of EF trials. First, individuals must be able to monitor the accuracy of their response. Second, temporary storage or prolonged activation of the original stimulus and the associated response would be needed, while the underlying representations are adjusted by the learning mechanism. Third, feedback modulation requires efficient verification and regulation of behaviour and possibly the deliberate manipulation of representations, which rely heavily on attentional and executive resources. When any of these elements fail, individuals can improve their performance with an EL intervention.

In further support of the idea that executive dysfunction may contribute to the effectiveness of EL learning, Fillingham, Sage, and Lambon Ralph (2005) found that participants who showed greater performance with EF learning were those with the best working and recall memory and attention. These findings suggest that executive functions, which also contribute to effective explicit memory, may underlie the effectiveness of EL learning.

In further addressing the variability in the effectiveness of EL learning, a number of studies investigated factors that can enhance its efficacy. To investigate the influence of elaborative processing on EL learning, Lubinsky et al. (2009) compared the effects of EL and EF learning under experimenter-provided (i.e., the experimenter providing the target word) and self-generated (i.e., the participant generating the target word in response to a semantic cue) learning in older adults and individuals with aMCI in learning words and sentences. Overall, EL learning resulted in better free recall, cued recall and delayed recognition compared to EF learning. There was an added benefit to memory performance for both groups when EL learning was combined with self-generation and when memory was tested by cued recall.

Tailby and Haslam (2003) also examined EL learning and whether the method could be improved by providing semantic cues during learning to enable adult participants with explicit memory deficits to generate responses themselves without error. Participants were adults with acquired deficits in explicit memory. The self-generation, elaborative EL method resulted in superior memory performance compared to standard EL learning, consistent with the findings of Lubinsky et al (2009).

This contrast between results of EL and EF learning with healthy individuals with intact memory and executive functioning and individuals with memory impairments raises questions around how to maximize learning for typically developing children across different developmental stages. Based on developmental research on memory and previous studies of EL learning, younger children with a less developed ability than older children to inhibit irrelevant responses would likely benefit more from EL learning, with EF learning being more detrimental to learning. Further, older children who are presumed to have better developed semantic knowledge/networks would likely benefit more from self-generation than younger children.

Studies of EL learning in Children

A study by Metcalfe and Kornell (2007) investigated factors that may influence learning in Grade 6 students who had very low literacy and academic performance scores. The first factor examined was generation (i.e., generate only if confident about the answer vs. generate whether certain or not vs. read only). This design addressed the effects of making errors versus not making errors during learning. The second factor was feedback (i.e., showing the correct answer if the participant does not come up with the correct response). The study revealed that generation was more effective in learning than the read only condition, and that errors that were corrected did not interfere with learning.

Although EL methods have been incorporated into educational programmes for children with learning needs (Metcalfe and Kornell, 2007), few studies have examined its benefit relative to trial and error learning in children. Landis et al. (2006) examined the effectiveness of EL versus EF or trial and error learning in children with memory impairments between the ages of 6 and 18 years. The children were required to learn novel science and social science facts over a period of three weeks under EL and EF conditions and memory for these facts were tested under different delay intervals. The EL learning advantage varied as a function of retention interval, injury severity, and age. For example, at two days, the EL learning advantage was seen only for children with a mild brain injury. At seven days, only younger children showed an advantage of EL learning, and younger children who sustained a moderate brain injury showed the greatest advantage of EL compared to EF learning, as opposed to those with mild and severe injury who showed only a trend towards an EL advantage. At 77 days, younger children with severe injury showed an EL treatment advantage.

Haslam et al. (2012) addressed this gap in the literature by investigating EL learning principles in young people with acquired brain injury between the ages of 11 and 16. They also examined a more active form of EL learning in which participants generated their own responses. It was predicted that both the experimenter provided and subject-generated EL conditions will produce better learning outcomes than EF or trial and error learning and that self-generation would prove the more effective of the EL principles. This study examined 15 children with acquired brain injury and 15 controls. For controls, there was no effect of learning condition. However, for the patient group, learning under both EL conditions was significantly better than the EF condition, although the difference between the standard and self-generated EL conditions was not significant. Given the variability in these findings, it was suggested that EL learning is not consistently more effective than EF learning. Haslam et al. (2012) attributed the differences in results to the differences in the age range of participants and the different learning tasks utilized.

Following up on the mixed results observed in studies of EL learning in children, Warmington, Hitch, and Gathercole (2013) examined the use of EL learning in the acquisition of new words in typically developing children and examined individual differences in working memory, literacy, phonological awareness, general cognitive ability and processing speed that may contribute to the effectiveness of the approach. Forty-nine children between the ages of 7 and 9 participated in the study. For the learning task, 10 spoken nonwords were paired with 10 novel pictured objects and divided into two sets of five pairs. Children learned the nonword names for the objects in each set via two learning methods: EF and EL learning. Learning was assessed using an object naming test presented immediately after training. Individual differences in processing speed and vocabulary were significantly positively associated with performance in learning new words using EF but not EL learning. It was speculated that the independence of EL learning from cognitive skills known to be important in explicit memory, including processing speed, vocabulary and working memory arises because it relies instead on implicit memory. The results were also consistent with the suggestion that EF learning is heavily dependent on rapid information processing and cognitive resource management to facilitate error correction during encoding. The effectiveness of EL learning in patients with memory impairments as well as the variable results obtained from studies with children and healthy adults has contributed to suggestions around the cognitive mechanisms surrounding EL learning.

Although the relationship between executive functions and EL learning has not been investigated in children, Nordvik, Schanke, and Landro (2011) examined whether memory span and working memory are related to weaker memory performance on a digit recall task, following error exposure in 60 university students. Errors were found to have a significant negative impact on immediate free recall. For both high and low memory span load, the incongruent distractors more significantly reduced immediate memory recall than congruent distractors. The authors suggested that errors might resemble distractors in that they divert attention away from the target stimuli and differ from distractors by interfering with executive functioning processes.

Purpose of the Present Study: Investigating EL Learning and the Generation Effect in Children

Theories and hypotheses explaining the effectiveness of EL learning have examined the possible contributions of explicit and implicit memory abilities in patients with dementia, the role of working memory and resistance to interference when errors are made during learning and the influence of generation on the effectiveness of EL learning. Given the developmental variability in the different abilities implicated in the effectiveness of EL learning and the generation effect in children, the first goal of this study was to investigate the effectiveness of EL versus EF learning under both self-generation and experimenter provided conditions across three age groups (ages 8 to 10 years, 11 to 13 years, and 14 to 16 years). Based on the developmental literature, and hypotheses explaining the effectiveness of EL learning, the first hypothesis was that children would recall more information under the EL than EF learning condition and that the advantage for EL learning would be greater for younger children. As younger children’s resistance to interference and working memory ability are still developing, they would be expected to have more difficulty inhibiting irrelevant responses (i.e., errors during learning) than older children who would have a better developed ability to resist interference.

The second goal of this study was to examine the degree to which the generation of items based on semantic definitions improves the benefit of EL learning and whether this benefit is related to age. It was predicted that semantic generation of targets during errorless encoding would improve recall and that this advantage would be greater for older than for younger children, due to more developed semantic networks that would facilitate the encoding and retrieval of the information.

The third goal of this study was to explore the relationship between children's ability to inhibit irrelevant responses and their performance in the EF learning conditions. It was predicted that children with a greater ability to inhibit irrelevant responses would recall more information under the EF learning conditions than children with a lower ability to inhibit irrelevant responses. According to developmental studies of executive functions, the benefit of EL learning would be most significant from ages 7 to 13, with little benefit after this age.

The final goal of the study was to examine the relationship between verbal and category fluency and performance under the self-generation conditions. It was predicted that children with greater fluency, would recall more information in the Self-Generation conditions than children with weaker fluency.

Method

Participants

The study sample consisted of 60 children, ages 8 to 16. The sample size was determined using a power analysis with a small to medium effect size (.2 to .5) and an alpha level of .05. The children were divided into three age groups: Group 1 consisted of children ages 8 to 10 (12 females, 8 males, M_{age} = 8.65 years, SD = 0.88); Group 2 consisted of children ages 11 to 13 (12 females, 8 males, M_{age} = 11.95 years, SD = 0.83) and Group 3 consisted of children ages 14 to 16 (11 females, 9 males, M_{age} =14.90 years, SD = 0.85). English was the primary language for all participants. Exclusion criteria included (a) identification for special education services, (b) a known disorder associated with cognitive or memory deficits (e.g., learning disability, epilepsy, ADHD) and (c) a history of head injury. Participants were recruited through advertisements in newspapers and public libraries, as well as through York University's Psychology Department Listserv. Children received a $10 movie pass as a token of appreciation for their participation.

Materials

Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). The WASI is a short and reliable measure of intelligence, yielding the three traditional Verbal, Performance, and Full Scale IQ scores. The four subtests tap various facets of intelligence, such as verbal knowledge, visual information processing, spatial and nonverbal reasoning, and crystallized and fluid intelligence. This test was used to ensure that participants' IQ scores were within the broad normal range and that there were no significant differences in IQ between the groups.

The reliability coefficients for the children's sample range from .86 to .93 for Vocabulary, from .81 to .91 for Similarities, from .84 to .93 for Block Design and from .86 to .96 for Matrix reasoning. For the children's sample, the average reliability coefficients of the WASI subtests range from .87 to .92. The reliability coefficients for the IQ scales range from .92 to .95 for both the VIQ, PIQ, and from .95 to .97 for the Full Scale IQ.

All of the WASI subtests used for the current study have been shown to correlate with the corresponding subtests on the Wechsler Intelligence Scale for Children (WISC), which is a more comprehensive test of intellectual functioning. The correlation coefficient is .72 for Vocabulary, .69 for Similarities, and .74 for Block Design. The coefficient for Verbal IQ (VIQ) is .82, and for Performance IQ (PIQ) is .76, suggesting that the subtests and IQ scales of the WASI measure constructs similar to those measured by the WISC.

Delis Kaplan Executive Function System (D-KEFS) Verbal Fluency and Color-Word Interference Test (Delis, Kaplan, & Kramer, 2001). The Verbal Fluency Tests of the D-KEFS assess letter and category fluency in the oral format and are sensitive to frontal involvement in general, and left frontal involvement in particular, and are composed of three conditions: (a) Letter Fluency, which requires the examinee to say words that begin with a specified letter as quickly as possible in three trials of 60 seconds each; (b) Category Fluency, which requires the examinee to say words that belong to a designated semantic category as quickly as possible in three trials of 60 seconds each; (c) Category Switching, which is a means of evaluating the examinee's ability to alternate between saying words from different semantic categories as quickly as possible for 60 seconds.

The Color-Word Interference Test is a measure of both inhibition and cognitive flexibility. This test consists of two baseline conditions (basic naming of color patches and basic reading of words that denote colors in black ink). The third condition is the interference condition, during which the examinee must inhibit reading the words denoting colors in order to name the dissonant ink colors in which those words are printed (e.g., the word *red* printed in blue ink must be read as *blue*). The fourth condition requires the examinee to switch back and forth between naming the dissonant ink colors and reading the conflicting words and is a measure of both inhibition and cognitive flexibility.

Split-half reliability estimates are good for Color-Word (.62 to .86) and Verbal Fluency - Letter Fluency Condition (.68 to .90). Studies have shown the D-KEFS to be sensitive to executive function deficits in a wide variety of clinical groups (Delis et al., 2004).

Experimental Measures. The materials for the EL and EF learning conditions comprised 120 words of four to seven letters in length. Sixty of the words were target words, and 60 were used as substitutes. All the target words were concrete nouns. No two target words began with the same two-letter stem. Target words had at least four possible stem completions for the appropriate word length. The age of acquisition for the words did not exceed 5 years of age. For each of the target words, a semantically rich description was created for use in the self-generated EL condition (see Appendix C for word lists and their descriptions). Pilot testing for the semantic descriptions was conducted on 10 children of various ages to ensure that the semantic information was sufficient to yield an error-free identification of the word. Each target word had a “substitute” word with the same two-letter stem. These words were used in the EF learning condition if participants correctly guessed the target word on the first attempt. If participants correctly guessed the target word on the first attempt, they were told they were incorrect, and the substitute word became the target word. The 60 words were assigned to one of five lists. The lists of 12 target words were equivalent in terms of average word frequency, age at acquisition, and word length.

Procedure

Participants were tested over two sessions on the same day, with a 10-min break in between. The first session comprised the neuropsychological measures, and the second session comprised the EL and EF learning conditions. In the EL and EF learning conditions, the word stem for every word (i.e., the first two letters of the word to remembered) was presented to the participant on a card (e.g., Wa_____). In the baseline learning condition, participants were presented with a word stem and were immediately informed by the experimenter of the to-be–remembered word and were shown a card with the complete word. Participants were then required to write down the target word. In the EL- experimenter provided (EL-EP) learning condition, participants were presented with a word stem and were immediately informed by the experimenter of the to-be–remembered word, shown a card with the complete word and given the definition of that word (e.g., I’m thinking of a word that begins with WA____and that word is WATCH and it is something you wear on your wrist to tell you the time). Participants were then required to write down the target word.

In the EL-subject-generated (EL-SG) condition, the word stem was presented along with a definition of the target word (e.g., I'm thinking of a word that begins with CA and it is a sweet baked food made of flour, eggs, sugar and flavouring and you eat it at birthday parties). Participants were encouraged to say the target word only if they were sure of the correct response. If uncertain, additional clues were provided to support the participant in generating the correct word. When the participant generated the correct word, they were shown the word on a card and asked to write it down. In the EF-experimenter provided (EF-EP) condition, participants were provided with the word stem and provided with three possible nouns, each printed on a card that could complete the stem, two of which were the incorrect words and the last of which was the target word. Then, the experimenter informed the participant of the correct word and the participant was given the definition (e.g., I'm thinking of a word that begins with RA and it's not RAIN and it's not RADIO, it's RABBIT, a furry animal that hops and has long ears and a short tail). In the EF-subject generated (EF-SG) condition, participants were given the word stem (e.g., I'm thinking of a word that begins with TH. Can you guess what it is?) and were told that they had a maximum of two guesses to identify the correct target. Participants were told the correct word if they did not guess correctly after two guesses. If participants provided the correct response on their first guess, they were told that they were incorrect, and the target word was replaced by a corresponding substitute word. This ensured that at least one error was made for each stimulus item. The participant was then shown the correct word and instructed to write down the target word.

Following the presentation of each list, participants were asked to count backwards from 50. After every learning condition, a free recall test required participants to write down as many words as they could remember from the list in any order. Following the free recall test, a cued recall test was given during which participants were provided with the first two letters of each word to be remembered and asked to write it down if they recalled it. The cards used for the cued recall test were presented in random order.

Results

All analyses were completed using SPSS Version 22. An alpha level of .05 was used. The Bonferroni criterion for significance was used for all post hoc pairwise comparisons.

Intellectual and Neuropsychological Measures

Table 1 displays the means and standard deviations for IQ for each age group. A one-way Analysis of Variance (ANOVA) revealed no significant differences between the participants' Verbal IQ, $F(2) = .89$, $p = .42$, ηp2 = .03 or Performance IQ, $F(2) = .24$, $p = .79$, ηp2 = .01 across the three age groups, and all groups performed within the normal range. Mean performance on the D-KEFS measures is displayed in Table 2 as a function of group. Standard scores on the D-KEFS measures were compared across the three age groups. Significant group differences were found on the following measures: Category Switching Correct, $F(2) = 4.44$, $p < .05$, ηp2 = .14, Inhibition, $F(2) = 7.41$, $p < .01$, ηp2 = .21 and Inhibition/Switching Errors, $F(2) = 3.50$, $p < .05$, ηp2 = .11. Post hoc analyses revealed better performance in Group 1 (ages 8 to 10) compared to Group 3 (ages 14-16), on Category Switching Correct. Group 1 also outperformed Groups 2 (ages 11-13) and 3 on Inhibition. Finally, Group 1 performed better than Group 2 on Inhibition/Switching errors. Despite these few statistical differences, all performance was in the normal range on all measures for each group.

Table 1.

IQ Across the Age Groups

	Group		
	1	2	3
	M (SD)	M (SD)	M (SD)
Age	8.6 (0.9)	12.0 (0.8)	14.9 (0.8)
Verbal IQ	112.6 (14.4)	112.2 (15.7)	107.0 (14.0)
Performance IQ	109.9 (15.0)	108.9 (14.1)	107.0 (11.4)

Table 2.

Standard Score (SS) Means and Standard Deviations for D-KEFS Measures by Group[1]

	Group			
	1 (n = 20)	2 (n = 20)	3 (n = 20)	*P*
Letter Fluency	10.95 (2.68)	10.85 (3.79)	9.75 (3.23)	Ns
Category Fluency	11.30 (2.60)	11.75 (3.42)	9.50 (3.19)	Ns
CategorySwitching Correct	12.05 (2.60)*	11.35 (3.42)	9.45 (2.44)*	< .05
CategorySwitching Accuracy	11.30 (2.54)	11.90 (3.19)	9.95 (2.37)	Ns
Inhibition	13.35 (2.30)**	11.40 (2.28)	10.45 (2.68)**	< .01
Inhibition/Switching	11.90 (2.90)	11.20 (1.88)	10.55 (2.56)	Ns
Inhibition Errors	10.90 (1.77)	9.75 (2.90)	9.90 (2.42)	Ns
Inhibition/Switching Errors	11.65 (3.41)*	9.65 (1.79)*	10.85 (1.60)	< .05

*Significant at the .05 level
**Significant at the .01 level

Order and List Analyses

Although the 5-word lists presented in the five learning conditions were counterbalanced for the order presented and the learning conditions (EL-EP, EL-SG, EF-EP, EF-SG and Baseline) to which the lists were assigned, a 5 (Order) X 5 (List) X 3 (Age Group) ANOVA was conducted

[1] Age-based standard scores were used to allow for differentiation between below average, average and above average performance on the D-KEFS measures.

to determine if there were any order or list effects across the groups for either free or cued recall, which might require statistical correction. Age group did not interact with either order or list for free or cued recall. Therefore, these two variables were not included in the subsequent analyses.

A mixed-model ANOVA was used with Learning condition (EL, EF), and Generation (SG, EP) as the within- subjects factor and Age Group (1, 2, 3) as the between-subjects factor. The dependent variable was the number of words correctly recalled in the free recall and Cued Recall conditions.

Hypothesis 1: Older children will display greater memory recall overall than younger children.

As expected, for free recall, there was a significant main effect of age, $F(2) = 35.05$, $p < .001$, $\eta p2 = .4$. Follow-up pairwise comparisons revealed that Group 3 (ages 14-16) performed significantly better than Group 2 (ages 11-13) which performed significantly better than Group 1 (ages 8-10). Group 3 recalled about 1.2 (+/- .5) more words than Group 2 and about 2.7 (+/-.5) more words than Group 1. Group 2 recalled about 1.6 (+/- .5) more words than Group 1.

Similarly, a significant age effect was found for Cued Recall, $F(2) = 29.72$, $p < .001$. Follow-up pairwise comparisons revealed significant differences between Groups 1 (ages 8-10) and 2 (ages 11-13), and Groups 1 (ages 8-10) and 3 (ages 14-16), with Group 1 recalling fewer words than both Groups 2 and 3. Group 2 recalled about 2.2 more words than Group 1 and Group 3 recalled about 2.5 more words than Group 1. There was no significant difference between Groups 2 and 3 on Cued Recall.

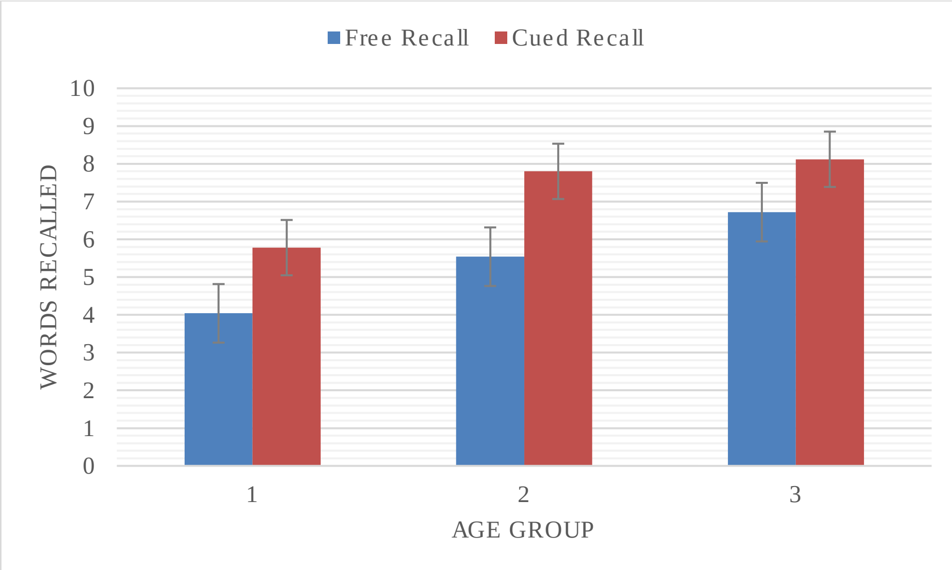

Figure 2. Free and Cued Recall Performance by Age Group

Hypotheses 2 and 3: Children will recall more words under the EL learning condition than under the EF learning condition, and this benefit will be greater for younger than older children. Children will recall more words when generating their own responses under the EL condition than when provided with the words and this benefit will be greater for older than for younger children.

For free recall, there were no significant main effects of EL versus EF learning, $F(1, 230) = 1.56$, $p = .22$, or SG-EP , $F(1, 230) = 2.28$, $p = .14$, manipulations. Contrary to predictions, there were no interactions between EL/EF conditions and age, $F(2, 230) =.24$, $p = .79$, or the EP/SG conditions and age, $F(2, 230) = 1.18$, $p = .31$, for free recall.

For cued recall, there was a significant main effect of the EL (M=7.83 +/- .2 words) versus EF (M =6.63 +/- .2 words) learning manipulation, $F(1, 229) = 16.76$, $p < .001$, but no significant effect of the SG versus EP manipulation, $F(1, 229) = 3.52$, $p = .10$. Contrary to predictions, there were no interactions between EL/EF conditions and age, $F(2, 229) = .01$, $p = .99$), or the EP/SG conditions and age, $F(2, 229) = 2.22$, $p = .11$, for cued recall.

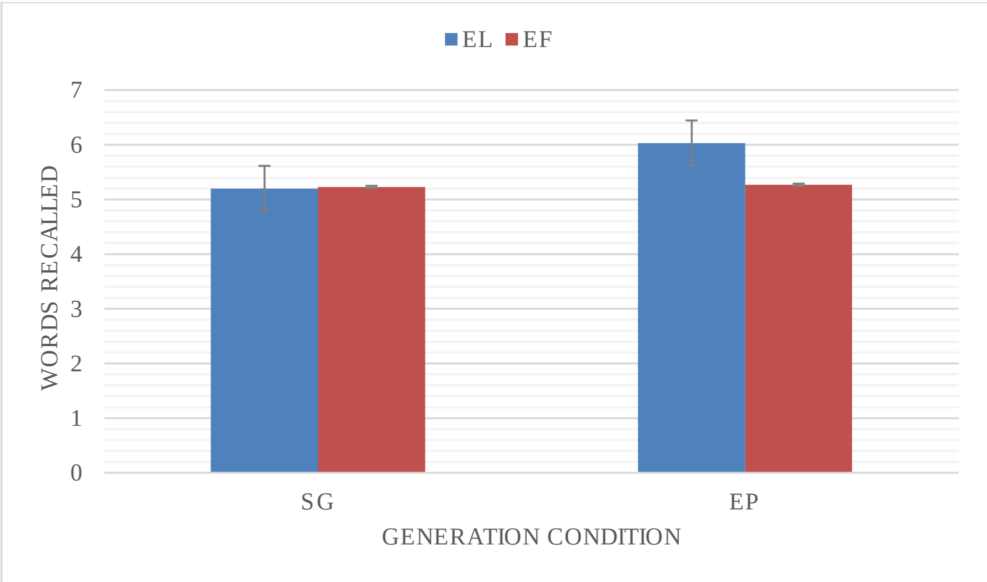

Figure 3. Free Recall for the Errorless/Errorful and Subject-Generated/Experimenter-Provided Conditions

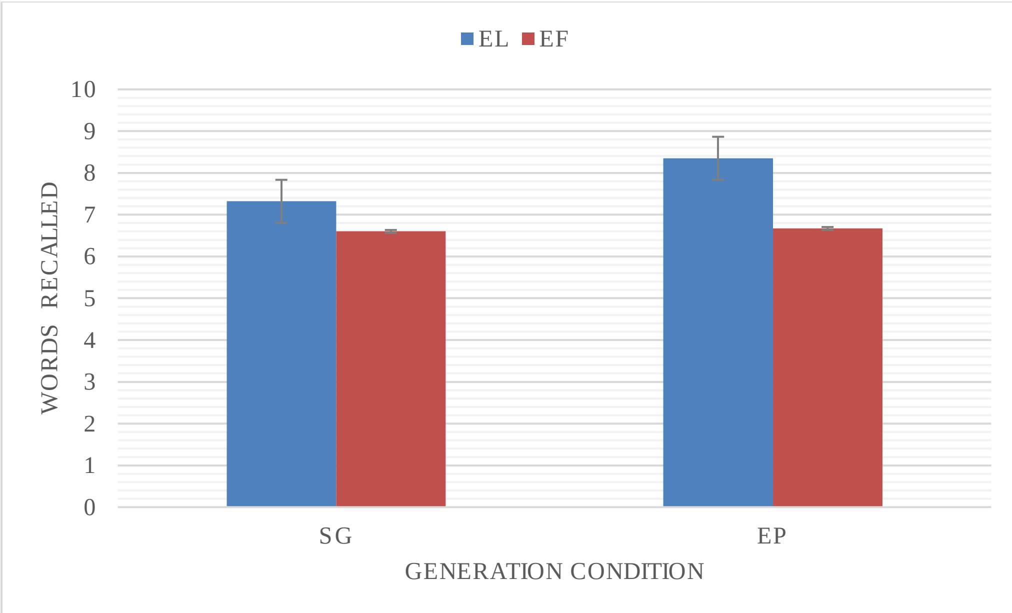

Figure 4. Cued Recall for the Errorless/Errorful and Subject-Generated/Experimenter-Provided Conditions

Comparison of the Five Learning Conditions

Memory for the words under all five learning conditions, including the baseline condition on Free and cued recall was compared using 3 (Age Group) X 5 (Condition) repeated measures ANOVAs. For free recall, no Age Group by Condition interaction was found, $F(8) = 0.71$, $p = .68$, a significant main effect of condition, $F(4) = 2.67$, $p < .05$, ηp2 = .04, was found. Although participants recalled, on average, more words under the EL-EP condition, as compared to the other conditions, follow-up pairwise comparisons did not result in significant differences. Follow-up pairwise comparisons revealed that, overall, children recalled more words under the EL-EP condition than the baseline, $p = .07$, and EL-SG, $p = .08$, condition.

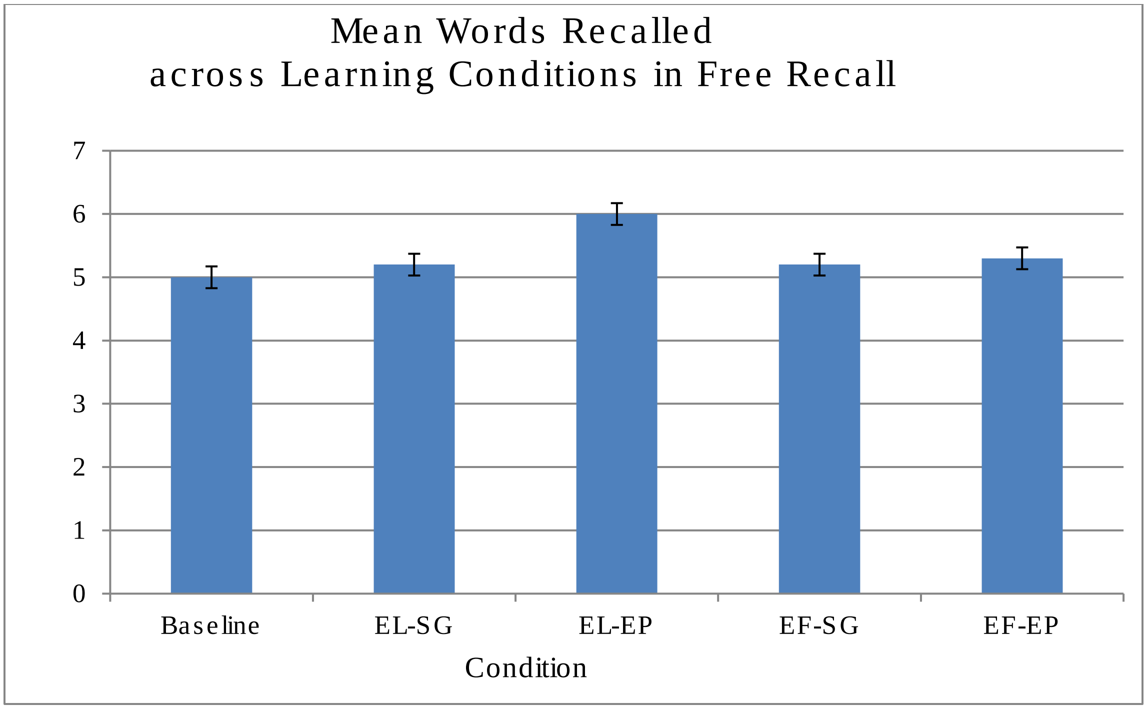

Figure 5. Free Recall Across Learning Conditions

EL-SG = Errorless-Subject Generated
EL-EP = Errorless-Experimenter Provided
EF-SG = Errorful-Subject Generated
EF-EP = Errorful-Experimenter Provided

Similarly, for cued recall, there was no Age Group by Condition interaction, $F(8) = 1.69$, $p = .10$. However, there was a significant main effect of condition, $F(4) = 7.72$, $p < .001$, ηp2 = .12. Follow-up pairwise comparisons revealed significant differences between the EL-EP and EF-SG conditions, as well as between the EL-EP and EF-EP conditions with better performance under the EL-EP condition (M = 8.4 +/-.3), as compared to both the EF-SG (M = 6.6 +/-.3) condition and the EF-EP (M = 6.7 +/- .3) condition.

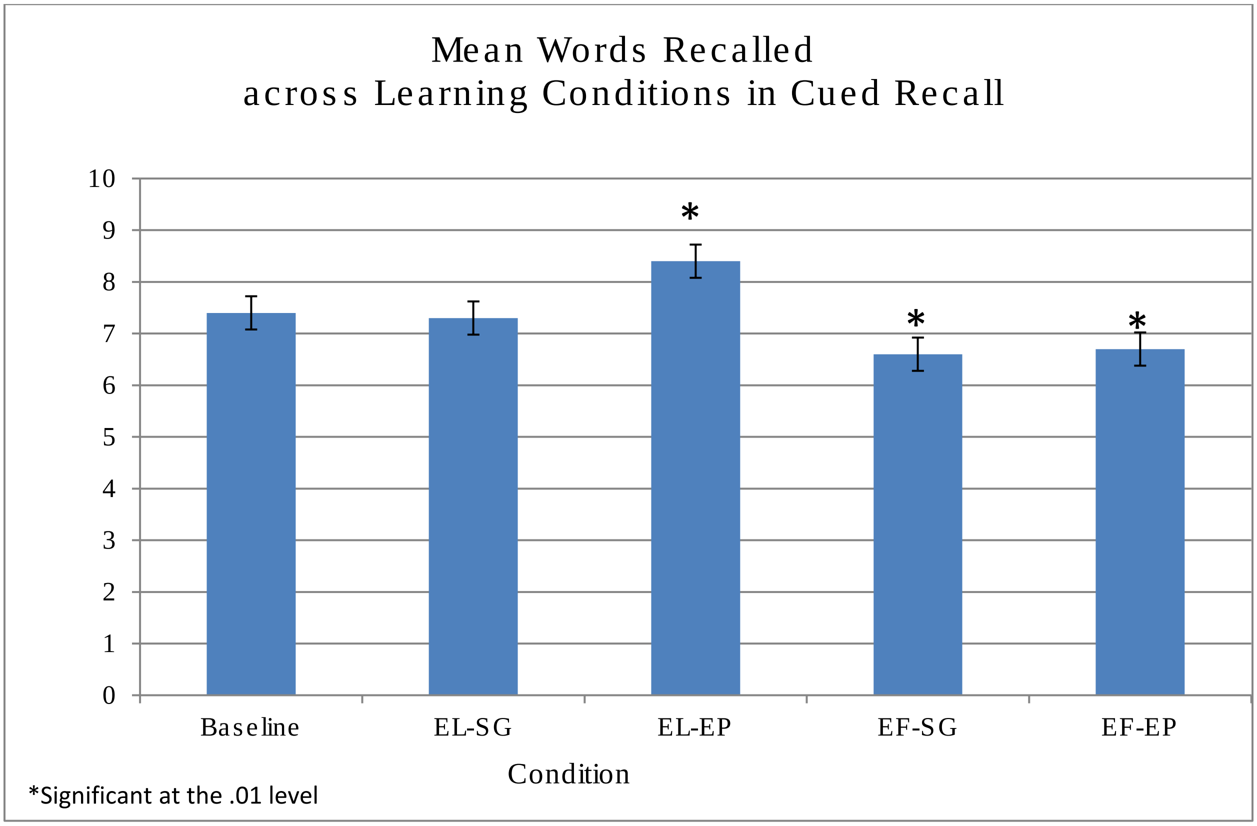

Figure 6. Cued Recall Across the Learning Conditions

EL-SG = Errorless-Subject Generated
EL-EP = Errorless-Experimenter Provided
EF-SG = Errorful-Subject Generated
EF-EP = Errorful-Experimenter Provided

Hypothesis 4: Children with a greater ability to inhibit irrelevant responses would recall more information under the EF learning conditions than children with a lower ability to inhibit irrelevant responses.

Given the prediction that performance under the EF conditions would be related to the participants' ability to inhibit irrelevant responses, Pearson correlations were used to determine the relationship between performance under the EF conditions (EF-SG free and cued recall and EF-EP free and cued recall) and the Inhibition measures on the D-KEFS (Inhibition, Inhibition/Switching, Inhibition Errors and Inhibition/Switching Errors) for the overall sample. There were no significant correlations between these variables in the overall sample. To further investigate whether this relationship may be related to age, Pearson correlations were determined for the above variables for each age group separately. For Group 1 (ages 8-10), no significant correlations were found between the inhibition measures and the EF learning conditions. For Group 2 (ages 11-13), significant correlations were found between EF-EP free recall and Inhibition/Switching, between EF-EP cued recall and Inhibition/Switching, and EF-EP cued recall and Inhibition Errors. For Group 3 (ages 14-16), significant correlations were found between EF-SG free recall and Inhibition, and EF-SG cued recall and Inhibition.

Table 3.

Correlations Between EF Learning Conditions and D-KEFS Inhibition Measures by Age Group

	Inhibit	Inhibit/Switch	Inhibit Errors	Inhibit/Switch Errors
Age Group 1				
Free Recall				
EF-SG	.02	.18	.22	.16
EF-EP	-.01	.39	.16	.17
Cued Recall				
EF-SG	.27	.14	.31	-.05
EF-EP	.02	.40	.19	.15
Age Group 2				
Free Recall				
EF-SG	.09	.22	.23	-.13
EF-EP	.29	.55*	.42	-.03
Cued Recall				
EF-SG	-.08	-.06	.10	-.38
EF-EP	.37	**.48***	**.60****	.025
Age Group 3				
Free Recall				
EF-SG	**.60****	.42	.36	.20
EF-EP	.12	-.39	.05	.16
Cued Recall				
EF-SG	**.66****	.38	.24	.29
EF-EP	.15	-.10	.16	.28

*p<.05
**p<.01

Hypotheses 5: Children with greater verbal fluency, would recall more information in the Self-Generation conditions than children with weaker fluency.

To test the hypothesis that more elaborate semantic knowledge and executive functions (i.e., Verbal Fluency and Inhibition) and therefore the degree of accessibility to verbal and semantic information may facilitate memory performance under self-generation conditions, Pearson correlations were determined between the self-generation conditions and standard scores on the Verbal/Letter Fluency and Category Fluency measures. There were no significant correlations between the fluency measures and performance in the self-generation conditions. To determine whether correlations are related to age, correlations between the executive functioning measures were determined for each age group separately. A significant positive correlation was found between learning in the EF-SG condition and Category Fluency in Group 3 (ages 14-16).

Table 4.

Correlations Between SG Learning Conditions and D-KEFS Fluency Measures by Age Group

	Letter Fluency	Category Fluency
Age Group 1		
Free Recall		
EL-SG	.31	.32
EF-SG	-.17	.05
Cued Recall		
EL-SG	.26	.20
EF-SG	.12	-.28
Age Group 2		
Free Recall		
EL-SG	.39	.11
EF-SG	.15	.13
Cued Recall		
EL-SG	.18	.16
EF-SG	.01	.13
Age Group 3		
Free Recall		
EL-SG	.10	.31
EF-SG	.31	**.51***
Cued Recall		
EL-SG	.44	.13
EF-SG	.28	.24

*p<.05

Discussion

This study investigated the effectiveness of Errorless (EL) versus Errorful (EF) learning in typically developing children ages 8 to 16, under both self-generation (SG) and experimenter-provided (EP) conditions. The developmental literature on memory suggests that a number of changes in cognitive development would contribute to the effectiveness of EL learning with and without self-generation at different ages. Based on developmental theories and studies of memory in children (e.g., Fischer, 1980; Pascual-Leone, 2011; Schneider, 2015), children's resistance to interference and working memory abilities improve with age. Therefore, we expected that younger children would be more likely to have difficulty inhibiting irrelevant responses than older children and would show better learning under the EL relative to the EF learning conditions. Children with a greater ability to inhibit irrelevant responses should recall more information under the EF learning conditions than children with a lower ability to inhibit irrelevant responses. According to developmental studies of executive functions (e.g., Brocki & Bohlin, 2004), the benefit of EL learning would be most significant from ages 7 to 13, with little benefit after this age. Further, memory studies suggest that older children's increase in semantic knowledge can facilitate recall (e.g., Ghatala, 1994), which would suggest that older children would show better recall under conditions that require the semantic generation of words as compared to conditions during which the words are provided.

Age Differences in EL and EF Learning

As predicted, children recalled significantly more words (an average of 1.2 more words) under the EL learning conditions than under the EF learning conditions. However, this advantage of EL learning was found for only cued but not for free recall. Contrary to expectations, this advantage was not related to age. The better word recall in the EL learning conditions found with this sample of typically developing children is consistent with previous studies examining EL learning in children with brain injuries. Haslam et al. (2012) found that EL learning was more beneficial than EF learning in children with Acquired Brain Injury, ages 11 to 16. However, they did not find a significant advantage of EL learning with their control group, which they attributed to a ceiling effect in that group. The current study used a longer list and participants were presented with the list once, which may have led to the task being more challenging and therefore showing the benefit of EL learning.

Contrary to expectations, there was no interaction between memory performance in the EL learning conditions and age. It was hypothesized that younger children would show a greater benefit from EL learning than older children. Given that the younger group performed better relative their same-aged peers on the D-KEFS inhibition measure, it is possible that they were better able to resist interference during the EF learning conditions than what would be typical of younger children.

The fact that EL learning showed a significant advantage during cued recall (i.e., being provided with the first two letters of each word learned) but not free recall may stem from the nature of the encoding processes. As cued recall may have relied more on perceptual processes, the nature of the presentation during encoding in this study may have facilitated children's ability to retrieve the information during cued recall. Children were given the same two-letter stem during encoding and cued recall, which may have increased the compatibility between the processes used at encoding and retrieval. This is consistent with the transfer appropriate processing theory, which states that when the processes used at encoding and recall are similar; the recall of information would require fewer processing resources (e.g., attention, retrieval efforts), whereas if they were incompatible, greater resources would be needed (DeWinstanley et al., 1996).

Baddeley and Wilson (1994) carried out the earliest comparisons of EL and EF learning in adults and found that whereas neurologically intact groups showed equivalent performance for the two methods, individuals with amnesia showed uniformly better performance on same-session stem completion tests after EL learning. The EL advantage was attributed to the relatively intact implicit memory and dysfunctional explicit memory systems in amnesia. Evans et al. (2000) also suggested that the superiority of EL over EF learning may be linked to how memory is probed at final test, with EL learning more likely to show an advantage on tests that can be completed by primed representations rather than requiring explicit recall. Therefore, EL methods might not be the preferred approach when explicit recall of learned information is required and the individual lacks that ability. Thus, the EL learning advantage in cued recall may be attributed to children's stronger implicit/nondeclarative memory than explicit /declarative memory, as the latter requires the use of more active retrieval strategies that are still developing in children. Cued recall requires fewer strategies for retrieval (e.g., organizational and mnemonic strategies) than does free recall. Many of the older children in this study were in fact observed to use active strategies during encoding that would have facilitated their recall of the lists. This is reflected in the main effect of age on memory performance in this sample. The superior performance under EL-EP condition as compared to the EF conditions in cued recall may reflect the increased use of strategies, such as rehearsal as well as the reduction of interference.

EL Learning and Self-Generation

In contrast to the adult literature in which there is an advantage with EL learning and self-generation (Lubinksy et al.; Tailby & Haslam, 2003), the current study failed to a find a benefit of self-generation for typically developing children. This lack of a self-generation effect in children is consistent with Haslam et al.'s (2012) study that also found no effect of adding self-generation to the EL learning condition in both controls and children with acquired brain injury. However, Haslam et al. (2012) did find a numerical advantage of self-generation in their study and attributed the lack of significant results to a possible lack of statistical power. However, as the generation conditions were not identical across studies, it is possible that the degree of time and effort required for self-generation may have contributed to its effectiveness. For instance, in the current study as well as in the Haslam et al. (2012) study, children were provided with a descriptive definition to ensure that no errors were made. Other studies (e.g., Lubinksy et al., 2009) utilized procedures in the self-generation condition that may have required more time and effort. For example, in Lubinsky et al.'s study, semantic cues were progressively provided. It has been suggested that the harder the test and the greater effort required during encoding, the greater the benefit to subsequent memory. For example, Fielder et al. (1992) explained the generation effect as a result of greater mobilization of processing resources. A number of studies supported the relationship between the difficulty of the generation task and the extent of the generation effect, which was attributed to the amount of cognitive effort used when generating the target word (Gardiner, Smith, Richardson, Burrows & Williams, 1985; Slamecka & Fevreiski, 1983; Taconnat & Isingrini, 1996).

Tasks used in other studies of EL learning (e.g., Lubinksy et al., 2009) may have allowed for more associative learning and retrieval, which could provide for more consistency between the encoding and retrieval conditions. The benefit of the EL learning condition on cued recall and not free recall is consistent with transfer-appropriate processing theory, which suggests that memory performance is not only determined by level of processing, during which associating meaning with information increases memory performance, but also by the similarity between encoding and retrieval conditions. In addition to the proposed possibility that the current study used a more passive approach to tap into children's semantic knowledge, which could have reduced the level at which information was processed at study, children may have relied more on the perceptual features at study as they were presented with the words. It would be beneficial to further investigate the conditions under which self-generation in children aids memory retrieval. It is possible that with more active associative generation, the hypothesized effect of greater development of semantic networks would lead to older children benefitting more than younger children from word generation. Tasks involving more associative learning may be more effective in facilitating retrieval due to increased number of item-specific activated semantic characteristics, as would be predicted by the semantic hypothesis of the generation effect.

Comparison of the Learning Conditions

Comparisons of the five learning conditions revealed that children showed better free recall performance under the EL-EP condition than the baseline and EL-SG conditions. It may have been that the provision of the word definition in the EL-EP condition, which was absent in the baseline condition, allowed for deeper processing of the words. Although the EL-SG condition minimized errors and, in most cases, errors were not made (6 errors across all 60 participants), there were occasions when participants took additional time to find the words or expressed that they guessed the word 'in their head' prior to the provision of the definition that would allow for a correct identification of the word. Therefore, the EL-SG condition may have been more ‘Errorful’ than intended, or the processing resources involved in finding the words may have interfered with the use of other strategies. However, the small number of errors did not allow for such statistical comparisons in the current study.

The advantage of the EL-EP condition in free recall may have been due to an increased use of strategies that facilitated retrieval of the words. It may be that in the EL-SG condition, the focus and effort placed on generating the word to be recalled took resources away from utilizing other metacognitive and mnemonic strategies for memory retrieval. McCurdy, Ryan and Leshikar (2017) suggested that generation effects may be larger when participants are free to generate materials and that the level of the generation constraint can influence the mnemonic benefit of this effect.

Future studies would need to address the influence of conditions at encoding and retrieval, and whether the generation effect in children varies depending on encoding and retrieval conditions. For example, a recent study (Cyr & Anderson, 2015) found that younger and older adults do not learn differently from errors, but that trial-and-error learning led to better memory relative to EL learning if the cue, error and target were related conceptually. This was based on the idea that studies that find a benefit of errors examine conceptual learning (i.e., providing a category as the cue) among younger adults and those that find errors to be detrimental to learning examine non-conceptual learning (i.e., utilizing lexical conditions, by providing a word stem as the cue) among older adults and individuals with memory impairments (Cyr & Anderson, 2015).

Executive Function Measures

The argument that the self-generation condition may not have tapped the degree of accessibility or development of semantic knowledge is supported by the general lack of significant correlations between the SG conditions and the verbal and category fluency measures. It was hypothesized that children with more elaborative semantic networks would benefit more from the SG condition. Again, it may have been that the self-generation condition did not tap into the participants' semantic knowledge in the way that semantic associative learning did, and therefore did not allow for the depth of processing that was implicated in previous studies (Lubinsky et al, 2009; Schneider, 2015). As mentioned previously, it is also possible that the retrieval conditions did not allow for access to semantic information, as the retrieval cues were perceptually based and no semantic cues were provided at retrieval. However, the significant correlation between Category Fluency and the EF-SG condition suggests that within the oldest group, children with better category fluency may also utilize more active associative strategies to facilitate their recall. It is possible that older children relied more on their semantic/conceptual knowledge in learning new words, which may have led to its having more of an impact on their learning than younger children, who would have relied less on this ability.

Consistent with expectations, some measures of interference were related to performance in the EF conditions. Although interference was unrelated to performance in the EF learning conditions in the overall sample, it was related to EF learning in the two older age groups. Specifically, performance on the Inhibition/switching task was related to both EF-EP free and cued recall among children ages 11-13. For children ages 14-16, performance on the inhibition task was related to both EF-SG free and cued recall.

The failure to find an overall relationship between the executive functioning measures and performance in the EF learning conditions may be due to executive functions being in the average or above average range in this sample. It may be that in children with impaired executive functioning (e.g., children with ADHD and brain injury), the impact of making errors would be more detrimental to learning. The correlations found in the older groups may also be a reflection of other metacognitive or executive functioning abilities that may have predicted performance under more demanding learning conditions and which may themselves correlate with the inhibition measure (the Stroop task). For example, Brocki et al. (2004) found that a Stroop-like task, which was presumably assessing the ability to inhibit prepotent responses, did not converge with other inhibitory measures but loaded on a working memory/fluency factor. The Stroop task requires that a response not only be withheld but that the participant also shifts to a new response; this requires strong working memory and mental flexibility. Therefore, the lack of relationship between the executive functioning measures and memory performance in the youngest group may reflect the idea that most children in this age range did not utilize the metacognitive processes required to improve performance on memory measures, and that may relate to the inhibition measures. As children get older, their executive functioning and metacognitive processes may become better predictors of performance on memory measures, especially as demands increase (Schneider, 2015).

The relationship between cognitive skills known to be important for memory performance and EF learning may be more pronounced with the learning of novel information or with more demanding tasks that put more of a load on executive functioning. For example, Warmington et al. (2014) found that individual differences in processing speed and vocabulary were associated with the learning of new words using EF but not EL learning, and that EL learning was independent of the cognitive skills known to be important in explicit memory, including processing speed, vocabulary, and working memory.

Limitations and Future Directions

A few limitations of the current study have been noted. Although every effort was made to ensure that the lists were equal in terms of average word frequency, age at acquisition, and word length, some lists allowed for more associative learning as they contained words from more similar categories. Further, the word lists used consisted of basic information (i.e., simple concrete words) and therefore, the results cannot be generalized to the learning of higher order, abstract, or unfamiliar material. Another limitation of the current study, which may also be a limitation in previous studies, is that the conditions cannot be classified as purely EL or EF. Some children reported that they were 'guessing in their heads' the words during the EL conditions so one cannot be certain that EL tasks were truly without error. Also, given that sometimes children needed to be given alternate words if they guessed correctly the first time in the EF-SG condition, lists were not always identical. Although counterbalancing the lists addressed this limitation to some degree, it is not certain that any differences in the lists did not impact performance.

Finally, there were differences in the neuropsychological profiles of the children across the three age groups, with the youngest children showing stronger performance relative to their age group on measures of executive functioning. This may have masked any age differences in EF learning related to Executive Functioning ability, as the youngest group's performance on these measures may have been more comparable to the older groups. As participants volunteered for the study, it is possible that younger children with stronger executive functioning chose to participate, leading to a selection bias.

Future studies can further investigate the aspects of executive functions that predict whether making errors would be detrimental to learning. Given that working memory has been strongly implicated in the ability to resist interference, further investigations can examine its relationship with making errors during learning and children's ability to recall information. Future studies can also investigate the differences in EL and EF learning under different encoding and retrieval learning conditions during repeated learning sessions and their effect on long-term recall of information.

Future studies can also utilize computerized presentation of stimuli that can allow for a measure of response time and learning efficiency that would be more difficult to measure with paper and pencil administration. Computerized administered can also better control for presentation time and pacing of the learning trials.

Clinical and Educational Implications

This study found that EL learning was more beneficial than EF learning for cued recall and that inhibition was related to memory performance in EF conditions for older children. Although there was a small benefit of EL learning in typically developing children, questions remain about the most effective ways to teach children with executive functioning and working memory weaknesses. Many studies have reported that making errors when learning has no detrimental effect on learning as long as feedback is provided. However, if children receive feedback but have difficulty with executive functioning (i.e., shifting, flexibility, working memory, inhibition), an EL approach may be more beneficial. For example, children with pervasive developmental disorders (PDD) have significant difficulty with a number of executive functions, including shifting and flexibility, and often show rigid patterns of responses and a rigid adherence to rules. Therefore, if errors become a part of what is learned in a novel task, the child may persist with a pattern of responses that produces more errors (Mueller, Palkovic, & Maynard, 2007). One commonly used procedure for teaching children with PDD is stimulus fading, which is an error-reducing technique. For example, with this technique, if teaching a child to discriminate between a pen and a pencil, the pen may be presented in a larger size and the pencil would be presented in a smaller size, the pencil would then be enlarged gradually until to the two pictures are the same size and the child would be required to respond only to the pen.

Further research on the advantage of EL learning in children with significant executive functioning difficulties would shed some light on when EL learning would be most beneficial and when EF learning accompanied by feedback would benefit children's learning because of the increased effort it entails. Given the findings from this study suggesting a relationship between executive functioning measures and the ability to learn under EF conditions, as well as previous research suggesting that other abilities (i.e., processing speed and vocabulary) contribute to learning under EF conditions, it may be difficult to make specific conclusions about the effectiveness of EL and EF learning in children without an understanding of their cognitive profile. More research is needed to investigate the variables that can consistently predict the effectiveness of such learning techniques.

Conclusions

This study provides further support for the effectiveness of EL learning on cued recall in a pediatric sample of typically developing children and sheds some light on some of the factors that can influence its effectiveness. The results suggest that the match between encoding and retrieval conditions may an important factor during learning and may have implications for teaching children and in supporting them in retrieving information. The findings also emphasize the importance of recognizing individual differences in children's learning profiles when evaluating the effectiveness of a specific learning approach. Although knowing children's developmental stage and therefore what cognitive abilities they possess can be informative in providing the appropriate learning approach, individual differences (e.g., in processing speed, executive functions) need to also be considered. The EL learning approach and the use of cued recall may be a promising approach in teaching children who may lack the cognitive skills (e.g., inhibition, processing speed) necessary to facilitate explicit recall and error correction. However, further investigations utilizing a wider range of tasks may shed light on the usefulness of this approach in educational settings.

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Appendix A

RESEARCH INFORMATION FORM

TITLE OF STUDY: Developmental Aspects of Errorless Learning and the Generation Effect.

Investigators

Lila Elkhadem, M.A.	**Ph.D. Candidate, Clinical-Developmental Psychology** **York University**
Mary Desrocher, Ph.D.	**Associate Professor** **Psychology Department, York University**

Purpose of the Research
The purpose of this research is to examine the development of memory in children ages 8 to 16 and how developmental changes in semantic knowledge and executive functioning (e.g., inhibition) can affect children's ability to learn.

Description of the Research
Participants in this study will be children ages 8 to 16. Participation will involve completing an abbreviated measure of intelligence and tasks assessing executive functioning and language fluency (approximately 1 hour). For example, children will be asked to provide meanings of words and to tell the examiner how two words are alike, and complete 'puzzle' tasks involving putting blocks together and completing geometric designs. Children will also be asked to generate words, that begin with a specific letter or that belong to a specific category. In addition, participants will be required to read words, which will be presented in different colors, and to name the colors in which words are printed. In addition, participants will complete 5 memory tasks. On these tasks, children will be given word stems and asked to complete them. Once they are presented with the words, their memory for the words, within 5 different conditions, will be assessed with recall and cued recall tasks. Total time for participation is approximately 2 hours.

Potential Harms, Discomforts, or Inconvenience
The tasks will be administered in a game-like format, and are fun to do. However, some children may feel uncomfortable being tested or may find some tasks difficult. If at any time, your child becomes tired or frustrated, we will stop the testing.

Potential Benefits
You will receive a research report outlining your child's performance on the standardized measures (the abbreviated scale of intelligence, language fluency and executive functioning). You will be contributing to the understanding of factors influencing children's memory development, which has strong implications for how children learn.

Confidentiality

Confidentiality will be respected and no information that discloses the identity of your child will be released or published without consent. We will not publish any information that reveals who you are. If you decide to withdraw from the study, all associated data collected will be immediately destroyed. We will ensure that confidentiality will be provided to the fullest extent possible by law. The principal investigator will use ID numbers on the files to ensure confidentiality. Data will be stored in a locked filing cabinet for the duration of the study, and only individuals directly involved with data collection will have access to the data. Once the study is complete and data is analyzed, the files and protocols containing the data will be shredded and discarded.

Reimbursement

Participants will receive a $10 movie pass as a token of appreciation for participating. Parents will be reimbursed for any parking or travel expenses incurred from participating in the study.

Participation

Participation in research is voluntary. If you choose on behalf of your child to participate in the study, you can withdraw your child from the study at any time, for any reason and you will still receive the promised compensation. Your decision to participate, withdraw from the study or your refusal to answer any particular questions will not impact upon your relationship with York University, the researchers or any other group associated with this research project. If you decide to withdraw from the study, all associated data collected will be immediately destroyed.

This research has been reviewed and approved by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Sr. Manager & Policy Advisor for the Office of Research Ethics, 5th Floor, York Research Tower, York University.

If you require any additional information about this research study, please do not hesitate to contact Lila Elkhadem or Dr. Mary Desrocher.

Sincerely,
Lila Elkhadem

Appendix B

Name of participant: ___________________________________
Date of Birth: (mm/dd/yy) __________________________

Country of birth (if not from Canada): _________________________________

If not from Canada, has your child been in Canada 5 years or more? [ ] yes [ ] no

Most common language spoken in home: [ ] English [ ] Other:_________________

[ ] Combination of English and other language: ____________________

Child History

Has your child, who is participating in this research project, ever had or been diagnosed with the following (if yes, please provide further information):

Attention Deficit/Hyperactivity Disorder	[ ] no	[ ] yes – explain:________________
Anxiety	[ ] no	[ ] yes – explain:________________
Autism Spectrum Disorder	[ ] no	[ ] yes – explain:________________
Depression	[ ] no	[ ] yes – explain:________________
Diabetes	[ ] no	[ ] yes – explain:________________
Epilepsy	[ ] no	[ ] yes – explain:________________
Gifted and Talented	[ ] no	[ ] yes – explain:________________
Head Injury	[ ] no	[ ] yes – explain:________________
Learning Disability	[ ] no	[ ] yes – explain:________________
Other chronic illness	[ ] no	[ ] yes – explain:________________
Other psychiatric illness	[ ] no	[ ] yes – explain:________________

Is Child attending an English speaking school? ________________

Appendix C

Word Lists

List 1	List 2	List 3	List 4	List 5
Balloon	Sandwich	Button	Blanket	Present
Flower	Grapes	Rabbit	Jacket	Diaper
Pencil	Potato	Window	Chair	Garage
Mirror	Bread	Doctor	Alien	Robot
Lemon	Clown	Glove	Apple	Socks
Mouse	Horse	Piano	Fence	Stage
Shoes	Watch	Spoon	Magic	Ticket
Toast	Table	Thumb	Plate	Teeth
Comb	Fork	Lamp	Lion	Frog
Neck	Tree	Park	Head	Swan
Book	Bell	Turtle	Meat	Snow
Drum	Cake	Face	Hair	Bicycle

Appendix C

Word Lists with Alternate Words and Definitions

LIST 1

1) **Balloon –** A bag made of rubber that is filled with air and it comes in many colours and is found at birthday parties.
   Banana - A long curved fruit that has a thick yellow skin.
   Basket

2) **Flower –** Part of a plant that has petals and has a nice smell. You can use them to make bouquets to give to people or for decoration.
   Flag – A piece of cloth in the shape of a rectangle or triangle with colours and designs used as a symbol of a country.
   Flute

3) **Pencil –** A long thin tool used for writing or drawing and can be sharpened and erased.
   Peach – A fruit that has yellow or reddish skin covered with a soft fuzz and is sweet and juicy and has a large pit.
   Pear

4) **Mirror –** A smooth surface that you can see yourself in. It is usually made of glass with a coat of shiny metal on the back.
   Milk – White liquid produced by cows and collected for people to drink.
   Microphone

5) **Lemon –** A small fruit with yellow skin that has sour juice.
   Letter – A written message that you put in an envelope and send or give to someone.
   Lever

6) **Mouse –** A very small animal with gray or brown fur. They have pointed faces, round ears and long tails with no fur. They are known to eat cheese.
   Mother – The female parent.
   Monkey

7) **Shoes –** Something you wear on your feet for protection and is usually made of leather.
   Shirt – A piece of clothing for the top part of the body. It is usually open at the front and has a collar and sleeves.
   Shape

8) **Toast –** Bread that has been sliced and browned in the oven or toaster.
   Tomato – A red fruit with a juicy pulp, which can be eaten raw or cooked and is used to make ketchup.
   Tower

9) **Comb –** Thin piece of plastic or other metal that has teeth along one side – used to smooth and tidy your hair.
Couch – Large piece of furniture made for several people to sit on at the same time. A sofa.
Corn

10) **Neck –** The part of the body that connects the head with the body.
Nest – Structure built by birds using twigs and mud to lay eggs and raise their young.
Nectar

11) **Book –** Sheets of paper held together between 2 covers that people can read.
Bottle – A container with a narrow neck and no handle. Used to hold or pour liquids. Usually made of glass or plastic.
Boot

12) **Drum –** An instrument shaped like a cylinder and is played by hitting it with sticks or the hands.
Dream – Pictures or visions you see when you are sleeping.
Dress

LIST 2

1) **Sandwich –** An item of food made up of 2 pieces of bread with meat, cheese or other filling between them.
Salad – A mixture of cold vegetables, such as lettuce, tomato, and cucumber, served with a dressing.
Sand

2) **Grapes –** A smooth-skinned juicy green or purple fruit that can be used to make wine and you buy it in bunches.
Grass – A green plant that is on the ground, with narrow pointed leaves that covers lawns and meadows.
Ground

3) **Potato -** A round or oval shaped vegetable that is light coloured on the inside and its skin can be brown, yellow or red. Used to make French fries.
Pocket – A small piece of material, open at the top and sewn onto clothing. Forms a bag for keeping small objects.
Poem

4) **Bread** – A food made by baking a dough of flour.
Brush – A tool made of stiff hairs or bristles that have been fastened to a handle. Used of grooming, painting, or scrubbing.
Broom

5) **Clown** – An actor who wears funny clothes, make-up and sometimes a red nose to make people laugh and he performs at the circus or at parties.
Cloud – A white or gray mass of fine drops of water or ice high in the earth's atmosphere.
Clay

6) **Horse** – A large hoofed mammal with short hair, a long mane and long tail. Used for riding, racing, and to pull loads.
House – A building in which people live.
Honey

7) **Watch** – Something you wear on your wrist to tell you the time.
Water – A clear liquid that has no taste or odor. Makes up rain, rivers, oceans, and lakes. Is a requirement for most forms of life.
Wagon

8) **Table** – A piece of furniture supported by legs with a flat surface to put things on.
Taxi – A car that people pay to take them places.
Tail

9) **Fork** – a tool with a handle with two or more points, used for eating.

Foot – The end part of the leg of humans and other animals, on which the body stands and walks.
Forest

10) **Tree -** A woody plant that has a long main truck and many branches. They usually grow quite tall.
Truck – A big vehicle often used to transport things.
Trip

11) **Bell** – A hollow metal cup that makes a ringing sound when hit. Used at churches and school.
Belt – A strip of cloth, leather, or other material worn around the waist.
Bench

12) **Cake** – A sweet baked food made of flour, eggs, sugar and flavouring and you eat it at birthday parties.
Carrot – A long, thick, orange vegetable.
Camel

LIST 3

1) **Button** – A small round flat disk that fastens (or holds) clothing together by fitting it through a slit or loop.
   Bubble – A small round body of gas surrounded by a thin liquid film. Round and floaty and can make with your mouth using a soapy solution.
   Bucket

2) **Rabbit** – A furry animal that hops and has long ears and a short tail.
   Rain – Drops of water that form in the clouds that fall from the sky to the earth.
   Radio

3) **Window** – An opening in a wall or vehicle that lets in air and light and provides a view out.
   Winter – The coldest season of the year – comes right after the fall.
   Wind

4) **Doctor** – A person you go see when you are sick so that he/she can check you and give you medicine.
   Door – Part of the room that you can open and close and is used to close off an entrance.
   Donut

5) **Glove** – A covering for your hand that has separate parts for each finger and the thumb and is often used in winter to keep your hands warm.
   Glass – A hard clear material that breaks easily and is used to make windows, bottles, mirrors, etc.
   Globe

6) **Piano** – A musical instrument with a keyboard and many wire strings, played by pressing keys that cause small hammers to strike the strings.
   Pillow – A soft pad filled with stuffing and used for resting your head on while sleeping.
   Pigeon

7) **Spoon** – A tool with a small, shallow bowl at the end, a handle and is used for eating, stirring, serving or measuring.
   Spider – A small animal with eight legs. They spin webs in which they nest and catch insects to eat.
   Sprinkler

8) **Thumb** – The short, thick first finger on our hands that makes it easy for us to pick up and grasp things.
   Thief – Someone who steals.
   Throat

9) **Lamp** – A device that gives off light. It can be made up of an electric bulb along with a shade or cover.

Ladder – A pair of side pieces joined by horizontal bars used for climbing.
Lake

10) **Park** – A large public green area used for playing or relaxing and taking walks.
Paper – A thin material made from wood and used for writing on, wrapping and covering walls.
Palace

11) **Turtle** – Reptile that moves slowly and is enclosed in a scaly domed shell that it can hide in by putting its head and think legs inside.
Turkey – A large bird with a bald head. It is eaten on festive occasions such as Thanksgiving and Christmas.
Tulip

12) **Face** – Front part of the head from the forehead to the chin and from ear to ear.
Family – A group made up of a parent or parents and their children and all related by blood.
Father

LIST 4

1) **Blanket –** A large piece of fabric used as a cover for warmth when sleeping.
Blood – Red liquid in our bodies that contains oxygen and nutrients that pumps through the veins and arteries of humans and animals.
Block

2) **Jacket –** A short coat used as a piece of outer clothing.
Jail – A building in which a government keeps people who are waiting for a trial or who have been found guilty of breaking the law.
Jar

3) **Chair –** A piece of furniture for one person to sit on that has 4 legs, and a back.
Cherry – Small, round fruit that grows on a tree. It is red and has a hard pit in the centre.
Church

4) **Alien –** A creature from another planet.
Alligator – A large reptile with short legs, a long body and tail and a long wide snout. It lives in rivers, lakes, swamps and it is related to crocodiles.
Album

5) **Apple –** A hard round fruit with while insides and it has red, green or yellow skin. Often used to make pie.
Apron – A garment that covers all or part of the front of the body and is worn to protect the clothing underneath e.g., when cooking.
Apricot

6) **Fence –** A structure used to close off an area to keep people or animals in or out.
Feather – One of the soft and light parts of a bird that grows from the skin and covers its body.
Ferry

7) **Magic –** Tricks used for fun but that suggest supernatural powers. Can be performed at a circus or show.
Match – Thin strip of word with a material at the end that lights up then struck against something.
Machine

8) **Plate –** A flat smooth object used to eat off of.
Planet – A large celestial body in the solar system. Examples are the Earth, Mars Mercury, and Venus.
Plum

9) **Lion –** A large, very strong mammal with short fur and they are meat eaters. Males have a mane of longer hair around the neck and head.
Line – A long, thin straight mark.
Lips

10) Head – The top of a person's body which contains the brain, eyes, nose, ears and mouth.
Heart – The organ that pumps blood through the body of a person or animal.
Heaven

11) Meat – The flesh of animals when used as food.
Medal – Flat, small piece of metal that has a design or words stamped on it, used as an honour or reward.
Meadow

12) Hair – The many strands growing on a person's head. Usually long in girls and short in boys.
Hand – The part of a person's arm that is used for holding things.
Hammer

LIST 5

1) **Present –** A gift. Something you would give someone, such as for their birthday.
Prince – Son of a king.
Prom

2) **Diaper –** What baby wears instead of underwear so he/she would not wet themselves.
Dinosaur – Very large extinct reptile that lived millions of years ago – some ate plants and some ate meat.
Diary

3) **Garage –** The part of a building or house where you store or park a car.
Garden – Piece of land where you plant flowers, trees, and plants.
Game

4) **Robot –** Mechanical machine or device that looks like a human.
Road – Long concrete path where cars go – you drive on it.
Robin

5) **Socks –** What you wear on your feet before putting on your shoes. Made of cloth.
Soap – Something you use along with water to wash your hands.
Soldier

6) **Stage –** Raised floor or platform where people perform.
Stem – Stalk or trunk of a flower or plant.
Stairs

7) **Ticket –** A card or piece of paper used as proof of payment when entering a movie or special event, such as a concert.
Tiger – Animal from the cat family – related to lions. Often orange and black.
Tissue

8) **Teeth –** Hard bone in your mouth that you use to eat and chew.
Teacher – Someone who teaches.
Tear

9) **Frog –** A small green jumping animal with smooth, moist skin, long back legs, webbed feet and no tail. It is an amphibian.
Fruit – Part of the plant you eat and it is often sweet.
Friend

10) **Swan –** A white bird with a graceful neck.
Swing – An activity at the park where you sit and move back and forth.
Sword

11) **Snow –** Soft, white flakes of ice that fall from the sky to the earth and you need it to go skiing.

Snake – A long reptile that slithers.
Snack

12) **Bicycle –** A light vehicle with 2 wheels, one behind the other, a small seat and handle bars for steering and pedals that make the wheels move.
Bird – A flying animal with feathers and wings.
Binder

Appendix D

Counterbalancing Spreadsheet

	Trial1		Trial2		Trial3		Trial4		Trial5	
Participant	**List**	**Cond**	**List**	**Cond**	**List**	**Cond**	**List**	**Cond**	**List**	**Cond**
1	4	EF-EP	3	EL-SG	5	EF-SG	2	EL-EP	1	Control
2	5	EF-SG	4	EF-EP	1	Control	3	EL-SG	2	EL-EP
3	1	Control	5	EF-SG	2	EL-EP	4	EF-EP	3	EL-SG
4	2	EL-EP	1	Control	3	EL-SG	5	EF-SG	4	EF-EP
5	3	EL-SG	2	EL-EP	4	EF-EP	1	Control	5	EF-SG
6	4	EL-SG	3	EF-SG	5	EL-EP	2	Control	1	EF-EP
7	5	EF-EP	4	Control	1	EL-SG	3	EL-EP	2	EF-SG
8	1	EF-SG	5	EL-EP	2	EF-EP	4	EL-SG	3	Control
9	2	Control	1	EL-SG	3	EF-SG	5	EF-EP	4	EL-EP
10	3	EL-EP	2	EF-EP	4	Control	1	EF-SG	5	EL-SG
11	4	EF-SG	3	EL-EP	5	Control	2	EF-EP	1	EL-SG
12	5	Control	4	EL-SG	1	EL-EP	3	EF-SG	2	EF-EP
13	1	EL-EP	5	EF-EP	2	EL-SG	4	Control	3	EF-SG
14	2	EL-SG	1	EF-SG	3	EF-EP	5	EL-EP	4	Control
15	3	EF-EP	2	Control	4	EF-SG	1	EL-SG	5	EL-EP
16	4	EL-EP	3	Control	5	EF-EP	2	EL-SG	1	EF-SG
17	5	EL-SG	4	EL-EP	1	EF-SG	3	EF-EP	2	Control
18	1	EF-EP	5	EL-SG	2	Control	4	EF-SG	3	EL-EP
19	2	EF-SG	1	EF-EP	3	EL-EP	5	Control	4	EL-SG
20	3	Control	2	EF-SG	4	EL-SG	1	EL-EP	5	EF-EP
21	4	Control	3	EF-EP	5	EL-SG	2	EF-SG	1	EL-EP
22	5	EL-EP	4	EF-SG	1	EF-EP	3	Control	2	EL-SG
23	1	EL-SG	5	Control	2	EF-SG	4	EL-EP	3	EF-EP
24	2	EF-EP	1	EL-EP	3	Control	5	EL-SG	4	EF-SG
25	3	EF-SG	2	EL-SG	4	EL-EP	1	EF-EP	5	Control
26	4	EF-EP	3	EL-SG	5	EF-SG	2	EL-EP	1	Control
27	5	EF-SG	4	EF-EP	1	Control	3	EL-SG	2	EL-EP
28	1	Control	5	EF-SG	2	EL-EP	4	EF-EP	3	EL-SG

29	2	EL-EP	1	Control	3	EL-SG	5	EF-SG	4	EF-EP
30	3	EL-SG	2	EL-EP	4	EF-EP	1	Control	5	EF-SG
31	4	EL-SG	3	EF-SG	5	EL-EP	2	Control	1	EF-EP
32	5	EF-EP	4	Control	1	EL-SG	3	EL-EP	2	EF-SG
33	1	EF-SG	5	EL-EP	2	EF-EP	4	EL-SG	3	Control
34	2	Control	1	EL-SG	3	EF-SG	5	EF-EP	4	EL-EP
35	3	EL-EP	2	EF-EP	4	Control	1	EF-SG	5	EL-SG
36	4	EF-SG	3	EL-EP	5	Control	2	EF-EP	1	EL-SG
37	5	Control	4	EL-SG	1	EL-EP	3	EF-SG	2	EF-EP
38	1	EL-EP	5	EF-EP	2	EL-SG		Control	3	EF-SG
39	2	EL-SG	1	EF-SG	3	EF-EP	5	EL-EP	4	Control
40	3	EF-EP	2	Control	4	EF-SG	1	EL-SG	5	EL-EP
41	4	EL-EP	3	Control	5	EF-EP	2	EL-SG	1	EF-SG
42	5	EL-SG	4	EL-EP	1	EF-SG	3	EF-EP	2	Control
43	1	EF-EP	5	EL-SG	2	Control	4	EF-SG	3	EL-EP
44	2	EF-SG	1	EF-EP	3	EL-EP	5	Control	4	EL-SG
45	3	Control	2	EF-SG	4	EL-SG	1	EL-EP	5	EF-EP
46	4	Control	3	EF-EP	5	EL-SG	2	EF-SG	1	EL-EP
47	5	EL-EP	4	EF-SG	1	EF-EP	3	Control	2	EL-SG
48	1	EL-SG	5	Control	2	EF-SG	4	EL-EP	3	EF-EP
49	2	EF-EP	1	EL-EP	3	Control	5	EL-SG	4	EF-SG
50	3	EF-SG	2	EL-SG	4	EL-EP	1	EF-EP	5	Control
51	4	EF-EP	3	EL-SG	5	EF-SG	2	EL-EP	1	Control
52	5	EF-SG	4	EF-EP	1	Control	3	EL-SG	2	EL-EP
53	1	Control	5	EF-SG	2	EL-EP	4	EF-EP	3	EL-SG
54	2	EL-EP	1	Control	3	EL-SG	5	EF-SG	4	EF-EP
55	3	EL-SG	2	EL-EP	4	EF-EP	1	Control	5	EF-SG
56	4	EL-SG	3	EF-SG	5	EL-EP	2	Control	1	EF-EP
57	5	EF-EP	4	Control	1	EL-SG	3	EL-EP	2	EF-SG
58	1	EF-SG	5	EL-EP	2	EF-EP	4	EL-SG	3	Control
59	2	Control	1	EL-SG	3	EF-SG	5	EF-EP	4	EL-EP
60	3	EL-EP	2	EF-EP	4	Control	1	EF-SG	5	EL-SG

Appendix E

MEMORY TASK INSTRUCTIONS

For the next set of tasks, I will ask you to do five memory tests. For each test, you will learn a list of words. All the words will be 'things' or nouns like towel or pear and not other types of words, like verbs (or actions) or adjectives. You will learn each list in a different way. I will give you specific directions before each list. After learning each list, I will give you a number and have you count backwards from that number for a few seconds. Then I will have you write as many of the words as you can remember.

Errorful-Self Generated Encoding

Learning Phase

I'm going to show you the first two letters of each word that I am thinking of followed by a blank line and I will have you try to guess the word I want you to remember. I'll give you two guesses before I will tell you the word I want you to remember. I will have you write it down and will give you the meaning of the word. Any questions?

For each word: I am thinking of a word that begins with _____ (show stem) can you guess what it is?
First 2 guesses – no good guess please try again.

After second guess – the word I want you to remember is _____ please write it down.
Give definition.

Count backwards from 30.

Recall phase: Please write down as many of the words from the list as you can remember.

Cued Recall: Now I'm going to have you try to recall the list of words again but this time I am going to give you some help.
For each word: One of the words began with ____ (show stem). Do you remember what it was?

Errorless-Experimeter Provided

Learning Phase

I'm going to show you the first 2 letters of a word that I want you to remember. Then I will have you write that word down. Then, I will give you the meaning of the word. Any questions?

For each word: I am thinking of a word that begins with ___(show word stem), and it is _____(show word on card). Please write that word down. It is (give definition).

Count backwards from 30.

Recall: Please write down as many of the words from the list as you can remember

Cued Recall: For each word – one of the words began with ______ (show stem) Do you remember what it was?

Errorful-Experimenter Provided Encoding

Learning Phase

I'm going to show you the first 2 letters of each thing that I am thinking of followed by a blank line and then I will tell you some words that complete the stem, including the one that I want you to try to remember. And then I will have you write that word down. Then I will give you the meaning of that word. Any questions?

For each word: I am thinking of a word that begins with _______ (show stem).

First 2 trials: ____completes this word stem, but that is not the word I want you to remember (show card).

Third Trial: The word I want you to remember is ________ (show word on card) and say it. Please write that down. It is (give definition).

Count backwards from 30.

Recall phase: Please write down as many of the words from the list as you can remember.

Cued Recall: Now I'm going to have you try to recall the list of words again but this time I am going to give you some help.

For each word: One of the words began with ____ (show stem). Do you remember what it was?

Errorless-Self Generated Encoding

Learning Phase
I will show you the first 2 letters of each thing that I am thinking of followed by a blank line and then I will describe the word to help you guess the correct word. Listen carefully, if the description does not help you, ask for more information.

And then I will have you write that word down. Any questions?

For each word; I am thinking of a word that begins with ________and it is __ (Give definition). Can you guess what it is? (when they guess it, say yes, please write that down).

Count backwards from 30.

Recall Phase: Please write down as many of the words from the list as you can remember.

Cued Recall: Now I'm going to have you tell me the list of words again but this time I am going to give you some help.
For each word: One of the words began with _____(show stem). Do you remember what it was?

Baseline

I will show you the first 2 letters of a word followed by a blank line then I will show you each word for a few seconds. Take a look at the word and write it down and try your best to remember it (present for about 3 seconds each).

Count backwards from 30.

Recall phase: Please write down as many of the words from the list as you can remember.

Cued Recall: Now I'm going to have you try to recall the list of words again but this time I am going to give you some help.
For each word: One of the words began with ____ (show stem). Do you remember what it was?