Inhibitory Control as a Mediator of Individual Differences in Rates of False Memories in Children and Adults

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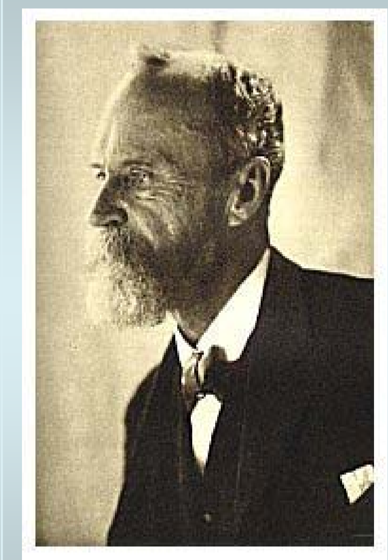
"The most frequent source of false memory is the accounts we give to others of our experiences… We quote what we should have said or done rather than what we really said or did; and in the first telling we may be fully aware of the distinction. But ere long the fiction expels the reality from memory and reigns in its stead alone."

William James, Principles of Psychology.

1890:373-374



Abstract

The primary aim of this dissertation is to address an important issue of individual susceptibility to false memories. Specifically, what is the role inhibitory control (IC) in children's and adult's propensity to producing false memories? Inhibitory control within the context of the current study is defined on the basis of performance on selective attention tasks. Inhibitory control is discussed within this dissertation as it is reflected in two selective attention tasks, Stroop and Negative Priming. While the false memory effect, as reflected in the Deese/Roediger and McDermott paradigm (Roediger & McDermott, 1995), is one of the most widely studied memory phenomenon, the current study is important as it provides some insights into the relation between attention and memory. An interesting finding in the DRM false memory effect is that participants often report having a clear false memory of having seen or heard the non-presented critical lure item (CL item). Such memory illusions have been informative on how memory works. The current study adds to this body of research by providing converging evidence of how individual differences in the sensitivity to the false memory effect may occur, and how this sensitivity may reflect the same IC mechanisms involved in selective attention tasks.

The basic notion examined within this dissertation is that when recognition memory is tested in the DRM paradigm, individuals have to select information that was studied and simultaneously inhibit highly activated yet non-presented information in memory, in order to correctly reject the CL item. If the notion that individual differences in sensitivity to the false memory effect is indeed related to a basic IC mechanism, then a relationship should be found between measures of IC in selective attention tasks and rates of false memories in the DRM test.

The current study incorporates three experiments. Experiments 1 and 2 are broken down into parts ‘a’ and ‘b’, with each part varying in respect to the IC measure. In part a, participants were assigned to an inhibitory control group (IC group) on the basis of Stroop interference. In part b, participants are assigned to IC groups on the basis of a combined measure of inhibitory control that is, Stroop and Negative Priming. The third experiment assigned participants on the basis of a combined measure of IC, and then considered the relation between the duration of IC over a number of DRM word-lists presented simultaneously prior to the recognition test. Experiment 3 also compared the robust effect of IC on the propensity to produce false memories across all three experiments.

The results of this study can be summarized as follows. In each experiment there was clear evidence of a relation between IC estimates and proportion of false memories. As predicted, individuals assigned to a Less IC group produced a higher proportion of false memories than those assigned to the More IC group. Inhibitory control differences did not modulate differences in correct or incorrect recognition in general (hits and false alarms to unrelated distractors). This second finding is important because it suggests a specific effect of IC in false memories, rather than a general breakdown in memory processes. The IC effect in false memories occurred in children (8-year olds and 10-year olds) as well as adults. Furthermore, the IC effect appeared to be additive with age; i.e., all groups produced a similar pattern across all three experiments. Last, the combined estimate of IC was found to be a more sensitive measure of false memories than a single index of IC; however, this was found in relation to adults but not for children.

A number of additional manipulations and measures of interest were also included. Experiment 2 found clear evidence of an effect of IC on remember responses, not only were Less IC individuals more likely to produce false alarms to critical lure items, they were also more likely to distinctly respond they “remembered” the CL item as opposed to only “knowing” the CL had been presented. Examination of reaction times (RTs) to false alarms as a function of IC group found the Less IC group were faster to make false alarm responses to CL items, whereas the More IC group were slower to make false responses CL items. As predicted the relation between IC and the false memory effect was modulated by the random versus blocked presentation manipulation in Experiment 3. Specifically, decreased rates of false memories were found in the random presentation format compared to the blocked format. Interestingly however, a small effect of IC group in false memories was found even in the random condition.

From this study it can be concluded that individual susceptibility to the false memory effect is in part modulated by inhibitory control. Individuals who demonstrate less effective IC show a greater propensity to false memories than those who demonstrate more effective IC. The IC effect of false memories was found to be robust, with converging evidence found across all three experiments. In relation to the development of inhibitory control, consistent with the research of Pritchard and Neumann (2004, 2009), and Lechuga and colleagues (2006), the results of this study suggest IC is fully developed in young children. However, their ability to accurately encode, retain and retrieve information would appear to develop at a different rate than IC. Specifically, it may be that while younger children are able to utilize IC in memory processes, they have yet to fully develop a richly interconnected semantic network. On the other hand, older children and adults would appear to have a more fully developed semantic network.

This series of experiments presents a novel demonstration of the relation between inhibitory control and false memories. As such, this study has the potential to provide new insight into a cognitive mechanism that may be responsible for both developmental trends and for individual differences in the regulation of false memories. Moreover, if the mechanism responsible for mediating false memories is causally linked to performance on selective attention tasks in the systematic way that is proposed, it may be possible in the future to utilize IC measures to assist in identifying individuals who have an exaggerated propensity to form false memories, as well as those more prone to resist them.

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Terms and Abbreviations

IC	Inhibitory control
Stroop	Stroop color-word interference task
NP	Negative priming
Incongruent	Stroop stimuli that conflict in relation to semantic meaning of the color-word and the target response
Neutral	Stroop stimuli that are neutral in relation to semantic meaning of letter-strings and the target response
Stroop Interference	Proportional RT latency and error rates between Incongruent stimuli in comparison to Neutral stimuli
Prime trial	Incongruent Stroop stimuli
Probe trial	Neutral Stroop stimuli
Prime-probe couplet	Presentation of a prime trial immediately followed by a probe trial
IR	Ignored repetition in which the previously ignored distractor information becomes the target response on the subsequent trial
IR Probe trial	Ignored repetition including a high degree of conflict between prime and probe trials
Control Probe trial	Low degree of conflict between prime and probe trials
NP Effect	Proportional RT latency and error rates between IR Probe trials in comparison to Control Probe trials
RTs	Response times
DRM	Deese/Roediger and McDermott Word List Task
SW-lists	DRM word lists comprising 10 semantic plus 3 unrelated words
SPW-lists	DRM word lists comprising 10 semantic plus 3 words phonologically related words
CL	Critical lure word related to the semantic concept of a single DRM word list
Hits	Correct recognition of previously studied DRM word lists
UnIntrusions	Incorrect recognition of unrelated test items as previously studied words
FA	False Alarms to critical lure words – incorrectly recognizing a CL as a previously studied word
Remember	Subjective rating of confidence indicating a an item is a previously remembered event
False Remember	Rating a false alarm to a critical lure word as a remembered event
SDT	Signal Detection Theory
d'	*d'* prime, referring to a discriminability index derived from SDT

Blocked Format	Standard presentation of DRM word lists: sequential presentation of five SPW-lists words.
Random Format	Presentation of five SPW-lists dispersed in a randomized order within one list.

Chapter 1: Is Cognitive Inhibitory Control a Mediator of False Memories in Children and Adults?

The phenomenon of false memories has been of interest to psychologists for a long time. For example, in his classic textbook *Principles of Psychology*, William James (1890) noted human memory is far from infallible, observing that false memories occur frequently as a result of processes involved in both the formation of a memory and in the retrieval of information from memory. Observation that false memories occur when children and adults are exposed to information about non-experienced events is found in the analyses of transcripts of interviews (Ceci & Bruck, 1995), and in empirical research (Howe, Wimmer, & Blease, 2009a; Loftus, 2005; Roediger & McDermott, 1995; Strange, Garry, & Sutherland, 2003; Zaragoza & Mitchell, 1996). Recently, the focus of research has shifted from detecting false memories to understanding mechanisms that may account for the occurrence of false memories, and detecting individual differences in susceptibility to false memories (e.g., Roediger & McDermott, 1995: Howe, Wimmer, Gagnon, & Plumpton, 2009b; Reyna, Holliday, & Marche, 2002; Watson, McDermott, & Balota, 2004). A question that often arises from false memory research is whether children and adults can be induced to form a false memory of an event that they have not experienced (Holliday, Reyna, & Brainerd, 2008; Watson et al., 2004).

The current study endeavored to go beyond such a question by way of examining in a unique way whether individual differences in susceptibility to false memories can be detected, and whether those more susceptible to false memories are also more likely to rate a false memory as a remembered event. The inhibitory control abilities of children and adults were assessed utilizing a Stroop color-word task and a NP task. Individuals were then ranked according to inhibitory control efficiency and assigned to either less effective, moderately effective, or more effective inhibitory control groups. Of particular interest was whether individuals who were effective in their ability to inhibit concurrently competing distractor information, and who show evidence of the effect of such inhibition by way of increased response latencies and higher error rates when required to respond to the previously ignored stimuli, would also show more effective inhibition of distractor information on a memory task. More critically, would the opposite pattern be evident in individuals classified as showing less effective inhibition. In this instance, would those who showed ineffective inhibition of concurrently competing distractor information, and who showed evidence of reduced response latencies and lower error rates when responding to this previously ignored information, also show higher rates of intrusions of competing task-irrelevant distractor information on a memory task?

1.1 False Memories in the DRM Paradigm

When referring to false memories within the context of the present study, these are defined as the incorrect recognition of a word semantically associated to a thematically related list of words, such as DRM word lists (Roediger & McDermott, 1995). In this instance, false memories are measured as the number of times participants incorrectly judge a word that is semantically associated to the thematically related DRM word lists, referred to as the critical lure item (CL), but is not presented as part of the study list, as a previously studied word (Roediger & McDermott, 1995). Research indicates that in general, within the DRM word list task the rate of incorrect recognition of critical lure (CL) items nears the rate of correct recognition of previously studied words (Roediger & McDermott, 1995; Watson et al., 2003). As such, the DRM word list task provides a robust measure of false memories and allows a comparison of developmental trends and individual differences in the propensity of semantically associated yet non-studied words to intrude into recall.

Individual rates of false memories were assessed on the basis of the proportion of false alarms resulting from variants of DRM word lists (Watson et al., 2003). Participants studied a list of words converging on a central primary thematic associate, e.g., *warm, blanket, pillow, cozy, dreamy,* related to the non-presented primary thematic associate of *sleep.* On the subsequent recognition test, the non-presented primary thematic associate *sleep* is presented as a test item (referred to as a *critical lure* item or CL; see Roediger & McDermott, 1995). False alarms occur when participants incorrectly recall or recognize the CL item as a previously studied list item. This allowed a comparison of false alarm rates between children and adults assigned to less, moderate, or more effective inhibitory groups. The key variation utilized in the current study was the combined use of two versions of DRM word lists. Specifically, the first type of DRM word lists contained 13 words (10 semantically interrelated words and three non-related words), and are referred to in the current study as Semantic Word lists (SW-lists). The other type of DRM word lists contained 13 words (10 semantically interrelated words and three phonologically interrelated words), and are referred to in the current study as Semantic plus Phonological Word lists (SPW-lists; adapted from Watson et al., 2003). See Appendix A for examples of word lists used in the current study.

Participants were presented with both SW- and SPW-lists. In each case, during the test phase individuals were required to indicate whether a test word was a previously studied word. Embedded in each test list is a CL item that was not presented as part of the study list. The CL was semantically related to the thematically interrelated list words, phonetically related to the phonological list words, but has no relationship to the non-thematically related words. False alarms occur when the CL is judged to be a previously studied word. Previous research has indicated higher rates of false alarms result from DRM lists containing both thematically and phonetically related words, in comparison to alarm rates associated with SW-lists (Watson et al., 2003). Theoretical accounts for false alarms to CL words suggest that the presentation of thematically interrelated words activates a mental representation of the primary primary thematic associate of the word list. The main proposition pursued here is the possibility that false alarms to CLs result from ineffective inhibition of this mental representation, which could lead to an increased likelihood of the CL being judged to have been presented within the DRM list.

1.2 Overview False Memory Research

One explanation for the occurrence of false memories posits that exposure to information, whether through everyday conversations or during experimental research, becomes incorporated into memory through a process referred to as *constructive memory* (Schacter, Norman, & Koutstaal, 1998). From this viewpoint, memory retrieval is said to be a process of pattern completion, in which components of an event are reactivated, which in turn activates additional relevant or related components, until a complete event is recalled (Schacter et al., 1998). As such, when children and adults recall events from memory, some individuals may fail to distinguish between events they have experienced, mental representations activated during the retrieval of related information, or information obtained from others, with the result being that some individuals form a false memory of an event through constructive memory processes (Conway, 2009; Schacter et al., 1998; James, 1890). What is less clearly understood is why it is that some individuals show a greater propensity to forming false memories while others seem more resistant to intrusions into memory of false information.

To assist in understanding factors related to individual differences in rates of false memories, it is helpful to look at false memory research pertaining to children and adults. First, examination of memory recall in children reveals that variations in susceptibility to false memories are found between children of the same age and differing ages (Anastasi & Rhodes, 2008; Brainerd, Forrest, Karibian, & Reyna, 2006; Bruck, Melynk, & Ceci, 1997). For example, using both recall and recognition measures, Anastasi and Rhodes (2008) found children aged 5- to 8-years produced lower levels of false memories than adults when presented with thematically related word lists. Their results showed a typical developmental trend of a negative relationship between age and false memories evident for both adult- and child-normed lists. Children and adults were found to incorrectly recall or recognise non-studied words that were semantically associated to the presented list items, as having been previously studied. However, younger children were less likely than adults to recall or recognise semantically associated yet non-studied words as previously studied words. More recently, Howe and colleagues demonstrated that regardless of age, susceptibility to false memories occurred when the associative strength of list items was varied (2009a). In this instance, both children and adults produced higher rates of false recall when word lists comprised individual words high in associative strength compared to word lists comprising words low in associative strength.

Second, a study conducted by Lövdén (2003) indicates that inhibitory mechanisms may contribute to individual differences in rates of false memories in adults. Adults aged 20- to 80-years were assessed using a variety of inhibitory control measures, with false memories measured as the number of non-studied critical lure items incorrectly recognized as previously studied DRM list items, and falsely remembering an unstudied category-related item as previously studied. The results of Lövdén's study showed those who were assessed as having impaired inhibitory control were also found to produce higher false memory rates on both a DRM memory task and category related lists. Lövdén suggests that impaired inhibitory processes may cause a failure to reduce activation of related information, which in turn results in high rates of false recognition of words related to study words, but not presented during the study phase. On the basis of research such as this, it would appear that inhibitory processes may contribute to the ability to discriminate between target information and competing information that is similar yet incorrect.

In order to assess inhibitory control in a manner synonymous with an activation-suppression account of mental representations, the current study utilized the well known Stroop color-word test (Dalrymple-Alford & Budayr, 1966). Inhibitory control in this sense is defined as the ability to effectively suppress a mental representation of the semantic meaning of a task-irrelevant, conflicting color-word in order to respond to the concurrent font-color it is printed in. In relation to inhibitory control and the DRM task, this may be characterized as the ability to effectively inhibit activation of the mental representation of the task-irrelevant, conflicting CL associated with the primary thematic associate of a DRM word list, in order to identify the critical lure item as a non-studied word. While researchers have hypothesized that younger children's memories are less reliable than older children or adults (see Ceci & Bruck, 1995, for a comprehensive review), it is also apparent that factors other than age mediate differences in accurate memory retrieval processes. In fact, regardless of age, some individuals appear to be more susceptible to false memories than others (Howe et al., 2009b, Lövdén, 2003).

One difficulty that arises when investigating complex cognitive mechanisms such as inhibitory control within experimental research is that most studies of inhibitory control provide an indices measure based on performance across a range of tasks. For example, researchers typically adopt the method of assessing cognitive control by means of a battery of executive function tasks (Davidson, Amso, Anderson, & Diamond, 2006). A potential drawback of such an approach is that it then becomes difficult to determine whether inhibitory control refers to volition, planning, purposive action, or effective performance (Lezak, Howieson, & Loring, 2004). For example, closer examination of the combined measure of inhibitory control utilized by Lövdén (2003) raises an important question. Specifically, whether combining the performance on diverse tasks into a single measure provides an index of inhibitory control. In this case Lövdén's measure of inhibitory control was derived from participants' ability to overcome a reflexive response of looking at an initial visual cue, refraining from producing a sequential number string rather than generating a random number string, as well as performance on a Stroop task (2003). It may be more accurate to state that assessing an individual's performance on such tasks provides a measure of inhibitory control that combines motor performance and inhibitory control (Lezak et al., 2004). However, it is less certain whether these combined tasks truly reflect inhibitory control within the context of active suppression of a mental representation, as the combined measure also reflects speeded mental processing abilities and psychomotor output (Lezak et al., 2004).

Research such as Lövdén's indicates a need for further research to determine whether inhibitory mechanisms that automatically prevent interference from competing distractor information (Neumann & DeSchepper, 1991; 1992) contribute to modulating rates of false memories in both children and adults in the manner proposed. In light of this, the current study defines inhibitory control as the cognitive processes that enable activated yet highly competitive, mental representations to be inhibited in order to make a correct response to targeted information. In this way, the ability to inhibit task-irrelevant competitive information in selective attention tasks is argued to provide a measure of inhibitory control that is synonymous with the ability to inhibit the task-irrelevant, highly competitive CL, in order to correctly identify the CL as a new word.

1.3 Inhibitory Control in Selective Attention Tasks

In relation to the Stroop color-word task used in the current study, participants were presented with four color-words (blue, green, yellow, and red) and letter strings presented in one of the four ink colors (e.g., zopt in either blue, green, yellow, or red ink). Incongruent Stroop stimuli consisted of four color-words presented in a conflicting ink color, such as the color-word blue presented in red ink. Neutral Stroop stimuli consisted of a number of different letter strings, varying in length from three to six letters, presented in one of four ink colors. In the case of incongruent Stroop stimuli, the semantic meaning of the color-word is thought to interfere with the individual's ability to respond to the ink color (Dalrymple-Alford & Budayr, 1966; Pritchard & Neumann, 2009). This is evident in longer RTs, higher error rates, or both. As neutral Stroop stimuli present no such conflict, a comparison of proportional RT latencies and error rates between incongruent and neutral stimuli provides a method for calculating an index of inhibitory control. This allowed individuals to be ranked according to this index of inhibitory control, and assigned to one of three inhibitory control groups: less effective (Less IC), moderately effective (Mod IC), and more effective (More IC). Those demonstrating a greater degree of Stroop interference were assigned to the Less IC group, those demonstrating a moderate degree of Stroop interference to the Mod IC group, and those demonstrating a lesser degree of Stroop interference to the More IC group.

With the exception of Experiments 1a and 2a, The NP task was incorporated within the Stroop color-word task. In this instance, Stroop stimuli were utilized to provide prime-probe couplets. A prime trial consisted of incongruent Stroop stimuli (e.g., the color-word blue presented in red ink), which was immediately followed by a probe trial consisting of neutral Stroop stimuli (e.g., the letter string ‘zopt’ presented in blue ink). Two NP conditions were compiled, an ignored repetition (IR) condition, in which incongruent Stroop stimuli were immediately followed by the corresponding neutral Stroop stimuli (Figure 1.1), and a control condition in which incongruent Stroop stimuli were immediately followed by non-corresponding neutral Stroop stimuli (Figure 1.1). In this way, the IR condition probe trial provides a high degree of conflict between prime-probe couplets, while the control condition presents less conflict between the prime and probe. Figure 1.1 below provides an example of IR and control prime-probe couplets and the relationship between the IR probe and the control probe.

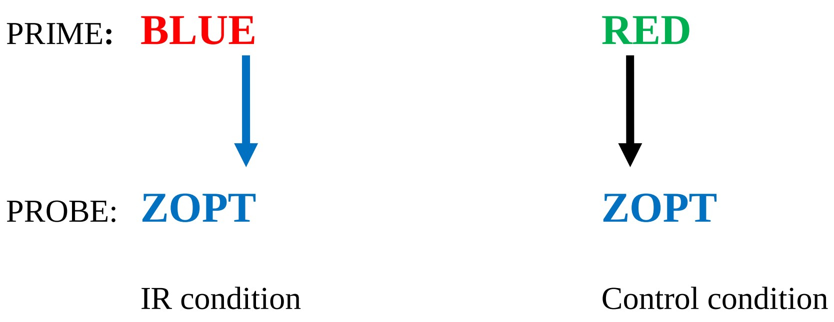

Figure 1.1 Illustration depicting the relationship between prime-probe couplets in the IR and control conditions. ***Note:*** **→ *competing* distractor information, → *no competing* distractor information.**

Negative priming effects in the current study were measured as the proportional degree of interference between prime-probe couplets in the IR condition in comparison to the control condition. Negative priming effects are evident in larger RT latencies, or higher error rates, or both, when the previously ignored meaning of the color-word becomes the target response on the subsequent trial (Neill & Westberry, 1987; Pritchard & Neumann, 2009). Negative priming effects occur as the effective inhibition of the ignored semantic meaning of a color-word on the prime trial interferes with the ability to respond to the ink color when it becomes the target response on the probe trial (Neill & Westberry, 1987; Pritchard & Neumann, 2009). As Figure 1.1 illustrates, a greater degree of conflict between target and distractor stimuli is expected in the IR condition in comparison to the control condition. On the basis of the NP task, individuals were again assigned to one of three inhibitory control groups based on the proportional degree of NP effects. Those demonstrating more effective inhibitory control should show a higher proportion of RT latencies and error rates on a NP task when presented with IR prime-probe couplets in comparison to control prime-probe couplets, due to their relatively more effective inhibition of the meaning of the previous color word. In contrast, those demonstrating less effective inhibitory control should show a lower proportion of RT latencies and error rates on a NP task when presented with IR prime-probe couplets in comparison to control prime-probe couplets, due to their relatively less effective inhibition of the meaning of the color word. The combined index of inhibitory control allowed individuals to be classified as demonstrating less effective inhibitory control on the basis of a higher proportion of Stroop interference and reduced NP effect (Less IC), moderate inhibitory control on the basis of proportionally moderate Stroop interference and NP effect (Mod IC), and more effective inhibitory control on the basis of proportionally less Stroop interference and greater NP effect (More IC).

The following sections provide an overview of the current study and the methods utilized for assessing and measuring inhibitory control and false memories. The current status of false memory will be reviewed, along with the proposed dual processes of activation-suppression in accounting for false memories. This will be followed by examination of a theoretical account of inhibitory control in both selective attention tasks and memory tasks, as well as the evidential support for the role of inhibitory control in memory tasks.

1.4 Inhibitory Control and Individual Differences in Memory Performance

One of the challenges of everyday life is to select and maintain accurate relevant information in the presence of a welter of irrelevant, competing, and potentially distracting influences (Tipper & Weaver, 2008). While the exact methods accounting for the extraction and later representation of information in memory are not clearly understood, it has been proposed that in everyday experiences these processes most often occur automatically and without conscious control (Conway, 2009, McDermott, 1996). Accurate memory can therefore be conceptualized as reliant upon automatic processes that enable information to be retained and recalled through activation of relevant internal representations while inhibiting competing yet irrelevant information (Roediger, Dudai, & Fitzpatrick, 2007). Within this context, false memories may arise from intrusions of activated competing representations, occurring as information is encountered, encoded, retained, or later recalled (Anderson, 2003; Anderson & Spellman, 1995; Howe, 2005; James, 1890).

Activation-suppression models of attention posit that when selectively attending to a target, an excitatory mechanism enhances or maintains an internal representation of the targeted information while an inhibitory mechanism actively inhibits or suppresses the initially activated internal representation of irrelevant distracters (Neumann & DeSchepper, 1991, 1992; Tipper, 1985). Of relevance to the present purposes, Neumann and DeSchepper (1992) demonstrated that the same inhibitory mechanism involved in selective attention performance may also function to suppress irrelevant distractors in memory tasks (see also, Neumann, Cherau, Hood, & Steinnagel, 1993). As spreading activation is characterized as a fundamental concept in the field of cognitive science, the possibility that an inhibitory counterpart acts in a similar manner would appear to be feasible (Neumann et al., 1993). For example, just as the strength of spreading activation has been found to increase as the semantic overlap between target items increases (Howe et al., 2009b) the efficacy of inhibitory control may also be impacted on by the extent of the conceptual overlap between target items and distactor items (Neumann et al., 1993). Therefore, by assessing individual differences in inhibitory efficacy in two selective attention tasks, the degree to which inhibitory efficacy is involved in the false memory effect associated with the DRM memory task may also potentially be assessed.

Inhibitory control in this sense refers to the ability to overcome competing information when responding to target information. For example, in a Stroop color-word interference task, a correct response to the targeted ink-color requires the inhibition of the automatically activated semantic meaning of the irrelevant color-word (Dalrymple-Alford & Budayr, 1966; Tipper & Weaver, 2008). Delays in response times are evidence of concurrent competition between the task relevant and task-irrelevant components of the stimuli. It follows that greater Stroop interference may be indicative of impaired inhibitory control. While effective inhibitory control is evident in reduced Stroop interference, the cost of effective inhibitory control can also be assessed in NP tasks when previously ignored stimuli become the target stimuli on the subsequent trial. Here, a benefit is followed by a cost in processing, but due to the same inhibitory control mechanism. Likewise, impaired inhibitory control is evident heightened Stroop interference when the semantic meaning of a color word competes with the ink-color it is printed in, but the cost due to impaired inhibitory control should be followed by a relative benefit in processing evident in reduced NP effects. Here a cost is followed by a benefit in processing, but again due to the same mechanism. Negative Priming effects are evidenced by delayed responses, or greater errors, or both, when the previously ignored semantic meaning of the color-word becomes the target response required on the subsequent trial (Dalrymple-Alford, 1966; Neumann & DeSchepper, 1991; for a review see Fox, 1995). It is arguably the case that if the semantic meaning of the prior color-word is less effectively inhibited when the font-color becomes the target, reduced response costs should occur (Neumann & DeSchepper, 1999; Tipper & Weaver, 2008). It may therefore be surmised that less effective inhibitory control should yield greater Stroop interference and reduced NP effects, whereas more effective inhibitory control should yield less Stroop interference and increased NP effects.

Although a widely held view contends that children have diminished inhibitory control when dealing with task-irrelevant distractors in selective attention tasks (Tipper, Bourque, Anderson, & Brehaut, 1989), it has recently been shown that such selective inhibitory capacities are intact in young children (Pritchard & Neumann, 2004, 2009; see also Bub, Masson, & Lalonde, 2006). For example, Bub and colleagues investigated whether younger children are more susceptible to Stroop interference due to a failure to suppress the irrelevant word dimension or an inconsistent application of the task. Sixty-five children 7- to 11-years old were tested on degree of Stroop interference as measured by both RT latencies and response accuracy (Bub et al., 2006). Stroop interference was determined by response latency in the incongruent condition compared to the neutral condition. Converging evidence of Stroop interference was evident in both increased response times to incongruent stimuli and increased errors. The results of Bub et al. (2006) suggest that young children are capable of suppressing the meaning of the color-word in order to respond to ink-color, with Stroop interference reported in both increased RT latencies, and higher error rates (Bub et al., 2006). Thus individual rather than age-related differences in inhibitory control can be detected utilizing selective attention tasks, such as the Stroop task.

A recent study by Pritchard and Neumann (2009) also provides evidence that NP effects are observable in both children and adults. Children as young as 5-years of age were found to demonstrate intact NP effects, with comparable rates of NP effects found between children, adolescents, and adults. Most studies examining the development of inhibitory control in children suggest inhibitory control abilities develop alongside maturation of the prefrontal cortex (Dagenbach & Carr, cited in Pritchard & Neumann, 2009. Pritchard and Neumann (2009) propose that the inhibitory control involved in Stroop interference resolution and NP effects may reflect cognitive processes that are independent of the development of the prefrontal cortex. In accounting for the discrepancy between studies investigating NP effects in children (Tipper et al., 1989), Pritchard and Neumann (2009) proposed that inhibitory control is mediated by a neural system responsible for automatic inhibitory processes that mature early in development, as opposed to neural systems responsible for intentional, effortful inhibitory processes that develop alongside maturation of the prefrontal cortex (see also Lechuga, Moreno, Pelegrina, Gómez-Ariza, & Bajo, 2006). Evidence of NP effects in young children might indicate that inhibitory control emerges early and acts automatically in suppressing mental representations of intrusive, potentially distracting information. While NP findings such as those of Pritchard and Neumann (2009) indicate similar rates of NP are found between young children, older children, and adults, it is also obvious from such research that inherent variations in NP effect occur within and across each age-group. This raises the possibility that individual differences in inhibitory control efficiencies may be detected in children and adults using Stroop color-word interference as well as a NP task.

Individual differences in inhibitory control efficiencies have also been reported in relation to selective attention tasks. For example, Neumann and DeSchepper (1992) found people display a range of efficiencies in ridding themselves of potentially interfering effects of competing, task-irrelevant information. Specifically, Neumann and DeSchepper found participants demonstrating a greater degree of inhibitory control experienced less impairment from task-irrelevant distractors in a selective attention task. The results of Neumann and DeSchepper's research led to the proposal that the same inhibitory mechanism that moderates performance in a selective attention task, may also operate in memory tasks (see also Neumann et al., 1993). For present purposes, this suggests that individuals can be ranked according to the degree of inhibitory control demonstrated in Stroop interference and NP effects, and thereby classified as having either less or more efficient inhibitory control. Moreover, individuals who demonstrate relatively greater inhibitory control in a selective attention task should also show evidence of heightened inhibitory control in a DRM task (Roediger & McDermott, 1995), by producing fewer false alarms, if the same or a comparable inhibitory mechanism operates in both. By identifying a cognitive mechanism potentially responsible for modulating false alarms in the DRM memory task, the current study may provide insight into a causal mechanism for the faulty creation of memories for events that never occurred.

1.5 Evidential Support for the Role of Inhibition in False Memories

Retrieval of information is just one example of a memory process requiring inhibitory control (Anderson, 2003). When information is retrieved from memory, the function of memory is to activate previously encoded relevant information, while the function of inhibitory control is to inhibit activated yet irrelevant information (Anderson, 1983; Anderson, 2003; Barkley, 1990; Neumann et al., 1993). As information is activated in memory, competition from related memory traces triggers inhibitory mechanisms (Anderson, 2003; Neumann et al., 1993). This process of inhibitory control in memory is also consistent with other cognitive domains, such as language comprehension (Gernsbacher & Faust, 1991; Gernsbacher, Varner, & Faust, 1990), and possibly executive control functions related to inhibition of responses (Anderson & Bell, 2001; Barkley, 1990; Lövdén, 2003). Age-related increases in false memories have also been suggested to occur as a result of the inability to differentiate between activation of relevant information and activation of related yet task-irrelevant information (Balota, Dolan, & Duchek, 2000; Roediger, Balota, & Watson, 2001). In addition, Sommers and Huff (2003) demonstrated that performance on the Stroop color-word interference test was related to susceptibility to false memories. In relation to the retrieval of semantically associated information, impaired recall results from an inability to effectively inhibit concurrently competing information, evident in experiments utilizing retrieval-induced forgetting (Anderson & Bell, 2001). Therefore, a higher rate of intrusions of semantically associated information is likely to reflect impaired inhibitory control.

Evidential support for the role of inhibitory control in language comprehension also comes from the work of Gernsbacher and colleagues (Gernsbacher & Faust, 1991; Gernsbacher & Robertson, 1999; Gernsbacher et al., 1990). Such research demonstrates that inhibitory mechanisms play a role in the retrieval of meanings of words. For example, when participants are presented with a stream of individual words in a sentence, initially information that is associated with the meaning or possible alternative meaning of a word is activated. When the context indicates the correct meaning, incorrect or irrelevant meanings are inhibited (Gernsbacher & Robertson, 1999). The process of inhibition of irrelevant and competing information is also evident in impaired performance. For instance, when presented with the sentence *He lit the match,* inappropriate meanings of the word “match”, such as *competition, corresponds,* or *equal,* are suppressed. The cost of this suppression is evident when participants are later required to determine whether the sentence *He won the match* makes sense. In this instance, Gernsbacher and Robertson’s research found participants produced considerably slower response times as a result of an inhibitory process (1999). While alternative explanations for such impairments have been proposed, explanations based on activation and decayed activation cannot account for the inhibitory cost evident in such research. For example, activation accounts suggest the alternative meaning of *match* should have decayed over time and not have impeded the subsequent comprehension decision (Gernsbacher & Robertson, 1999). Instead, they concluded that slower response times reflect inhibition of alternative or competing information applied at the time of study, or retrieval, or both.

To demonstrate the effect of competing information in the retrieval process, Anderson and Bell (2001) provide evidence from experiments utilizing retrieval practice. When participants practice retrieving some of the facts about a presented topic, inhibition of facts not practiced is seen in the impaired recall of non-practiced facts (Chan, 2009). For example, after reading a short paragraph about the Big Bang Theory, participants engage in retrieval practice by way of answering a series of questions, such as “After the Big Bang, gravity condensed clumps of matter together and these clumps eventually formed …?” (Chan, 2009). Of particular relevance to the current study, inhibition of related concepts is also found, such as impaired recall of topics containing similar concepts to the practiced items. While explanations based on limited attentional resources account for impaired recall of facts related to the topic, but not practiced, such explanations cannot account for impaired recall of facts related to non-practiced topics containing similar concepts (Anderson & Bell, 2001). Rather, in much the same way as visual selective attention allows objects to be attended to, inhibitory mechanisms may facilitate retrieval of active concepts by inhibiting or suppressing competing concepts (Neumann & DeSchepper, 1992). In this case, despite retrieval practice of studied items, highly activated non-studied competitor concepts that are inefficiently inhibited are more likely to intrude in recognition memory.

An example of inhibitory control in memory retrieval can be seen in the outcome of retrieval induced forgetting experimental designs (RIF). In this case, participants study a list of words or word pairs, followed by a practice session in which some of the studied items are retrieved from memory, either by way of word-stem or word-fragment completion tasks (Anderson & Spellman, 1995). When tested, as expected, participants showed impaired recall of unrelated items that are not practiced, but more importantly even more impaired recognition of non-practiced related words (Anderson & Bell, 2001, Anderson, 2003; Starns & Hicks, 2004). The ability to suppress interference from distractor information within RIF tasks is thought to be reliant on automatic or unintentional inhibitory processes with children and adults demonstrating comparable inhibitory control effects (Lechuga et al., 2006). Retrieval induced forgetting experiments provide further evidence that inhibitory control may be the mechanism by which memory is protected from intrusions of activated irrelevant information (Anderson & Green, 2001; Groome & Grant, 2005; Shilling, Chetwynd, & Rabbitt, 2002). Despite this evidence, research on the developmental aspects of inhibitory control in selective attention tasks remains limited (Pritchard & Neumann, 2009). While the research referred to above provides evidential support for the proposal that individual's can be ranked according to differences in effective inhibitory control, it is not known whether children who demonstrate ineffective inhibitory control on a Stroop color-word task would also demonstrate ineffective inhibitory control of critical lure items on the DRM word task, and in a similar fashion as adults who demonstrate ineffective inhibitory control.

If inhibitory control facilitates accurate memory recall (Anderson & Green, 2001), then a consistent prediction would be that those who show more effective inhibitory control of competing information, should also show more effective inhibitory control as a result of retrieval practice, and by extension should also show greater accuracy when required to recall information from memory. Evidence of an inverse relationship between the magnitude of RIF and memory accuracy has recently been reported (Groome & Grant, 2005). Groome and Grant compared the degree of RIF with scores on a cognitive failure questionnaire (CFQ, Broadbent, Cooper, Fitzgerald & Parkes, 1982). The results of their study indicated that the ability of individuals to inhibit irrelevant information may indeed be related to their cognitive performance in everyday life. Individual differences in inhibitory control may thus account for individual differences in memory performance (Anderson & Bell, 2001; Groome & Grant, 2005).

If inhibitory control aids recall by preventing intrusions into memory from irrelevant or competing information, then those with less effective inhibitory control should show higher rates of false recognition on tasks requiring inhibition or suppression of competing information, despite retrieval practice. For example, when participants study a short article containing a number of related facts about a particular topic, retrieval practice has been shown to increase accuracy and decrease intrusions of non-practiced information. The results of RIF experiments such as Chan's (2009), indicate that during retrieval practice, related yet not practiced concepts become activated, and are then inhibited in order to allow an accurate response. Retrieval practice therefore would appear to facilitate activation-suppression processes by way of strengthening activation of related items and increasing inhibition of irrelevant information.

Anderson and Bell (2001) suggest such errors occur during the process of recall when the ability to overcome interference from conflicting or distractor information relies on the ability to inhibit related, yet irrelevant, facts. While others suggest that activation of semantically associated yet non-studied information occurs at the time of study (e.g., Roediger & McDermott, 1995), it is also possible that activation and inhibitory processes play an important role in memory at the time of encoding, consolidation, or retrieval. In any case, it is possible that the intrusion of such information occurs as a direct result of the impaired ability to overcome conflict from competing information, in the same way that the impaired ability to resolve the conflict between color-words and font color results in heightened Stroop interference and reduced NP. The effect of impaired inhibitory control is especially evident in the retrieval of semantically associated information. According to Anderson and Bell, impaired recall results from an inability to effectively inhibit concurrently competing information, evident in increased false recognition of words or statements not previously presented (2001). The research outlined in this section indicates that inhibitory mechanisms play an important role in the facilitation of accurate retrieval of concepts, and inhibitory mechanisms also facilitate language comprehension by inhibiting inappropriate meanings.

1.6 Overview of the Current Study

The overall aim of the current study was to investigate whether inhibitory control mediates individual differences in false memories in children and adults. The first experiment compared rates of false memories of children 8- and 10-years of age, and adults, assigned to one of three inhibitory control groups. Inhibitory control was measured as the percentage of RT interference and error rates occurring when participants complete a Stroop color-word task. By calculating a percentage of RT interference between the mean of the median RTs of the incongruent versus neutral Stroop conditions, in conjunction with error rates, it enabled participants to be ranked according to their individual degree of interference in comparison to other participants. Individual participants were then assigned to a Less IC, a Mod IC, or a More IC group. All participants then completed a DRM word-list task comprising two list types, SW- and SPW-lists. Rates of intrusions of critical lure items, correct recognition of target words, and incorrect recognition of unrelated test items were compared across age and inhibitory control groups. Adults in Experiment 1 were assessed on the Stroop interference and degree of NP effect, to determine whether a combined index of inhibitory control based on Stroop interference and NP effect provides a more sensitive measure of inhibitory control than Stroop interference alone. The crucial findings of Experiment 1 indicated that children and adults assigned as less efficient inhibitors produced significantly higher rates of false alarms of critical lure items than those assigned as more efficient inhibitors. Experiment 1 also demonstrated that assigning adults to inhibitory control groups on the basis of a combined index of inhibitory control was a more fine-grained measure of inhibitory control than a single index of inhibitory control. This was evident in the magnitude of the discrepancy between rates of false alarms when adults were assigned to IC groups on the basis of a combined index of IC (Stroop interference and degree of NP effect), compared to those assigned on the basis of Stroop interference alone.

The second experiment aimed to replicate and extend the findings of Experiment 1, by comparing rates of false alarms between children and adults assigned to less, moderate, or more efficient inhibitory control groups. As with Experiment 1b, children and adults completed a Stroop and NP task, and were assigned to inhibitory control groups on the basis of degree of RT interference and error rates calculated as a single index or a combined index. All participants completed a DRM word-list task as in Experiment 1; however, participants completed a retrieval practice task between study and test phases. The critical findings of Experiment 2 replicated those of Experiment 1, in that those assigned as less efficient inhibitors produced significantly higher rates of false alarms than those assigned as more efficient inhibitors. Again, as with Experiment 1, a combined index of inhibitory control based on Stroop interference and NP effect was found to be a more sensitive measure than a single index. While retrieval practice was found to lower overall rates of false alarms, a significant difference between inhibitory control groups remained evident, thus extending the results of Experiment 1.

Experiment 3 examined whether differences in rates of false alarms would remain evident when participants studied DRM word-lists presented in a blockedized format: all words pertaining to a single word-list presented sequentially, followed by the next word-list, and so forth until five word-lists have been presented; compared to a randomized format: all words pertaining to one of five word-lists presented in randomized order. As it has been suggested that the presentation of individual items pertaining to a single word-list facilitates the automatic processing of semantic associations between list items and the critical lure item (Roediger & McDermott, 1995; Howe et al., 2009a; Watson et al., 2003), Experiment 3 aimed to determine whether presenting five DRM word-lists in randomized format disrupted the automatic processing of semantic associations between list items and the critical lure item. The critical finding of Experiment 3 indicated that while presenting five DRM word-lists in randomized order results in an overall reduction of false alarms, as with Experiments 1 and 2, a significant difference none the less remained evident between rates of false alarms between adults assigned as less efficient inhibitors and those assigned as more efficient inhibitors. The experimental design of presenting five DRM word-lists in randomized format appeared to be beyond the memory processing abilities of children 8- and 10-years of age. Correct and incorrect recognition of target and unrelated test items was near to or fell below the level of chance. Increased error rates were also found in adults, as across all three inhibitory control groups, higher rates of unrelated items were incorrectly recognized as previously studied words, and fewer target items were correctly recognized as previously studied items. Taken together, the results of Experiments 1, 2, and 3 suggest the presentation of semantically interrelated words enhances activation of a mental representation of the primary thematic associate of a word list. The successful inhibition of this activation could plausibly be the mechanism by which the CL is correctly identified as a new word (i.e., not a legitimate list item). For example, if the CL is effectively inhibited, the associated mental representation would be less active and less likely to be as active as real list words, and thus avoided in the recollection process. By extension therefore, less effective inhibition of this activation could potentially be a deficiency in this mechanism which enables the CL intrude into recollection, resulting in a false memory.

1.7 Summary

In summary, research relating to the occurrence of false memories indicates there is an apparent lack of understanding into why some children and some adults form false memories and why others do not. Importantly, few studies have examined the potential role of cognitive processes and how these may contribute to individual differences in children and adults and their propensity to form false memories. The current study will therefore examine the role of inhibitory control in selective attention tasks and in the ability to suppress activation of mental representations on a memory task. In this ways, it aims to isolate a potential cognitive mechanism responsible for the occurrence of false memories and an explanation for individual differences in false memories. More specifically, the dynamic interplay between excitatory and inhibitory mechanisms will be examined to determine whether it is possible that those who demonstrate less efficient inhibitory control may be more susceptible to false memories as they may be less able to automatically inhibit the spread of activation from studied list items to the non-studied, critical lure item (Neumann & DeSchepper, 1992). From this, it may be possible to extrapolate the finding that inhibition is the counterpart to spreading activation underlying Stroop interference and the NP effect (Neumann & DeSchepper, 1991) to that of individual differences in false memories in a DRM memory task.

As accurate recognition of information may be reliant on the ability to inhibit irrelevant information, then effective inhibitory control may also be evident in lower rates of false memories. In relation to the DRM word list task, since presentation of individual list items automatically activates the non-studied critical lure item (Howe et al, 2009a; Roediger & McDermott, 1995), the inability to effectively inhibit activation of the CL item is deemed to result in the intrusion of the CL into recognition memory. Thus, individuals who show less effective inhibition of the mental representation of color-words on the Stroop task and less NP effect may also show ineffective inhibition of the mental representation of the CL on the DRM task, which would be evident in higher rates of false alarms. Conversely, those who show more effective inhibitory control on the Stroop task and greater NP effect may also show more effective inhibitory control on the DRM word list task, which would be evident in lower rates of false alarms.

The primary aim of the current study is to investigate whether differences in rates of false memories on the DRM word list task can be determined on the basis of inhibitory control on a Stroop color-word and NP task. The specific predictions are: 1) Since successful resolution of a Stroop interference task may involve an inhibitory process (e.g., Dalrymple-Alford & Budayr, 1966), children and adults who show greater Stroop interference can be classified as less effective inhibitors, whereas those who show less Stroop interference can be classified as more effective inhibitors; 2) As NP effects may also involve inhibitory processes (Neumann & DeSchepper, 1992; Pritchard & Neumann, 2004, 2009), children and adults demonstrating less NP can be classified as less effective inhibitors, whereas children and adults demonstrating greater NP can be classified as more effective inhibitors; 3) regardless of age, those assigned to the less effective inhibitory control group will produce a higher proportion of false alarms on the DRM word list task; 4) while intervening retrieval practice between study and test will reduce overall proportions of false alarms, children and adults demonstrating less effective inhibitory control should continue to produce significantly more false alarms of critical lure items than those demonstrating more effective inhibitory control; 5) a higher proportion of *Remember* judgments in relation to false alarms will be evident for those demonstrating less effective inhibitory control, indicating that the critical lure item has remained activated resulting in its intrusion into recognition; 6) proportionally faster RTs to CLs within the context of *remember* judgments should also indicate greater confidence that the CL was a previously studied word.

Chapter 2: False Memories as Measured by the DRM Memory Task

While the role of inhibitory control in the generation of false memories has yet to be examined in the manner proposed by the current study, explanations of a higher rate of false memories found in experimental designs incorporating lists of semantically associated words, suggest inhibitory control may play an important role. The following section compares the theoretical accounts of activation, associative, and activation-suppression models of false memories, to determine which model provides a potential mechanism for the occurrence of false memories. This will be followed by a review of age-related differences and developmental trajectories in false memories. An explanation for the use of Remember judgments and RT latencies as a means of measuring individual differences in inhibitory control will also be provided, alongside an illustrative model of the dynamic interplay between activation and inhibitory processes in memory. Last, an explanation for the experimental manipulations incorporated within the current study will be outlined.

2.1 Activation, Associative, and Activation-Suppression Accounts of False Memories

To account for robust findings of high rates of false memories, Roediger and McDermott (1995) proposed that the intrusion of CL items occurs as a result of combined activation processes during encoding and retrieval phases. For example, as participants study words such as *bed*, *pillow*, and *blanket*, the non-presented word *sleep* becomes automatically activated through a process of spreading activation within a semantic network (Anderson & Spellman, 1995; Collins & Loftus, 1975; Howe, et al., 2009a; Roediger & McDermott, 1995). In conjunction with processes of activation at the time of study, the recognition of initial test words in the DRM memory task enhances the activation of the remaining semantically related list items, as well their thematically related concept.

Within this context, false alarms of the word *sleep* during a recognition test may also result from the spread of activation from tested list items to the non-studied concept of *sleep* within this semantic network (Collins & Loftus, 1975, Roediger & McDermott, 1995; Roediger, Neely, & Blaxton, 1983). Specifically, during the test phase participants again encounter items from the studied word list. This could then result in the same spreading activation from test items to the task-irrelevant primary thematic associate or CL, as occurred during the initial study phase. Put another way, false recognition of the CL *sleep* is primed by previous activation of words semantically related to the primary thematic associate of *sleep* as participants encounter list items. What is not clearly understood is whether inhibitory processes act on the CL item at the time of study (encoding) or at the time of test (retrieval), or a combination of both. For present purposes, it could be argued that accurate recognition of target words is reliant not only on effective inhibition of the activated CL at the time of study, but also when it is presented during the recognition-test phase. Inhibitory control in this sense would facilitate accurate recognition in much the same way that accurate responses on selective attention tasks requires the inhibition of concurrently competing information in order to quickly select and respond to target stimuli.

Theoretical explanations such as associative models of false memories (Howe, 2005), posit that the presentation of individual word lists comprising semantically related words causes the spread of activation between related concepts by way of a semantically associated network (Collins & Loftus, 1975). In this way, intrusions into memory of the word *sleep* is accounted for as individuals generate and process automatically activated associations within their knowledge base (Howe et al., 2009a).

However, an associative model provides only a partial explanation of false alarms, accounting for the process of activation and therefore intrusions of CL items, see Figure 2.1. Yet this model fails to account for incidences in which the CL is correctly identified as a new word or for individual differences in rates of false alarms to CLs.

An associative model does not account for the ability of individuals to overcome such activation, or why some individuals are better able to overcome intrusions from the activated CL item whereas others are not. On the other hand, a complementary activation-inhibition mechanism might account for both the intrusion of CL items and for individual differences in the rates of intrusions of CL items. Specifically, as individual list items are encountered, the mental representation of the CL item is activated and requires an inhibitory process in order to accurately recognize the CL item as a new word. In this way, it can be argued that the intrusion of the CL item results from the inability to resolve this competing interference. While an associative model provides an explanation accounting for increased rates of false alarms as the associative strength is manipulated between list items and CL items (Dewhurst, Bould, Knott, & Thorley, 2009; Howe et al., 2009a), this is not consistent across all individuals within such studies (Dewhurst et al., 2009; Howe et al., 2009a; 2009b; Roediger & McDermott, 1995; Watson et al., 2003). Therefore, lower rates of false alarms plausibly result from the ability of some individuals to successfully overcome activation of the CL item by way of inhibitory processes.

2.2 Individual and Age-related Differences in False Memories

While an associative-activation theory provides an explanation for the intrusion of CL items into memory, the cognitive mechanism accounting for the ability or inability to overcome such activation is less clear (Howe et al., 2009a), and is rarely addressed by researchers. For example, while individual and age-related differences in rates of false alarms to CL are often found, (for examples, see Dewhurst & Robinson, 2004; Howe, 2005; Watson, Bunting, Poole & Conway, 2005), explanations for lower rates of false alarms are often accounted for by way of mechanisms of activation (Meade, Watson, Balota, & Roediger, 2007), or mechanisms of retrieval (Luo & Craik, 2009). Those that do consider the role of inhibitory control tend to do so in the context of age-related differences between younger and older adults (Lövdén, 2003; Sommers & Huff, 2003). The current study is novel in that it examined the role of inhibitory control within the context of individual and age-related differences, and by doing so extends the theoretical accounts of false memories in manner that can be applied to the development of cognitive mechanisms in children and adults.

In relation to age-related differences, children typically produce lower rates of intrusions of CL items when presented with DRM lists, compared to adults. From such research it has been concluded that children are better than adults at avoiding false memories within the context of the DRM memory task (Howe, 2005; Howe et al., 2009a). However, closer examination of such research reveals that just as adults differ in rates of false memories (Clancy, McNally, Pitman, Schacter, & Lenzenweger, 2002), some children might be more effective in their ability to inhibit activation of CL items resulting in fewer false alarms. Therefore, while a developmental trajectory indicates adults produce higher rates of false memories than children, individual differences in inhibitory control in both adults and children may account for individual differences in the occurrences of false memories.

Research consistently demonstrates young children are less susceptible to false memories than older children or adults in situations when false memories are generated spontaneously, as reportedly occurs when participants study DRM word lists (Brainerd

& Reyna, 2005; Howe, 2005; Howe et al., 2009a; Howe et al., 2009b). Due to such findings, age-related differences in rates of false memories in the DRM memory task are thought to result from the interaction between the automaticity with which children process semantic relations between list items and the CL, the development of their semantic-knowledge base, and their cognitive abilities (Howe et al., 2009b). Of particular interest to the current study, Howe et al. also demonstrated that regardless of age, rates of false memories in younger and older children as well as adults increased as the number and strength of semantic associations between the CL and word-list items increased. In view of such results, the current study was designed to shed light on the variability of not only children, but also the propensity of adults to construct false memories by testing the hypothesis that inhibitory control plays an important role in the prevention of false memories.

In order to extend our knowledge of the underlying mechanisms accounting for false memories, the current study set out to replicate some of the findings of previous research within the context of an activation-inhibition framework (Alberts, 2005). Alberts observed that 8- and 10-year old children who demonstrated less effective inhibitory control also produced higher rates of false alarms of CLs. A question that arises is whether adults classified as less effective inhibitory control would also produce higher rates of false alarms of CLs. Therefore, the current study examined individual differences in inhibitory control and false alarms in children aged 8- and 10-years, as well as adults. Eight-year-old children were chosen to represent the youngest age group, but they were nevertheless deemed to have sufficiently advanced reading skills for such lists. Two versions of DRM word lists were selected for the current study (Watson et al., 2003, see Appendix A for examples of the two versions of DRM lists). This allowed a potential internal replication of individual differences in rates of false memories between groups (less versus more inhibitory control, and between 8-, 10-year olds, and adults).

The two different word lists also provided a within-group manipulation, allowing a comparison between inhibitory control groups in terms of susceptibility to false alarms when presented with either semantically related word lists (SW-lists), or semantically related word lists with additional phonological associates, referred to as semantic and phonological word lists (SPW-lists; Watson et al., 2003). Based on the findings of Watson and colleagues, higher rates of false memories are predicted when participants study SPW-lists compared to SW-lists. It is thought that the inclusion of words that are phonologically related to the critical lure increases the activation of critical lures during study, resulting in increased incidents of critical lure intrusions into memory during recognition tests. As the inclusion of phonologically related words within DRM lists may increase activation of CL items, it is also possible that those classified as less efficient inhibitors may have greater difficulty overcoming intrusions from CL items when presented with SPW-lists compared to those classified as more efficient inhibitors. .

Figure 2.1 illustrates how the inclusion of words phonologically related to the critical lure may increase activation of the non-studied CL item in SPW-lists. In this case, presentation of words such as *bed, soft, pillow,* alongside phonological associates such as *sheep*, *keep* and *beep,* cause activation of mental representations associated with bed, soft, pillow, and words that are phonologically related to the critical lure item *sleep,* in turn activating a mental representation of the concept *sleep*. As SPW-lists contain 13 items that potentially activate the critical lure item, SPW-lists may require a greater degree of inhibitory control in order for participants to correctly identify the CL item as a new word. The SW-lists contain only 10 items that potentially activate the CL item, and may require less inhibitory control. While higher rates of false alarms are expected when participants study SPW-lists, those demonstrating less effective inhibitory control may produce higher rates of false alarms than those demonstrating more effective inhibitory control.

Because each participant is presented with both versions of DR*M* word lists, it may be possible to detect differences between groups in terms of rates of false memories related to SPW-lists in comparison to SW-lists. For example, higher rates of false alarms to SPW-lists for both less and more efficient inhibitory control groups may indicate that the addition of words phonologically related to the CL item, along with words that are semantically related to the CL item, increases both the degree of activation and inhibitory control applied to the CL item. This pattern of increased excitatory and suppressive processes may be evident in higher false alarm rates to SPW-lists for those classified as less efficient inhibitors in comparison to those classified as more efficient inhibitors. Higher overall rates of false alarms to SPW-lists produced by children and adults would also replicate and extend the findings of previous research such as Watson and colleagues (2003). As associative strength has been found to play an important role in the production of false memories in adults and children (Howe et al., 2009b), and in accordance with associative–activation theory, the current study predicts an overall increase of both veridical and false recognition for both adults and children when studying SPW-lists.

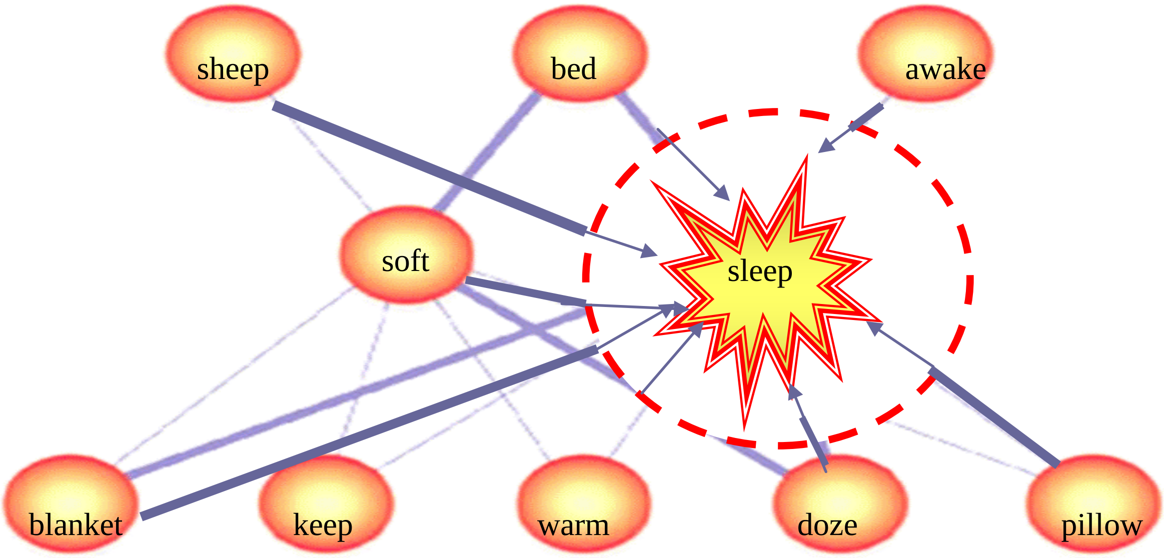

Figure 2.1 Schematic diagram of spreading activation from list words to the non-presented CL word sleep. Note: ⟶ activation, ▬ ▬ = inhibitory control.

2.3 Measures of Individual Differences

Along with assessing false memories by measuring false alarms to CL items on the basis of classification as less, moderate, or more inhibitory control, instructing participants to judge their subjective recollection of CL items provides an additional measure of individual differences in the susceptibility to form false memories. One method for assessing the strength of activation of CL items is to instruct participants to assess their subjective recollective experience of test items by way of *remember* and *know* judgments (Norman & Schachter, 1997, Tulving, 1985). In this case, *remember* judgments are considered to be a measure of vivid subjective recollection, whereas a *know* judgment is considered to be an estimate of familiarity (Tulving, 1985). Higher rates of *remember* in comparison to *know* judgments are said to occur as participants retrieve associative information about CL items in the same manner that they retrieve associative information about list items (Norman & Schacter, 1997). A robust finding reported by researchers is that of high rates of *remember* responses to CL items, indicating participants consciously recollect specific details of the CL as if it were presented at the time of study (Norman & Schacter, 1997). In line with an activation-inhibition account of memory, individuals who produce both high rates of false alarms and *remember* responses to CL items, could be said to be more susceptible to the automatic processes of activation and less able to effectively overcome such activation as the CL is presented at the time of the test. Therefore, another focus of the current study is on individual differences in *remember* judgments; *know* judgments were included to provide an alternative choice response, but are not included in analyses.

While target items are thought to be more strongly activated due to the automatic processing of associative links as list items are studied, it is likely that both targets and CL items vary in the amount or strength of activation associated with each item (Meade et al., 2007; Roediger & McDermott, 1995). To account for high rates of false alarms within the context of *remember* judgments, it has been suggested that participants set a criterion for the amount of memory evidence or activation, required for each item in order to make an “old” and *remember* responses (Starns, Lane, Alonzo & Roussel, 2007). For example, test items that exceed this criterion are responded to as “old” and those that fall below this criterion are responded to as “new”. In view of this, individuals identified as having less effective inhibitory control should show greater sensitivity in their propensity to respond “old” CL items, whereas those in identified as having more effective inhibitory control should show less sensitivity to respond “old” to CL items.

An important factor to consider is that it is typically assumed that the familiarity values of both hits and false alarms are normally distributed, with the mean of the target distribution above the mean of the CL distribution. However, during the test phase participants are presented with an unequal number of target items in comparison to critical lure items, with typical ratios of 5 target items to 1 CL item (e.g., Watson et al., 2003). In view of this, the current study examined the proportion of *remember* judgments to false alarms alongside the time taken to respond “old” to both target and CL items. The speed at which an individual responds across experimental conditions is assumed to reflect the time taken to process information and differences in cognitive abilities associated with the task at hand (Faust, Balota, Spieler, & Ferraro, 1999). For example, if an individual who demonstrates poorer inhibitory control shows faster response times when producing false alarms compared to an individual who demonstrates relatively better inhibitory control, then it could be concluded that faster response times for the first individual may be indicative of not only semantic priming effects (Faust et al., 1999), but also their inability to effectively overcome activation of crucial lure items resulting from semantic priming. More specifically, as proposed by the current study, differences in response latencies for individuals designated as less efficient inhibitors may be a direct result of the inability to inhibit automatic activation associated with CL items. In this way, just as those identified as demonstrating more effective inhibitory control by showing weak interference on the Stroop task, coupled with a strong NP effect (response latency cost when the previously ignored item becomes the subsequent target item), may also show a delay in response times to CL items associated with inhibitory mechanisms acting on activation of the CL.

While Faust and colleagues (1999) study did not involve RTs to a DRM memory task, the principles they outline are applicable to the current study. Specifically, interpreting differences between groups in terms of differences in overall response latencies may result in erroneously reaching the conclusion that individual’s within groups differ in terms of their cognitive abilities. In view of this, Faust et al. recommend transforming response latencies to reduce the risk of Type 1 errors. For example, as the time taken to complete a task may equate to the amount of information processing associated with the task, this relationship can be expressed in terms of a single number allowing a comparison of differences between groups in respect to their overall cognitive speed and amount of processing applied to the stimuli as a function of their inhibitory control abilities.

Assessment of an individual's performance on a task is partially reliant on the ability to accurately measure the ability to correctly detect a target (referred to in this sense *signal* strength), the ability to overcome distractor information (referred to in this sense as *noise*). For example, individual performance on recognition tasks is often characterized by the discrepancy between the number of hits (correctly recognizing target test items as a previously studied list items), unrelated intrusions (incorrectly recognizing unrelated test items as previously studied list items), false positives or false alarms (incorrectly recognizing critical lure items as previously studied list items), and correct rejection (correctly recognizing a critical lure or unrelated test item as not previously studied (Macmillan & Creelman, 1991). Due to the fact that rates of false alarm are often found to be similar to hit rates in the DR*M* paradigm, examining higher hit rates in isolation is not necessarily indicative of accurate memory performance (Macmillan & Creelman, 1991). Likewise, examining high false alarm rates in isolation may not necessarily be indicative of less accurate memory performance. It is therefore necessary to utilize a means of discriminating between an individual's propensity to correctly recognize target items from their propensity to produce false alarms, and their propensity to produce errors in general.

In order to interpret individual differences in response time latencies and ratings of false *remember* responses, a number of important factors were considered. First, research indicates children may produce slower overall response times than adults due to slower speeded mental processing abilities rather than changes within a particular cognitive domain (Pritchard & Neumann, 2009). Therefore, an age-group by experimental condition interaction, based on raw response time (RT) data, may represent an over additive effect of speeded mental processing abilities. In order to overcome this and consistent with previous research, RT data were transformed via a *z*-score transformation in accordance with Faust et al. (1999). Second, a discriminability index score was calculated for each individual to allow a comparison between groups on the basis of mean transformed RT distributions to false alarms in relation to correct recognition of test-items.

One method of measuring differences between groups in terms of susceptibility to produce false alarms is to utilize measures such as recognition discriminability. Discriminability in this sense refers to the ability of an individual to distinguish target words from distractor words, or *signal* from *noise* (Macmillan & Creelman, 1991). The current study utilizes the Signal Detection Theory parameter *d'*. Importantly, *d'* provides a discriminability index as a single measure of overall recognition performance, by way of accounting for an individual's propensity to correctly recognize target items relative to their propensity to produce false alarms.

2.4 Manipulating Rates of False Memories through Experimental Design

Early observations of learning suggested that repeatedly studying information aided later recall (Ebbinghaus 1885, cited in Karpicke and Roediger, 2007). Test procedures are commonly used to assess how much information has been learned and retained; however, as Tulving (1967) points out, the test phase itself provides another opportunity for learning (Karpicke & Roediger 2007). In view of Tulving's work, Karpicke and Roedigier examined whether repeated study or repeated testing increased accurate recognition. Their results confirmed those of Tulving, in that repeated testing rather than repeated studying enhanced retention of information, leading these authors to conclude that testing in itself is a powerful means of improving recognition. An interesting finding of the effect of repeated learning is that while correct recognition or recognition may improve, rates of false alarms to CL items also consistently continue to increase (Gallo, 2004). In this instance, Gallo found no evidence of reduced false recognition following recognition of previously studied items (2004).

As mentioned, previous research has suggested the false memory illusion in the DRM memory task arises from the activation of associations between list items and the CL at the time of study (Dewhurst et al., 2009). However, as Roediger and McDermott point out, during free recall participants are more likely to recall CL items towards the end of the test phase (1995; Dewhurst et al., 2009). By manipulating the opportunity of participants to form associations between list items at the time of study, Dewhurst and colleagues were able to demonstrate the crucial role of the initial activation of CL item following the presentation of study items. Participants were presented with semantically associated items in either a blocked format or in randomized format. In blocked presentation formats, participants are presented a word list, one word at a time, with each list containing words relating to one primary thematic associate. In a randomized format, participants study words from a number of DRM word-lists presented in random order, in this case the words presented relate to more than one primary thematic associate. Of interest to the current study, is the finding that presentation mode influences rates of false recognition of CL items, with higher overall rates of false alarms when words are presented in a blocked format (Dewhurst et al., 2009). This increase, due to blocking, was interpreted as resulting from processes that automatically generate associations between target items and CL items.

As can be seen in Table 2.1, the findings of a number of studies provide evidential support for the experimental manipulations and measures of interest utilized by the current study. For example, Howe et al. (2009b) found an overall increase in false alarms as the associative strength between individual list items was increased. This was found to occur for all age groups, with 8-year olds also demonstrating increased rates of false alarms as a result of increased associative strength. Karpicke and Roediger (2007) demonstrated the process of testing memory is itself a means of improving memory, with repeated testing acting as form of retrieval practice. While a number of potential explanations could account for such findings, one possible explanation in line with an activation-inhibition account of selective attention, is that impaired inhibitory control accounts for the relatively high rates of false alarms that were found to persist despite retrieval practice (Gallo, McDermott, Percer, & Roediger, 2001; Watson et al., 2004), ranging from a mean of .31 for younger adults following 5 study-test trials, to a mean of .58 for older adults. As mentioned previously, Dewhurst and colleagues (2009) found higher rates of false alarms when participants were presented with DRM word lists in blocked format, with lower rates of false alarms when participants are presented with a number of DRM word lists presented in randomized format. While reliable reports of participants subjectively rating false alarms as “remembered” events are typically observed in the DRM paradigm, Jou, Matus, Aldridge, Rogers, and Zimmerman (2004) also found that participants produced faster RTs when confidently rating false alarms as previously experienced, and slower RTs when less confident. Faust and colleagues suggest SDT allows for a comparison of RTs in a manner that accounts for variations in speeded responses between individuals and within groups (1999). By utilizing SDT, differences in RTs can be attributed to the cognitive processes applied when participants respond to stimuli, such as less or more effective inhibitory control. Lastly, Toglia Neuschatz, & Goodwin (1999) demonstrated the persistence of the false memory illusion despite experimental manipulations decreasing the opportunity for participants to automatically form associations between list items.

Table 2.1: *Outline of FAs as assessed by DRM based research*

Author(s)	Measures	Summary of Results
Howe et al., 2009b	12, 15-item lists (6 DRM lists, and 6 category lists)	1) A linear trend of lower rates of false recall in younger children, compared to older children, and in comparison to adults. Higher rates of FAs in DRM lists compared with category lists. 2) Regardless of age, FAs were contingent on variations in associative strength between list items and CLs.
Karpicke & Roediger, 2007	Sixty unrelated words.	Repeatedly studying items did not increase accurate recall, whereas repeated retrieval practice by way of testing enhanced accuracy rates.
Watson et al., 2004	Four 15-item DRM word lists	An age-related dissociation: younger adults benefited from retrieval practice, e.g., lower FAs, older adults showed no benefit from retrieval practice, e.g., higher FAs.
Jou et al. 2004	DRM Word Lists Remember and RTs	Found participants produced faster RTs when subjectively rating a response as more confident, and produced slower RTs when rating a response as less confident.
Faust et al., 1999	Slowed Response Times	Utilising Signal Detection Theory parameter *d'*, the relationship between RTs and responses provides a comparison of cognitive processing as a function of inhibitory control.
Dewhurst et al., 2009	20 DRM & 20 Categorized Lists vs. Randomized Lists.	False memories produced by DRM and Categorized lists are influenced by associations between lists items and the CL activated at the time of study. Consistently higher rates of FAs were found for DRM lists compared to Categorized lists.
Toglia et al., (1999)	DRM word lists in blocked or random presentation order.	Increased rates of false alarms to critical lures following blocked presentation format.

Note: DRM = Deese/Roediger & McDermott word list task, CL = Critical Lure item, FA = False Alarms to CLs, RTs = response times

2.5 Summary

In summary, while modifications to the DRM procedure used by other researchers should provide key insights, the most important and novel component of the present study is the inclusion of measures of inhibitory control. Inhibitory control in this sense should facilitate accurate recognition in that those who demonstrate more effective inhibitory control should produce fewer FAs to CLs in the DRM memory task. The current study suggests that this occurs in much the same way that accurate responses on selective attention tasks requires the inhibition of concurrently competing information in order to quickly select and respond to target stimuli. However, differences between those identified as less or more effective inhibitors of competitive, task-irrelevant information, should be restricted to FAs, whereas similar rates of veridical recognition should occur for target items. Inhibitory control as defined in the current study should only moderate task-irrelevant information that intensely conflicts with targeted information. The hypothesis of interest was whether children and adults classified as having less inhibitory control on both the Stroop and NP tasks would produce more false memories than children and adults classified as having more inhibitory control. Such findings would indicate that memory falsification might be an outgrowth of inhibitory control capacities – the sort of inhibitory capacity whose function is to resolve the conflict in Stroop-like selective attention and negative priming tasks (Dalrymple-Alford & Budayr, 1966; Neill & Westberry, 1987; Neumann & DeSchepper, 1991).

Activation and associative models provide a partial explanation of false alarms, accounting for the process of activation and therefore intrusions of CL items. However, both of these models fail to account for individual differences in rates of false memories. Examination of an activation-suppression model of memory processes provides a potential mechanism for the intrusion of semantically related concepts activated during encoding, retention and/or retrieval of information. The current study argues that it is the inability to suppress or inhibit the activation of the semantic concept of the DRM word list that results in individuals incorrectly identifying the CL item as a previously studied word. Put another way, the cognitive processes of activation and suppression act together in a dynamic manner to enhance veridical recognition of list items, and to prevent intrusions of CLs. However, it is on the basis of inhibitory control that higher rates of intrusions of CLs are predicted for those who demonstrate less effective inhibitory control.

Research that examines individual differences in rates of false memories typically examines such differences in younger versus older children, or children versus adults. For example, Dewhurst and Robinson (2004) found children aged 5-years produced fewer FAs to CLs in a DRM procedure than 8-year olds and 10-year olds. In relation to age-related differences, children are typically found to produce lower rates of intrusions of critical lure items when presented with DRM lists, compared to adults. On the basis of such research, it has been concluded that children are better able than adults to avoid false memories in relation to DRM word lists (Howe, 2005; Howe et al., 2009a). However, just as adults differ in rates of false memories (Clancy et al., 2002), it is also possible that some children, may be more effective in their ability to inhibit activation of CL items, resulting in fewer false alarms of strongly activated CL items. Individuals who demonstrate less effective inhibitory control should also show a greater propensity to rate false alarms to CL items as remembered events, as they are likely to be less effective in their ability to overcome automatic generation of associative activations and thoughts of CL items along with target items.

Chapter 3: Rationale, Aims and Hypotheses

As demonstrated in the previous section, research clearly indicates younger children produce lower rates of false alarms when presented with DRM word lists. Consistent with an activation-suppression account, inhibitory control may be the underlying mechanism accounting for individual differences in false alarms to CLs in the manner that inhibitory control accounts for individual differences in performance on selective attention tasks. In the following section, the rationale for comparing rates of false memories in children aged 8- and 10-years with those of adults will be provided. This will be followed by the rationale for including the measures of inhibitory control used in the current study. The rationale for including retrieval practice as an experimental manipulation will also be outlined. Last, the specific research questions related to each experimental manipulation and the predicted outcome will be provided. This section will conclude with the detailed hypotheses tested in relation to each experiment.

3.1 Comparing Rates of False Alarms in Younger Children (8-years of age) and Older Children (10-years of age), with Adults.

The current study aimed to extend the findings of previous research by demonstrating that rather than developmental trends accounting for individual differences in false alarm rates, inhibitory control also plays an important role in mediating differences within and across age groups. Brainerd, Reyna, and Ceci’s (2008) review of developmental trends evident in false memory research using the DRM task found consistent evidence of higher false alarm rates in adults compared to older children, with younger children demonstrating significantly fewer overall false alarms than older children and adults. These authors suggest that paradigms which make use of the associative connectivity between list items and the CL item, allow predictions regarding developmental differences in false memories. Specifically, it is likely that younger children have restricted development of semantic associations between list items, in comparison to older children and adults. Lower rates of false memories to DRM lists would reflect this limited ability of younger children to automatically generate associative links between list items. However, as researchers such as Pritchard and Neumann (2009) have demonstrated that even children as young as 5-years of age show NP effects, it is also feasible that individual differences in inhibitory control will be evident within age groups. Therefore, while adults are expected to produce higher overall rates of veridical recognition of target words along with higher rates of FAs than children, regardless of age, a reliable pattern of higher overall rates of FAs to CLs is expected associated with inefficient inhibitory control. The question to be answered is, would children 8- and 10-years of age, and adults, demonstrating less efficient inhibitory control, also produce significantly higher false alarm rates than children and adults demonstrating more efficient inhibitory control? If so, this would indicate that developmental differences alone cannot account for differences between children and adults in relation to rates of false alarms and veridical recollection.

While adults may demonstrate higher accuracy rates in recognition of target items, this does not coincide with lower rates of false memories. Instead, higher accuracy rates appear alongside higher rates of false memories. This trend is also evident across age groups. While younger children produce fewer false memories to DRM lists, they also recognize fewer target items, whereas, both higher false alarm rates and recognition of target items are found in older children. In view of this, the current study predicts that higher rates of false alarms to CLs resulting from ineffective inhibitory control should be evident in those assigned to the Less IC Group compared to those assigned to the More IC group. Importantly, there should be little or no difference in the correct recognition of target items between groups, nor should those assigned to the Less IC group produce higher intrusion rates of unrelated test items than the More IC group. Should this pattern of results emerge, it would indicate that the propensity to form false memories is not an outcome of a generalized trend to produce errors. By comparing false alarm rates between children 8- and 10-years of age and adults assigned to a less efficient inhibitory control group, against those assigned to a more efficient inhibitory control group, it will allow further examination of developmental trends in relation to the DRM memory illusion.

The inclusion of DRM word-lists containing words both semantically and phonologically associated to the critical lure item will allow further examination of the role of inhibitory control in relation to developmental trends. For example, Brainerd et al. (2008) suggest manipulations in the automatic generation of semantic associations between list items should also be reflected in differences in rates of false memories in adults and older children, but not necessarily in younger children. As Dewhurst and Robinson (2004) found lower rates of false memories in younger children when DRM word lists contained phonologically associated words, it is expected that children aged 8-years, regardless of inhibitory control, are likely to produce lower overall rates of false alarms than older children and adults. False alarms to CLs in the DRM word-list task are thought to occur as a result of activation of interconnected semantic networks, and younger children are thought to have yet to fully develop such semantic networks. In this way, 10-year old children and adults assigned to the Less IC group should produce similar rates of FAs to CLs associated with SPW-lists than SW-lists. Children aged 8-years assigned to the Less IC group are not expected to produce higher rates of FAs to SPW-lists in comparison to SW-lists, as they have yet to form complex, interconnected semantic networks, in the same manner as children aged 10-years and adults appear to (Dewhurst & Robinson, 2004). As Watson et al. (2003) found higher false alarm rates when participants studied DRM word –lists containing both semantically and phonologically associated words (SPW-lists), it could be argued that the addition of phonologically associated words increases the automatic generation of associative links between list items and the CL item. This increase in activation between semantic and phonologically associated list items may in turn result in an increase in the accuracy of adults and older children in their recognition of target items, and in their false recognition of CL items.

Anastasi and Rhodes found developmental differences in rates of false memories (2008). These authors developed word lists designed to be appropriate for the reading level of children aged 5 to 8 years. One half of the participating adults and children studied 6 adult-normed lists followed by 6 child-normed lists; with the remaining participants studying the same 12 lists in the opposite order. Results of this research showed that younger children produced lower rates of false memories compared to older children, with adults showing an even greater increase in false memories. Howe et al. (2009a), and Howe et al. (2009b), have also demonstrated that younger children appear to be less susceptible to the DRM false memory illusion. For example, Howe et al. (2009a) found fewer that CLs were falsely recognized by 7-year olds (.48) than by 11-year olds (.57). Holliday et al. (2008) also found a similar pattern of increasing rates of false memories across five age groups.

Howe et al. (2009b) suggest that the development of knowledge over time and experience, coupled with increased cognitive abilities accounts for age related differences in FAs. Howe et al. (2009b) also suggest that younger children are better able to prevent critical lure items in DRM word lists from intruding into recognition memory, as they are less likely to automatically process and generate associative links between presented list items and non-presented CLs. In contrast, research consistently shows that older children and adults automatically generate such associative connections. As such, increasing age is said to be associated with less cognitive effort in the automaticity involved in the processing of associative links between list items and CLs. Howe et al. (2009a) point out that research consistently finds factors influencing encoding, consolidation, storage, retention and retrieval in younger children also regulate memory processes in older children and adults. In addition, Howe et al. (2009a) conclude that the production of false memories in younger children can be accounted for by the same processes accounting for false memories in older children and adults.

3.2 Rationale for Comparing Rates of False Alarms on the Basis of a Combined Index of Inhibitory Control.

Inhibitory control may be measured on the basis of resistance to Stroop interference, and has been adopted to ascertain individual differences in attentional processes across typical and atypical populations (see Pritchard, Neumann, & Rucklidge, 2008). The results of Neumann and DeSchepper (1992) suggest that individuals actively inhibit potentially distracting information when identifying or responding to target information in selective attention and memory tasks. In both cases, information that has been actively inhibited should subsequently become more difficult to process. For example, when presented with incongruent Stroop stimuli, accurate responses require active inhibition of the semantic meaning of the distracting color-word in order to respond to the ink color. Likewise, when presented with DRM test lists, it is plausible that accurate responses may require the active inhibition of the associated, yet irrelevant, semantic theme of the DRM word list, which in this case is the critical lure item.

The effect of inhibitory control can also be measured when participants are required to respond to information that was previously ignored. For instance, in a negative priming task, information that is ignored on the prime trail becomes the target information on the following probe trial. Efficient inhibitory control in a NP task would be evidenced by NP effects as measured by the proportional degree of RT latencies, and higher error rates in IR probe trials in comparison to control probe trials (Neumann & DeSchepper, 1992; Tipper, 1985). As NP tasks provide an objective measure of cognitive functioning (Fox, 1995), less efficient inhibitory control should be evident in reduced NP effects. If inhibitory control is genuinely involved in Stroop interference resolution and NP effects, then assigning individuals to less, moderate, or more effective inhibitory control groups on a combined index should provide a more fine-grained measure than a single index.

Research exploring developmental differences in the ability to ignore distractor information has reliably demonstrated NP effects in young adults (Neumann, McCloskey, & Felio, 1999; Tipper & Driver, 1988). Likewise, research has firmly established that older adults show similar rates of NP as younger adults; just as young children have also been found to show NP effects (see Pritchard & Neumann, 2009). By comparison, older adults have sometimes been found to have greater difficulty in ignoring distractor information (Lövdén, 2003). Discrepancies in NP effects between younger and older adults have also been reported, with some researchers suggesting that aging processes may impair inhibitory mechanisms. For example, a meta-analysis of NP research found older adults demonstrate decreased NP effects in comparison to younger adults (Verhaeghan & De Meersman, 1998). A more recent meta-analysis contradicts this stance, as Gamboz, Russo, & Fox (2002) found identical amounts of NP in younger versus older adults. Research examining developmental differences in inhibitory control in children has also produced conflicting results (Pritchard & Neumann, 2004). As reliable evidence of NP effects in children have been reported, this would suggest that the ability to inhibit conceptual information is intact by the age of 5-years (Pritchard & Neumann, 2004).

3.3 Rationale for Comparing False Alarms following Retrieval Practice

It has been proposed that the correct retrieval of a studied word during a test phase is reliant on dual processes; that of maintaining memory representations of the exact word as well as inhibiting competing or distractor information (e.g., Levy & Anderson, 2002). Accordingly, an activation-suppression model suggests that during retrieval of words, activation to competitive task-irrelevant concepts, such as semantically related non-presented words, must be inhibited by way of deactivation of competing representations in memory (Starns & Hicks, 2004). For example, repeatedly retrieving information from memory increases accurate recognition through priming effects, or repeated activation of target items (Huber, Cark, Curran, & Winkielman, 2008). Therefore, when a practice phase is utilized, items that compete with retrieval of target words during the practice phase should be inhibited, resulting in a decrease of false recognition of non-presented semantically related words during the test phase (Starns & Hicks, 2004).

3.4 Specific Aims and Hypotheses for Experiments 1, 2, and 3

Against this background, the following section outlines the research aims and hypotheses relating to each experiment. In all experiments, the primary interest was in rates of FAs to CLs between children and adults assigned to the Less IC group than those assigned to the More IC group. Those assigned to the Mod IC group were not included in the analysis of FAs, as they do not clearly demonstrate less or more effective inhibitory control and therefore could not be easily assigned to the Less or More IC groups.

Experiment 1: *Aims.* As research has already established age-related differences in false memories in DRM list, why compare differences in rates of false memories between younger children, older children and adults? The current study aims to extend such research by demonstrating that age alone is not the only factor contributing to susceptibility to false memories. Specifically, Experiment 1 aimed to establish whether individual differences in rates of false memories can be detected on the basis of inhibitory control. Experiment 1 also aimed to define inhibitory control in children and adults as measured by either Stroop interference, or combined Stroop and NP effect. This provided a means of comparing whether a single index or a combined index provided a more fine-grained measure of inhibitory control.

Experiment 1: Hypotheses. While adults were expected to produce higher overall rates of false memories than children, it was predicted that 8- and 10-year olds who demonstrate less effective inhibitory control should produce similar trends in rates of FAs, with both Less IC children and Less IC adults producing more FAs than the More IC group within each age group. In this way, differences in rates of false memories between groups classified on the basis of inhibitory control and age should provide convergent evidence of fully developed inhibitory control in young children. Those that produce higher rates of false memories were also predicted to produce similar rates of accurate recognition, and not to produce higher rates of intrusions of unrelated test items. In this case, the classification of inhibitory control should demonstrate that the propensity to produce higher rates of false memories alongside accurate recognition of targets results from the inability of those demonstrating less inhibitory control to overcome competition from the automatically activated CL.

Importantly, the absence of significant differences in hit rates of target items, or intrusions of unrelated test items will provide support for the argument that false memories arise from inefficient inhibitory control rather than a general error in memory processes.

Experiment 2: Aims. The primary aim of Experiment 2 was to examine whether engaging in retrieval practice between study and test phases would reduce overall rates of false alarms to CLs. And, more importantly, whether the propensity to false alarms differs as a function of inhibitory control regardless of retrieval practice. Experiment 2 also aimed to determine whether children and adults classified as having less effective inhibitory control were also more likely to confidently rate their judgment of the CL as a previously studied word as a remembered event. In addition, Experiment 2 aimed to verify that a combined index of inhibitory control provides a more sensitive measure than a single index. Finally, Experiment 2 aimed to examine differences in RTs to target words and CLs as a function of inhibitory control, and whether faster RTs to CLs occur as a result of participants' inability to overcome activation of CL.

Experiment 2: Hypotheses: As with Experiment 1, it was predicted that children and adults demonstrating less efficient inhibitory control on the basis of Stoop interference and combined Stroop interference and Negative Prime effect should produce higher rates of false alarms to CLs than children and adults demonstrating more inhibitory control. More importantly, despite engaging in retrieval practice, children and adults demonstrating less inhibitory control should produce higher rates of false alarms than those demonstrating more inhibitory control. Examination of *remember* and *know* judgments was expected to provide evidential support for the hypothesis that the rating of a FA as a remember event is associated with inhibitory control. Children and adults demonstrating less effective inhibitory control were predicted to show a greater propensity to judging CLs as *remember* events, than those children and adults demonstrating more effective inhibitory control. Children and adults assigned to the Less IC group were also expected to produce faster RTs to CLs in relation to RTs to target items, than those assigned to the More IC group.

Experiment 3: Aims. The primary aim of Experiment 3 was to determine whether overall higher rates of false alarms to CLs would be found in those demonstrating less inhibitory control despite varying presentation format, whereas those demonstrating more inhibitory control should show a reduced propensity to false alarms when word lists are presented in randomized format. By manipulating the ability to form associative links between list items, by way of word lists containing both semantically and phonologically related words, this may allow greater distinction between differences in age and inhibitory control in relation to false memories to CLs. Also, Experiment 3 aimed to investigate whether differences in RTs to target words and CLs vary between three different DRM presentation procedures: Experiment 1 which included a filler task between presentation of a DRM list and the recognition test, Experiment 2 which included retrieval practice rather than a filler task, and Experiment 3 in which DRM lists were presented in blocked and randomised presentation formats, without a filler or a retrieval practice task.

Experiment 3: Hypotheses: The primary hypothesis was that while overall higher rates of false alarms to CLs were expected when DRM word lists were presented in Block versus Random presentation formats, those assigned to the Less IC group would continue to produce higher rates of false memories than those assigned to the More IC group.

3.6 Summary

Given the findings described above, the current study predicts that a developmental trajectory of lower false alarms will be found in children 8-years of age compared to children 10-years of age, with adults producing the highest rate of false alarms. Despite age-related differences, inhibitory control was predicted to differentiate susceptibility to false alarms within age groups. Also, children 8- and 10-years of age and adults who demonstrate less effective inhibitory control were expected to produce higher rates of false alarms than children and adults demonstrating more effective inhibitory control.

Extensions of the evidence outlined above suggest that individuals who are more effective at actively inhibiting distracting information should produce fewer intrusions of distracting information into recognition memory. In relation to selective attention, resolution of interference from competing task-irrelevant information is said to be reliant on effective inhibitory control. Such conflict is apparent on the Stroop task when the semantic meaning of the color-word conflicts with the target response when it is the ink-color. Therefore, regardless of age, those that demonstrate less Stroop interference should also produce fewer intrusions of CLs on the DRM task due to more effective inhibitory control. Those, who are less effective at actively inhibiting distracting information on a Stroop task, should also produce higher rates of intrusions of distracting information such as CL items. Likewise, NP has been suggested to produce interference from previously inhibited information when the task requires a response to previously ignored information. Greater negative priming effects arise when the benefit of effective inhibition of a distractor item in a preceding trial is followed by a cost in processing, due to the same inhibitory control mechanism. On the other hand, reduced negative priming effects arise as the cost of ineffective inhibition is followed by a benefit in processing, again due to the same inhibitory control mechanism. Therefore, those who show greater resistance to Stroop interference and greater NP effect should also show fewer intrusions of critical lure items. On the other hand, those who show less resistance to Stroop interference and less NP effect should also show higher intrusions of critical lure items. In this way, a combined Stroop Interference and NP effect index may provide a finer-grained measure of inhibitory control, and therefore may allow detection of greater differences in the propensity of individuals to form false memories regardless of developmental processes.

It was expected that children and adults demonstrating more effective inhibitory control would show a greater benefit from retrieval practice evident in a reduction in false alarms. Conversely, those who demonstrate less effective inhibitory control were not expected to benefit from retrieval practice in the same manner, evident in less of a reduction in false alarms. Of interest to this study is whether children and adults who demonstrate less inhibitory control would show a reduction in rates of false memories when a practice phase is included. Also of interest, is whether reduced false alarms would coincide with increased hits to target items when children and adults engaged in retrieval practice prior to a test phase.

Three primary hypotheses were tested in the current experiments: (1) On the basis of recent research (Brainerd & Reyna, 2004; Brainerd, Reyna, & Forrest, 2002; Dewhurst & Robinson, 2004; Howe et al., 2009b), these experiments aimed to determine if the typical developmental trajectory of increased rates of false alarms would be replicated, or whether individual differences in inhibitory control would moderate differences in rates of false alarms. Specifically, overall adults were expected to produce higher rates of false recognition of CLs than 10-year-old children, who were also expected to produce higher rates of false recognition of CLs than 8-year-olds (Howe et al., 2009a). (2) More importantly, evidence of a developmental trajectory of false alarms was expected to systematically vary as children and adults were assigned to less and more effective inhibitory control groups. In this case, irrespective of age, children and adults who demonstrate less efficient inhibition were expected to produce higher false alarm rates of critical lures, than their more efficient counterparts (Conway, 2009). (3) Finally, it is predicted that while a general decrease in rates of false alarms would be observed when retrieval practice was incorporated (McBride, Coane, and Raulerson, 2006), children and adults who demonstrate less effective inhibitory control would continue to produce higher false alarm rates for critical lures than their more efficient counterparts.

Chapter 4: Method

The following section outlines the general method used in Experiments 1, 2, and 3. Where variations to this occur, this will be outlined in detail in relation to the relevant Experiment.

4.1 Materials and Design Stroop Color-word Interference Task.

As mentioned, a variation of the Stroop color-word task was utilized in the current study. This consisted of an incongruent condition, comprising the color-words, *blue*, *red*, *yellow*, or *green* presented in one of the other of these four ink colors (e.g., blue presented in red font), and a neutral condition comprising non-word letter strings (e.g., *juchw*, *zopt*, etc.) presented in blue, red, green, or yellow ink. All words and random letters strings were presented in Arial size 48 font in the centre of a computer screen against a black background. There were ten practice trials and 300 test trials, of which 50% were incongruent and 50% were neutral, presented in random order by way of SuperLab Pro™, Version 2.0, software. Median reaction times (RT) and error rates were tabulated by way of Microsoft© Office Excel©.

4.2 Inhibitory Control Measures Involving Stroop and Negative Priming Tasks

Stroop interference consisted of the proportional difference in RTs and error rates between incongruent trials and neutral trials (i.e., mean RT in the incongruent condition minus mean RT in the neutral condition divided by 1000). Percentage of Stroop interference ($Stroop_{rank}$) was calculated on the basis of the mean of median RTs to incongruent minus the mean of median RTs to neutral trials multiplied by 1000. Percentage of error rates were calculated in a similar manner according to mean error rates in the incongruent condition minus mean error rates in the neutral condition divided by 1000 ($Error_{rank}$). A proportional Stroop interference score was then calculated for each individual on the basis of a combined ranking by adding Stroop interference and error rate rankings ($Stroop_{rank}$ + $Error_{rank}$).

The Negative Priming effect was calculated for individual in much the same way. The Negative Priming effect consisted of the proportional difference in RTs and error rates between IR probe and control probe trials. The percentage of NP effect was calculated on the basis of the mean of median RTs to IR probe trials minus the mean of median RTs to control probe trials, coupled with the proportion of errors in NP probe trials (NP_{rank} + NP $Error_{rank}$). A proportional Negative Priming effect score was then calculated for each individual participant.

4.3 Materials - DRM Memory Task

The word list task comprised study words arranged into twenty 13-word-lists (see Appendix A). Two list types were used; Semantic Word-lists (SW-list) containing 10 semantically associated words and three non-associated words, and Semantic plus Phonological Word-lists (SPW-list) containing 10 semantically associated words with three phonologically associated words. Twenty SPW test lists and 20 SW test lists were also compiled corresponding to SPW and SW study lists; consisting of five studied words, four non-studied words selected from non-presented word-lists, and the CL corresponding to the presented list. These items were randomized for each test list with the constraint that the CL always occupied serial position 5, 7, or 9. In Experiment 1, children were presented with study and test lists by way of Microsoft© PowerPoint© presentation, in Arial size 56 font in the centre of the screen, with lower case letters in white against a black background. For adults in Experiment 1, and for all other experiments, children and adults were presented with study and test lists in Arial size 56 font in the centre of the screen, with lower case letters in white against a black background by way of SuperLab Pro™, Version 2.0, software. Mean proportion of hits (correct recognition of target items), unrelated intrusions (incorrect recognition of unrelated items), and false alarms (incorrect recognition of critical lure items) were calculated by way of Microsoft© Office Excel©, as were mean Remember responses, and median reaction times (RT).

4.4 Measures – DRM Memory Task.

For all experiments, correct recognition (Hits) consisted of the proportion of list words correctly recognized as previously studied old words. Unrelated Intrusions consisted of the proportion of unrelated items words incorrectly recognized as old words. False memories consisted of the proportion of false alarms to critical lure items incorrectly recognized as previously studied old words. For Experiment 2 and 3, subjective experiences of false alarms were measured as *remember* or *know* judgments. Response time data was also collected in Experiment 2.

4.5 Design – DRM Memory Task.

A mixed design was used for the word-list memory task in all experiments. For Experiments 1 and 2, the between-subjects variables were age (8- versus 10-year-olds vs. adults) and group (less vs. more efficient inhibitors). The within-subjects variable was list type (SW- vs. SPW-lists). For Experiment 3, the between-subjects variable was presentation format (blocked vs. random), with list type (SW- vs. SPW-lists) the within-subjects variable. For Experiments 1 and 2, list types were presented in regular alternation and counterbalanced with half of the participants in each age group beginning with a SW-list and the remaining half with a SPW-list see Appendix C. Table 4.1 provides an overview of each experiment, key manipulation, and participants.

Table 4.1: *Overview of Experimental Design*

Experiment 1 Key Manipulation Participants	Experiment 2 Key Manipulation	Experiment 3 Key Manipulation
Non-verbal filler task	Retrieval Practice	Blocked vs Random
Stroop vs. Stroop+NP	Stroop vs. Stroop+NP	Stroop+NP
Children	Children vs. Children	Children
Adults vs. Adults	Adults vs. Adults	Adults

Note: Filler task = multiplication tables completed by children and adults between study and test phases, Retrieval Practice = completed word fragments of DRM lists

4.6 Procedures

Approval to conduct this research was obtained from the Human Ethics Committee, University Canterbury. Letters of explanation and consent forms were distributed to parents via local primary schools. All children were tested following parental consent and their own assent was obtained on the day of testing. Children were taken in small groups to a room set aside for the experiment, with each participant completing the experiment individually. One hour was allocated to complete both tasks.

Instructions for both the Stroop task and the word-list task were read aloud and presented visually. Responses for the Stroop task were made by pressing a colored sticker matched to font colors; blue, green, red, and yellow; placed on the keys *z b c* and *m*. Immediately following the completion of the Stroop task, participants were familiarized with the concepts of *old* and *new* in the context of memory tests for events. Participants were also instructed to indicate whether they remembered seeing a word before, whether knew they had seen a word before, or whether the word was a new word. For Experiments 2 and 3, *remember* responses were made by pressing a sticker marked *R* placed on the *h* key. *Know* responses were made by pressing a sticker marked *K* placed on the *j* key. *New* responses were made by pressing a sticker marked *N* placed on the *k* key. Definitions for *remember* and *know* responses were followed by simplified examples of what each of these types of judgments about memory would entail within the context of the DRM memory task.

Experiment 1:

Each thematically interrelated list was presented one at a time, all participants completed a non-verbal filler task between study and test phases, see Table 4.1. Words were presented at the rate of 1 word per second, with 250ms between individual list items. Once all 13 list items were presented, instructions appeared on the screen indicating participants were to fill in the multiplication tables provided for approximately 45 seconds. See Appendix A for SW- and SPW-lists. A tone then sounded followed by the appearance of the words “get ready for the test”, this remained on screen for approximately 5 seconds, followed by instructions to begin the test phase. Test items were presented individually, appearing on screen above the prompt (“R” for remember, “K” for know, “N” for new). Each test item remained on screen until a response key was pressed. After all study lists and test lists were presented, instructions appeared on the screen informing participants the experiment was finished and thanking them for their participation. Approximate time to complete DRM memory task was 25 minutes per participant, with each session taking approximately one hour to complete. Presentation order of SW- and SPW lists were counterbalanced to ensure equal presentation of both list types, see Appendix C.

Experiment 2:

A similar presentation format was adopted for Experiment 2, with a retrieval practice task replacing the non-verbal filler task. As in Experiment 1, individual list items were presented one at a time. Once all items pertaining to a list were presented, participants were instructed to complete word fragments on the sheet provided, see Appendix B. The delay interval between individual list items and study and test phases were as with Experiment 1. Likewise, prompts to begin test phases with reminders regarding *remember* and *know* judgments presented below individual test items. The presentation orders of SW- and SPW-lists were counterbalanced as shown in Appendix C. Children were tested on two occasions, approximately 1 week apart, with word lists 1 – 10 presented at time 1, and word lists 11 – 20 presented at time 2. As with Experiment 1, the approximate time to complete DRM memory task was 25 minutes, with each session taking approximately one hour to complete.

Experiment 3:

Participants were presented with 10 SPW-lists, selected on the basis the SPW-lists were found to produce a higher rate of false alarms than SW-lists. A key manipulation differentiating Experiment 3 from the previous experiments was the presentation format and the removal of the filler task or retrieval practice task between the study and test phases. Half of the participants studied 5 SPW-lists presented in blocked format, and 5 SPW-lists presented in randomized order. The remaining participants studied 5 SPW-lists presented in randomized order followed by 5 SPW-lists presented in blocked format. As in Experiments 1 and 2, a prompt appeared on screen indicating the test phase was about to begin, with a reminder of Remember, Know, and New responses appearing below individual test items. List items were again presented at the rate of one word per second, with 250ms between individual items, and test items remained on screen until a response was made. The approximate time to complete Experiment 3 was 25 minutes.

Figure 3.1 depicts the presentation order of study lists, filler or retrieval tasks, and presentation of test lists for Experiments 1, 2, and 3.

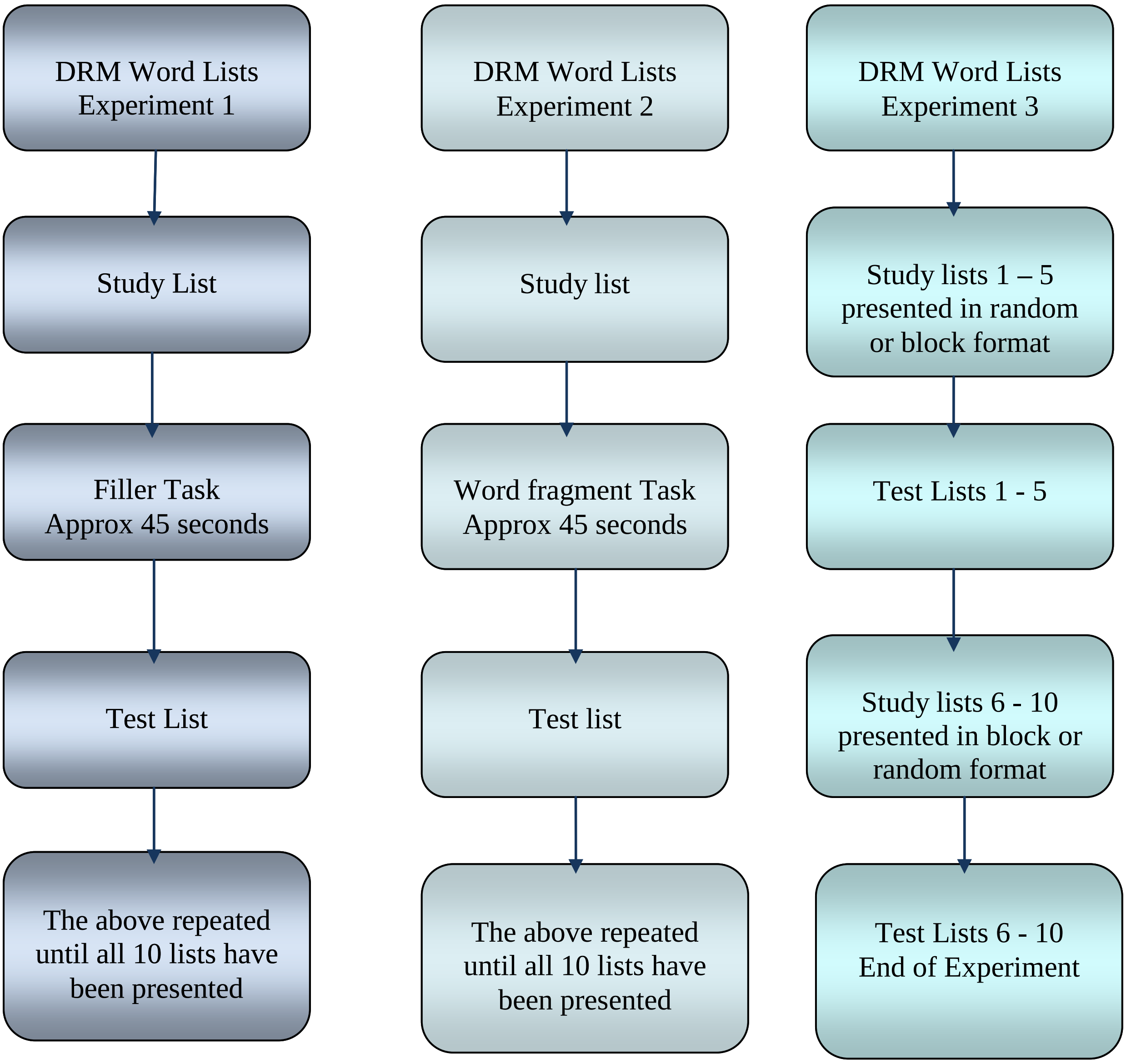

Figure 4.1 **Schematic diagram illustrating the DRM test procedures across Experiments 1, 2, and 3.**

Chapter 5: Experiment 1: Propensity of Adults and Children to Form False Memories on the Basis of Inhibitory Control

In Experiment 1, individual differences in the propensity to produce false alarms in a memory task were examined on the basis of classification of inhibitory control efficiency on a Stroop color-word interference test. An index of inhibitory control was calculated on the basis of the degree of Stroop interference. That is, the proportion of response time (RT) latencies and error rates when responding to the ink color of a conflicting color-word, in comparison to responding to the ink color in the absence of semantic conflict. Children and adults were then assigned to one of three inhibitory control groups: Less IC, Mod IC, and More IC. Those demonstrating a greater degree of Stroop interference were assigned to the Less IC group, those demonstrating a moderate degree of Stroop interference to the Mod IC group, and those demonstrating a lesser degree of Stroop interference to the More IC group. Differences in rates of false alarms were then compared between inhibitory control groups to determine whether those demonstrating less effective inhibitory control produced significantly higher rates of false alarms than those demonstrating more effective inhibitory control.

Experiment 1 also examined whether a combined index of attentional inhibitory control, that of Stroop interference and NP effect, was a more fine-grained measure of inhibitory control than Stroop interference alone. A NP effect is measured as the proportional degree of interference between prime-probe couplets: prime trials consisting of incongruent Stroop stimuli with probe trials consisting of neutral Stroop stimuli. As mentioned previously, the negative priming effect was calculated for each individual on the basis of the proportional difference between RT latencies to IR probe and control probe trials. Negative priming effects occur as the effective inhibition of the semantic meaning of a color-word on the prime trial interferes with the ability to respond to the ink color in the absence of semantic conflict. On the basis of the combined Stroop color-word task and NP task, individuals were again assigned to one of three inhibitory control groups based on the degree of Stroop interference and NP effects; Less IC, Mod IC, and More IC. On the basis those demonstrating more effective inhibitory control show a higher proportion of RT latencies and error rates on a NP task. In contrast, those demonstrating less effective inhibitory control should show a lower proportion of RT latencies and error rates on the measure of NP due to their less effective inhibition of the meaning of the previous color-word. Accordingly, the combined index of inhibitory control classification of individuals was determined as follows: less effective inhibitory control yields greater Stroop interference effect, in combination with reduced NP effect (Less IC), moderate inhibitory control yields moderate Stroop interference effect in combination with moderate NP effect (Mod IC), and more effective inhibitory control yields less Stroop interference effect in combination with greater NP effect (More IC).

5.1 Experiment 1a: Comparison of Individual Differences in False Alarms between Children and Adults as Function of Inhibitory Control

In Experiment 1a, children aged 8-year olds (n = 71, 47% males), 10-year olds (n = 76, 51% males)[1], and 99 adults (49% males) completed the Stroop interference task to establish individual degree of inhibitory control. All groups then completed the DRM memory task presented in the following manner: first, a study phase, second, a non-verbal filler task, and thirdly, a test phase; repeated for each of the 10 DRM word lists. Based on Stroop interference as an index of inhibitory control, false alarm rates were

[1] Results relating to children participating in Experiment 1 were first reported in an unpublished master’s thesis (Alberts, 2005).

examined to determine whether children and adults who demonstrated less efficient inhibitory control produced higher false alarm rates of critical lures. Experiment 1a examined rates of false alarms as a function of a single index of inhibitory control and between children and adults. In Experiment 1b, a new group of adults (n = 109) completed both a Stroop and NP task; false alarm rates were then compared between those assigned as less or more efficient inhibitors as a function of this combined index of inhibitory control. This was followed by a comparison of rates of false memories between both groups of adults to determine whether a combined index of inhibitory control proved to be more sensitive in detecting individual differences in false alarms to CLs than a single index of inhibitory control.

5.1.1 Experiment 1a: Results

An alpha level of .05 was used for all statistical tests, with Bonferroni corrections for multiple comparisons selected for post-hoc analyses. Effect sizes referring to partial eta squared (η_p^2) or Cohen's *d* are included, as are 99% confidence intervals (CI) unless otherwise indicated. As preliminary analyses of this and the following experiments indicated no main effect or interactions involving gender, this variable was eliminated from all subsequent analyses.

Because our primary interest was in contrasting the extreme thirds of the efficiency distribution (i.e., between those demonstrating less or more inhibitory control), statistical analyses below and for all subsequent studies, focuses on contrasts between these two groups (Less IC vs. More IC). The middle group is excluded because it is not as straightforwardly classifiable as either more or less efficient on this continuum. For the sake of completeness and reference, however, summary data for all experiments are provided for all groups in relevant Tables.

5.1.2 Formation of Groups

Separately for children and adults completing the Stroop interference task, participants were first ranked according to the percentage of Stroop interference ($Stroop_{rank}$) encountered on the basis of mean reaction times (i.e., mean RT in the incongruent condition minus mean RT in the neutral condition divided by 1000). Second, participants were ranked in a similar manner according to mean error rates ($Error_{rank}$) in the incongruent condition minus mean error rates in the neutral condition divided by 1000. A combined ranking was calculated by adding Stroop interference and error rate rankings ($Stroop_{rank}$ + $Error_{rank)}$. Those in the lower third of the distribution were designated more efficient inhibitors due to showing relatively lower overall interference; whereas those in the upper third were designated less efficient inhibitors due to their comparatively greater Stroop interference.

The less efficient inhibitory control (Less IC) group contained 49 children: 25 8-year-olds (15 males and 10 females), and 24, 10-year-olds (8 males and 16 females) and 33 adults; the moderate inhibitory control (Mod IC) group contained 49 children: 22, 8-year-olds (9 males and 13 females), and 27, 10-year-olds (16 males and 11 females) and 33 adults; and the more efficient inhibitory control (More IC) group contained 49 children: 24, 8-year-olds (11 males and 13 females), 25, 10-year-olds (8 males and 17 females), and 33 adults. In relation to children, those assigned to the Less IC group (M =.12, ±.03) differed in terms of mean proportion of Stroop interference and errors from those assigned to the more inhibitory control group (M = .02, ±.01). In relation to adults, those assigned to the less inhibitory control group (Less IC) differed in terms of mean proportion of Stroop interference and errors (M = .04, ± .01) from those assigned to the more inhibitory control group (More IC; M = -.06, ± .02). See Appendix E for RT and error rate data for children and adults, and for all groups.

5.1.3. Experiment 1a: Correct and Incorrect Recognition

Mean proportions of “old” responses of children and adults to targets (hits) and unrelated items (unrelated intrusions) as a function inhibitory control and list type are presented in Table 5.1. Proportions of overall hits and unrelated intrusions were analyzed in separate 2 (Group: Less IC versus (vs.) More IC) x 3 (Age: 8- vs. 10- vs. adults) x 2 (List: SPW vs. SW) mixed analysis of variance (ANOVA). The between-subjects variables were age and group, and the within-subjects variable was list type. The developmental trajectory was one of increased accurate recognition in adults in comparison to children, F (2, 158) = 25.17, $p < .01$, $\eta_p^2 = .24$, with adults correctly recognizing more target items (*M* = .84), than 10-year olds (*M* = .80), with 8-year olds correctly recognizing fewer target items (*M* = .66). There was also a main effect of list type, F (2,158) = 7.46, $p = .01$, $\eta_p^2 = .05$, with more targets from SPW-lists (*M* = .78) correctly recognized than SW-lists (*M* = .68). Consistent with the data patterns in the top portion of Figure 5.1, the main effect of inhibitory control did not reach significance, $F < 1$.

Regarding unrelated items, again the developmental trajectory was one of fewer errors evident in adults (*M* = .04) in comparison to children, with 8-year olds (*M* = .38) incorrectly recognizing more unrelated items as previously studied words than 10-year olds (*M* = .19), F (2,158) = 115.38, $p < .01$, $\eta_p^2 = .59$. Again no main effects were found between list type, or between the less and more efficient inhibitor groups, $F < 1$, $p > .05$, $\eta_p^2 < .01$. See the top portion of Table 5.1 for data relating to hits, and the lower portion for unrelated Intrusions.

Table 5.1: *Experiment 1a: Mean Proportion of Test Words Correctly and Incorrectly Recognized by Children and Adults as a Function of a Single Index of IC*

		Group		
		Less IC	Mod IC	More IC
Response	Age	*M* (StdE)	*M* (StdE)	*M* (StdE)
Hits	8-year olds	.69 (.03)	.69 (.03)	.63 (.03)
	10-year olds	.82 (.03)	.80 (.03)	.79 (.03)
.	Adults	85 (.02)	.83 (.02)	.83 (.02)
SW-lists	8-year olds	.68 (.03)	.69 (.03)	.60 (.03)
	10-year olds	.80 (.03)	.80 (.03)	.78 (.03)
	Adults	.85 (.02)	.82 (.02)	.82 (.06)
SPW-lists	8-year olds	.70 (.03)	.69 (.04)	.65 (.03)
	10-year olds	.83 (.03)	.80 (.03)	.80 (.03
	Adults	.86 (.02)	.84 (.02)	.85 (.02)
URIntrusions	8-year olds	.40 (.03)	.31 (.03)	.35 (.03)
	10-year olds	.19 (.03)	.20 (.03)	.21 (.03)
	Adults	.06 (.01)	.05 (.01)	.03 (.01)
SW-lists	8-year olds	.42 (.03)	.30 (.04)	.36 (.03)
	10-year olds	.19 (.03)	.21 (.03)	.23 (.03)
	Adults	.06 (.01)	.05 (.01)	.03 (.01)
SPW-lists	8-year olds	.39 (.04)	.32 (.04)	.34 (.04)
	10-year olds	.18 (.04)	.19 (.03)	.19 (.04)
	Adults	.06 (.01)	.06 (.01)	.03 (.01)

Note: IC = Inhibitory Control, Hits = correctly recognizing a previously studied word as old, URIntrusions = Unrelated Intrusions, incorrectly recognizing a new word as old, StdE = standard error

5.1.4 Experiment 1a: False Alarms

The main interest was in the effects of inhibitory control on differences in rates of false alarms between individuals. Proportion of false alarms were entered into a 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10- vs. adults) x 2 (List Type: SW vs. SPW) mixed ANOVA. Again, the between-subjects variables were age and group, and list type was the within-subjects variable. Table 5.2 illustrates that overall rates of false alarms between children and adults assigned to Less IC and More IC groups were found to be similar to correct recognition of target items. Table 5.2 presents mean false alarms of children and adults to critical lures in relation to inhibitory control. As can be seen, children demonstrating less efficient inhibitory control produced higher rates of false alarms across both list types than children classified as having more inhibitory control. The same was true for adults. False alarms according to list type produced a significant main effect, F (2,158) = 12.66, p = .01, η_p^2 = .07, with overall higher rates of false alarms to CLs in SPW-lists (M = .72) than CLs in SW-lists (M = .63). The developmental trajectory revealed decreased rates of false alarms for younger children, F (2,158) = 7.87, p < .01, η_p^2 = .09, with 8-year olds producing fewer false alarms (M = .58), than 10-year olds and adults. There was little difference between the 10-year olds (M = .72) and adults (M = .74), however. Most crucially, assignment to Less IC or More IC groups also produced a main effect, F (2,158) = 6.38, p = .01, η_p^2 = .04, with those in the Less IC group producing higher overall false alarm rates (M = .72) than those in the More IC group (M = .63). Post-hoc analysis was conducted based on nine, pair-wise comparisons, with the critical p value adjusted accordingly. Overall, those aged 8-years assigned to the More IC group produced significantly fewer false alarms than children aged 10-years also assigned to the More IC group, t(47) = 3.32, p < .01. Consistent with this finding, children aged 8-years assigned to the More IC group produced significantly fewer false alarms than adults assigned to the More IC group, $t(55) = 3.51$, $p < .01$. No other significant differences were found, with all t's < 2.82.

Table5.2: *Experiment 1a: Comparison of FA as a Function of Age and Inhibitory Control Group*

		Group			
		Less IC	ModIC	More IC	
List	Age	*M* (StdE)	*M* (StdE)	*M* (StdE)	Difference
Overall FAs					
	8-year olds	.65 (.04)	.51 (.03)	.50 (.04)	.15
	10-year olds	.75 (.04)	.74 (.04)	.69 (.04)	.06
	Adults	.77 (.04)	.72 (04)	.70 (.05)	.07
SW-lists					
	8-years	.62 (.05)	.45 (.06)	.43 (.06)	.19
	10-years	.68 (.06)	.73 (.06)	.66 (.06)	.02
	Adults	.75 (.05)	.72 (.06)	.65 (.05)	.10
SPW-lists					
	8-years	.68 (.05)	.57 (.05)	.58 (.05)	.10
	10-years	.81 (.05)	.76 (.05)	.72 (.05)	.09
	Adults	.80 (.04)	.73 (.04)	.75 (.05)	.10

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists CLs incorrectly recognized as *old*, Overall = mean percentage of false alarms regardless of list type, FA = false alarms, StdE = standard error; Difference = Less IC vs. More IC

Figure 5.1 illustrates the overall differences between children and adults in rates of hits and false alarms as a function of inhibitory control. As can be seen, a greater discrepancy in rates of false alarms is apparent between children aged 8-years, than between children aged 10-years and adults. Closer examination indicates children aged 8-years produced significantly more false alarms to CLs when assigned to the Less IC group (M = .65), than those assigned to the More IC group (M = .50), t (47) = 2.76, p = .01. No significant differences were found between children aged 10-years assigned as Less IC or More IC (p < .10), and adults assigned as Less IC or More IC (p < .15).

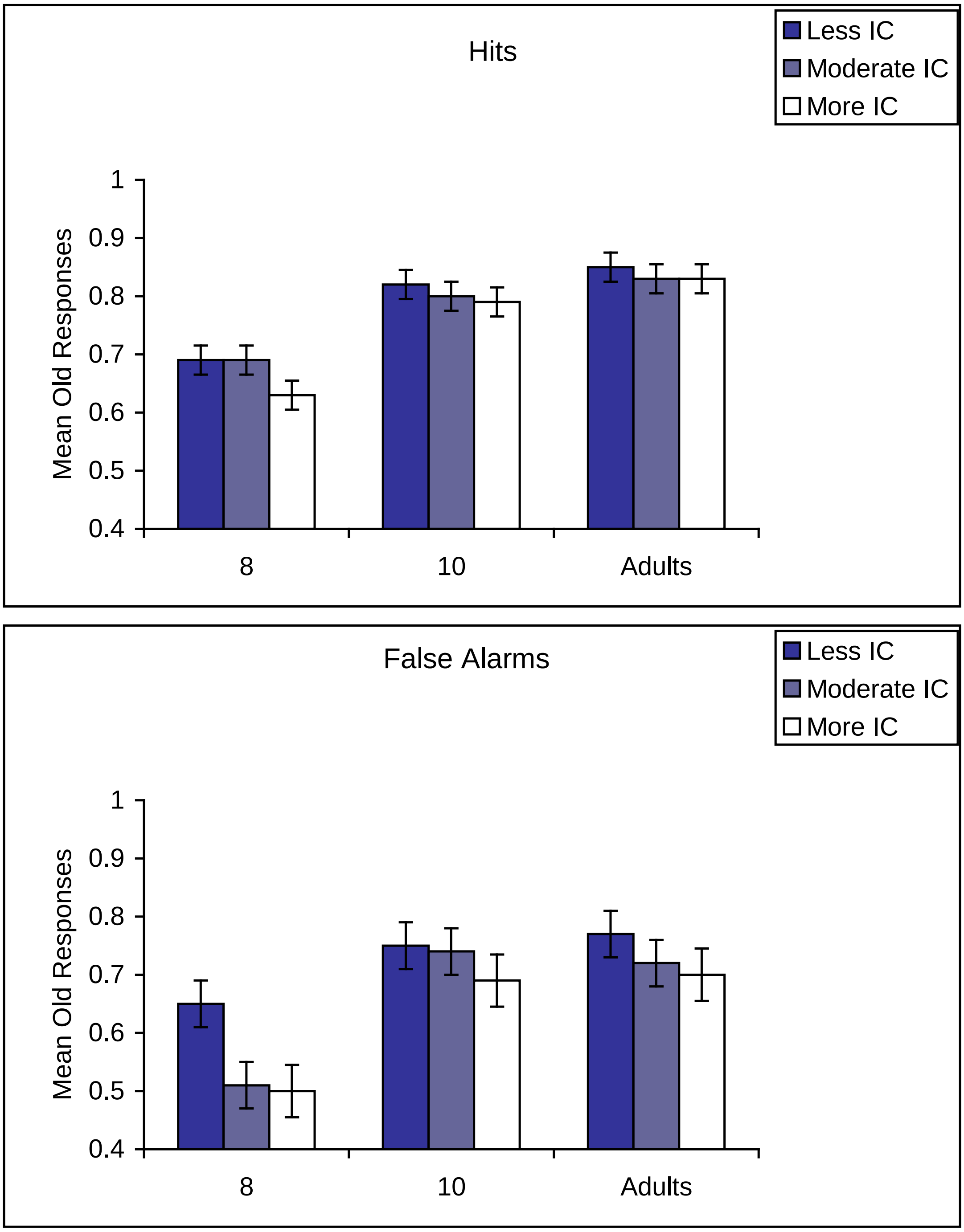

Figure 5.1. Experiment 1a: Mean Probability of Children and Adult's Responses to Targets and CLs as a Function of Inhibitory Control classification. *Note*: IC = inhibitory control, FA = false alarms to CLs, vertical bars denote standard error

Discussion

Three important findings emerged from Experiment 1a: (1) individual differences in rates of false alarms were identified utilizing Stroop interference as a measure of inhibitory control; (2) while younger children produced fewer false alarms than adults, overall children and adults classified as less efficient inhibitors produced a higher rate of false memories than those classified as more efficient inhibitors; and (3) while less efficient inhibitory control was found to relate to higher rates of false memories, higher rates of false memories were not found to relate to less accurate recognition or to increased errors.

These results indicate that children and adults demonstrating less effective inhibitory control on the basis of a selective attention task do indeed produce significantly higher rates of false memories in the DRM memory task than those who demonstrate more efficient inhibitory processing. Of interest though, children aged 8-years demonstrating less effective inhibitory control produced significantly higher rates of false alarms than children aged 8-years demonstrating more effective inhibitory control. This trend was also evident in children aged 10-years and adults demonstrating less effective inhibitory control in comparison to children aged 10-years and adults demonstrating more effective inhibitory control. In this instance it would appear that intrusions of critical lures into memory may occur as a result of spreading activation. For example, as individuals encounter the words *warm*, *blanket*, *pillow*, etc., the internal representation of the critical lure is activated. It is likely this activation occurs at the time of study, and again during the test phase. In this way, both the initial study and test phase produce a strongly activated representation of the critical lure item (Chan, McDermott, & Roediger, 2006; Gerearts, Smeets, Jelicic, van Heerden & Merkelbach

2005; Howe, 2005; 2009a). Those classified as less efficient inhibitors may not be able to as effectively utilize an inhibitory mechanism to suppress automatic activation of such irrelevant representations whenever they occur. Consequently, for such individuals critical lure items remain strongly activated, leading to elevated false alarms as critical lures intrude into recognition. The next experiment will test these findings further to determine whether greater differences in rates of false alarms can be detected between groups based on combined Stroop interference and NP effects.

5.2.1. Experiment 1b: Comparison of True and False Recognition between Adults as a Function of a Combined Index of Inhibitory Control

A new sample of 109 adults (47% males) completed a variation of the Stroop task to establish Stroop interference, as well as NP effects. The main hypothesis tested in Experiment 1b was that classifying participants on the basis of a combined index of inhibitory control (Stroop interference and NP effect), should result in even greater differences in rates of false memories between less and more effective inhibitory control groups than a single index (Stroop interference). This would indicate that Stroop interference coupled NP provides a more sensitive index of inhibitory control than Stroop interference alone.

5.2.2. Formation of Groups

Groups were formed on the basis of a combined index of inhibitory control, utilizing a variation of Stroop and NP tasks (hereafter referred to as the StroopNP task and StroopNP effect). The NP task was incorporated within the Stroop color-word task, with Stroop stimuli providing prime-probe couplets. Prime trials consisted of incongruent Stroop stimuli immediately followed by a probe trial consisting of neutral Stroop stimuli. In this way, the probe trial provides an ignored-repetition condition. Control prime-probe couplets were used consisting of incongruent Stroop stimuli immediately followed by neutral Stroop stimuli, in which there was no relationship between the prime and probe. Participants were ranked according to a combination of Stroop interference and NP. For example, percentage of Stroop RT interference between neutral and incongruent trials coupled with proportion of errors in incongruent trials, plus percentage of NP effect between NP prime and probe trials coupled with proportion of errors in NP probe trials ($Stroop_{rank}$ + Stroop $Error_{rank)}$ plus (NP_{rank} + NP $Error_{rank).}$ Those with a greater degree of Stroop interference and less NP effect, were assigned to the Less IC group (N= 37) those with a lesser degree of Stroop interference and a greater degree of NP effect were assigned to the More IC group (N = 37). Those who could not be easily classified as either inefficient or efficient inhibitors were assigned to the Mod IC group (35 adults).

On the basis of combined Stroop interference and NP effect, proportional interference scores were calculated for each individual. Individuals were then assigned to Less IC, Mod IC, or More IC groups. Differences between groups in terms of Stroop interference ranged from a mean interference score of .04 (± .04), with a mean NP effect score of -.04 (± .04), for those in the Less IC group, to a mean Stroop interference score of -.04 (± .04), and NP effect score of .03 (± .04), for those in the More IC group. Figure 5.2 below illustrates differences between groups in terms of StroopNP effect. Those assigned to the Less IC group demonstrate greater Stroop interference and less NP effect, with the opposite pattern evident in those assigned to the More IC group. See Appendix E for RT and error rate data for all groups.

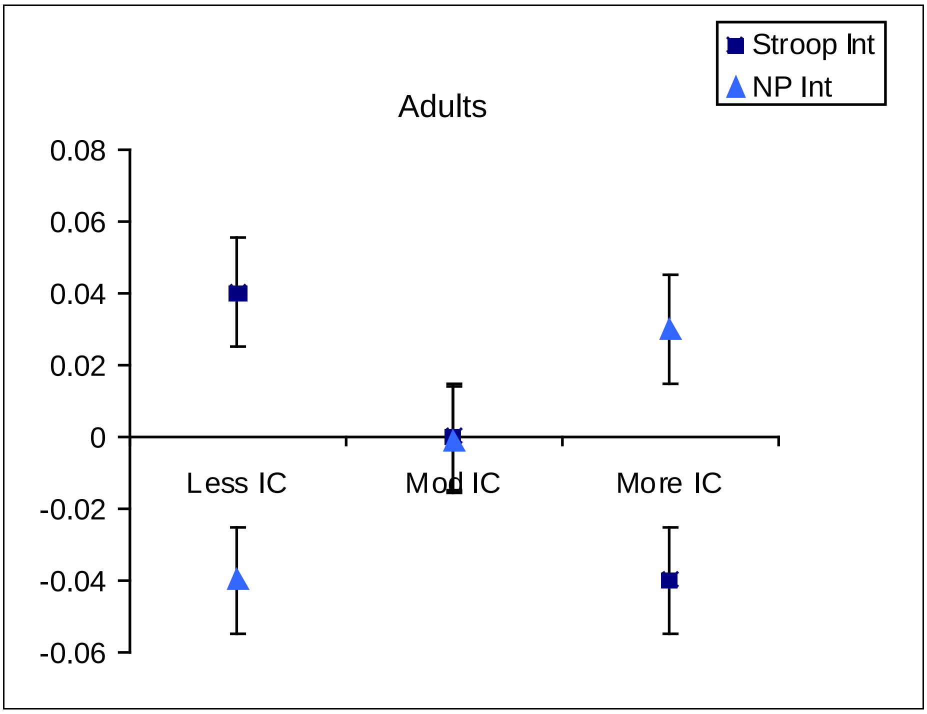

Figure 5.2: Experiment 1b: Differences between Adults Assigned to Inhibitory Control Groups in terms of StroopNP effect. *Note:* IC = inhibitory control, error bars denote standard error

5.2.3. Experiment 1b: Correct and Incorrect Recognition

Mean proportions of "old" responses of adults to targets (hits) and unrelated items (unrelated intrusions) as a function inhibitory control and list type are presented in Table 5.3. Proportions of overall hits and unrelated intrusions were analyzed in separate 2 (Group: Less IC vs. More IC) x 2 (List Type: SW vs. SPW) mixed ANOVA's. The between-subjects variables was group and list type provided the within-subjects variable. Table 5.3 illustrates the differing rates of correct recognition between list types. The mixed ANOVA revealed these differences were statistically significant, with both groups correctly recognizing fewer target items from SW-lists (M = .82) than target items from SPW-lists (M = .86), F (1,72) = 8.45, $p < .01$, $\eta_p^2 = .11$. However, no significant differences were found between groups in terms of correct recognition of target items or incorrect recognition of unrelated items, F's < 1.

Table 5.3: *Experiment 1b: Mean Proportion of Test Words Correctly and Incorrectly Recognized by Adults as a Function of IC Classification in the StroopNP task*

		Group	
	Less IC	Mod IC	More IC
Response	*M* (StdE)	*M* (StdE)	*M* (StdE)
Hits Overall	.85 (.02)	.86 (.02)	.83 (.02)
SW-lists	.84 (.02)	.85 (.02)	.81 (.06)
SPW-lists	.86 (.02)	.87 (.02)	.87 (.02)
URIntrusions Overall	.06 (.01)	.06 (.01)	.03 (.01)
SW-lists	.05 (.01)	.05 (.01)	.02 (.01)
SPW-lists	.07 (.01)	.07 (.01)	.07 (.01)

Note: IC = Inhibitory Control, Hits = correctly recognizing a previously studied word as old, URIntrusions = Unrelated Intrusions, incorrectly recognizing a new word as old, StdE = standard error

5.2.4 Experiment 1b: False Alarms

As indicated in Table 5.4, the trend was for higher overall rates of false alarms produced by those assigned to the Less IC group compared to those assigned to the More IC group. Mean rates of false alarms to CLs were entered into a 2 (Group: Less IC vs. More IC) x 2 (List type: SW-lists vs. SPW-lists) mixed ANOVA, with the group providing the between-subjects variables, and list type the within subject variable. Those assigned to the Less IC group were more likely to rate CLs as previously studied list words, than those assigned to the More IC group. Differences in rates of false alarms between groups was found to be statistically significant, F (1,72) = 20.30, $p < .01$, $\eta_p^2 = .22$, with those assigned to the Less IC group producing more false alarms ($M = .80$) compared to those assigned to the More IC group ($M = .58$). The interaction between group and list type was also significant, F (1,72) = 4.22, $p = .04$, $\eta_p^2 = .06$, with those assigned to the Less IC group producing lower rates of false alarms to CLs in SW-lists than SPW-lists (M's = .77 vs. .82), while those in the More IC group produced higher rates of false alarms to CLs in SW-lists than SPW-lists (*M*'s = .63 vs. .53). Post-hoc analysis revealed no significant differences in rates of false alarms to CLs in either SW- or SPW lists produced by the Less IC Group ($p > .05$), and those produced by the More IC group ($p > .05$).

Table 5.4: *Experiment 1b: Mean Proportion of FA to CLs Recognized by Adults as a Function of IC Classification in the StroopNP task*

	Group		
	Less IC	Mod IC	More IC
List Type	*M* (StdE)	*M* (StdE)	*M* (StdE)
Overall	.80 (.04)	.70 (.04)	.58 (.04)
SW-lists	.77 (.05)	.67 (.04)	.63 (.05)
SPW-lists	. 82 (.04)	.73 (.04)	.53 (.04)

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists CLs incorrectly recognized as *old*, Overall = mean percentage of false alarms regardless of list type, FA = false alarms, StdE = standard error

Discussion

Taken together, the results of Experiment 1b closely replicate the main trends observed Experiment 1a. However, in Experiment 1b a robust effect of inhibitory control was found, with those adults assigned to the Less IC group producing significantly higher rates of false alarms than those assigned to the More IC group. Once again, no significant differences were found between these groups in terms of correct and incorrect recognition of target items and unrelated items. Taken together, Experiments 1a and 1b suggest that individual differences in rates of false alarms can be observed on the basis of differing degrees of inhibitory control. In the next analysis, rates of false alarms were compared between adults assigned as less or more efficient inhibitors on the basis of a single (Stroop interference) or a combined (Stroop interference plus NP effect) index of inhibitory control.

5.3: Comparison of True and False Recognition between Adults as a Function of a Single or Combined Index of Inhibitory Control

A main interest in Experiment 1a and 1b concerned the effects of assignment to groups on the basis of a single versus a combined index of inhibitory control. Table 5.5 presents overall proportions of false alarms as a function of group assignment based on inhibitory control index, and list type. The differences between Less IC and More IC groups in terms of false alarms based on a single versus a combined index of inhibitory control, suggests that consistently higher rates of false alarms are evident between groups when individuals are assigned on the basis of a combined index of inhibitory control. Proportions of false alarms to CLs of adults classified on the basis of a single versus combined index of inhibitory control were entered into a 2 (Group: Less IC vs. More IC) x 2 (Inhibitory Control Index: Stroop vs. Stroop + NP) x 2 (List: SW-lists vs. SPW-lists) mixed ANOVA. The between-subjects variables were inhibitory control index and group, with list type as the within-subjects variable. Rates of false alarms differed significantly between groups, F (1,134) = 14.76, p <.01, η_p^2 = .10, with higher overall rates of false alarms found for Less IC (M = .79), compared to the More IC group (M = .64). A marginal interaction was found between group and inhibitory control index, F (1,134) = 3.40, p = .07, η_p^2 = .02, with a greater difference in overall rates of false alarms found between those classified as Less IC (M = .80) versus More IC (M = .58), on the basis combined Stroop interference and NP effect, compared to those classified as Less IC (*M* = .77) and More IC (*M* = .70) on the basis of Stroop interference alone.

Table 5.5: *Experiment 1: Comparison of FA as a function of Inhibitory Control Group and Inhibitory Control Index*

		Group		
List type	IC Index	Less IC(StdE)	More IC(StdE)	Difference
Overall				
	Stroop	.77 (.04)	.70 (.04)	.07
	Stroop + NP	.80 (.04)	.58 (.04)	.22
SW-lists	Overall	.76 (.03)	.64 (.03)	
	Stroop	.75 (.05)	.65 (.05)	.10
	Stroop + NP	.77 (.05)	.63 (.05)	.14
SPW-lists	Overall	.81 (.03)	.64 (.03)	
	Stroop	.80 (.04)	.75 (.04)	.05
	Stroop + NP	.82 (.04)	.53 (.04)	.29

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists CLs incorrectly recognized as *old*, Overall = mean percentage of false alarms regardless of list type, FA = false alarms, StdE = standard error.

Table 5.5 illustrates the difference in rates of false alarms found between those assigned to Less IC groups compared to the More IC groups on the basis of a single versus combined index of inhibitory. Of note, greater differences were found between Less IC and More IC when classification was based on Stroop interference and NP effect, suggesting a combined measure of inhibitory control was a more sensitive measure of individual differences in false alarms. An interaction between list type and inhibitory control index was also found, F (1,134) = 4.93, p = .03, η_p^2 = .04, while those assigned to the Less IC group produced overall higher rates of false alarms to CLs in SPW-lists than those in the More IC group, this was not the case for SW-lists (.81 vs.

.76); no difference was found between overall rates of false alarms and list type between those assigned to the More IC group (.64 vs. .64).

A three-way interaction was also found between list type, group, and inhibitory control index, F (1,134) = 4.46, p = .04, η_p^2 = .03, with similar rates of false alarms found between Less IC and More IC regardless of inhibitory control index when presented with SW-lists, whereas a greater difference in false alarms to SPW-lists was found between Less IC and More IC classified on the basis of StroopNP task compared to the difference in false alarms to SPW-lists found between Less IC and More IC classified on the basis of Stroop interference. Post-hoc analysis was conducted based on six, pair-wise comparisons between overall rates of false alarms produced by groups assigned on the basis of a single index of inhibitory control versus a combined index, with the critical *p* value corrected accordingly. The difference in overall rates of false alarms between those assigned to Less IC and More IC groups based on a combined inhibitory control index was significant, $t(72) = 4.69$, $p < .01$. Of interest, a statistically significant difference was also found between rates of false alarms produced by those assigned to the More IC group on the basis of a single versus a combined inhibitory control index, $t(68) = 2.51$, $p < .01$. No other significant differences were found, *t*'s < 2.39.

The interaction between rates of false alarms based on SPW-lists between Less IC and More IC groups as a function of inhibitory control is illustrated in Figure 5.3 below. As can be seen, overall higher rates of false alarms were produced by those assigned to the Less IC groups than those assigned to the More IC groups. However, greater overall differences in rates of false alarms are evident when assignment to Less IC or More IC groups was based on a combined index of inhibitory control.

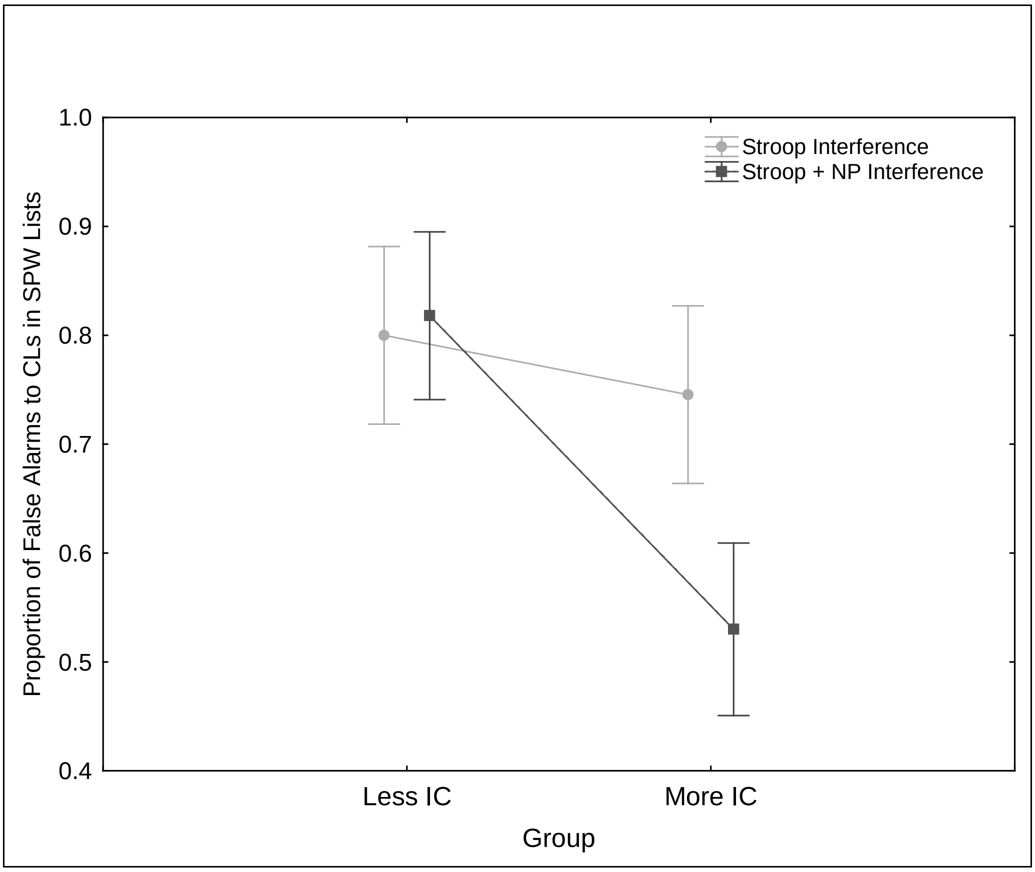

Figure 5.3. Experiment 1: Comparison of FAs to SPW-lists as a function of Group and Inhibitory Control Index. Note: IC = inhibitory control, error bars denote 99% CI

Post-hoc analysis was conducted to further understand the interaction between rates of false alarms as function of list-type, inhibitory control index, and assignment to the Less IC and More IC groups. As expected, the difference in rates of false alarms in SWP-lists between those assigned to the Less IC group compared to those assigned to the More IC group on the basis of a combined index was statistically significant, $t(72) = 6.24$, $p < .01$. Again, of interest, the difference between rates of false alarms in SWP-lists produced by those assigned to the More IC group on the basis of a single index of inhibitory control versus a combined index was also statistically significant, $t(68) = 4.59$, $p < .01$. No other comparisons reached statistical significance, t's < 2.59.

Discussion Experiment 1

To summarize, the findings from Experiments 1a and 1b indicate that individual differences between adults and children in terms of propensity to false alarms can be detected on the basis of inhibitory control. The most critical findings from these first experiments were that as greater differences in rates of false alarms were found between groups assigned on the basis of Stroop interference and NP effect, suggesting that a combined index of inhibitory control was a more sensitive measure of individual susceptibility to the false memory illusion evident in the DRM paradigm. This would suggest that the inhibitory control required to successfully overcome Stoop interference results in residual interference, as seen in the NP effect. More importantly, this would suggest a similar process of inhibitory control is involved in successfully overcoming interference from activation of the critical lure item in the DRM memory task. Furthermore, examination of results across accurate and inaccurate memory indices revealed that there were no differences between the less and more efficient inhibitors regarding hits and unrelated intrusions. Notably, the complete absence of effects on these particular memory indices was coupled with highly significant and robust differences on false alarms to critical lures. Taken together, the results of these first experiments confirm two important predictions. First, using selective attention tasks, the current study identified children and adults demonstrating less or more efficient inhibitory control. Second and more significantly, children and adults demonstrating less efficient inhibitory control consistently produced higher false alarm rates of critical lures than their more efficient counterparts; however, this did not translate to a general pattern of memory errors. While the general developmental trajectory was of increased accurate recognition in adults compared to younger children, when inhibitory control was taken into account it was found that 8-year olds who demonstrated less inhibitory control produced significantly higher rates of false alarms then 8-year olds demonstrating more inhibitory control. Also of note, 10-year olds demonstrating less efficient inhibitory control produced similar rates of false alarms as adults demonstrating less efficient inhibitory control. As there were no significant interaction effects between age and inhibitory control, it can be deducted that inhibitory control accounted for differences between groups in false alarm rates. The implications of these findings suggest inhibitory control plays a crucial role in the occurrence of false memories.

Experiment 1b determined inhibitory control on the basis of Stroop interference and NP effect, allowing participants to be classified as either less efficient inhibitors based on higher Stroop interference and lower NP effect, or more efficient inhibitors based on lower Stroop interference and higher NP effect. As in Experiment 1a, participants classified as having less efficient inhibitory control produced a significantly higher overall rate of false memories than participants classified as having more efficient inhibitory control. Again as with Experiment 1a, the absence of a consistent pattern of errors in the proportion of list words recognized supports the proposal that false memories do not result from a general failure in memory accuracy. The results of Experiment 1b provide evidential support that the ability to inhibit the activated internal representation of the primary thematic associate prevents the intrusion of the CL in recognition. Conversely, the inability to effectively inhibit an activated internal representation allows the CL item to intrude into recognition, resulting in a false memory.

Apparently, the ease with which an individual brings an event to mind increases the probability that the experience of the event is attributed to a memory (Jacoby, Kelley, & Dywan, 1989). In this way, the higher number of false memories produced by less efficient inhibitors adds additional weight to the argument that the CL in DRM lists becomes activated at some point, but is less effectively inhibited by children and adults who have less efficient inhibitory control. The results of Experiment 1 provide compelling evidence for the existence of an inhibitory mechanism in selective attention and memory tasks whose broad function involves task-irrelevant distractor exclusion (Neumann & DeSchepper, 1992; Neumann et al., 1993; see also Anderson & Spellman, 1995). The results so far suggest participants actively inhibit automatically activated internal representations of related yet irrelevant information. In view of this, Experiment 2 will examine whether these results can be replicated with the inclusion retrieval practice. In this case it is expected that while retrieval practice will increase overall accuracy of both adults and children, those assigned to Less IC groups will continue to produce higher rates of false alarms, and as with Experiment 1b, a combined index of inhibitory control is expected to detect greater differences between groups than a single index of inhibitory control.

Chapter 6: Experiment 2: Propensity of Adults and Children to Form False Memories on the Basis of Inhibitory Control and Retrieval Practice

The aim of Experiment 2 was to replicate the critical findings of Experiment 1, that is to provide converging evidence of the role of inhibitory control in the generation of false alarms. In addition, Experiment 2 also sought to clarify whether a combined index of inhibitory control was a more sensitive measure for detecting individual differences in the propensity to produce false alarms. Experiment 2 set out to demonstrate that while the expected reduction in false memories was found following retrieval practice, those assigned to the Less IC group should produce higher rates of false alarms than those assigned to the More IC group. Examination of RT latencies should also demonstrate that those in the Less IC group are faster when making false alarm responses than those in the More IC group.

6.1 Introduction Experiment 2

Investigations in memory retrieval support the notion that inhibitory control facilitates selective memory retrieval in much the same way as visual selective attention allows objects to be attended to (Anderson & Bell, 2001). Inhibitory control during retrieval occurs as competitor concepts become activated, in this case, accurate retrieval may be reliant on the ability to inhibit activated-irrelevant information in order to allow relevant information to be selected. Therefore, highly active competitor concepts that are effectively inhibited do not intrude in recognition, whereas those that are less effectively inhibited do intrude resulting in a false alarm.

To examine the impact of inhibitory control in memory retrieval, participants typically study a list of words followed by a practice session in which some of the studied items are retrieved from memory, either through stem completion or word fragment completion tasks (Anderson & Spellman, 1995). When tested, participants not only show impaired recall of items not practiced, but also even more impairment of unpracticed competitors (Anderson, 2001a, 2003; Starns & Hicks, 2004). However, research also indicates that while retrieval practice impairs recall of non-practiced items, this does not appear to extend in the same manner to false recognition of CL items. For example, Watson and colleagues (2004) found that while overall accuracy increased following retrieval practice, overall rates of intrusions of CL items did not, in fact they decreased. Specifically, following single study-test trials false alarms for younger adults ranged from .38 to .44, following five study-test trials false alarms for younger adults ranged from .19 to .24. For older adults, following single study-test trials false alarms ranged from .38 to .58, following five study-test trials false alarms ranged from .24 to .68. A breakdown in the ability of older adults to effectively inhibit activation of the CL item, despite retrieval practice, has been suggested to account for age related differences in false alarms between older and younger adults (Sommers & Huff, 2003).

While there are numerous studies investigating the impact of retrieval practice on adult's memory, there is a dearth of research on the impact of retrieval practice and children's memory, especially in relation to the DRM word list task. However, while not directly related to the current study, Friedman and Kemp (1998) found retrieval practice had no impact on the accuracy of children's judgment of the recency of autobiographical events. Lechuga and colleagues (2006) found retrieval practice increased accurate recall, with both adults and children demonstrating an improvement in recall even though overall adults had a higher level of recall than children. These authors conclude inhibitory mechanisms underlying memory processes are similar across age groups, with no developmental differences when completing retrieval induced forgetting tasks. As the type of inhibition involved in Stroop interference and NP effects has been demonstrated to remain constant across development (Pritchard & Neumann, 2004), differences in false alarms should remain evident between inhibitory control groups despite retrieval practice. However, as few studies have examined the effect of retrieval practice on children's false alarms and the DRM task, it is less clear whether a developmental trajectory of fewer false alarms will be evident following retrieval practice.

According to Signal Detection Theory an individual's ability to discriminate target items from distractor items is determined by the amount of evidence available in memory and cognitive processes used to reach a decision (Koppell, 1977; Wickens, 2002). In relation to response latencies it is assumed that more difficult decisions take more time, resulting in longer RTs (Koppell, 1977). In this way, the difference in response latencies between false alarm responses and correct identification of target items reflects differences in the amount of cognitive processing applied to the decision making process (Macmillan & Creelan, 1991). The current study proposes that such differences in response latencies are also reflective of inhibitory control in the same way that response latencies in the NP task reflect the cost of inhibitory control applied to when the target item was the to-be-ignored distractor.

A logical extension of this assumption would therefore be that within the context inhibitory control, faster RTs when participants make a false *remember* response to critical lure items provide a measure of ineffective inhibitory control, and slower RTs to false *remember* responses provide a measure of effective inhibitory control. Figure 6.1 depicts the possible relationship between false alarms between individuals assigned on the basis of less or more effective inhibitory control. In this representation, the vertical line in the centre of the figure represents the mean RTs to false alarms and correct identification of target items by those assigned to the Mod IC group. Should those in the Less IC group demonstrate faster RTs when making false alarms in relationship to their RTs when correctly responding to target items, then the distribution of RTs of the Less IC group will fall to the left of the mean RTs of the Mod IC group. The discriminabiltity index score (*d'*) would therefore be negative. Conversely, should those in the More IC group demonstrate slower RTs when making false alarms in relationship to their RTs when correctly responding to target items, then the distribution of RTs of the More IC would fall to the right of the distribution of RTs of the Mod IC group. The discriminability index score (*d'*) in this case would be positive.

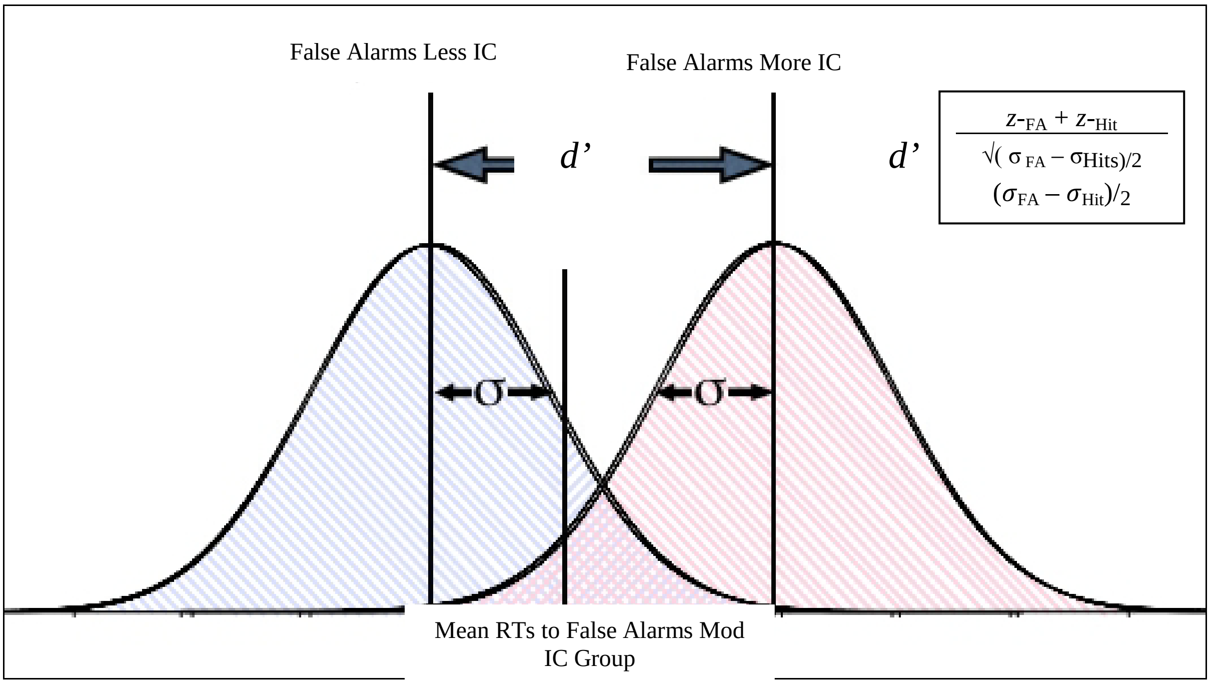

Figure 6.1: Signal Detection Theory representation of relationship between RTs to false alarm responses and correct identification of target items. *d'* represents degree to which RTs to false alarms produced by those in the Less IC and More IC group would deviate from mean RTs to false alarms produced by those in the Mod IC group. Note: z = z-score, σ standard deviation.

By extension, those that show greater inhibitory control on a selective attention task should also show greater benefit from retrieval practice, evident in reduced false alarms, whereas those that show less inhibitory control may not show such a benefit, evident in higher rates of false alarms. In view of these questions, the following experiment was designed to test the hypothesis that those assigned to the Less IC group would continue to produce higher rates of false alarms than the More IC group, despite engaging in retrieval practice. On the other hand, those participants assigned to the More IC group are expected to show a reduction in overall rates of false alarms compared to the Less IC group, as a result of retrieval practice.

Experiment 2a examines rates of false alarms, false remember responses, and RTs as a function of a single index of inhibitory control between children and adults. In Experiment 2b, children were assigned to inhibitory control groups on the basis of combined Stroop interference and NP effect, with a new group of adults who completed the Stroop interference and NP task; false alarm rates, false *remember* responses, and RTs were then compared between those assigned as less or more efficient inhibitors as a function of this combined index of inhibitory control. This was followed by a comparison of false alarm rates, false *remember* responses, and RTs, between both children and adults in Experiments 2a and 2b, to determine whether a combined index of inhibitory control proved to be more sensitive in detecting individual differences in false alarms to CLs than a single index of inhibitory control.

6.1.1 Experiment 2a and 2b: Participants.

A new sample of children were recruited, with 50 8-year olds, and 36-10 year olds completing the experiment, with 86 children in total (46% male). The children were tested twice, with approximately 14 days between each test. This allowed a within-sample comparison of rates of false memories in relation to inhibitory control measured by Stroop interference (Experiment 2a), and StroopNP effect (Experiment 2b). Two groups of adults participated; 147 undergraduate students completed a Stroop Interference task and DRM memory task (Experiment 2a), and 94 undergraduate students completed a StroopNP task and the DRM memory task (Experiment 2b), both groups of adults received course credits for their participation. Participants were male and female (39% male), 16 to 56 years of age (males M = 21.92, females M = 20.47).

6.1.2 Experiment 2a and 2b: Measures.

Correct recognition was measured as the proportion of targets correctly recognized as previously studied (hits). Unrelated intrusions were measured as the incorrect recognition of unrelated items as previously studied words. False memories were measured as the proportion of false alarms to critical lure items, incorrectly recognized as previously studied list words. Participants also rated the veracity of their recognition of test items, by pressing keys corresponding to *remember*, *know*, or *New* responses. Response time data to *remember* responses to hits and false alarms were also collected.

6.1.3 Experiment 2a and 2b: Discriminability Index.

The discriminability index score *d'* was calculated in accordance with Koppell (1997) as follows: 1) The frequency distribution of false alarms and hit rates for individuals within the Less IC, Mod IC, and More IC groups, was calculated as a *z*-score ($z = X - \mu/\sigma$), with X being individual mean false alarms or hit rates, μ = mean of the inhibitory control group, and σ = standard deviation of the inhibitory control group. 2) The mean shift in distributions of false alarms and hits as a function of inhibitory control was calculated as *d'* ($z_{FA} - z_{Hits}/\sqrt{(}\ \sigma_{FA} - \sigma_{Hits}/2)$.

6.1.4 Experiment 2a and 2b: Materials and Design.

Stroop color-word trials were presented as in Experiment 1. Negative Priming trials consisted of a prime-probe pair, with Stroop incongruent trials comprising the prime trials, and Stroop neutral trials comprising the probe trials. Stroop trials consisted of ten practice trials, and 300 test trials of which 50% were incongruent trials and 50% were neutral trials, presented in random order; the negative priming task consisted of 75 prime trials and 75 probe trials. Stroop trials and negative prime/probe couplets were randomly presented. The memory task used the same DRM word lists as described in Experiment 1, and were presented by way of SuperLab Pro™, Version 2.0, software, at the rate of 1 word per second. Responses were made by participants pressing stickers placed on *h*, *j*, and *k* keys. Word fragment lists were also compiled for each DRM list, see Appendix B.

A mixed design was used for the word-list memory task. The between-subjects variables were age (8- vs. 10-year-olds vs. adults), group (less vs. more efficient inhibitors), and inhibitory control index (Stroop vs. StroopNP). The within-subjects variable was list type (SPW- vs. SW-lists). List types were presented in regular alternation and counterbalanced with half of the participants in each age group beginning with a SW-list and the remaining half with a SPW-list, see Appendix C.

6.1.5 Experiment 2a and 2b: Procedure.

Instructions and presentation of Stroop task and DRM memory tasks procedures were identical to those described in Experiment 1. The exception being that between the presentation of a DRM word list and test phase, children and adults were instructed to complete word fragments of the just studied lists (see Appendix B).

6.2 Experiment 2a: Results

An alpha level of .05 was used for all statistical tests, with .01 selected for post-hoc analyses. Where appropriate, effect sizes referring to partial eta squared (η_p^2) or Cohen's *d*, and 99% CIs are also included. Bonferroni corrections were applied for post-hoc comparisons of significant interactions.

Again, because our primary interest was in contrasting the extreme thirds of the efficiency distribution, between those assigned to the Less IC group and those assigned to the More IC group, statistical analyses below and focus on contrasts between these two groups. The middle group (Mod IC) is excluded because it is not as straightforwardly classifiable as either more or less efficient on this continuum. For the sake of completeness and reference, however, summary data for all groups are provided in relevant tables.

6.2.1 Formation of Groups:

Data collection and allocation to groups was similar to that described in Experiment 1, with the addition of retrieval practice between study and test phases. As outlined in Experiment 1, the primary interest was in contrasting the extreme thirds of the efficiency distribution statistical analyses below involves contrasts between these two groups (total number 72 participants), with summary data for all three groups presented in relevant tables.

First, children were ranked according to Stroop Interference as in Experiment 1. A combined ranking was calculated by adding Stroop interference and error rate rankings ($Stroop_{rank}$ + $Error_{rank)}$. Those in the lower third of the distribution were designated as more efficient inhibitors and were assigned to a more inhibitory control group (More IC), whereas those in the upper third were designated as less efficient inhibitors and were assigned to a less inhibitory control group (Less IC). The Less IC group contained 29 children (14, 8-year-olds, and 15, 10-year-olds) and 48 adults, the moderate inhibitory control (Mod IC) group contained 29 children (16, 8-year-olds, and 13, 10-year-olds) and 48 adults; and the More IC group contained 29 children (13, 8-year-olds, and 16, 10-year-olds) and 48 adults. In relation to children, those assigned to the Less IC group (*M* =.06, ±.05) differed in terms of mean proportion of Stroop interference and errors from those assigned to the More IC group (*M* = -.08, ±.05). In relation to adults, those assigned to the Less IC group differed in terms of mean proportion of Stroop interference and errors (*M* = .06, ± .02) from those assigned to the More IC group (*M* = -.05, ± .02). See Appendix E for RT and error rate data for children and adults, and for all groups.

6.2.2 Experiment 2a: Correct and Incorrect Recognition as a Function of a Single Index of Inhibitory Control

Mean responses to target and unrelated items are presented in Table 6.1. Total mean responses to target items were entered into separate 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-year olds vs. Adults) x 2 (List type: SW vs. SPW-lists) mixed ANOVAs. The between-subjects variables were age and group, and list type the within-subjects variable. As the top portion of Table 6.1 illustrates, overall children produced lower rates of correct recognition of previously studied words compared to adults. Consistent with this, the lower portion of Table 6.1 illustrates that overall children also produced higher rates of incorrect recognition of previously studied words compared to adults. Analysis revealed a significant main effect of age, with the developmental trajectory one of improved recognition evident in adults (M= .84), in comparison to 10-

year olds (*M* = .79), and 8-year olds (M= .76), $F(2,148) = 7.76$, $p < .01$, $\eta_p^2 = .09$. No other main effects reached significance, and the results show no significant interactions, all *F*'s < 1.

In relation to unrelated intrusions, a significant main effect of age was also found, with the developmental trajectory was one of decreased error rates in recognition for adults (*M* = .04), in comparison to 10-year olds (*M* = .20), with 8-year olds producing the highest rate of errors (*M* = .24), $F(2,148) = 64.03$, $p < .01$, $\eta_p^2 = .46$,. No main effects or significant interactions were found, *F*'s < 1.

Table 6.1: *Experiment 2a: Comparison of Children's and Adults Veridical Recognition as a function of Age, Inhibitory Control Group*

			Group	
		Less IC	Mod IC	More IC
Response/list	Age	*M* (StdE)	*M* (StdE)	*M* (StdE)
Hits	Children	.79 (.02)	.77 (.02)	.77 (.02)
	Adults	.85 (.02)	.81 (.02)	.83 (.02)
SW-lists	8-year olds	.78 (.06)	.71 (.03)	.72 (.03)
	10-year olds	.79 (.03)	.80 (.04)	.79 (.04)
	Adults	.86 (.02)	.80 (.02)	.82 (.02)
SPW-lists	8-year olds	.80 (.03)	.76 (.03)	.74 (.03)
	10-year olds	.78 (.03)	.81 (.04)	.81 (.04)
	Adults	.84 (.02)	.82 (.02)	.83 (.02)
URIntrusions	Children	.21 (.02)	.23 (.02)	.23 (.02)
	Adults	.04 (.01)	.04 (.01)	.03 (.01)
SW-lists	8- year olds	.22 (.03)	.29 (.02)	.28 (.03)
	10-year olds	.21 (.03)	.20 (.04)	.21 (.04)

	Adults	.05 (.01)	.03 (.01)	.03 (.01)
SPW-lists	8-year olds	.20 (.03)	.24 (.03)	.26 (.03)
	10-year olds	.22 (.03)	.19 (.04)	.19 (.04)
	Adults	.04 (.02)	.06 (.02)	.03 (.02)

Note: IC = Inhibitory Control, Hits = correctly recognizing a previously studied word as old, URIntrusions = Unrelated Intrusions, incorrectly recognizing a new word as old, StdE = standard error.

6.2.3 Experiment 2a: False Alarms

As indicated in Table 6.2, children and adults assigned to the Less IC group produced higher overall rates of false alarms to CLs than children and adults assigned to the More IC group. Rates of false alarms to CLs of children and adults classified on the basis of a single index of inhibitory control were entered into a 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-year olds vs. adults) x 2 (List: SW-lists vs. SPW-lists) mixed ANOVA. Again, group and age provided the between-subjects variables, with list type the within subjects variable. A significant main effect of group was found, $F(2,148) = 14.53$, $p < .01$, $\eta_p^2 = .09$, with those assigned to the Less IC group producing on average more false alarms ($M = .70$) than those assigned to the More IC group ($M = .52$). Age also produced a main effect, with the developmental trajectory again of decreased rates of false alarms for 8-year olds, ($M = .53$), in comparison to 10-year olds ($M = .55$), while adults produced a greater number of false alarms ($M = .73$), $F(2,148) = 11.12$, $p < .01$, $\eta_p^2 = .13$.

Further analysis was conducted to understand differences in overall rates of false alarms between children aged 8-, and 10-years, and adults. Post-hoc analysis required nine, pair-wise comparisons, with the critical *p* value adjusted accordingly. The difference in overall rates of false alarms produced by 8-year olds assigned to the Less

IC group compared to those assigned to the More IC group was found to be statistically significant, $t(27) = 3.08$, $p < .01$. Of interest, the difference between rates of false alarms produced by children aged 8-years assigned to the More IC group compared to adults assigned to the More IC was also statistically significant, $t(60) = 4.56$, $p < .01$. No other comparisons reached statistical significance, with all *t*'s < 2.98.

As can be seen in the top portion of Table 6.2, overall 8-year olds assigned to the More IC group produced fewer false alarm rates for both SW- and SPW-lists than 8-year olds assigned to the Less IC group or 10-year olds or adults assigned to either Less or More IC groups. Of note, 8-year olds assigned to the Less IC group produced more false alarms to CLs in SW-lists than SPW-lists, whereas 10-year olds and adults assigned to the Less IC group produced more false alarms to CLs in SPW-lists than CLs in SW-lists. The interaction between age, group and list type also reached significance, $F(2,148) = 3.11$, $p = .05$, $\eta_p^2 = .04$. In this case, 8-year olds assigned to the More IC group produced fewer false alarms when presented with SW-lists ($M = .38$), compared to 10-year olds ($M = .49$), and adults ($M = .68$). Whereas, 8-year olds assigned to the Less IC group produced similar rates of false alarms when presented with SW-lists ($M = .77$), compared to 10-year olds ($M = .61$), and adults ($M = .72$). Post-hoc analyses were conducted separately for each list type, based on nine pair-wise comparisons, with the critical *p* value corrected to .005. Results indicated a significant difference in rates of false alarms to SW-lists between children aged 8-years and adults assigned to the More IC group, $t(60) = 4.61$, $p < .01$. Likewise, a significant difference was also found in rates of false alarms to SPW-lists between 8-year olds compared to adults assigned to the More IC group, $t(60) = 4.15$, $p < .01$. A significant difference was found in rates of false alarms to SPW-lists between 8-year olds compared to adults assigned to the Less IC group, $t(60) = 3.15$, $p < .01$. Last, a significant difference was found in rates of false alarms to SPW-lists between adults assigned to the Less IC group compared to adults assigned to the More IC group, $t(94) = 3.92$, $p < .01$. No other comparison reached statistical significance, *t*'s < 2.85.

Table 6.2: *Experiment 2a: Comparison of Children's and Adults FA as a function of Age, Inhibitory Control Group*

			Group		
		Less IC	Mod IC	More IC	
Response Type	Age	*M* (StdE)	*M* (StdE)	*M* (StdE)	*p*
Overall	8-year olds	.70 (.06)	.42 (.06)	.39 (.06)	<.01
	10-year olds	.63 (.06)	.57 (.08)	.48 (.07)	ns
	Adults	.78 (.04)	.67 (.03)	.68 (.04)	.05
SW-lists	8-year olds	.77 (.07)	.47 (.06)	.38 (.06)	<.01
	10-year olds	.61 (.07)	.58 (.08)	.49 (.08)	ns
	Adults	.72 (.04)	.62 (.04)	.68 (.04)	ns
SPW-lists	8-year olds	.63 (.08)	.37 (.07)	41 (.07)	.05
	10-year olds	.64 (.07)	.56 (.09)	.47 (.09)	ns
	Adults	.84 (.04)	.75 (.04)	.68 (.04)	<.01

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists CLs incorrectly recognized as *old*, Overall = mean percentage of false alarms regardless of list type, FA = false alarms, StdE = standard error

Overall rates of false alarms as a function of inhibitory control, age, and list type are illustrated in Figure 6.2. As can be seen in Figure 6.2, greater differences in rates of false alarms were evident between groups based on inhibitory control, rather than between age groups, or between list type. While 8-year olds assigned to the More IC group produced the lowest overall rates of false alarms regardless of list type, overall 8-year olds assigned to the Less IC group produced a similar rate of false alarms regardless of list type, with both 10-year olds and adults assigned to the Less IC group producing higher overall rates of false alarms to SPW-lists.

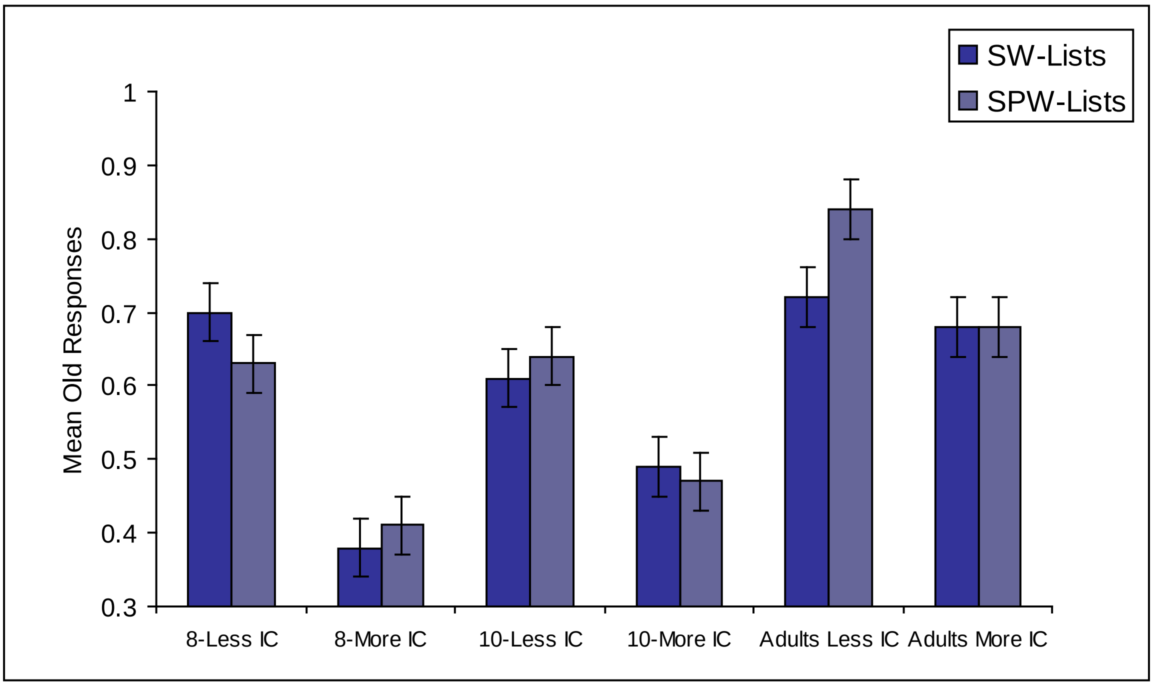

Figure 6.2. Experiment 2a: Comparison of FAs as a function of Age, Group and Inhibitory Control Index. Note: IC = inhibitory control, error bars denote 99% CI

6.2.4. Comparison of Remember and Know Judgments as Function of Inhibitory Control

Frequency of *remember* responses were calculated on the basis of mean number of *remember* judgments and standard deviations calculated for each group. Mean proportion of *remember* judgments for each group are presented in Table 6.3.

Table 6.3: *Experiment 2a: Mean Proportions of Correct and Incorrect Remember Responses as a function of Age, Inhibitory Control Group*

		Group		
		Less IC	Mod IC	More IC
List	Age	*M* (StdE)	*M* (StdE)	*M* (StdE)
Hits				
	8-year olds	.92 (.06)	.92 (.05)	.82 (.05)
	10-year olds	.95 (.05)	.70 (.07)	.89 (.06)
	Adults	.81 (.03)	.82 (.03)	.79 (.03)
SW-lists/8-year olds		.92 (.06)	.92 (.05)	.84 (.05)
	10-year olds	.97 (.05)	.68 (.07)	.91 (.06)
	Adults	.82 (.03)	.81 (.03)	.80 (.03)
SPW-lists/8-year olds		.92 (.06)	.91 (.05)	.80 (.05)
	10-year olds	.94 (.06)	.72 (.07)	.87 (.06)
	Adults	.80 (.03)	.82 (.03)	.79 (.03)
URIntrusions				
	8-year olds	.45 (.07)	.44 (.06)	.36 (.06)
	10-year olds	.37 (.07)	.36 (.08)	.31 (.08)
	Adults	.10 (.04)	.10 (.04)	.12 (.04)
SW-lists/8-year olds		.53 (.09)	.41 (.08)	.34 (.08)
	10-year olds	.45 (.08)	.33 (.10)	.31 (.11)
	Adults	.09 (.05)	.09 (.05)	.09 (.05)
SPW-lists/8-year olds		.37 (.09)	.47 (.08)	.39 (.08)
	10-year olds	.30 (.09)	.39 (.11)	.33 (.11)
	Adults	.11 (.05)	.10 (.05)	.15 (.05)

Note: IC = Inhibitory Control, Hits = correctly recognizing a previously studied word as old, URIntrusions = Unrelated Intrusions, incorrectly recognizing a new word as old, StdE = standard error.

The mean proportion of *remember* responses to target items based on age and inhibitory control, are presented in Table 6.3 above. Tthe trend was for higher rates of false *remember* responses for those in the Less IC group in comparison to those produced by the More IC groups. The main effect of age was significant, $F(2,148) = 4.19$, $p = .02$, $\eta_p^2 = .05$. Interestingly, in this case the developmental trajectory was one of higher rates of *remember* responses for 10-year olds ($M = .92$), followed by 8-year olds ($M = .87$), with adults producing the least number of *remember* responses ($M = .80$). No other main effects were significant or interactions reached significance, all *F*'s < 1.

As shown in Table 6.3, overall children were more likely to produce incorrect *remember* responses to unrelated items than adults, $F(2,148) = 17.94$, $p < .01$, $\eta_p^2 = .20$. Mean rates of false alarms were calculated for each age group regardless of group. This indicated that the developmental trajectory was of improved recognition in adults, as adults produced the fewest proportion of incorrect *remember* responses ($M = .11$), in comparison to 10-year olds ($M = .34$), with 8-year olds producing significantly more *remember* responses ($M = .40$).

As our main interest was in differences in false *remember* responses to CLs, the frequency of false *remember* responses, mean RTs, and *d'* were submitted to analyses. Table 6.4 presents mean proportion of *remember* responses to false alarms, with the frequency of false alarms per group presented in the top portion of the table, and RTs and *d'*, as a function of list type, age, and inhibitory control presented in the lower portion. Mean number of false *remember* responses were entered into a 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW- vs. SPW-lists) mixed ANOVA. Again, group and age provided the between-subjects variables, and list-type the within-subject variable. The main effect of group reached significance,

$F(1,148) = 4.00$, $p = .05$, $\eta_p^2 = .03$, with children and adults assigned to the Less IC group producing overall more false *remember* responses. Mean percentage of false alarms were calculated for each group regardless of age, which indicated those in the Less IC group produced higher rates of false alarms ($M = .74$) than those assigned to the More IC group ($M = .63$). The interaction between list type and group also reached significance, $F(1,148) = 5.72$, $p = .02$, $\eta_p^2 = .04$, with those assigned to the Less IC group producing a higher number of false *remember* responses to CLs in SPW-lists ($M = .78$) than to CLs in SW-lists ($M = .71$), whereas as those assigned to the More IC group produced more false *remember* responses to SW-lists ($M = .69$) than SPW-lists ($M = .56$).

Table 6.4: *Experiment 2a: Mean Proportions of Remember Responses, RTs, and d', to FA as a function of Age, Group and Inhibitory Control*

List	Age	Group: Less IC *M* (StdE)	F	Mod IC *M* (StdE)	F	More IC *M* (StdE)	F
	8-year olds	.72 (.08)	79%	.70 (.07)	72%	.64 (.07)	72%
	10-year olds	.83 (.08)	87%	.50 (.10)	60%	.58 (.09)	55%
	Adults	.68 (.04)	81%	.59 (.04)	70%	.68 (.04)	79%
SW-lists *R* responses							
	8-year olds	.71 (.10)		.65 (.09)		.71 (.09)	
	10-year olds	.78 (.10)		.54 (.12)		.72 (.11)	
	Adults	.64 (.05)		.51 (.06)		.64 (.05)	
SPW-lists *R* responses							
	8-year olds	.72 (.09)		.74 (.08)		.56 (.08)	
	10-year olds	.88 (.09)		.44 (.11)		.45 (.11)	
	Adults	.72 (.05)		.66 (.05)		.72 (.05)	

List	Age	RTs(ms)	*d'*	RTs (ms)	*d'*	RTs (ms)	*d'*
SW-lists *R* responses							
	8-year olds	2004	-.46	1485	-.03	1511	.06
	10-year olds	1932	-.50	1186	-.01	1061	.18
	Adults	1535	-.17	1451	.00	1179	.11
SPW-lists *R* responses							
	8-year olds	1260	-.33	1201	-.03	1335	.47
	10-year olds	1241	-.13	1528	-.01	1654	.10
	Adults	1124	-.72	1590	.00	1520	.22

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists, CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists, CLs incorrectly recognized as *old*, *R = remember* responses, F = frequency of false alar*M* responses, *d'* = discriminability index, ms = milliseconds, StdE = standard error

Mean RTs to *remember* responses to critical lure items were entered into a 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW- vs. SPW-lists) mixed ANOVA. The between-subjects variables were age and group, the within-subjects variable was list type. Results indicated the interaction between list type and group was significant, $F(1,148) = 13.38$, $p < .01$, $\eta_p^2 = .11$, with those in the Less IC group producing faster overall RTs when making a false *remember* response to CLs in SPW-lists than SW-lists, whereas those in the More IC group produced faster RTs to CLs in SW-lists than SPW-lists. Post-hoc analysis confirmed that the difference in RTs to SPW- vs. SW-lists produced by those in the Less IC group was significant at the $p = .01$ level, and the difference between the RTs to SPW-lists between those in the Less IC group and the More IC group was also significant at the $p < .01$ level.

Mean *d'* scores were entered into a 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW vs. SPW) mixed ANOVA. Again, group and age provided the between-subjects variable, and list type the within subject variable. Results confirmed the main effect of group, $F(1,148) = 12.55$, $p < .01$, $\eta_p^2 = .08$, indicating those assigned to the Less IC group produced faster overall RTs when making a false *remember* response in comparison to their overall RTs when correctly identifying target items as previously studied words (*d'* = -.38), while those in the More IC where slower to respond when making a false *remember* response in comparison to their overall RTs when correctly identifying target items (*d'* = .16). No other main effects or interactions reached significance, *F*'s < 1.

The following analyses included the Mod IC group, as the propensity of the Mod IC group to produce false *remember* responses in relation to hits, provided a comparison for the mean distribution of RT *d'* scores of the Less IC and More IC groups. Further investigation of differences in mean false *remember* RTs distributions between groups were undertaken, with separate comparisons made between the mean distribution of RT *d'* scores of the Less IC and More IC in relation to the mean distribution of RT *d'* scores of the Mod IC group. As Figure 6.3 illustrates, there was a significant difference in the overall mean distribution of RT *d'* scores of the Less IC group in comparison to the Mod IC group, $F(1, 145) = 6.25$, $p = .01$, $\eta_p^2 = .04$, indicating those in the Less IC group produced a greater shift in the mean distribution of RTs of false *remember* responses (*d'* = -.38) in relation to correct *remember* responses, in comparison to the mean distribution of RTs of false and correct *remember* responses of the Mod IC group (*d'* = -.01). In contrast, no significant difference was found in terms of the mean distribution of RTs of false *remember* responses in relation to correct *remember* responses between the More IC group and Mod IC group, $F < 1$.

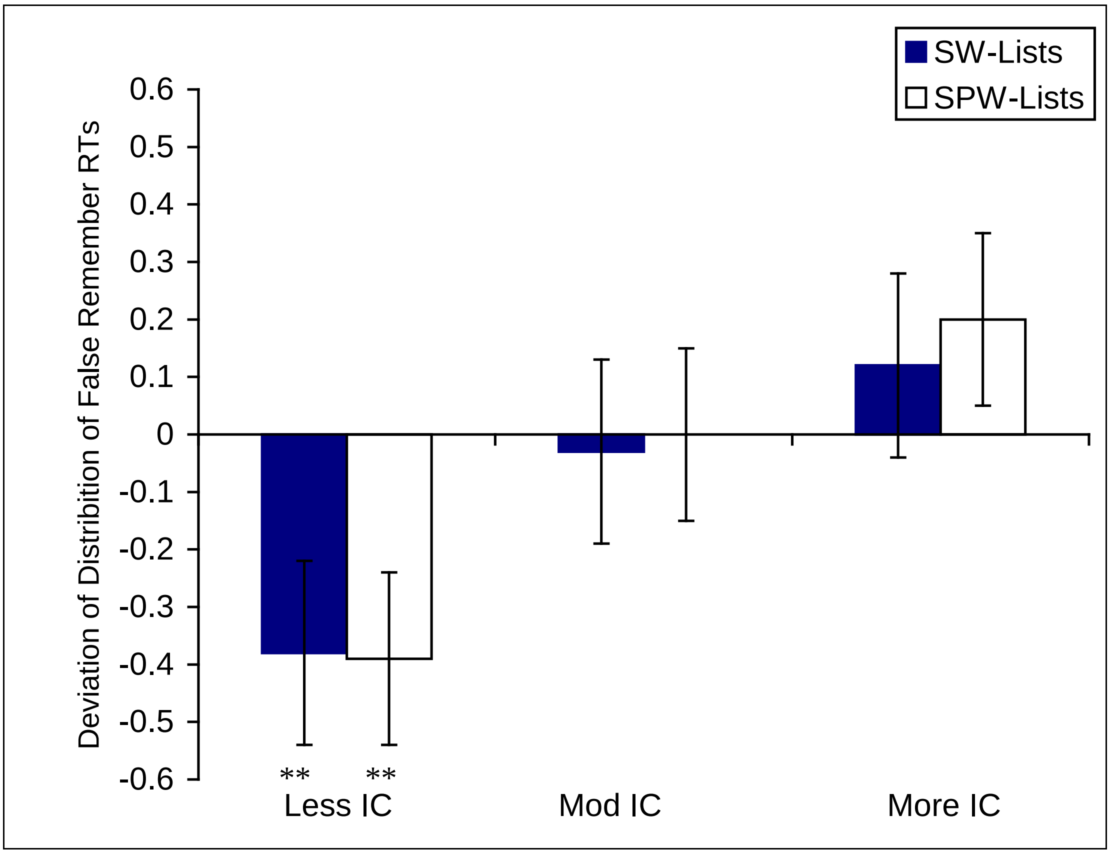

Figure 6.3 Experiment 2a: Differences in mean RT distributions to Remember responses between inhibitory control groups in terms of a single index. Note: IC = inhibitory control, ** = p = .01, error bars denote standard error.

Discussion Experiment 2a

Taken together the results of Experiment 2a replicate the critical findings of Experiments 1a and 1b: 1) overall, children and adults demonstrating less effective inhibitory control produced higher rates of false alarms than children and adults demonstrating more effective inhibitory control, 2) again, no significant differences in veridical recognition was found between groups, that is children and adults demonstrating less effective inhibitory control were as accurate in correctly recognizing target items, and in their ability to correctly reject unrelated items. As in Experiments 1a and 1b, the developmental trajectory was one of improved accurate recognition in adults compared with children, with children producing a rate of errors in comparison to adults. In this case, regardless of inhibitory control children recognized fewer target items and produced more unrelated intrusions, however, this pattern was also found in the context of fewer false alarms. It would appear from these results, that higher rates of false alarms produced by adults were coupled with higher rates of correct recognition. Put another way, while overall adults produced higher rates of false alarms, they were also more accurate in their correct recognition of previously studied words, and in their correct recognition of unrelated test items.

In relation to subjective ratings of false alarms, a number of interesting findings emerged. First, while non-significant, a trend emerged of those demonstrating less effective inhibitory control producing higher rates of *remember* responses in relation to their correct recognition of target items. Second, this trend was replicated in relation to false alarms in that again children and adults demonstrating less effective inhibitory control produced higher rates of false *remember* responses alongside higher overall rates of false alarms. Third, no evidence of significant differences in false *remember* responses related to age emerged, suggesting that children and adults assigned to the Less IC group experienced the intrusion of CLs as a remembered event, while children and adults assigned to the More IC group were less likely to do so. Examination of RTs to false *remember* responses indicates that while those in the Less IC group were slower to make *remember* responses to CLs in SW-lists than those in the More IC group, when presented with SPW-lists those assigned to the Less IC group were faster to make false *remember* responses than those in the More IC group. Mean *d'* scores provide further support that those in the Less IC group are more likely to make faster false *remember* responses. Specifically, the mean distribution of RTs of the Less IC group when responding to CLs in comparison to responses to target items, showed a greater overall deviation away from the mean distribution of RTs of those demonstrating moderate inhibitory control. Furthermore, those assigned to the More IC group while more likely to make slower overall false *remember* responses to CLs in comparison to target item, this deviation in the distribution of mean RTs of false and correct *remember* responses was significant in comparison to the Mod IC group.

6.3. Experiment 2b: Comparison of True and False Alarm Rates between Children and Adult, using a Combined Index of Inhibitory Control.

Formation of Groups: Participants who completed the StroopNP task were ranked according to a combination of Stroop interference and NP effect, see Figure 6.4. Groups were formed on the basis of percentage of Stroop RT interference between neutral and incongruent trials coupled with proportion of errors in incongruent trials, plus percentage of NP effect between NP IR probe trials and control probe trials, coupled with proportion of errors in NP IR probe trials ($Stroop_{rank}$ + Stroop $Error_{rank)}$ plus (NP_{rank} + NP $Error_{rank).}$ Those with a greater degree of Stroop interference and less NP effect, were assigned to the Less IC group (29 Children, and 31 adults) those with a lesser degree of Stroop interference and a greater degree of NP effect were assigned to the More IC group (29 Children, and 31 adults). The remaining participants were assigned to the Mod IC group, and were excluded from further analysis as they could not be easily classified as either inefficient or efficient inhibitors (28 Children and 32 adults). On the basis of combined Stroop interference and NP effect, proportional interference scores were calculated for each individual. In relation to children, differences between groups in terms of Stroop interference ranged from a mean interference score of .04 (± .01), with a mean NP effect score of -.02 (± .01), for those in the Less IC group, to a mean Stroop interference score of -.04 (± .01), and NP effect score of .03 (± .01), for those in the More IC group. In relation to adults, differences between groups in terms of Stroop interference ranged from a mean interference score of .04 (± .04), with a mean NP effect score of -.03 (± .03), for those in the Less IC group, to a mean Stroop interference score of -.04 (± .03), and NP effect score of .04 (± .04), for those in the More IC group. See Appendix E for RT and error rate data for children and adults, and for all groups.

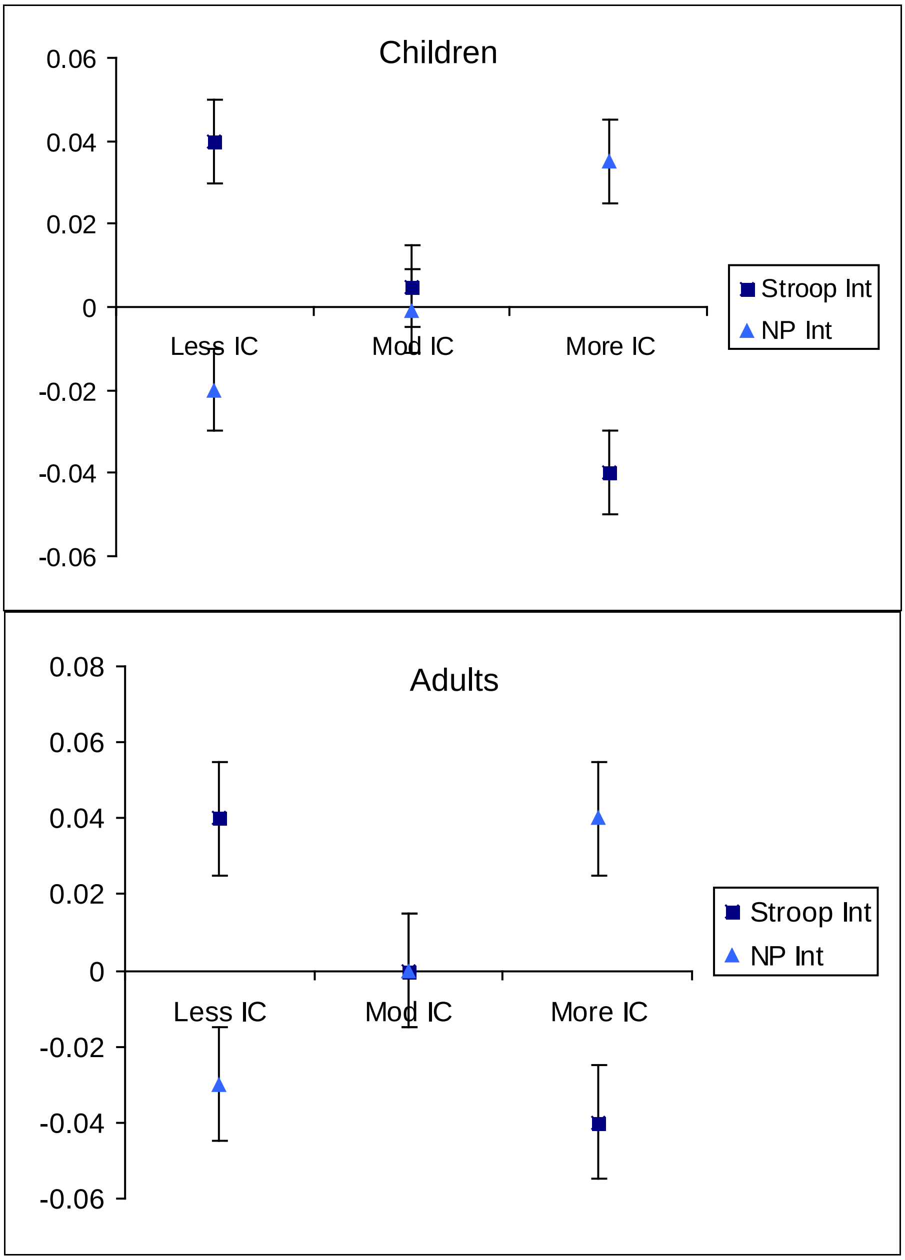

Figure 6.4. Experiment 2b: Differences between children and adults assigned to inhibitory control groups in terms of a combined index. Note: IC = inhibitory control, error bars denote standard error.

6.3.2. Experiment 2b: Children and Adults –True and False Recognition as a Function of a Combined Index of Inhibitory Control.

Mean rates of responses of children and adults to target and unrelated items were entered into separate 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW vs. SPW-lists) mixed ANOVA. The between-subjects variables were age and group, the within-subjects variable was list type. As can be seen in the top portion of Table 6.5, a significant difference in terms of correct recognition of target words was found between children and adults, $F(2,114) = 4.41$, $p = .02$, $\eta_p{}^{,2} = .07$. In this case, the developmental trajectory was one of increased correct recognition for adults (*M* = .83), followed by 10-year olds (*M* = .78), with 8-year olds correctly recognizing slightly fewer target items (*M* = .76). The main effect of group also reached significance, $F(2,114) = 5.08$, $p = .03$, $\eta_p{}^{,2} = .04$, with children and adults assigned to the Less IC group correctly recognizing more target items (*M* = .82) than those assigned to the More IC group (*M* =.76). Results also showed no significant interactions between age, groups, and list type, *F*'s < 1.

Table 6.5: *Experiment 2b: Comparison of Children and Adults Veridical Recognition as a function of Inhibitory Control Group*

		Group		
		Less IC	Mod IC	More IC
List Type	Age	*M* (StdE)	*M* (StdE)	*M* (StdE)
Hits	8-years	.79 (.03)	.69 (.03)	.72 (.03)
	10-years .	83 (.04)	.74 (.04)	.74 (.03)
	Adults	.83 (.02)	.87 (.02)	.83 (.02)
SW-lists	8-years	.79 (.02)	.68 (.02)	.73 (.04)
	10-years	.82 (.04)	.76 (.04)	.73 (.04)
	Adults	.83 (.02)	.88 (.02)	.82 (.02)
SPW-lists	8-years	.79 (.03)	.71 (.03)	.71 (.04)
	10-years	.84 (.04)	.72 (.04)	.74 (.04)
	Adults	.84 (.02)	.86 (.03)	.84 (.02)
URIntrusions	8-years	.35 (.05)	.28 (.05)	.23 (.05)
	10-years	.19 (.06)	.24 (.06)	.23 (.06)
	Adults	.07 (.04)	.10 (.04)	.02 (.04)
SW-lists	8-years	.34 (.05)	.28 (.05)	.23 (.06)
	10-years	.20 (.07)	.21 (.06)	.23 (.06)
	Adults	.05 (.04)	.09 (.04)	.02 (.04)
SPW-lists	8-years	.35 (.05)	.29 (.05)	.23 (.06)
	10-years	.18 (.07)	.28 (.06)	.23 (.06)
	Adults	.10 (.04)	.12 (.04)	.03 (.04)

Note: IC = Inhibitory Control, Hits = correctly recognizing a previously studied word as old, URIntrusions = Unrelated Intrusions, incorrectly recognizing a new word as old, StdE = standard error.

As Table 6.5 shows, overall children incorrectly recognized more unrelated items as previously studied words than adults. This was evident in the main effect of age, $F(2,114) = 16.21$, $p < .01$, $\eta_p{}^{,2} = .22$, with 8-year olds producing a higher number of errors (*M* = .29) than 10-year olds (*M* = .21), and adults producing the fewest number of errors (*M* = .05). Importantly, again there was no main effect of group, and no interactions reached significance, *F*'s < 1.

6.3.3. False Alarms

Mean responses to CLs of children and adults were entered into a 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW vs. SPW-lists) mixed ANOVA. Again, group and age provided the between-subjects variable, with list type the within subject variable. As can be seen in Table 6.6, the robust main effect of group was once again significant, *F* (2,114) = 7.58, *p* = .01, η_p^2 = .06. Overall, children and adults assigned to the Less IC group produced higher rates of false alarms to CLs (*M* = .70) compared children and adults assigned to the More IC group (*M* = .57). Interestingly, while there was a pattern of increasing rates of false alarms associated with age, with 8-year olds producing fewer alarms (*M* = .59) than 10-year olds (*M* = .64) and adults (*M* = .68), this was no longer significant.

Mean false alarms as a function of list type were then entered into separate 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) ANOVAs. Group and age provided the between-subjects variables, and list type the within subject variable. A significant difference was found between groups in terms of false alarm rates to SW-lists, *F*(2,114) = 4.48, *p* = .04, $\eta_{p'}^2$ = .04, as those in the Less IC group produced higher rates of false alarms (*M* = .67) than those in the More IC group (*M* = .55). A main effect of group was also found in relation to false alarms to SPW-lists, *F*(2,114) = 6.30, *p* = .02, $\eta_{p'}^2$ = .05, with those assigned to the Less IC group producing higher rates of false alarms to SPW lists (*M* = .72) than those assigned to the More IC group (*M* = .60). In addition, the main effect of age reached significance, *F*(2,114) =

4.15, p = .02, $\eta_{p'}^{2}$ = .07, with the developmental trajectory one of increasing rates of false alarms associated with age: overall 8-year olds produced fewer false alarms (*M* = .57) than 10-year olds (*M* = .67), with adults producing the highest number of false alarms (*M* = .73).

Table 6.6: *Experiment 2b: Comparison of FA as a function of Age, Group and Inhibitory Control*

			Group	
		Less IC	Mod IC	More IC
List	Age	*M* (StdE)	*M* (StdE)	*M* (StdE)
Overall	8-year olds	.65 (.06)	.56 (.08)	.53 (.07)
	10-year olds	.67 (.08)	.50 (.07)	.60 (.07)
	Adults	.77 (.04)	.60 (.05)	.58 (.04)
SW-lists	8-year olds	.64 (.07)	.57 (.07)	. 58 (.08)
	10-year olds	.64 (.10)	.58 (.09)	.56 (.08)
	Adults	.74 (.06)	.54 (.06)	.51 (.05)
SPW-lists	8-year olds	.66 (.06)	.56 (.06)	.49 (.07)
	10-year olds	.70 (.09)	.41 (.08)	.64 (.07)
	Adults	.80 (.05)	.66 (.05)	.65 (.05)

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists CLs incorrectly recognized as *old,* Overall = mean percentage of false alarms regardless of list type, FA = false alarms, StdE = standard error.

Remember Judgments: Table 6.7 shows mean proportions of remember responses to targets, and unrelated items as a function of age, inhibitory control and list type. Proportion of remember responses were analyzed in separate 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW vs. SPW) mixed ANOVAs. The between-subjects variables were age and group, the within-subjects variable was list type.

Table 6.7: *Experiment 2b: Mean Proportions of Correct and Incorrect Remember Responses as a function of Age, Inhibitory Control Group*

			Group	
List	Age	Less IC *M* (StdE)	Mod IC *M* (StdE)	More IC *M* (StdE)
Hits	8-year olds	.91 (.04)	.83 (.04)	.83 (.05)
	10-year olds	.91 (.06)	.87 (.05)	.85 (.04)
	Adults	.78 (.03)	.86 (.03)	.80 (.03)
SW-lists	8-year olds	.90 (.04)	.87 (.05)	.81 (.06)
	10-year olds	.87 (.07)	.84 (.06)	.84 (.05)
	Adults	.80 (.04)	.87 (.03)	.84 (.04)
SPW-lists	8-year olds	.92 (.05)	.79 (.05)	.81 (.06)
	10-year olds	.95 (.07)	.90 (.06)	.86 (.05)
	Adults	.76 (.04)	.84 (.04)	.77 (.04)
URIntrusions	8-year olds	.31 (.08)	.38 (.08)	.36 (.09)
	10-year olds	.61 (.10)	.45 (.10)	.30 (.09)
	Adults	.37 (.06)	.40 (.06)	.16 (.06)
SW-lists	8-year olds	.41 (.10)	.40 (.10)	.30 (.11)
	10-year olds	.61 (.15)	.36 (.12)	.31 (.11)
	Adults	.37 (.08)	.30 (.08)	.13 (.08)
SPW-lists	8-year olds	.21 (.10)	.36 (.10)	.42 (.11)
	10-year olds	.61 (.15)	.53 (.12)	.30 (.11)
	Adults	.38 (.04)	.51 (.08)	.19 (.08)

Note: IC = Inhibitory Control, Hits = correctly recognizing a previously studied word as old, URIntrusions = Unrelated Intrusions, incorrectly recognizing a new word as old, StdE = standard error.

A significant main effect of group was found, F (1,115) = 5.21, p = .02, η_p^2 = .04. As can be seen in Table 6.7, both children and adults assigned to the Less IC group produced higher rates of *remember* responses to unrelated lures (M = .43) compared to those assigned to the More IC group (M = .27). No significant differences or interactions were found between children and adults, in terms of *remember* responses to correct recognition of target items, or between list type, all F's < 1.

The effect of inhibitory control on *remember* responses to false recognition of critical lures was also examined. Mean proportion of false *remember* responses were entered into a 2 (Group: Less IC vs. More IC) x3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW- vs. SPW-) mixed ANOVA. Group and age provided the between-subjects variables, and list type the within subject variable. Mean false *remember* responses and the frequency of false *remember* responses as function of overall false alarm rates are presented for children and adults for each group in the upper portion of Table 6.8. Examination of these results indicates that not only are children and adults assigned to the Less IC group were more likely to incorrectly recognize critical lure items a previously studied word, they are also more likely to rate their response as a remembered event. A significant effect of inhibitory control on false alarm rates was also found in relation to false *remember* responses, F (1,113) = 11.02, p < .01, η_p^2 = .09, with higher false *remember* responses for those in the Less IC group (M = .68) than those in the More IC group (M = .49). A significant main effect of list type was also found, F (1,113) = 4.12, p = .04, η_p^2 = .04, as participants produced more false *remember* responses in relation to SPW-lists (M = .62), in comparison to false *remember* responses in relation to SW-lists (M = .55).

Table 6.8: *Experiment 2b: Mean Proportions and Frequencies of Remember Responses to FA as a function of Age, Group and Inhibitory Control*

		Group					
		Less IC		Mod IC		More IC	
List	Age	*M* (StdE)	*F*	*M* (StdE)	*F*	*M* (StdE)	*F*
	8-year olds	.73 (.06)	58.40	.71 (.07)	62.48	.38 (.07)	34.96
	10-year olds	.78 (.10)	58.50	.54 (.08)	63.18	.49 (.07)	42.63
	Adults	.67 (.05)	54.27	.61 (.05)	43.31	.59 (.05)	35.99
SW-lists							
	8-year olds	.75 (.08)		.64 (.08)		.38 (.09)	
	10-year olds	.84 (.12)		.68 (.10)		.50 (.09)	
	Adults	.60 (.06)		.57 (.06)		.52 (.05)	
SPW-lists							
	8-year olds	.72 (.07)		.79 (.08)		.38 (.12)	
	10-year olds	.73 (.12)		.40 (.10)		.48 (.09)	
	Adults	.75 (.06)		.64 (.06)		.66 (.06)	
		RTs (ms)	*d'*	RTs (ms)…	*d'*	RTs (ms)…	*d'*
SW-lists *R* responses							
	8-year olds	1413	-.49	1485	.00	1511	.11
	10-year olds	1516	-.32	1742	.00	1824	.13
	Adults	1487	-.07	1049	.00	1106	.17
SPW-lists *R* responses							
	8-year olds	1309	-.78	1588	.00	2549	.73
	10-year olds	883	-.13	1048	.00	1487	.18
	Adults	1192	-.25	1367	.00	1492	.36

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists, CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists, CLs incorrectly recognized as *old*, *R = Remember* responses, F = frequency of false alarm responses, *d'* = discriminability index, RTs- reactions times, ms = milliseconds, StdE = standard error

As can be seen in Figure 6.5, post-hoc analysis confirmed that children and adults assigned to the Less IC group produced significantly higher rates of false *remember* responses than 8-year olds assigned to More IC group (p =.001). Post-hoc analysis also indicated 8-year assigned to the Less IC group produced significantly more false *remember* responses than 8-year olds in the More IC group (p = .02), and 8-year olds assigned to the More IC group also produced significantly fewer false *Remember* responses than adults assigned to the Less IC group (p = .02).

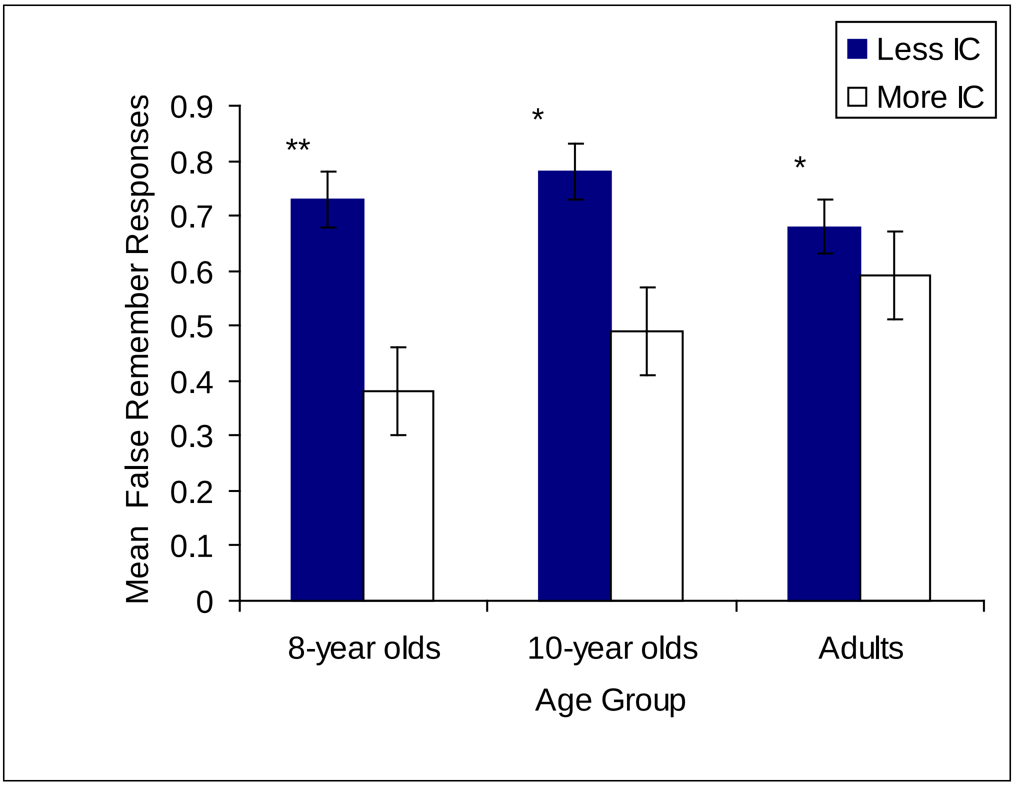

Figure 6.5. Experiment 2b: Differences between children and adults assigned to inhibitory control groups in terms of false *Remember* responses. Note: * = p < .05, ** = p < .01, error bars denote standard error.

Mean RTs to false *remember* responses, alongside *d'* scores for each group, are presented in the lower portion of Table 6.8. Mean RTs to *remember* responses were entered into a 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW- vs. SPW-lists) mixed ANOVA. The between-subjects variables were age and group, the within-subjects variable was list type. The main effect of group neared significance, *F*(1,85) = 3.46, *p* =.07, η_p^2 = .04, with faster RTs to false *remember* responses produced by those in the Less IC group (*M* = 1300), in comparison to the slower RTs to false *remember* responses produced by those in the More IC group (*M* = 1662). No other main effects or interactions reached significance, *F*'s < 1.

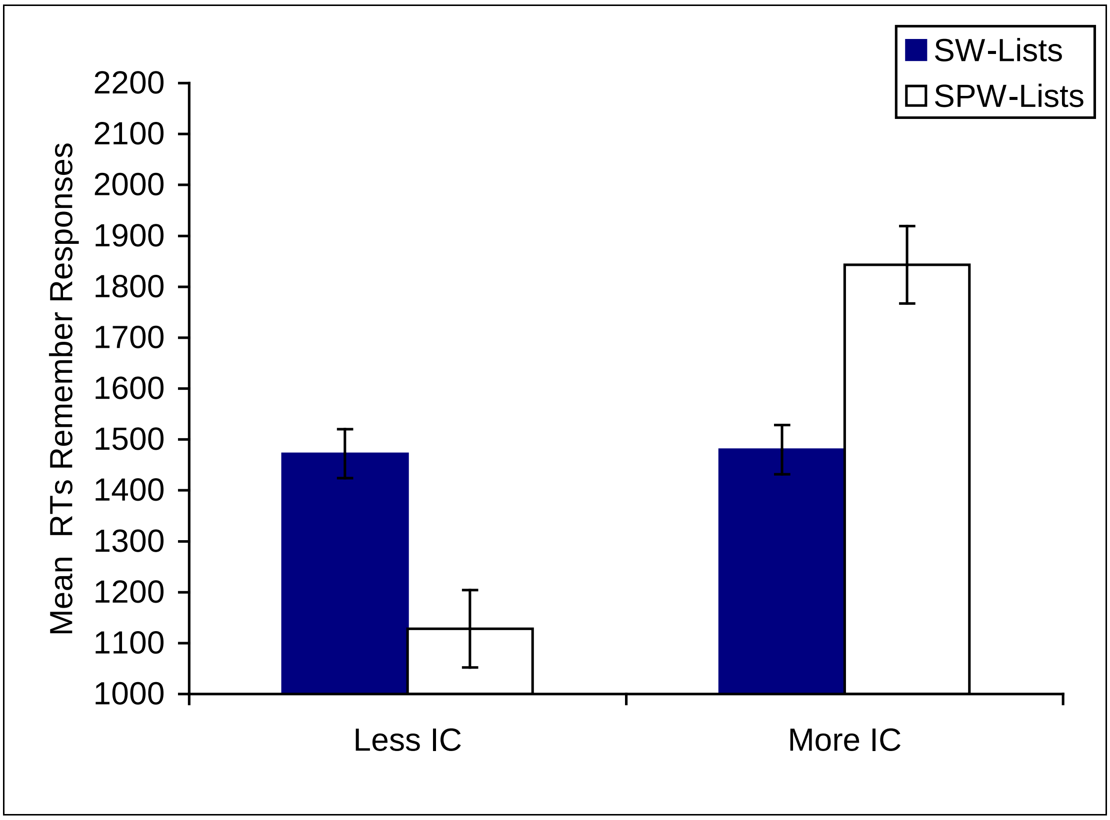

Figure 6.6. Experiment 2b: Differences in mean RT to *Remember* responses of children and adults assigned to inhibitory control groups in terms of the StroopNP task. Note: IC = inhibitory control, error bars denote standard error.

Mean *d'* scores were entered into a 2 (Group: Less IC vs. More IC) x 3 (Age: 8- vs. 10-years vs. adults) x 2 (List type: SW vs. SPW) mixed ANOVA. The between-subjects variables were age and group, the within-subjects variable was list type. Results confirmed the main effect of group, *F*(1,113) = 6.45, *p* =.01, η_p^2 = .05, indicating those assigned to the Less IC group produced faster overall RTs when making a false *remember* response in comparison to their overall RTs when correctly identifying target items as previously studied words (*d'* = -.27), while those in the More

IC where slower to respond when making a false *remember* response in comparison to their overall RTs when correctly identifying target items (*d’* = .42). No other main effects or interactions reached significance, *F*’s < 1.

Further investigation of differences in mean false *remember* RTs distributions between groups were undertaken, with separate comparisons made between the mean distribution of RT *d’* scores of the Less IC and More IC in relation to the mean distribution of RT *d’* scores of the Mod IC group. While overall those in the Less IC group were found to produce faster RTs when making false *remember* responses in relation to their responses to target items, the mean distribution of RTs was not found to deviate significantly from those in the Mod IC group (*p* = . 11). However, a near significant difference was found between those in the More IC and Mod IC groups, $F(1,113) = 3.38$, $p = .07$, $\eta_p^2 = .03$, as the More IC group slower RTs when making false *remember* responses in comparison to their RTs to target items, deviated significantly from the mean distribution of RTs of the Mod IC group. The deviations in the distributions of mean false remember RTs between groups is shown in Figure 6.7 below.

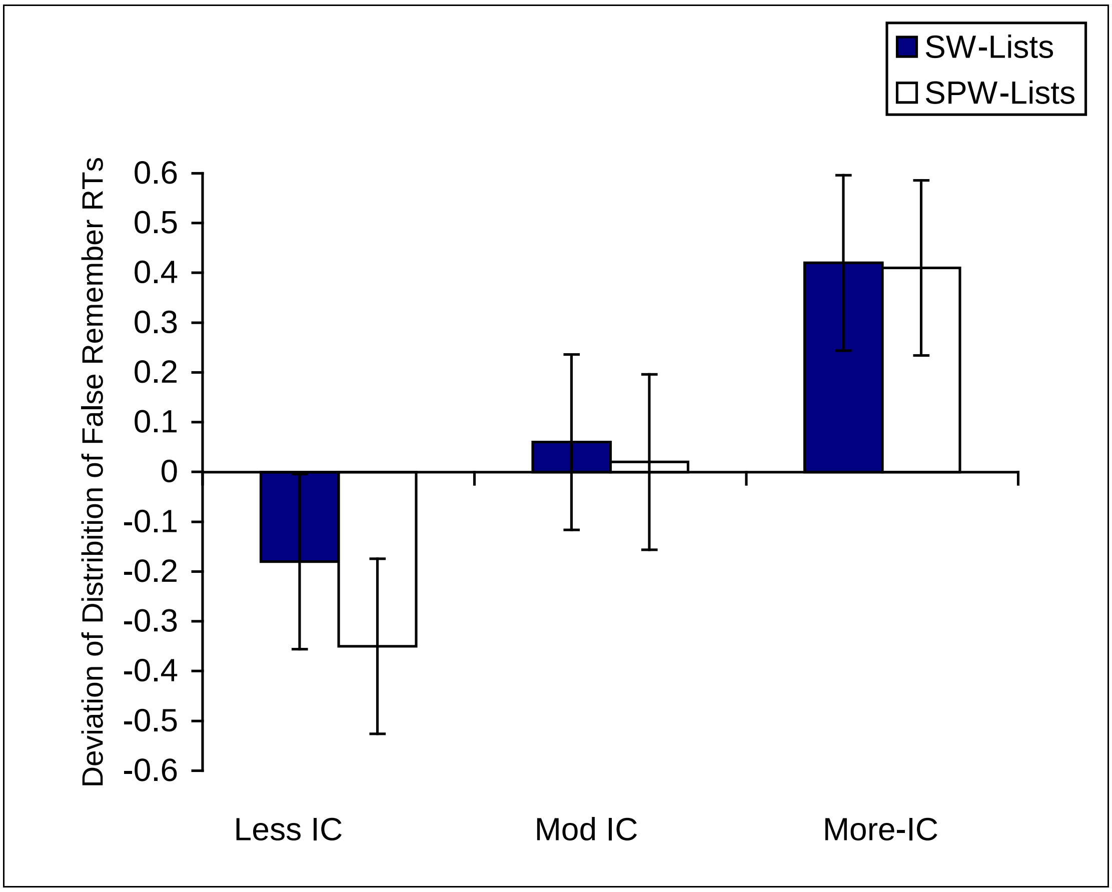

Figure 6.7. Experiment 2b: Differences in mean RTs distributions to Remember responses between inhibitory control groups in terms of a combined index. Note: IC = inhibitory control, error bars denote standard error.

Discussion Experiment 2b

In summary, the results of Experiment 2b replicate the critical findings of Experiment 2a. Taken together these results confirm the robust effect of inhibitory control on differences in rates of false alarms. Overall, children and adults demonstrating less effective inhibitory control produced higher rates of false alarms than children and adults demonstrating more effective inhibitory control. While differences in rates of false alarms based on age occurred, there were no consistent patterns of significant differences in rates of false alarms based on age. For example, similar rates of false alarms were found in each age group within the Less IC group when presented with SW-lists, whereas children assigned to the Less IC produced fewer false alarms than

Less IC adults when presented with SPW-lists. On the other hand, More IC children produced fewer false alarms than More IC adults regardless of list type. These findings are important for two reasons, first, converging evidence of a higher rate of false memories for those demonstrating less effective inhibitory control were found, and second a combined index of inhibitory control was found to account for a greater degree of variance between groups in terms of false alarms than age alone. However, as overall younger children were found to produce fewer false alarms than adults, this may reflect differences in terms of the development of interconnected semantic networks. Specifically, as the intrusion of the CL is thought to occur as a result of spreading activation between presented target words and the non-presented primary thematic associate, reduced rates of false alarms in children may result from a less developed semantic network whereas increased rates of false alarms may result from more fully developed semantic networks. In this way there may be an interaction between the role of inhibitory control and rates of false alarms in children and adults, in that differences in inhibitory control may play a greater role in individual differences in false memories for adults and less so for children. In general Experiment 2b demonstrated that those who are less effective in overcoming interference from competing information and who then show the related cost when the initially ignored information then becomes the target information, are in the same way less able to overcome interference from the CL item when it is presented as a test item.

No significant differences in veridical recognition were found between groups, suggesting that children and adults demonstrating less effective inhibitory control are also accurate in correctly recognizing target items, and in their ability to correctly reject unrelated items. While the developmental trajectory was one of increased accurate recognition in adults and overall higher rates of errors in children, this pattern was not found to be a significant factor in terms of false alarms. Rather, it would appear from these results that higher rates of false alarms produced by children and adults demonstrating less effective inhibitory control was not associated with less accurate recognition of previously studied words, or nonrelated test items.

In relation to subjective judgment of false alarms, the pattern of higher rates of false and correct *remember* responses in relation inhibitory control also emerged in Experiment 2b. Again, no evidence of significant differences in false *remember* responses related to age emerged, suggesting that children and adults assigned to the Less IC group experienced the intrusion of CLs as a remembered event, while children and adults assigned to the More IC group were less likely to do so. Consistent with this interpretation, examination of RTs to false *remember* responses indicates that overall those assigned to the Less IC group were faster to make false *remember* responses, with mean *d'* scores providing further support that those in the Less IC group are more likely to make faster false *remember* responses. While not statistically significant, examination of *d'* scores indicated the mean distribution of RTs of the Less IC group when responding to CLs in comparison to responses to target items, showed a greater overall deviation away from the mean distribution of RTs of those demonstrating moderate inhibitory control, as did those assigned to the More IC group.

6.4.1 Comparison of False Alarm Rates between Children as a Function of a Combined Index of Inhibitory Control and Retrieval Practice

Mean rate of false alarms of children were entered into a 2 (Group: Less IC vs. More IC) x 2 (IC Index: Stroop vs. Stroop plus NP) x 2 (List Type: SW vs. SPW) mixed ANOVA. Group and inhibitory control index provided the between-subjects variables, and list type the within subjects variable. Again the robust main effect of group was apparent, F (1,110) = 25.83, $p < .01$, $\eta_p^2 = .19$, regardless of inhibitory control index, children assigned to Less IC groups produced higher overall rates of false alarms (M's = .65, .66) than children assigned to More IC groups (M's = .43, .53). As can be seen in Table 6.9, a marginal interaction was found between list type, group, and inhibitory control index, F (1,110) = 3.29, $p = .07$, $\eta_p^2 = .03$. In this case, a greater difference in rates of false alarms between groups was found when children were assigned to groups on the basis of a combined index of inhibitory control compared to those assigned on the basis of a single index of inhibitory control.

Table 6.9: *Comparison of Children's False Alarms as a Function of Inhibitory Control Group and Inhibitory Control Index*

		Group		
List type	IC Index	Less IC	More IC	Difference
Overall FAs				
	Stroop	.65 (.04)	.43 (.04)	.22
	Stroop + NP	.66 (.04)	.53 (.04)	.13
SW-lists	Stroop	.69 (.05)	.43 (.05)	.26
	Stroop + NP	.64 (.05)	.57 (.05)	.07
SPW-lists	Stroop	.64 (.04)	.44 (.04)	.20
	Stroop + NP	.68 (.04)	.57 (.04)	.11

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists CLs incorrectly recognized as *old*, Overall = mean percentage of false alarms regardless of list type, StdE = standard error presented in parentheses.

To further understand differences in false alarm rates between groups and inhibitory control index, mean false alarms as a function of list type were entered into separate 2 (Group: Less IC vs. More IC) x 2 (Index: Stroop vs. Stroop plus NP) ANOVA's. Group and inhibitory control index again provided the between-subjects variables, with list type the within subjects variable. In relation to false alarms to CLs in SW-lists, as expected a significant difference was found between groups, F (1,110) = 15.38, $p < .01$, $\eta_p^2 = .12$. As can be seen in Table 6.9, children assigned to Less IC groups produced more false alarms than those assigned to More IC groups. In relation to false alarms to CLs in SPW-lists, again as expected a significant difference was found between groups, F (1,110) = 25.31, $p < .01$, $\eta_p^2 = .18$, and as can be seen Table 6.9, those assigned to Less IC groups produced higher rates of false alarms than those assigned to More IC groups.

6.4.2. Comparison of False Alarm Rates between Adults as a Function of Inhibitory Control Index and Retrieval Practice

Mean rates of false alarms of adults were entered into a 2 (Group: Less IC vs. More IC) x 2 (Index: Stroop vs. StroopNP) x 2 (List Type: SW vs. SPW) mixed ANOVA. The between-subjects variables were group and inhibitory control index, the within-subjects variable was list type. Results show a main effect of list type, F (1,156) = 16.77, $p < .01$, $\eta_p^2 = .10$, with higher rates of false alarms to CLs in SPW-lists ($M = .75$) than CLs in SW-lists ($M = .66$). A main effect of groups was also found, F (1,156) = 14.26, $p < .01$, $\eta_p^2 = .08$, with those assigned to Less IC groups producing higher rates of false alarms ($M = .77$) than those assigned to More IC groups ($M = .59$). A significant interaction was also found between groups, inhibitory control index, and list type, F (1,156) = 5.30, $p = .02$, $\eta_p^2 = .03$, with a greater difference in false alarm rates found between Less IC and More IC groups assigned on the basis of a combined inhibitory control index when presented with SW-lists (M's = .73, .52) compared to the difference between Less IC and More IC groups assigned on the basis of a single index of inhibitory control (M's = .72, .68). As Table 6.10 below shows, similar differences in rates of false alarms to CLs in SPW-lists were found between Less IC or More IC groups assigned on the basis of a combined IC index (M's = .80, .66), compared to differences between Less IC and More IC groups assigned on the basis of a single IC index (M's = .84, .68).

Table 6.10: *Comparison of Adult's False Alarms as a Function of Group and Inhibitory Control Index*

		Group		
List type	IC Index	Less IC	More IC	Difference
Overall	Stroop	.78 (.03)	.68 (.03)	.10
	Stroop + NP	.77 (.04)	.59 (.04)	.18
SW-lists	Stroop	.72 (.04)	.68 (.04)	.04
	Stroop + NP	.73 (.05)	.52 (.05)	.21
SPW-lists	Stroop	.84 (.03)	.68 (.04)	.16
	Stroop + NP	.80 (.04)	.66 (.04)	.14

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists CLs incorrectly recognized as *old,* Overall = mean percentage of false alarms regardless of list type, StdE = standard error presented in parentheses.

Discussion Experiment 2

Taken together the results of Experiment 2a and 2b provide further evidence of higher rates of false alarms produced by individuals who demonstrate less effective inhibitory control. As in Experiment 1a and 1b, no significant differences were found between groups in terms of accurate recognition of target items, or in terms of incorrect recognition of unrelated test items, however, there was a trend indicating that those in the Less IC group were also more accurate in their veridical recognition. This would indicate that the role of inhibitory control in memory is similar to the role of inhibitory control in Stroop color-word interference task, specifically, in reducing interference from competing information by way of inhibition. In the case of less effective inhibitory control, the cost of greater accurate recognition is a higher rate of intrusions of critical lure items, and conversely the cost of more effective inhibitory control would appear to be less accurate recognition alongside fewer intrusions of critical lure items. In addition, Experiment 2b also demonstrated that a combined index of Stroop interference and NP effect provided a more fine-tuned measure of inhibitory control for adults. Greater discrepancies in rates of false alarms were found between inhibitory control groups when adults assigned to less or more effective inhibitory control groups on the basis of a combined index. Specifically, adults assigned to the Less IC group on the basis of Stroop interference and NP effect, overall produced significantly higher rates of false alarms than when adults were assigned to inhibitory control groups on the basis of Stroop interference alone (see Table 6.10). However, overall the magnitude of differences in false alarms was not found to be as large in Experiment 2b compared to Experiment 1b, which may have resulted from the effects of retrieval practice, in that retrieval practice appears to have reduced the overall rate of false alarms across all inhibitory control groups.

Examination of *remember* responses between Experiments 2a and 2b also indicated that those assigned as less effective inhibitors were also more likely to experience false alarms as remembered events. This interpretation was supported by differences in terms of mean RTs and discriminability index, suggesting false alarms made by the less effective inhibitory control group occur as a result of impaired inhibition of the highly activated critical lure item. On the other hand, the slower responses of those assigned as more effective inhibitors when producing a false alarm would appear to result from the process of inhibition of the strongly activated critical lure item, albeit this inhibition was not effective.

While not a primary focus of the current study, it is important to note that despite engaging in retrieval practice, high rates of false alarms were produced by those in the Less IC group. In comparison to Experiments 1a and 1b, children and adults in Experiment 2 assigned to the More IC group produced fewer false alarms. This would appear to suggest that those individuals demonstrating more effective inhibitory control showed more benefit from retrieval practice (evident in fewer false alarms), whereas those demonstrating less effective inhibitory control did not show appear to benefit from retrieval practice in the same manner (evident in a similar rate of false alarms, see Tables 5.5 and 6.6). In line with previous research, the current study found retrieval practice failed to eliminate rates of false alarms (McDermott, 1996). In relation to the current study, individuals who were better able to utilize inhibitory control showed evidence of reduced false alarm rates associated with retrieval practice. In this case it would appear that the presentation of semantically associated list items together at study increases the ease at which individuals automatically process the association between the list items and the critical lure (McDermott, 1996).

In contrast to the high rate of false alarms when DRM word lists are presented in blocked format, lower rates of false alarms are found when semantically associated items are dispersed throughout a list. For example, lower rates of false alarms to CL items occur when semantically associated items are presented in randomized order along with non-associated items. Of specific interest in the current study, was whether the difference between rates of false alarms produced by the Less IC and More IC groups could be reduced by manipulating the opportunity for the critical lure to become activated at the time of study. Experiment 3 examined this question by presenting DRM word lists in either blocked or randomized presentation order.

Chapter 7: Experiment 3: Examination of Rates of False Alarms as a Function of Presentation Format

Experiment 3 examined the impact of presentation format on rates of false alarms as a function of inhibitory control, with each participant presented with DRM word lists in blocked and random presentation formats. In the case of blocked presentation format, the thematic association between individual words is inherently obvious. In a random presentation format on the other hand, a number of DRM word lists are presented in randomized order, thus potentially making the thematic interrelationships between individual words less obvious. Experiment 3 also provided further replication of Experiments 1 and 2 by demonstrating a combined index of inhibitory control proved to be more sensitive in differentiating individual differences in overall rates of false memories.

7.1 Introduction Experiment 3

A consistent finding in research indicates that the false memory effect found in the DRM memory task persists despite experimental manipulations to increase accurate recall of studied items (Toglia, Neuschatz, & Goodwin, 1999). For example, previous research has found that repeated testing increases both veridical recall as well as false alarms (Payne, 1987 cited in Toglia et al., 1999). In the most commonly utilized DRM presentation formats, participants are presented with words in blocked format; that is a list of words organized around a central theme or semantic concept. A blocked presentation format is thought to increase the saliency of the semantic associations between list items and the critical lure item (Roediger & McDermott, 1995; Toglia et al., 1999). It is also suggested that the presentation of word lists organized around a central semantic theme enhances the ability to process and to access, automatic activations between studied items and the non-studied critical lure item (Tulving & Pearlstone, 1966). Consistent with this, Mather and colleagues (cited in Toglia et al., 1996), found participants produced higher rates of false alarms following a blocked presentation format in comparison to words presented in randomized order. Likewise, Toglia and colleagues also reported increased rates of both studied list items and false alarms related to blocked presentation format, suggesting that the blocked presentation format of word lists promotes semantic processing (1999). By extension, it could be inferred that presenting words in blocked format not only promotes the activation of semantic associations between list items, accounting for increased accurate recognition, but also promotes activation of the semantic association between list items and the critical lure item, accounting for increased rates of false alarms. However, reduced rates of false alarms may result from random presentation format, as less activation of the critical lure items occurs resulting in less inhibitory control required to prevent the critical lure from intruding into recognition memory.

The primary motivation for conducting Experiment 3 was to examine the persistence of the false memory effect when the presentation condition no longer facilitates the processing of the semantic associations between individual list items and the critical lure item. As has been demonstrated in Experiments 1 and 2, those that have greater difficulty in overcoming interference from the critical lure item produce higher rates of false alarms alongside high rates of accurate recognition of studied words. Therefore, a logical question to be asked is whether presenting DRM word lists in a randomized presentation format reduces overall rates of false memories for Less IC and More IC groups, or whether those in the Less IC group will continue to produce higher rates of false alarms despite randomized presentation format.

7.1.1 Participants

A new sample of 17 children were recruited, 10 eight-year olds and 7 10-year olds (42% male). Preliminary examination of data collected from children indicated their accuracy in detecting target items from unrelated test items fell below chance, correct recognition of target items was at 51%, with incorrect recognition of unrelated items at 49%. In view of this, the experiment with children was discontinued, and no further children were recruited or took part in the experiment. A new sample of 95 undergraduate psychology students were recruited (46% male), and received course credit for participating.

7.1.2. Formation of Groups

As Experiments 1 and 2 demonstrated a combined index of inhibitory control was a more sensitive measure than a single index, a combined index was utilized for Experiment 3. Participants who completed the StroopNP task were then ranked according to a combination of Stroop interference and NP effect, see Figure 6.4. Groups were formed on the basis of percentage of Stroop RT interference between neutral and incongruent trials coupled with proportion of errors in incongruent trials, plus percentage of NP effect calculated as proportion of RT interference and errors between IR NP probe trials in comparison to RT interference and errors in control NP probe trials ($Stroop_{rank}$ + $Stroop\ Error_{rank)}$ plus (NP_{rank} + $NP\ Error_{rank).}$ Those with a greater degree of Stroop interference and less NP effect, were assigned to the Less IC group (n = 32 adults) those with a lesser degree of Stroop interference and a greater degree of NP effect were assigned to the More IC group (n = 32 adults). The remaining group could not be easily classified as either inefficient or efficient inhibitors were assigned to the Mod IC group (31 adults). On the basis of the combined Stroop NP task, proportional interference scores were calculated for each individual. In relation to adults, differences between groups in terms of Stroop interference ranged from a mean interference score of .04, (± .04) with a mean NP effect score of -.03 (± .03), for those in the Less IC group, to a mean Stroop interference score of -.01 (± .03), and NP effect score of .03 (± .04), for those in the More IC group. See Appendix E for RT and error rate data for all groups.

7.1.3. Correct and Incorrect Recognition

Mean rates of responses to target and unrelated items of adults were entered into a 2(Group: Less IC vs. More IC) x 2(Presentation: Blocked vs. Random) ANOVA. The between-subjects variables were group and presentation format. In relation to correct recognition of target items, no significant differences were found between groups, or between groups in terms of presentation format, all *F's* < 1. In relation to incorrect recognition of unrelated items, again no significant differences were found between groups, or between groups in terms of presentation format, all *F's* < 1, as can be seen in Table 7.1.

Table 7.1: *Experiment 3a: Comparison of Adult's Veridical Recognition as a Function of Inhibitory Control and Presentation Format*

		Group	
	Less IC	Mod IC	More IC
List Type	*M* (StdE)	*M* (StdE)	*M* (StdE)
<u>Hits</u> Overall	.71 (.04)	.71 (.04)	.72 (.03)
Block	.71 (.04)	.70 (.04)	.72 (.04)
Random	.72 (.04)	.72 (.04)	.73(.04)
<u>URIntrusions</u>	.35 (.06)	.35 (.06)	.52 (.06)
Block	.29 (.11)	.30 (.11)	.45 (.11)
Random	.41 (.06)	.40 (.07)	.58 (.06)

Note: IC = Inhibitory Control, Hits = correctly recognizing a previously studied word as old, URIntrusions = Unrelated Intrusions, incorrectly recognizing a new word as old, StdE = standard error.

Mean rates of false alarms to CLs were entered into a 2(Group: Less IC vs. More IC) x 2(Presentation: Blocked vs. Random) ANOVA. The between-subjects variables were group and presentation format. As expected, presentation format produced a main effect, F (1,63) = 13.74, p < .01, η_p^2 = .18, with significantly higher rates of false alarms to CLs when word lists were presented in blocked format (*M* = .80) compared to false alarms to CLs when word lists were presented in random format (*M* = .65). A marginal effect of group was also found, F (1,63) = 3.51, p = .07, η_p^2 = .05, with higher overall rates of false alarms produced by those in the Less IC group (*M* = .77) compared to those in the More IC group (*M* = .68).

To further understand the impact of presentation format on rates of false alarms, false alarms as a function of presentation format and inhibitory control were entered into separate ANOVAs. In relation to blocked presentation format, the main effect of inhibitory control did not reach significance, $F < 1.5$, $p > .05$, $\eta_p^2 = .02$. In relation to randomized presentation format, the main effect of inhibitory control was significant, F (1,62) = 3.95, $p = .05$, $\eta_p^2 = .06$, with those in the Less IC group producing more false alarms of critical lures despite randomized presentation of DRM word lists, see Table 7.2.

Table 7.2: *Experiment 3a: Comparison of Adult's FA as a Function of a Combined Index of Inhibitory Control and Presentation format*

			Group	
		Less IC	Mod IC	More IC
List Type		*M* (StdE)	*M* (StdE)	*M* (StdE)
Overall FAs		.77 (.03)	.74 (.04)	.68 (.03)
	Block	.83 (.04)	.77 (.05)	.76 (.05)
	Random	.71 (.05)	.71 (.05)	.59 (.04)

Note: IC = Inhibitory control, SW-lists = Semantic plus non-semantic word-lists CLs incorrectly recognized as *old*, SPW-lists = Semantic plus phonological associates word-lists CLs incorrectly recognized as *old*, Overall = mean percentage of false alarms regardless of list type, FA = false alarms, StdE = standard error.

7.2. Comparison of False Alarms of Adults as a Function of a Combined Index of Inhibitory Control across Experiments 1, 2, and 3.

Mean rates of false alarms to CLs in SPW-lists of adults across all three experiments were entered into a 2(Group: Less IC vs. More IC) x 3 (Experiment: No Retrieval vs. Retrieval Practice vs. Random Presentation) ANOVA. Group and age provided the between-subjects variables, with list type the within subjects variable. The robust effect of group was once again apparent, F (1, 196) = 28.53, $p < .01$, $\eta_p^2 = .13$, with higher overall rates of false alarms produced by those assigned to Less IC groups ($M = .78$) compared to those assigned to More IC groups ($M = .60$). As Figure 7.1 below illustrates, regardless of experimental condition, adults demonstrating less effective inhibitory control produced higher overall rates of false alarms than those demonstrating more effective inhibitory control.

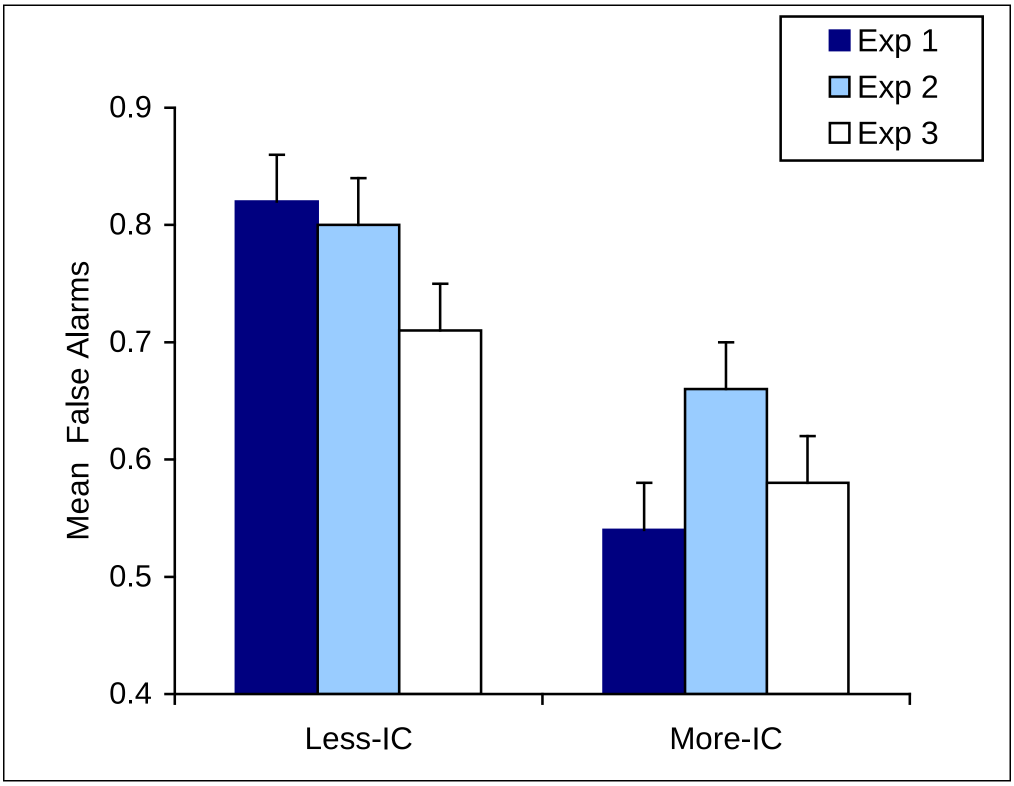

Figure 7.1 Comparison of false alarms as a function of experimental manipulation and inhibitory control. Note: IC = inhibitory control, Exp 1 = No Retrieval Practice, Exp 2 = Retrieval Practice, Exp 3 = Random Presentation, error bars denote standard error.

Discussion Experiment 3

The critical findings of Experiment 3 were of reduced rates of false alarms when participants were presented with 5 DRM word lists presented in randomized order in comparison to rates of false alarms when presented with 5 DRM word lists in blocked format. While the reduction in rates of false alarms was evident for both inhibitory control groups, those who demonstrated less effective inhibitory control continued to produce significantly higher rates of false alarms. In contrast, when DRM word lists were presented in blocked format, increased rates of false alarms were evident for both groups. Importantly, no significant differences were evident in veridical recognition between inhibitory control groups, suggesting that the intrusion of the critical lure into recognition memory occurs as a result of ineffective inhibition rather than as a result of a general error in recognition. Also of interest, lower rates of correct recognition of target items and higher rates of unrelated intrusions were evident for both groups. This would appear to indicate that the presentation of 65 words prior to the recognition test reduced the ability of participants to accurately discriminate between target and unrelated test items. This interpretation is also supported by the reduced accuracy of children when presented with 65 words prior to test, as children were found to be at about the level of chance in their correct recognition of target items.

Taken together, the results of Experiment 3 indicate that higher rates of false alarms occur when participants are presented with DRM word lists in blocked presentation format. This would suggest that as participants encounter semantically associated words within a single word list, the associations between list items automatically activates the associated critical lure item. On the other hand, when participants encounter associated words that are dispersed randomly within a list containing words not associated with the critical lure, this decreases the ability to automatically process semantic associations between list items, resulting in reduced activation of the critical lure word. The marginal effect of inhibitory control confirms this interpretation, as it would suggest that randomized presentation reduces the amount of activation spreading from associated list items to the critical lure, resulting in an overall reduction in the rate of intrusion of critical lure words into recognition memory. Those assigned to the Less IC group continued to produce significantly higher rates of false alarms despite the randomized presentation of words associated with more than one critical lure, indicating the inability to overcome interference from the activated critical lure items.

As the overall rate of unrelated intrusions evident in this final experiment were considerably higher than for the previous two experiments, an additional comparison was conducted between inhibitory control groups across Experiments 1, 2, and 3. Briefly, the results indicated participants assigned to the More IC group produced a significantly higher rate of incorrect recognition of unrelated items when presented with randomized DRM word lists (M = .60) compared to those assigned to the Less IC group (M = .42). This would appear to provide further evidential support for the claim that inhibitory control plays an important role in both the accurate recognition of previously studied list items, and in the production of false alarms of critical lure items. Specifically, while those in the More IC group consistently demonstrated more effective inhibition of the activated critical lure item, this did not appear to benefit this group in their accurate recognition of target items, as in this case the cost of such inhibitory control appeared to be less discrimination between target items and unrelated test items. Less effective inhibitory control appeared to facilitate correct discrimination between target items and unrelated items, with the cost of such inhibitory control being higher rates of intrusions of critical lure items.

Chapter 8: General Discussion

The current study demonstrated robust differences in individual susceptibility to form false memories of non-experienced events. This was achieved by assigning children and adults as less or more efficient inhibitors on the basis of performance on two selective attention tasks. Further discrepancies in false memory rates between less and more efficient inhibitors were also demonstrated when inhibitory control was measured on the basis of a combined index of inhibitory control, that of Stroop interference and NP effect, rather than a single index of inhibitory control. Taken together, the results of the current study suggest that assessing inhibitory control on the basis this combined index of inhibitory control proved to be a finer-grained measure of inhibitory control evident in increased differences in rates of false memories between individuals assigned to Less IC and More IC groups. Furthermore, experimental manipulations affecting the strength of conceptual associations between semantic items both at the time of study and at the time of test, provided converging evidence supporting the primary hypothesis of this study; namely that inhibitory control mediates individual differences in the propensity to form false memories.

Four key findings emerged from the present study: (1) individual differences in inhibitory control were able to be identified utilizing StroopNP tasks; (2) while overall 8-year olds produced fewer FAs, they were also less accurate producing fewer hits and more errors. However regardless of age, children and adults classified as less efficient inhibitors produced a higher rate of false memories than those classified as more efficient inhibitors; (3) while less efficient inhibitory control was found to relate to higher rates of false memories, higher rates of false memories were not found to relate to less accurate recognition or to increased errors; and (4) while a single index of inhibitory control differentiated those more susceptible to false alarms from those less susceptible to false alarms, a combined index of inhibitory control proved to be more sensitive in distinguishing individual differences in overall rates of false memories.

Taken together, the results of Experiments 1 confirm three important predictions. First, using a Stroop task, Experiment 1a identified children and adults demonstrating less or more efficient inhibitory control. Second and more significantly, children and adults demonstrating less efficient inhibitory control consistently produced higher rates of false alarms to critical lure items than their more efficient counterparts; however, this did not translate to a general pattern of memory errors. While the general developmental trajectory was of increased accurate recognition in adults and less accurate recognition for younger children compared to older children and adults. A crucial finding was that when inhibitory control was taken into account, then 8-year olds who demonstrated less inhibitory control produced significantly higher rates of false alarms then 8-year olds demonstrating more inhibitory control. Also of note, 10-year olds demonstrating less efficient inhibitory control produced similar rates of false alarms to adults classified in the same manner. Third, Experiment 1b utilized two selective attention tasks, allowing a combined index of inhibitory control to be calculated that was found to be a more superior measure of inhibitory control than a single index. Specifically, the magnitude of differences in rates of false alarms was found to be almost double when individuals were assigned as less, moderate, or more effective inhibitors on the basis of a combined index of inhibitory control.

Three critical findings emerged from Experiment 2. First, Experiment 2a provided converging evidence that higher rates of false alarms are produced by those individuals who demonstrate less effective inhibitory control. Second, Experiment 2b provided further evidence that inhibitory control assessed on the basis of a combined index of Stroop interference and NP effect was a more sensitive measure of individual differences in rates of false alarms as a function of inhibitory control. Third, as in Experiment 1, no significant differences were found between groups in terms of accurate recognition of target items, or in terms of incorrect recognition of unrelated test items. Additionally, an overall trend emerged indicating that those in the Less IC group were also more accurate in their veridical recognition. This would indicate that the role of inhibitory control in memory is similar to the role of inhibitory control in the Stroop color-word interference task. More specifically, it appears that inhibitory control functions to reduce interference from competing information by way of inhibition. The counterintuitive finding in the current study is that in the case of less effective inhibitory control, the cost of more accurate recognition is a higher rate of intrusions of critical lure items. Conversely, the benefit of more effective inhibitory control would appear to be fewer intrusions of critical lure items alongside less accurate recognition.

Examination of *remember* responses between Experiments 2a and 2b also indicated that those classified as less effective inhibitors were more likely to experience false alarms as remembered events. This interpretation was supported by differences in terms of mean RTs and the discriminability index, suggesting that false alarms made by the less effective inhibitory control group occur as a result of impaired inhibition of the highly activated critical lure item. On the other hand, the slower responses of those assigned as more effective inhibitors when producing a false alarm would appear to result from the partial inhibition of the strongly activated critical lure item. Furthermore, by calculating a discriminability index based on differences in terms of mean RTs to false alarms in relation to mean RTs to correct recognition of target items, suggests that children and adults demonstrating less effective inhibitory control are faster to make a *remember* response to CL items than to target items, whereas children and adults demonstrating more effective inhibitory control were slower to make a *remember* response to CL items in comparison to target items.

While not a primary focus of the current study, it is important to note that despite engaging in retrieval practice, higher rates of false alarms were produced by those in the Less IC group despite retrieval practice. This would appear to suggest that those individuals demonstrating more effective inhibitory control showed more benefit from retrieval practice (evident in fewer false alarms), whereas those demonstrating less effective inhibitory control did not appear to benefit from retrieval practice (evident in a similar rate of false alarms, see Tables 5.5 and 6.6). In line with previous research, the current study found that while retrieval practice reduced rates of false alarms, retrieval practice failed to eliminate false alarms (McDermott, 1996). Importantly for the current study, the benefit of retrieval practice was more evident for individuals who were better able to utilize inhibitory control. Of specific interest in the current study, was whether the difference between rates of false alarms produced by the Less IC and More IC groups could be reduced by manipulating the opportunity for the critical lure to become activated at the time of study. Experiment 3 examined this question by presenting DRM word lists in either blocked format or randomized presentation order.

The critical findings of Experiment 3 were of reduced rates of false alarms when participants were presented with 5 DRM word lists presented in randomized order. However, despite randomized presentation of DRM lists, a marginal difference was found in rates of false alarms as a function of inhibitory control. Those who demonstrated less effective inhibitory control continued to produce significantly higher rates of false alarms regardless of DRM word list presentation formats. As expected, when DRM word lists were presented in blocked format, increased rates of false alarms were evident for both groups. In this case it would appear that the presentation of semantically associated list items together at study increases the ease at which individuals automatically process the association between the list items and the critical lure (McDermott, 1996). In contrast, when semantically associated items are dispersed throughout a list, rates of intrusions of the critical lure items decrease; for example, when semantically associated items are presented in randomized order along with non-associated items. Importantly, no significant differences were evident in veridical recognition between inhibitory control groups, suggesting that the intrusion of the critical lure into recognition memory occurs as a result of ineffective inhibition rather than as a result of a general error in recognition. Also of interest, lower rates of correct recognition of target items and higher rates of unrelated intrusions were evident for both groups.

The results of Experiment 3 indicate that higher rates of false alarms occur when participants are presented with DRM word lists in blocked presentation format. It would appear that the associations between list items are automatically activated, resulting in activation of the associated CL item. When individual items from a number of word-lists are presented in random order, then this would appear to decrease the ability to automatically process semantic associations between list items, resulting in reduced activation of the critical lure word. The marginal effect of inhibitory control on rates of false alarms found in Experiment 3 supports this interpretation, as it would suggest that randomized presentation reduces the amount of activation spreading from associated list items to the critical lure, resulting in an overall reduction in the rate of intrusion of critical lure words into recognition memory. Specifically, those assigned to the Less IC group continued to produce significantly higher rates of false alarms despite the random presentation of words associated with more than one critical lure item, indicating the inability to overcome interference from the activated critical lure items.

Adults produced a higher rate of unrelated intrusions in Experiment 3 compared to Experiments 1 and 2. Of interest, while individuals assigned to the More IC group produced fewer false alarms to CL items in Experiment 3, they also produced a significantly higher rate of unrelated intrusions. From this it can be concluded that while presenting DRM lists in random order enabled this group to utilize inhibitor control more effectively to overcome activation of the CL, this did not translate into more accurate recognition overall. In addition, the Less IC group continued to produce a higher proportion of false alarms to CL items despite random presentation format.

To summarize, the results across Experiments 1, 2 and 3 provide robust evidential support indicating that children and adults classified as less efficient inhibitors on the basis of two selective attention tasks do indeed produce significantly higher rates of false memories in a DRM paradigm than those who demonstrate more efficient inhibitory processing. In this instance it would appear that intrusions of critical lures into memory occurs as a result of spreading activation that occurs during the process of encoding, is maintained during retention, and is more or less effectively suppressed during retrieval. For example, during study it is likely that individual list words repeatedly activate an internal representation of the critical lure, resulting in a strongly activated representation of the critical lure item (Chan, McDermott, & Roediger, 2006; Gerearts, Smeets, Jelicic, van Heerden & Merkelbach 2005; Howe, 2005; 2009a). Those classified as less efficient inhibitors may not be able to as effectively utilize an inhibitory mechanism to suppress automatic activation of such irrelevant representations. Consequently, for such individuals critical lure items remain strongly activated, leading to elevated false alarms as critical lures intrude into recognition.

8.1 Theoretical Implications

The critical outcome of this study confirms that children and adults who demonstrated greater difficulty inhibiting responses also had difficulty inhibiting words related to the meaning of word lists, which did not appear on the original word list. In this way, the primary hypothesis of the role of inhibitory control in the generation of false memories was supported. That is, the intrusion of information into recognition results from the inability to inhibit activated associated information. The results of the current study have several important implications for theoretical explanations of false memories. For example, the development of inhibitory control may account for the developmental trajectory of decreased rates of false alarms for younger children, and higher rates of false alarms for older children and adults. In this case, during the course of everyday experiences and through education, children develop increasingly complex interconnected networks of semantic associations. Therefore, lower rates of false alarms in younger children are likely to be a result of the combined factors of the development of such semantic networks (Howe et al., 2009b) in conjunction with the development of cognitive abilities such as inhibitory control (Pritchard & Neumann, 2009). When faced with situations where individuals are required to accurately retrieve information or events from memory, the process of retrieval activates these networks. Children and adults who are less efficient in inhibiting the activation of highly conflicting, irrelevant information may incorrectly recognition such information. Therefore it would appear from the results of this study that when children and adults are faced with the situation of deciding whether a specific event occurred, those individuals who demonstrate less effective inhibitory control appear to be more likely to form a false memory of the event.

The argument that inhibitory control may be a general mechanism underlying individual differences in false memories is further strengthened by differences in rates of false memories across development. Consistent with predictions from an activation-inhibition theory, rates of false memories were found to increase as inhibitory control decreased, which was also found to be related to age. For example, the activation of associative links relating to DRM lists is thought to be more effortful for 8-year old children, whereas for 10-year old children and adults such activation is thought to become more automatic (Howe et al., 2009b). In this way, 10-year olds and adults may require greater cognitive effort to inhibit activation of associative links, accounting for both differences across age and inhibitory control groups. However, the critical point at which the current study diverges from previous research is clearly demonstrated that when inhibitory control and age were examined, 8-year old children demonstrating less inhibitory control produced higher false alarm rates than 8-year old children demonstrating more inhibitory control, and 10-year old children demonstrating less inhibitory control produced a similar rate of false memories as adults which was significantly higher than that of children aged 10-years and adults demonstrating more inhibitory control. While the developmental literature suggests age related differences in rates of false memories occur due to the ability of children to access activated semantic networks (Howe et al.; 2009a), the results of the current study suggest that the ability to do so may also be mediated by individual differences in automatic processes such as inhibitory control. Research suggests that many variables associated with encoding, consolidation, storage, retention, and retrieval processes in younger children also regulate memory processes in older children and adults (Howe et al., 2009). What the current study adds to such research, is that both accurate and inaccurate recollection processes in children can be accounted for by the same mechanisms governing accurate and inaccurate recognition in adults; specifically, activation-inhibition accounts of false memories provides a more inclusive explanation for differences in false memories than developmental accounts alone.

Alternative explanations for the resolution of Stroop interference have also been put forward. For example, in Cohen, Dunbar, & McClelland's (1990) parallel distributed processing model (PDP), it is suggested that information is processed by way of activation of neural pathways representative of information (MacLeod, 1991). The PDP model proposes that the strength of activation moving along such pathways predicts the degree of interference in a Stroop task (Cohen et al., 1990; MacLeod, 1991). In relation to the Stroop task, the PDP model predicts the occurrence of Stroop interference on the basis that the strength of activation moving along neural pathways representing the semantic meaning of a color-word reaches a critical threshold eliciting a response (MacLeod, 1991). Therefore, according to PDP models of the Stroop effect, words are processed more rapidly than colors as a function of the strength of activation moving along pathways representing the semantic meaning of a color-word in comparison to the strength and spread of activation moving along pathways representing the ink-color (Cohen, Dunbar, Barch, & Braver, 1997).

Cohen's PDP model successfully simulates Stroop interference, in that the incongruent color-word typically interferes when the task requires a response to the ink color (Schooler, Neumann, Caplan, & Roberts, 1997a). However, as Schooler et al. point out, a PDP model fails to account for Stroop interference in situations in which the stimulus onset asynchrony (SOA) between the ink-color and the color-word is manipulated (1997b). Rather, Schooler and colleagues suggest that the dimension that produces interference, whether the dimension of the semantic meaning of a color-word or the ink-color, is dependent on the response requirements of a task (1997b). In this instance, when the task requires participants to respond to the ink-color of an incongruent color-word, the automatic encoding of the color-word produces sufficient activation to interfere with the task-specific response (Schooler et al., 1997a; 1997b). Of relevance to the current study is the assertion that Stroop interference results from the inability to effectively overcome interference from the semantic meaning of the color-word, and in particular that cognitive inhibitory control may be the mechanism accounting for such interference.

To account for such findings, Neumann and DeSchepper (1992) suggest that dual processes of excitatory and inhibitory mechanisms account for the degree of facilitation or interference found in selective attention tasks, such as the StroopNP tasks. The results of the current study provide support for this argument, in that complimentary excitatory and inhibitory resources point to cognitive inhibitory control as the mechanism accounting for the inability to overcome Stroop interference, reduced NP effects, and increased rates false alarm to CL items in the DRM task. Specifically, by examining the effective or ineffective resolution of Stroop interference in conjunction with degree of NP effect, it would appear that those who show increased RT latencies and error rates when presented with incongruent Stroop stimuli also show reduced NP effect, as a result of ineffective inhibitory control. Conversely, those who do not show increased RT latencies and error rates, and who also show increased NP effect, do so as a result of effective inhibitory control. More importantly, the consistent finding throughout the current study indicates that the elevated rates of false alarms associated with the assignment to the Less IC group on the basis of a combined index of inhibitory control, is a direct result of parallel processes of excitatory and inhibitory mechanisms.

Furthermore, examination of RT latencies when those in the Less IC group made *remember* responses in relation to RT latencies when responding to target items, in comparison to those in the More IC group, provides additional support for the inhibitory control proposal. On the basis of SDT analysis, the current study demonstrated that those assigned to in the Less IC group, on the basis of a combined index of inhibitory control, were found to produce significantly faster RT when making *remember* responses to CLs compared to *remember* responses to target items. The converse was also found, in that, those assigned to the More IC group produced slower RTs when making *remember* responses to CLs compared to *remember* responses to target items. Therefore, by examining individual differences in false alarm rates to CLs in the DRM word-list task, within the context of performance on two selective attention tasks, leads to the conclusion that utilizing divergent research paradigms of selective attention and false memory, appear to tap into a shared mechanism of inhibitory control.

In relation to selective attention theory, the ability to selectively inhibit distracting information is one mechanism that facilitates efficient target selection (Fox, 1995; Neumann & DeSchepper, 1992). In relation to the current study, correct responses to incongruent Stroop stimuli, requires an individual to effectively overcome interference from distractor information, in this case the semantic meaning of the color-word. Conversely, in relation to the NP task, ineffective responses to NP probe trials, results from the effective inhibition of the recently ignored NP prime trial (Fox, 1995; Neumann & DeSchepper, 1992, Pritchard & Neumann, 2004). That higher rates of intrusions of the CL into recognition responses were produced by those assigned to the Less IC group, is consistent with theoretical accounts of selective attention and false memories. In addition, as Fox (1995) points out, excitatory and inhibitory accounts of selective attention associated with Stroop interference and NP, are highly plausible. The ability of individuals to effectively suppress distracting information, whether in selective attention tasks or a memory task, not only reflects the operation of excitatory mechanisms at the time of study, but also reflects the operation of inhibitory mechanisms at the time of study, time of retrieval, or a combination of both.

At the outset of this paper it was suggested that inhibitory control may account for individual differences in memory, and more specifically, that accurate memory recollection is reliant in part on the ability to inhibit or suppress irrelevant information (Neumann & DeSchepper, 1992). While most researchers agree that the presentation of DRM lists results in activation of an internal semantic representation (for example Roediger & McDermott, 1995; Watson et al., 2003; 2005), this study is novel in that it provides evidential support for the claim that inhibitory control plays a crucial role in individual differences in false memories elicited by DRM lists. Furthermore, this study provides evidential support for the argument that inefficient inhibitory control may result in greater activation of critical lure items at study which combined with the inability to inhibit the activated internal semantic representation during retrieval, accounts for individual differences in false memories. In addition, the current study distinguished individuals who are less able to inhibit or ignore irrelevant information on the basis of two robust measures of selective attention. It would therefore appear that the role of inhibitory control goes beyond that of facilitating accurate visual selective attention, but also plays a crucial role in memory, particularly in false memories.

As alluded to in Howe et al. (2009), a growing body of evidence is forming that suggests the same model accounting for the occurrence of false memories in adults, can account for the development of false memories in children. The current study adds such research by demonstrating that not only does inhibitory control account for individual differences in susceptibility to false memories, but also for individual differences in false memories across development. Therefore, the current study provides evidential support to extend the associative-activation theory of false memories to include inhibitory control as a key mediator of false memories. Thus, a combined activation-inhibition theory of false memories provides a more inclusive explanation for not only the development of false memories, but also for individual differences in false memories.

8.2 Research Limitations

The first limitation of this study involves the method utilized for measuring inhibitory control. While performance on the Stroop task is assumed to measure inhibitory control, the underlying process of inhibition is only accessible by means of measureable behaviors elicited by the task. In this instance, the speed at which an individual responds to any given set of stimuli in combination with the number of errors made, is assumed to assess the underlying construct of inhibitory control (Faust et al., 1999). However, as selective attention can be described as comprising fundamental process of sustained attention, motivation, and effort, individual differences in performance on any one task may reflect combined variations in these processes. For example, a child or an adult’s performance on the Stroop task may reflect a general slowing of responses across the test interval as the individual loses motivation or interest in completing the task. As this was not factored into data analyses, the current study is not able to answer whether the results of these experiments addresses the issue of whether children and adults are able to maintain effortful concentration for a period of 30 to 45 minutes, rather than their susceptibility to false memories. In order to answer this question, future experimental research may benefit from analyzing RT latencies across test intervals in conjunction with RT latencies to experimental conditions.

A second limitation of this study relates to the use of a single measure of inhibitory control. As Pritchard and Neumann (2009) point out, inhibitory control is not a unitary concept, restricted to a single neural system. Rather, inhibitory control as defined by the current study is likely to reflect a combination of neural systems working in synchronization to perform the cognitive function of inhibitory control (Lezak et al., 2004; Nigg, 2000). Specifically, Lezak and colleagues (2004; p. 611) define the ability to adapt responses when faced with competing information as reliant on four components: (1) volition; (2) planning; (3) purposive action; and (4) effective performance. Yet as Lezak et al. (2004) point out, when attempting to assess cognitive abilities that tap into such domains, there remains a tension between the need to structure situations to elicit task appropriate behavior that is observable and measureable and in such a manner as to reflect the concept of inhibitory control, whereas in real life situations these structures are rarely apparent (Duncan, 1986; Lezak et al., 2004). Therefore, future research into the impact of inhibitory control on individual susceptibility to false memories may benefit from utilizing multiple measures of inhibitory control. For example, designating individuals as less or more effective inhibitors on the basis of combined performance on StroopNP tasks and standardized measures of inhibitory control that tap into the domains of selective attention, inhibitory responses, and goal directed behavior. In addition, utilizing standardized measures of inhibitory control, may allow comparisons between individuals’ designated as less or more effective inhibitors with normative data.

8.3 Implications and Directions for Future Research

Despite the limitations described above, the current study provides converging evidence that inhibitory control plays a crucial role in the propensity to form false memories.

Furthermore, this study provides extensive evidence across a range of experimental conditions that children and adults designated as less effective in their ability to inhibit activation of related yet competing information also produce higher rates of intrusions of critical lure items, coupled with an increased likelihood to rate false alarm responses as *remembered* events. To further advance our understanding of the underlying processes involved in both the formation of memory, and the propensity to form false memories, it may be useful to broaden the experimental designs described here to incorporate a wider range of selective attention and memory tasks. This could be achieved by way of including a variety of Stroop like stimuli – such as words and pictures, which may establish the ability to inhibit interference from a range of competing modalities. In relation to memory performance, it would be interesting to assess whether the propensity to form false memories persists when information is provided within a broader context, such as when DRM-word lists are presented in story format. For example, Dewhurst, Pursglove and Lewis (2007) found high rates of false alarms to critical lure items persisted despite providing additional semantic context which is thought to enhance accurate recognition.

In addition, future research may consider examining whether inhibitory control plays a role in the persistence of false memories over time. For example, while researchers have demonstrated that despite delays of hours, days, or even weeks, high rates of false alarms to critical lure items persist following the presentation of DRM word lists (McDermott, 1996). What is not known is whether those who show less effective inhibitory control continue to produce higher rates of false alarms when protracted delay periods are included.

8.3 Conclusion

In conclusion, as this series of experiments presents a novel demonstration of the relationship between inhibitory control in relation to selective attention tasks and false memories, this study has the potential to be the first to provide insight into a cognitive mechanism that maybe responsible for both developmental trends of false memories and for individual differences in the regulation of false memories. As individuals' recollect information, spreading activation may result in related yet irrelevant representations intruding into recognition. Individuals who are less able to effectively overcome such activation may in this way be more likely to incorrectly report information, incorrectly respond to questions, and form false memories. Moreover, if the mechanism responsible for mediating false memories is causally linked to performance on a Stroop color-word interference task and a NP task, in the systematic way we propose, it may be possible in the future to assist in identifying individuals who have an exaggerated propensity to form false memories, as well as those more prone to resist them.

References

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Appendix A: Presentations – peer reviewed

Alberts, J.W., Crucian, G.P., Neumann, E. **(2009)**. When our memories fail us: Exploring the accuracy and inaccuracy of memory. *International Neuropsychological Society, 37th Annual Conference,* held in Atlanta Georgia, USA. Poster presentation.

Alberts, J.W. (2009). The role of a dual activation-inhibition process in both false and accurate retrieval of information fro*M* memory. *International Neuropsychological Society, 37th Annual Conference,* held in Atlanta Georgia, USA. Poster presentation.

Alberts, J.W. (2009). Does age-related susceptibility to false memories account for developmental differences in rates of false memories? *International Neuropsychological Society, 37th Annual Conference,* held in Atlanta Georgia, USA. Poster presentation.

Alberts, J.W., Crucian, G.P., Neumann, E. **(2008).** When our memories fail us: The role of executive function in memory. *XXIX International Psychology Conference,* held in Berlin, Germany. Poster presentation.

Alberts, J.W., Neumann, E. **(2007)**. Who remembers things that didn't happen? Children low on inhibitory control are more susceptible to false memories. *Society for Research in Child Development.* Boston, Massachusetts, USA. Poster presentation.

Alberts, J.W., Neumann, E. **(2006)**. Who remembers things that didn't happen? The role of inhibition in false memories. *4th International Conference on Memory,* Sydney, Australia. Poster presentation.

Appendix B: DRM Study Lists

SW-lists	SPW-lists	SW-lists	SPW-lists	SW-lists	SPW-lists
mad (CL)	mad (CL)	car (CL)	car (CL)	lake (CL)	lake (CL)
angry	angry	truck	truck	river	river
fear	fear	bus	bus	water	water
hate	hate	train	train	stream	stream
rage	rage	van	van	boat	boat
temper	temper	tooth	tooth	swim	swim
hut†	fad‡	log†	par‡	rust†	make‡
fury	fury	drive	drive	summer	summer
top†	pad‡	yes†	bar‡	tone†	fake‡
cross	cross	jeep	jeep	creek	creek
fix†	had‡	web†	far‡	guest†	brake‡
pest	pest	race	race	brook	brook
happy	happy	keys	keys	fish	fish
fight	fight	garage	garage	ocean	ocean
bread (CL)	bread (CL)	slow (CL)	slow (CL)	cold (CL)	cold (CL)
butter	butter	fast	fast	hot	hot
food	food	quick	quick	snow	snow
eat	eat	stop	stop	warm	warm
sandwich	sandwich	lazy	lazy	winter	winter
wheat	wheat	snail	snail	ice	ice
clone†	dread‡	more†	blow‡	nest†	fold‡
jam	jam	careful	careful	wet	wet
holy†	head‡	fact†	glow‡	slot†	hold‡
milk	milk	wail	wait	frosty	frosty
imply†	tread‡	edge†	flow‡	time†	gold‡
flour	flour	traffic	traffic	chilly	chilly
jelly	jelly	turtle	turtle	heat	heat
dough	dough	speed	speed	freeze	freeze

sick (CL)	sick (CL)	king (CL)	king (CL)	smell (CL)	smell (CL)
doctor	doctor	queen	queen	nose	nose
nurse	nurse	crown	crown	breathe	breathe
medicine	medicine	prince	prince	sniff	sniff
health	health	princess	princess	stink	stink
hospital	hospital	palace	palace	hear	hear
game†	pick‡	types†	wing‡	turn†	cell‡
germ	germ	throne	throne	see	see
bond†	kick‡	lump†	sing‡	disk†	yell‡
ill	ill	chess	chess	pong	pong
left†	tick‡	weird†	bring‡	dunk†	bell‡
pale	pale	rule	rule	whiff	whiff
unwell	unwell	castle	castle	scent	scent
better	better	royal	royal	reek	reek

chair (CL)	chair (CL)	trash (CL)	trash (CL)	sweet (CL)	sweet (CL)
table	table	garbage	garbage	sour	sour
sit	sit	waste	waste	candy	candy
legs	legs	can	can	sugar	sugar
seat	seat	litter	litter	bitter	bitter
couch	couch	dirt	dirt	good	good
laser†	stair‡	hall†	cash‡	slide†	sleet‡
desk	desk	bag	bag	taste	taste
full†	fair‡	last†	rash‡	title†	greet‡
stool	stool	junk	junk	tooth	tooth
task†	pair‡	stump†	flash‡	room†	feet‡
sofa	sofa	rubbish	rubbish	nice	nice
wood	wood	sweep	sweep	honey	honey
cushion	cushion	scraps	scraps	soda	soda

man (CL)	man (CL)	pen (CL)	pen (CL)	sleep (CL)	sleep (CL)
woman	woman	pencil	pencil	bed	bed
husband	husband	write	write	rest	best

uncle	uncle	fountain	fountain	awake	awake
lady	lady	leak	leak	tired	tired
mouse	mouse	highlighter	highlighter	dream	dream
fit†	pan‡	gap†	hen‡	file†	weep‡
male	male	felt	felt	wake	cozy
owl†	fan‡	fur†	ten‡	load†	keep‡
father	father	scribble	scribble	snooze	snooze
bet†	ban‡	how†	den‡	hour†	steep‡
strong	strong	crayon	crayon	blanket	blanket
friend	friend	marker	marker	doze	doze
beard	beard	paper	paper	nap	nap

thief (CL)	thief (CL)	black (CL)	black (CL)	flag (CL)	flag (CL)
steal	steal	white	white	banner	banner
robber	robber	dark	dark	american	american
outlaw	outlaw	cat	cat	sign	sign
burglar	burglar	burnt	burnt	stars	stars
money	money	night	night	streamer	streamer
video†	grief‡	form†	hack‡	mug†	tag‡
cop	cop	funeral	funeral	stripes	stripes
globe†	chief‡	sock†	pack‡	fox†	rag‡
bad	bad	color	color	pole	pole
rent†	brief‡	habit†	slack‡	hip†	nag‡
jail	jail	blue	blue	wave	wave
gun	gun	death	death	raised	raised
crime	crime	ink	ink	country	country

smoke (CL)	smoke (CL)	town (CL)	town (CL)
cigarette	cigarette	city	city
puff	puff	crowded	crowded
blaze	blaze	state	state
billows	billows	streets	streets
smog	smog	country	country

wide†	joke‡	stork†	brown‡
ashes	ashes	village	village
wink†	poke‡	host†	down‡
chimney	chimney	shops	shops
cause†	broke‡	bike†	gown‡
fire	fire	buildings	buildings
tobacco	tobacco	malls	malls
flames	flames	place	place

Note. SW = Semantic plus three non-associated words, SPW = Semantic plus three phonologically associated words, CL = Critical lure word not presented at time of study, † = Filler words not semantically related to the CL ‡ = Phonological associates to the CL.

Appendix C: Word Fragment Lists Used in Experiment 2

mad (CL)	car (CL)	bread (CL)	lake (CL)	slow (CL)	cold (CL)
a n _ g _ y	t r _ c _	b _ t t _ r	r _ v _ r	f _ s _	h _ t
f _ a _ r	b _ s	f _ o _	w _ t _ r	q u _ c _	s n _ w
h _ t _	t r _ i _	w h _ a _	s t _ e _ m	s _ o _	w _ n _e r
r _ g _	v _ n	j _ m	s w _ m	s n _ i _	i _ e
f _ r _	d r _ v _	m _ l _	c r _ e _	w _ a _	f r _ s _ y
c _ o _ s	r _ c _	f _ o _ r	f _ s _	t u _ t _ e	c h _ l _ y
f _ g _ t	k _ y _	d o _ g _	o _ e _ n	s p _ e _	f r e _ z _

sick (CL)	king (CL)	smell (CL)	chair (CL)	trash (CL)	sweet (CL)
d o _ t _ r	q u _ e _	n _ s _	t _ b _ e	w _ s _ e	s _ u _
n_ r _ e	c r _ w _	s n _ f _	s _ t	c _ n	c _ n _ y
h e _ a _ t h	p r _ n _ e	s t _ n _	l _ g _	l i _ t _r	s _ g _ r
g _ r _	p a _ l _ c e	p _ n _	s _ a _	d _ r _	t _ s _ e
I _ _	t h _ o _ e	w h _ f _	d _ s _	r u _ b _ s h	n _ c _
p _ l _	r _ l _	s c _ n _	s t _ o _	s w _ e _	h _ n _ y
u n _ e _ l	r o _y _ l	r _ e _	w _ o_	s c _ a _ s	f _ z _ y

sleep (CL)	pen (CL)	thief (CL)	smoke (CL)	black (CL)	town (CL)
b _ d	p _ n c _ l	s t _ _ l	p _ f f	w h _ t _	c _ t _
r _ s _	w r _ t_	r _ bb _ r	b l_ z _	d_ _ k	s t _ t _
a w _ k _	l _ a _	m _ n _ y	b _ l l _ w s	n _ g _ t	s t _ _ t s
t _ r _ d	f _ l _	c _ p	s m _ g	c _ l _ u r	v _ l l _ g e

d _ e _ m	s c r _ b _ l e	b _ d	a _ h _ s	b l _ _	s h _ p _
d _ z _	c r _ y _ n	g _ n	f _ r _	d _ a _ h	m _ l _ s
n _ p	m a _ k _ r	c r _ m _	f l _ m _ s	i _ k	p l _ c _
flag CNL)					
b _ n n _ r					
s t _ r _					
s t r _ p _ s					
p _ l _					
w _ v _					
r _ i s _ d					
c o _ n t _ y					

Note. CL = Critical lure word not presented at time of study.

Appendix D: Study Set Combinations and Counterbalancing

	SPW LIST*	SW LIST*
	Set 1 - odd 1 – 9	Set 1 - odd 1 - 9
	Set 2 - even 2 – 10	Set 2 - even 2 - 10
	Set 3 - odd 11 – 19	Set 3 - odd 11 - 19
	Set 4 - even 12 – 20	Set 4 - even 12 - 20

Study Set Combinations

A	B	C	D
SW LIST - Set 1	SPW LIST - Set 3	SW LIST - Set 3	SPW LIST - Set 4
SPW LIST - Set 2	SW LIST - Set 4	SPW LIST - Set 1	SW LIST - Set 2

Counterbalancing

Participant Number	Study Set	Participant Number	Study Set
1	A	5	A
2	B	6	B
3	C	7	C
4	D	8	D

*Note: SW LIST = Semantic Word List
SPW LIST = Semantic/Phonological Word List

Appendix E: RT and error rate data

Experiment 1a: Stroop RT and Error rate data

	Incongruent		Neutral	
	RT	% Error	RT	% Error
Overall				
Children	1168.49	.06	1169.09	.04
Adults	689.84	.06	702.62	.05
Less IC				
8-years	1257.80	.06	1299.41	.05
10-years	1091.17	.05	1067.38	.02
Adults	703.67	.05	701.42	.02
Mod IC				
8-years	1220.96	.04	1236.05	.03
10-years	1112.30	.04	1143.74	.02
Adults	681.78	.07	687.57	.06
More IC				
8-years	1192.16	.08	1148.38	.03
10-years	1072.00	.08	1051.62	.07
Adults	684.08	.06	718.85	.06

Experiment 1b: Adults StroopNP Task RT and Error rate data

	Incongruent		Neutral		Prime		Probe	
	RT	% E	RT	% E	RT	%E	RT	%E
Overall	733.19	.06	730.74	.06	739.56	.07	742.73	.06
Less IC	677.70	.08	697.40	.08	713.30	.09	695.42	.08
Mod IC	765.56	.04	758.60	.03	768.19	.04	768.67	.03
More IC	756.30	.07	736.24	.06	737.19	.07	764.09	.08

Experiment 2a: Children and Adults Stroop RT and Error rate data

	Incongruent		Neutral	
	RT	% Error	RT	% Error
Overall				
8-years	1221.94	.06	1226.51	.03
10-years	1088.54	.06	1081.78	.04
Adults	733.19	.06	730.74	.06
Less IC				
8-years	1230.50	.06	1235.51	.04
10-years	1153.27	.07	1180.83	.06
Adults	677.70	.08	697.40	.08
Mod IC				
8-years	1230.51	.03	1245.11	.05
10-years	1063.85	.04	1049.76	.02
Adults	765.56	.04	758.60	.03
More IC				
8-years	1204.81	.09	1198.90	.03
10-years	1048.49	.06	1014.75	.03
Adults	756.30	.07	766.24	.04

Experiment 2b: Children and Adults StroopNP Task RT and Error rate data

	Incongruent		Neutral		Prime		Probe	
	RT	% E	RT	% E	RT	%E	RT	%E
Overall								
8-years	1229.88	.06	1227.43	.03	1237.19	.06	1238.68	.03
10-years	1080.03	.05	1085.75	.04	1077.60	.05	1085.79	.05
Adults	689.84	.06	702.62	.05	688.50	.06	694.04	.05
Less IC								
8-years	1249.32	.05	1301.44	.04	1313.68	.05	1282.32	.03
10-years	1044.97	.05	1080.25.03		1052.61	.05	1039.45	.03
Adults	703.67	.05	701.42	.02	700.40	.05	701.81	.04
Mod IC								
8-years	1198.14	.10	1176.15	.04	1181.48	.09	1165.23	.05
10-years	1067.70	.03	1100.40	.02	1078.93	.03	1080.32	.02
Adults	681.78	.07	687.57	.06	674.57	.08	682.88	.06
More IC								
8-years	1242.17	.03	1204.68	.02	1216.43	.03	1268.49	.02
10-years	1127.41	.08	1076.06	.06	1101.27	.08	1137.60	.08
Adults	684.08	.06	718.88	.06	690.52	.06	697.44	.06

Experiment 3: Adults StroopNP Task RT and Error rate data

	Incongruent		Neutral		Prime		Probe	
	RT	% E	RT	% E	RT	%E	RT	%E
Overall	692.05	.05	692.31	.04	687.59	.06	695.36	.06
Less IC	715.75	.05	696.94	.03	716.81	.05	730.58	.04
Mod IC	689.71	.05	684.53	.04	688.01	.05	622.75	.04
More IC	672.50	.06	695.45	.05	657.96	.08	692.75	.09

Appendix F: Analysis of Variance Tables Experiments 1 and 2

Table 5.1(a): Experiment 1Comparison of Test Words Correctly Recognized by Children and Adults as a Function of a Single Index of IC

Repeated Measures Analysis of Variance with Effect Sizes

	SS	DF	MS	F	p	Partial eta-squared
Group	0.11	1	0.11	2.72	0.10	0.02
Age	1.81	2	0.91	22.07	0.00	0.22
Group*Age	0.02	2	0.01	0.29	0.75	0.00
Error	6.49	158	0.04			
LIST	0.01	1	0.01	1.65	0.20	0.01
LIST*Group	0.00	1	0.00	0.00	0.95	0.00
LIST*Age	0.04	2	0.02	3.31	0.04	0.04
LIST*Group*Age	0.01	2	0.00	0.53	0.59	0.01
Error	0.99	158	0.01			

Table 5.1(b): Experiment 1a: Comparison of Test Words Incorrectly Recognized by Children and Adults as a Function of a Single Index of IC

Repeated Measures Analysis of Variance with Effect Sizes

	SS	DF	MS	F	p	Partial eta-squared
Group	0.01	1	0.01	4.14	0.04	0.03
Age	0.03	2	0.02	6.79	0.00	0.08
Group*Age	0.02	2	0.01	3.82	0.02	0.05
Error	0.39	158	0.00			
LIST	0.00	1	0.00	0.02	0.89	0.00
LIST*Group	0.00	1	0.00	0.26	0.61	0.00
LIST*Age	0.00	2	0.00	0.45	0.64	0.01
LIST*Group*Age	0.00	2	0.00	0.17	0.84	0.00
Error	0.12	158	0.00			

Table 5.2: Experiment 1a: Comparison of Children and Adults FA's as a Function of a Single Index of IC

Repeated Measures Analysis of Variance with Effect Sizes

	SS	DF	MS	F	p	Partial eta-squared
Group	0.70	1	0.68	6.48	0.01	0.04
Age	1.53	2	0.77	7.31	0.00	0.08
Group*Age	0.11	2	0.06	0.54	0.58	0.01
Error	16.56	158	0.10			
LIST	0.63	1	0.63	12.85	0.00	0.08
LIST*Group	0.01	1	0.00	0.10	0.75	0.00
LIST*Age	0.02	2	0.01	0.18	0.83	0.00
LIST*Group*Age	0.10	2	0.05	0.98	0.38	0.01
Error	7.73	158	0.05			

Table 5.3(a): Experiment 1b: Comparison of Test Words Correctly Recognized by Adults as a Function of a Combined Index of IC (StroopNP Tasks)

Repeated Measures Analysis of Variance with Effect Sizes						
	SS	**DF**	**MS**	**F**	**p**	**Partial eta-squared**
Group	0.01	1	0.01	0.47	0.49	0.01
Error	1.47	72	0.02			
LIST	0.04	1	0.04	8.45	0.00	0.11
LIST*Group	0.01	1	0.01	1.73	0.19	0.02
Error	0.38	72	0.01			

Table 5.3(b): Experiment 1b: Comparison of Test Words Incorrectly Recognized by Adults as a Function of a Combined Index of IC (StroopNP Tasks)

Repeated Measures Analysis of Variance with Effect Sizes						
	SS	**DF**	**MS**	**F**	**p**	**Partial eta-squared**
Group	0.03	1	0.03	3.68	0.06	0.05
Error	0.52	72	0.01			
LIST	0.01	1	0.01	4.07	0.05	0.05
LIST*Group	0.00	1	0.00	0.11	0.74	0.00
Error	0.13	72	0.00			

Table 6.2: Experiment 2a: Comparison of Children's and Adults FA as a Function of Age and Inhibitory Control Group

Repeated Measures Analysis of Variance with Effect Sizes						
	SS	**DF**	**MS**	**F**	**p**	**Partial eta-squared**
Group	2.55	2	1.27	11.12	0.00	0.13
Condition	1.66	1	1.66	14.53	0.00	0.09
Group*Condition	0.38	2	0.19	1.64	0.20	0.02
Error	16.94	148	0.11			
LIST	0.01	1	0.01	0.42	0.52	0.00
LIST*Group	0.12	2	0.06	2.07	0.13	0.03
LIST*Condition	0.00	1	0.00	0.13	0.72	0.00
LIST*Group*Condition	0.17	2	0.09	3.11	0.05	0.04
Error	4.15	148	0.028			

Table 6.6: Experiment 2b: Comparison of FAs as a function of Age and Inhibitory Control Group

Repeated Measures Analysis of Variance with Effect Sizes						
	SS	**DF**	**MS**	**F**	**p**	**Partial eta-squared**
Age	0.32	2	0.16	1.62	0.20	0.03
Group	0.74	1	0.74	7.58	0.007	0.060
Age*Group	0.15	2	0.07	0.69	0.51	0.01
Error	11.20	114	0.10			
LIST	0.11	1	0.11	2.54	0.11	0.02
LIST*Age	0.19	2	0.09	2.15	0.12	0.04
LIST*Group	0.00000	1	0.00	0.00	1.00	0.00
Error	5.00	114	.04			

Table 5.4: Experiment 1b: Comparison of Adults FA's as a Function of a Combined Index of IC (StroopNP Tasks)

Repeated Measures Analysis of Variance with Effect Sizes						
	SS	**DF**	**MS**	**F**	**p**	**Partial eta-squared**
Group	1.67	1	1.67	20.30	0.00	0.22
Error	5.92	72	0.08			
LIST	0.05	1	0.05	1.72	0.19	0.02
LIST*Group	0.25	1	0.25	8.30	0.01	0.10
Error	2.19	72	0.03			

Table 5.5: Experiment 1: Comparison of FA as a Function of Inhibitory Control Indices

Repeated Measures Analysis of Variance with Effect Sizes						
	SS	**DF**	**MS**	**F**	**p**	**Partial eta-squared**
Group	1.43	1	1.43	14.76	0.00	0.10
Condition	0.16	1	0.16	1.68	0.20	0.01
Group*Condition	0.33	1	0.33	3.40	0.07	0.02
Error	12.99	134	0.10			
LIST	0.17	1	0.17	4.93	0.03	0.04
LIST*Group	0.16	1	0.16	4.46	0.04	0.03
LIST*Condition	0.03	1	0.03	0.82	0.37	0.01
LIST*Group*Condition	0.05	1	0.05	1.45	0.23	0.01
Error	4.68	134	0.03			