THE QUANTITATIVE MEASUREMENT OF EXPLICIT AND IMPLICIT MEMORY AND ITS APPLICATIONS TO AN AGING POPULATION

A dissertation submitted by

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In partial fulfillment of the requirements
for the degree of
Doctor of Philosophy
in
Psychology

TUFTS UNIVERSITY
May 2012

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A new model was developed to measure separately the influence of the fundamental memory states of explicit memory, implicit memory, fractional storage and non-storage, called the Implicit Explicit Separation (IES) model. The IES was used in five experiments to analyze the dynamics of the fundamental memory types over various retention intervals in younger and older adults. The storage values from the IES model were fit to an existing memory model, the Two-Trace Hazard Model, which estimates the rate of memory loss in the retention interval. The results indicate that explicit memory degrades at a rate faster than implicit memory in younger adults. While explicit memory degrades at a similar rate in older adults as younger adults, implicit memory rises in the short term, and then remains stable in older adults. The rate parameters in the Two-Trace Hazard Model indicate that memory loss in older adults is much faster in the seconds immediately following item presentation than younger adults. Finally, in younger adults, very short term implicit memory increases to a point and then decreases across the retention interval, indicating that implicit storage is rising as a direct result of the degrading explicit storage system, supporting a single-memory system. Further, when these data are analyzed through a hazard function analysis, the conjunction of the two memory traces was peaked-shaped supporting the basis of the Two-Trace Hazard Model.

Acknowledgements

It is a great pleasure to thank everyone who helped me write my dissertation successfully. My first debt of gratitude must go to my advisor, Dr. Richard Chechile. He patiently guided me through the doctoral program and provided numerous hours of helpful advice in order to help me plan and complete my dissertation.

Special thanks to my committee, Dr. Ayanna Thomas, Dr. Robert Cook, and Dr. Jessica Chamberland for their guidance and helpful suggestions.

I am truly indebted and thankful to the members of the Memory and Cognition Laboratory. Most especially to Dan Barch for his help with the preparation of stimuli, a sounding board for computer programming, and Wednesday afternoon sing-alongs. Additionally, I would like to thank all the research assistants for their help piloting experiments, running subjects, and compiling raw data, including Clara Colon, and Brianna Smith.

Finally, I would like to thank my mother and father, Dr. and Mrs. Roger Sloboda for their love and support, and wonderful editing skills.

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Memory research has identified a dissociation between explicit and implicit memory, by analyzing the involvement of each of these memory subtypes in overall memory performance. Explicit memory is considered to be those memories requiring conscious recollection of information, whereby implicit memory is related to the unconscious residue of information still resident in the memory system. Implicit memory manifests itself in increased task performance without explicit memory for the task (Shachter, 1987). A number of researchers (Cohen & Squire, 1980; Graf & Schacter, 1985; Parkin, 1993; Johnson, 1983; Schacter, Chin, & Ochsner, 1993; Squire, 1986; Tulving, 1985; Weiskrantz, 1987) postulate that implicit and explicit memory are stored and maintained in a multiple system format. While others (Roediger, 1990; Rovee-Collier, 1997) believe that implicit and explicit memory comprise one unified system. While this debate is as yet unsettled, what is known is that explicit and implicit memories are separable in testing. The purpose of this research is to evaluate the means for testing these differences, to identify the limitations to the current research, and to support or negate the multiple memory systems view. Finally a new method for deciphering explicit and implicit memory in the context of experimental paradigms was developed.

Introduction

Implicit memory was initially conceived of as a savings, or residue, of learning, and in relearning tasks. This was a key assumption made as early as the initial work provided by Ebbinghaus (1885; 1913). Graf and Schacter (1985) described implicit memory as “a facilitation in the absence of explicit memory” (p.501). Although the idea of savings of information had been around for some time, the majority of research on the implicit/explicit distinction occurred during the later part of the 20th century (Schacter, 1987). This research has been conducted with patient populations who exhibit declining memory function, developmental studies, and finally on normal, healthy adults.

Patient Populations

People suffering from naturally occurring amnesia have difficulty with explicit memory, but there tends to be a sparing of implicit memory. This initial finding came from studying the amnesic patient H. M., who had a catastrophic loss of his explicit memory. H. M. underwent a bilateral medial temporal lobe resection to decrease the number of seizures from which he had been suffering. Two years after surgery, H. M. was still indicating the date as the year of his surgery, and his age at the time of surgery, leading his physicians to conclude that he was suffering from anterograde amnesia, or the inability to form and retain new memories. H. M. could remember memories from his childhood up to three years prior to surgery, and had a general intelligence level similar to his intelligence prior to surgery (Scoville & Milner, 1957). Over years of study, H. M. proved to have a systemic and pervasive breakdown of his explicit memory (Corkin, 2002). The conclusion that H. M. could not gain any new memories was premature, however. H. M. indicated residual learning through motor tasks (Corkin, 2002). After repeated testing, H. M. indicated increased abilities in completing procedural tasks such as the mirror tracing task (Corkin, 1968) and the Tower of Hannoi (Cohen & Corkin, 1981), and non-procedural implicit tasks such as repetition priming (Corkin, 2002). An important distinction is that while H. M. exhibited improved performance on indirect tasks, he had no conscious awareness of ever having done the tasks previously. In other words, H. M had an unconscious awareness of information without being consciously aware of its use. This unconscious use of previously learned information still bolstered performance, and led to researchers developing and studying to a great extent the differentiation between implicit and explicit memory (Corkin, 2002).

Studies involving various types of priming have provided evidence of implicit memory involvement that is separable from explicit memory in patients with amnesia (Schacter, 1987). Gabrieli, Keane, Zorella, and Poldrack (1997) found that, through repetition, amnesiacs were able to form relationships between previously unrelated word pairs, in light of the amnesiacs' lack of ability to explicitly identify old word pairs. McAndrews, Gilsky, & Schacter (1986) tested patients with complete, but nonsensical sentences and tested their memory of the context in which the sentences began to make sense. The rate at which participants were able to provide the correct response was compared between amnesic patients and controls. In this case, the performance of control participants was better than amnesic patients to a degree, but the amnesiacs still indicated some increase in sentence comprehension. Warrington and Weiskrantz (1968) found that amnesic patients were able to complete three-letter word stems with previous learned items despite no memory for having been previously presented the information. These studies demonstrate the sparing of implicit memory in combination with a detriment to performance on tasks of explicit memory.

Not all tests of implicit memory remain stable in amnesic patients. For instance, Verfaellie, Page, Orlando, and Schacter (2005) studied the effect of gist information by providing participants with word lists in a DRM procedure[1]. Similar to healthy adults, patients with amnesia were primed by the previously presented words. As expected in the DRM paradigm, the healthy controls indicated priming to the associated, non-presented lures. Unlike their healthy counterparts, the control group did not falsely remember the non-presented lures, instead developing priming effects only to those words that were previously presented. (Verfaellie et al., 2005).

Testing the dissociation between explicit and implicit memory has been generalized to patient populations other than global amnesiacs. Implicit memory has been shown to decay at a slower rate in memory-disordered patients with Alzheimer's disease, Huntington's disease, and Parkinson's disease (Heindel, Salmon, Shults, Walicke, & Butters, 1989). Heindel et al. (1989) provided evidences of a double dissociation of explicit and implicit memory in patients with Alzheimer's Disease and Huntington's Disease. Whereas patients with Huntington's Disease showed detriments in an implicit motor task, they performed adequately on a verbal priming task. This affect was opposite in patients with Alzheimer's Disease: in this case, Alzheimer's patients showed detriments in verbal implicit tasks, but not in motor tasks. Parkinson's patients indicated deficits in both types of implicit tasks (Heindel, et al., 1989). The researchers assert that these dissociations provide evidence for a multiple memory system, and that each disease provides evidence for impairment to each of the separate systems.

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[1] The Deese-Roediger-McDermott (DRM) (Roediger &McDermott, 1995) procedure presents to participants lists of semantically related words. In testing, participants are prone to falsely remembering an associated, yet never presented word.

[2] Perceptual identification tasks present to participants a word that is shown for only a

Developmental Studies

Changes in the implicit and explicit memory subtypes differ in aging in both childhood and into late adulthood. Older adults have a normal loss of the explicit system throughout time, while the implicit system remains relatively intact. Memory is thought to follow a “first in, last out” pattern throughout life (Schacter and Moscovitch, 1984, from Rovee-Collier, Hayne, and Colombo, 2001, p. 65). Following that principle, researchers have assumed that developmentally, implicit memory is formed prior to explicit memory in children and lasts longer than explicit memory through adulthood (Schacter & Moscovitch, 1984; Parkin, 1993). While the ability to use explicit memory in picture naming tasks increases across childhood, implicit memory remains invariant to age throughout childhood and into adulthood (Hayes & Hennessy, 1996). Evidence of implicit memory has been found in infants, whereas explicit memory generally forms around children one year of age or more. Indications of priming in children have been found as young as the infant stage using physiological responses to novel stimuli (Webb & Nelson, 2001). Anooshian and Seibert (1996) found gender differences in preschoolers and adults to be the same across implicit and explicit tasks. In other words, the increased rate of familiarity in females was the same in preschoolers as it was in adults.

An alternative viewpoint is that both the implicit and explicit memory subtypes may be available in the early stages of development, which is supported by evidence in recognition studies in infants. Rovee-Collier (1997) found similar dissociations between implicit and explicit memory in infants as adults, but with experimental manipulations that could be used with children. A classic infant recognition study counts leg kicks to novel and repeated mobiles. Rovee-Collier (1997) stated that the mobile paradigm in children is analogous to similar experimental manipulations of explicit memory in adults. This, she believes, challenges the assumption that the two systems develop separately, and instead develop in conjunction at a similar rate as one another, supporting a unified memory framework.

The majority of memory changes in healthy older adults occur in explicit memory (Nilsson, 2003). Older adults are generally considered people between the ages of 65 and 80, whereas younger adults are considered to be between the ages of 20 and 40, although some variation between studies exists. The changes in older adults, compared to younger adults, indicate the former group has a harder time learning new information (Albert, 2002), as well as a lower processing capacity (Burke & Light, 1981), which manifests in poorer scores on explicit memory tasks. Craik and Salthouse (2000) state that changes within memory subsystems do not occur because the system itself breaks down, but instead that the type of processing required to complete a task is no longer available or easily accessible. The inability to use newly learned information as easily as younger adults stems from a lack of access to information; stimuli may have been encoded, but older adults have a harder time using that information (Craik & Bialystock, 2006).

Alternatively, implicit memory remains relatively stable across the lifespan; whereas explicit memory is affected by age, older adults tend to perform equally well as younger adults on tests of implicit memory, such as priming and procedural tasks (Nilsson, 2003). When comparing younger and older adults, both age groups performed comparably on repetition, item, and associative priming. Implicit memory remained intact despite significantly lower recall performance in the elderly (Light, LaVoie, & Kennison, 1995). Schugens, Daum, Spindler, and Birmauer (1997) tested differences in implicit memory by employing a word-stem completion task (thus testing the effects of priming) and a mirror-reading test (testing skill acquisition), and discovered no significant differences across age groups in both tasks, even though there were recognizable differences in explicit memory.

Conditions of increased processing demands affect age-related sparing of the implicit system. Under conditions of divided attention Parkin (1993) found that younger adults showed a deficit in explicit memory equal to that of older adults, while older adults still performed worse than younger adults at tasks of implicit memory. Parkin (1993) argues, however, that the results indicate older adults have more trouble using the benefit of available explicit memory during tasks of implicit memory. Fleischman, Gabrieli, Wilson, Morro, and Bennett (2005) found that performance on indirect tasks was lower in older adults than in younger adults on two of four experiments, but concluded that these differences existed in situations with greater processing demands only. Finally, Craik and Salthouse (2000) assert that even when experiments find age-related differences in implicit memory the differences are substantially smaller than those found in experiments testing explicit memory.

The evidence for multiple memory systems in the developmental literature is at times contradictory. For instance, some research supports the notion that there exist two separate memory systems that develop in the early stages of life (Parkin, 1993; Schacter & Moscovitch, 1984), as well as the degeneration of explicit memory, with the general retention of implicit memory in later adulthood. Rovee-Collier (1997) challenged the assumptions of other researchers stating that in the early stages of development the evidence is for a unified memory system whose components develop in congruence, which is not consistent with the idea of two separate and non-interacting memory systems.

In these studies, researchers utilized process purity approaches to measure memory. Implicit and explicit memories are dissociated through a task manipulation. Based on the dissociation in patient studies and developmental studies, researchers sought to identify a similar dissociation of the memory subtypes with healthy patients. One very common method of research in the implicit and explicit literature is the process-purity method of measuring memory. This method has been integral in the development of evidence that implicit and explicit memory are two separable memory systems.

Task Dissociations

Historically, research involving healthy patients has used process-pure testing techniques, which assume that a task manipulation is required to separate the involvement of implicit and explicit memory. Direct tests of explicit memory use a method whereby the participant is actively searching memory stores for a correct answer. Such methods involve free- and cued-recall, as well as various recognition tasks. Implicit tasks target the retention of pertinent information without ever specifically addressing the information itself. Participants need not have conscious memory for previously performed tasks, or previously presented stimuli, but may show residual benefit on tasks such as priming and procedural memory. Implicit memory for information may manifest itself in decreased response time to previously learned information (in the case of perceptual identification, or lexical decision tasks), or increased use of target information in completing tasks like word-fragment or word-stem completion. The use of indirect tasks in comparison to direct tasks after exposure to experimental manipulation has been integral in the theoretical and evidentiary development of implicit and explicit memory.

There have been a number of papers that have argued there are independent variables that affect implicit and explicit memory differently. The vast majority of research has used task manipulations to conclude that differences exist in implicit and explicit memory. However, as will be discussed, there are a number of problems with such a conclusion, and the research will not be reviewed in depth. For a more in depth review of the task dissociation literature see Schacter (1987) and Roediger and McDermott (1993).

Task dissociations are predicated on the idea that a single task targets a single memory process. The assumption that the two processes of memory are pure of each other is fallible. In fact, it is very possible that each type of memory affects the other. It is also likely that any cognitive process is made up of multiple underlying processes, and a single task cannot address a single function. Chechile and Roder (1998) and Chechile (2007) have argued that no single dependent variable taps only one psychological process. Consequently, a claim that a task only involves a single latent cognitive process is itself a theoretical claim that cannot be justified without substantial validation information. It is for this reason Chechile and Roder (1998) and Chechile (2007) argue that one must utilize a detailed decomposing of psychological tasks in terms of a mathematical model that characterizes how the underlying psychological processes tap into the observable dependent measures. Many other investigators have also been unconvinced that there is a single task or dependent variable that solely measure either implicit or explicit memory. Conclusions about underlying memory processes may be premature and another method of testing memory may be necessary.

In spite of this criticism, a vast amount of literature using the task dissociation technique is available. An initial dissociation between implicit and explicit memory came from the use of the generation effect, which is a manipulation provided to participants during encoding. Words that are generated by the participant, as opposed to simply read, are remembered better (Slamecka & Graf, 1978) because explicit memory is stronger for generated items. After a generation learning paradigm, Jacoby (1983) provided participants with an explicit recognition task and an implicit perceptual identification task confirming that the condition in which participants generated items affected memory for the recognition task. Contrary to explicit memory, when participants completed a perceptual identification task, read words were more easily identified than those words that were generated. Although generating words increased item recognition, reading words increased the priming, or implicit activation of the words during an indirect task (Jacoby, 1983).[2] When conceptual and perceptual similarities exist among learning and testing situations, both implicit and explicit memory should benefit from the prior learning manipulations. Jacoby (1983) concluded that reading

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[2] Perceptual identification tasks present to participants a word that is shown for only a brief period of time. Participants need not have any memory for the word. However, residual effects from having previously seen the word will speed identification, which is a memory effect at the perceptual level. In the generation condition, participants never actually see the word, which would not provide the participant with a similar perceptual residue in the memory system. Additionally, participants may incorrectly generate a word, which would provide no memory residue for the participants. The priming advantage in the read condition may be an artifact of a differential rate of intact initial encodings.

words as opposed to generating them was perceptually congruent with the perceptual identification task. Because participants never read generated words, there was no perceptual representation on which to rely during the implicit task, causing the dissociation in the two types of memory. Extending this, Horton and Nash (1999) concluded that the generation of items during the study phase effects indirect tests of memory when the perceptual or conceptual nature of the tasks are a match during test. This means that if the perceptual nature of a task at study matches the perceptual nature at test, a reliable generation effect will be found; the same holds for conceptual matching, supporting the argument that explicit and implicit memory distinctions are simply an effect of transfer appropriate processes (Neill, Beck, & Molloy, 1990). Gardiner (1988) further emphasized the conclusions that there exists a negative effect of generation on implicit memory because both results suggest that there is transfer appropriate processing in implicit memory. When the transfer of processing is not available, negative effects of generation on implicit memory occur.

Like the generation effect, altering the level of processing affects explicit memory, but has negligible affects on implicit memory. Semantic encoding produces increases in explicit memory for words, but not for implicit stem completion tasks (Graf & Mandler, 1984). Rhyme generation increased explicit memory more so than a structural analysis of the words (Bowers, 1994) but had trivial effects on implicit memory. This result was confirmed when words and legal non-words (such as “jers”) were used as stimuli (Bowers, 1994). Mulligan (2002) presented participants with to-be-generated words either from transposed letters or word fragments as a non-semantic task, and generated words presented in the context of sentences as a semantic task. Results indicated that priming is affected by semantic generation, but not by non-semantic generation (Mulligan, 2002). In the non-semantic condition, the generated words affected only item recognition, not the implicit task, whereas both explicit and implicit memories were affected by semantic generation. Schacter and Graf (1986) discovered that any degree of elaborative encoding influenced both implicit and explicit memory for new word associations; however, the amount of elaborative encoding only affected explicit memory for the new associations (Schacter & Graf, 1986). In an auditory identification task and an auditory recognition task following a semantic versus non-semantic encoding condition (participants were either told to rate pitch, or rate to which categories the presented words belonged), the semantic task only affected explicit memory, not implicit memory (Schacter & Church, 1992).

The method of stimuli presentation can also differentially affect priming and recognition memory (McAndrews & Moscovitch, 1990). Priming effects are seen following visual presentations of words as opposed to auditory presentations; those words that were read by the participants indicated priming on anagram solutions more so than those words heard by participants. However, there was no effect of modality when participants were tested with a recognition test. If anything, argue McAndrews and Moscovitch (1990), there was a trend toward heard words being better recognized. Dew and Mulligan (2008) discovered that when words were presented aurally there was a greater influence on auditory priming than when the words were presented in an antonym-generating task. In the case of McAndrews and Moscovitch (1990) aurally presented words that were never seen were the least likely to show priming on a later anagram solution. McAndrews and Moscovitch's (1990) research was integral in determining that similarities between studied anagrams and tested anagrams were required in order for transfer appropriate processing, and the facilitation of previous exposure on implicit memory to occur. More specifically the perceptual nature of the words is important in anagram solution, and when the perceptual similarities do not exist between study and test, the benefit of previous exposure does not increase priming (McAndrews & Moscovitch, 1990).

Buchner and Wippich (2000) studied the reliability of process pure approaches and concluded that the reliability of implicit memory tests is low. Explicit memory for previously presented stimuli during implicit testing may unduly affect performance on implicit tasks. In recognition studies, which are considered a measurement of explicit memory, unconscious residue of a stimulus may increase correct response rates, resulting in better performance due to implicit involvement. Voss, Baym, and Paller (2008) discovered that participants accurately chose which of two stimuli they had previously seen, even though they had little explicit memory for the objects. The use of explicit information may be due to involuntary awareness of the implicit tasks. Participants may be aware of the experimental manipulation at hand and therefore have awareness of the previously learned tasks (Neill, et al, 1990; Mace, 2003). When comparing results on an indirect test of memory to those results on a task assumed to measure separate underlying influences concurrently, Toth, Reingold, and Jacoby (1994) discovered a dissociation between explicit and implicit memory on an indirect test. These results did not extend to automatic, or implied implicit memory alone, however. Toth, Reingold, and Jacoby (1994) argue that the rate of implicit involvement in the indirect test is attributable to explicit influences, thus proving that two separate tasks cannot adequately measure the influences of implicit and explicit memory.

Kinoshita (2001) provided a general conclusion that repetition priming is mediated by the involuntary awareness of the participants, because the awareness of a study episode comes from retrieval cues activating stored memories. Additionally, involuntary awareness of information leads to increased conceptual priming effects (Mace, 2003) such that when participants are aware of the study-test manipulation, they have a decreased amount of conceptual priming. Participants may be relying on both implicit and explicit memory to complete what are considered process pure tasks, contaminating the results (Buchner & Wippich, 2000), which supports Chechile and Roder (1998) and Chechile's (2007) claim that it is faulty to assume that using a single measure can assess a single construct.

In a review, Jacoby, Lindsay, and Toth (1992) state that the use of process pure approaches for evidence of multiple underlying systems is "similar to the use of projective tests to identify particular personality characteristics" (p. 807). With the arguments against process purity postulated here, it seems premature to argue on the basis of the multiple system frameworks. Instead, it seems plausible that research utilizing more appropriate testing techniques will support a single processing system of memory. If research analyzes differences in recall and recognition performance while holding implicit memory constant, and differences in recall and recognition still exist, a two-process theory of memory may be supported, otherwise the single-process theory would be supported (LaVoie and Light, 1994). The evidence from the process purity literature instead just describes different task requirements, rather than different memory systems (Jacoby, 1983).

Process Dissociation

To address these critiques, Jacoby (1991) proposed a process dissociation procedure (PDP) designed to test separately the involvement of implicit and explicit memory on a single task. The model not only has a means of separating the underlying mechanisms on which one single task is reliant, but is capable of measuring the magnitude of these effects following situations that may alter them (Jacoby, Lindsay, & Toth, 1992). If you are specifically able to recollect an item, it is assumed that there is explicit memory for item information; familiarity relies on implicit memory.

One major milestone of the PDP is that it uses mathematical approaches to describe the processes involved in a task, not the task itself (Jacoby, 1991). Dependent on experimental results, this may support the multiple memory systems argument based on task manipulations, not task dissociations. Regarding implicit memory in terms of process dissociation leads to a changing definition of implicit memory (Toth, Reingold, & Jacoby, 1994). Instead of viewing it as a means of measuring performance on indirect tests, implicit memory should be thought of as a limit to conscious control. This method of viewing implicit memory is testable through experimental manipulation (Toth, Reingold, and Jacoby, 1994).

Participants are presented with material from two sources followed by two test conditions, inclusion and exclusion. In the inclusion condition, participants are asked to complete a task that includes information from either of the two sources. The inclusion condition is assumed to rely on the processes of recollection as well as familiarity; it does not matter the degree to which information is remembered. The exclusion condition depends on recollection, requiring participants to incorporate information from only one of the two sources. Participants not only have to remember an item, but the source of that item as well. Any correct response on the exclusion condition is assumed to be indicative of explicit memory for that item.

The equations for conscious (*C*) and unconscious (*U*) memory are based on the proportion of correctly identified items (hits) and incorrectly identified items (misses) in the inclusion (*I*) and exclusion (*E*) conditions.

$$C = [hits(E) - misses(I)] \tag{1}$$

$$U = \frac{hits(E)}{[hits(E) - misses(I)]} \tag{2}$$

The PDP has been used to validate and extend the results from process pure studies, as well as provide a more detailed picture of the invariance of implicit memory across experimental manipulations. In the first use of the PDP, Jacoby (1991) presented participants with lists of words to be read and anagrams to be solved. Estimates for conscious processes were greater in the anagram condition than the read condition. Alternatively, unconscious processes were greater in the read condition than the anagram condition (Jacoby, 1991). Toth, Reingold, and Jacoby (1994) prompted participants to either read a word aloud, or to generate a target word missing from a read sentence. Words that were generated had a higher level of conscious influences; unconsciousness was influenced by read words more than generated words. The results indicated that generation increased explicit memory, whereas implicit activation influenced memory for read words. A similar conclusion was drawn from a classic process-pure indirect task. Because the contribution to performance of unconscious memory was greater in the indirect test than in the PDP, this suggests that the process-pure task was affected by explicit memory. The comparison provides evidence of the need for modeling procedures to disentangle the underlying memory processes.

Elaborative encoding has increased controlled processes invariant of unconscious processes (Reingold & Goshen-Gottstein, 1996). The associative repetition effect[3] was utilized with a PDP. After manipulating levels of processing, participants were asked to complete a three-letter word stem in inclusion and exclusion conditions. When participants had engaged in shallow encoding (simply reading the word-pair) the associative priming affect was found in implicit, but not explicit processes (Reingold & Goshen-Gottstein, 1996). Toth, Reingold, and Jacoby (1994) discovered that rates of controlled processes decreased between the semantic and non-semantic conditions of the levels-of-processing manipulation in a three-letter word stem task, but levels-of-processing did not affect unconscious processes. In a concurrent process pure test, there was a decrease in the level of memory between the semantic and non-semantic conditions, providing further evidence of the contaminating influences of explicit memory.

Attention at the time of encoding differentially affects recollection and familiarity in the PDP (Jacoby, 1991). Dividing attention, through an aurally presented number

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[3] Associative priming is the effect that occurs when participants make associations between unchanged, yet unrelated, target word pairs. When presented later there is more robust memory for target words, as opposed to when the target words are paired with a new unrelated word.

shadowing task, decreased the degree to which people rely on recollection in a false-fame (identifying non-famous people as famous) task but had no effect on familiarity (Jennings & Jacoby, 1993). Debner and Jacoby (1994) divided attention by asking participants to sum the numbers around word-stems. They observed a reduction in the amount of conscious perception from full to divided attention, but again no difference in unconscious perception. Jacoby, Toth, and Yonelinas (1993) provided participants with aurally presented words under full attention and written words either under full or divided attention. While divided attention affected recollection to the point where the estimate of conscious processes were zero, the manipulation left automatic processes unchanged. Comparing this to direct tests of recollection, Jacoby, Toth, and Yonelinas (1993) discovered an enlarged rate of recollection on the direct test indicating that there was some implicit involvement resulting in inflated rates of stem completion.

The PDP has been utilized to confirm other results from the process-purity literature. Yonelinas and Jacoby (1994) varied list-length so they could compare the rates of recollection and familiarity in a list-learning paradigm. Similar to results from the process pure literature, longer lists led to less recollection, but had no affect on familiarity. Both conscious and unconscious processes are increased with repeated stimuli as opposed to when those stimuli are presented once (Ngo, Brown, Sargent, & Dopkins, 2010).

In most of these studies, familiarity has remained invariant over experimental manipulations; however this is not always the case. Yonelinas and Jacoby (1994) noticed that familiarity based judgments occurred at a faster speed than did recollective judgments when holding response time constant. Debner and Jacoby (1994) used the

PDP to test presentation time where both conscious and unconscious rates increase as presentation time increases. However, there was a higher degree of unconscious perception for both presentation time conditions, indicating that unconscious processes had more influence on a stem completion task than did conscious processes. Finally, Ngo et al. (2010) discovered that familiarity ratings are affected more by conceptual processing as opposed to perceptual processing. When the conceptual nature of an object was studied, as opposed to the perceptual nature, familiarity increased (Ngo et al., 2010).

Criticism of the Process Dissociation Model

The PDP contains the following inherent assumptions: (1) the rules applied to make familiarity judgments remain the same across the inclusion and exclusion conditions, (2) the ability to recollect information is also the same across the inclusion and exclusion conditions, and (3) values for familiarity and recollection remain independent of one another, and should be uncorrelated when tested (Jacoby, 1991). Jacoby (1991) assumed having separate tasks for separate processes, such as the process pure approach, does not allow for discovering the independence of the two processes (Chechile & Meyer, 1976; Chechile & Roder, 1998; Chechile, 2007). As stated by Ratcliff, Van Zandt, and McKoon (1995) the model must always be considered in the context of its assumptions, and therefore researchers need to validate that the assumptions are correct.

Jacoby (1991) argues that the process pure approach does not allow for discovering the independence of implicit and explicit memory, as does the PDP. In light of this assumption, one initial critique came from Curran and Hintzman (1995). Through experimental manipulation, a correlation between recognition and familiarity surfaced. Furthermore, as the correlation between automatic and controlled processes increased, the ability of the PDP to identify correctly the input of automatic processes decreased. Thus, if an experimental manipulation increases the rate at which participants use controlled processes, such as strategies to increase the levels of processing, the influence of implicit memory will be underestimated (Curran & Hintzman, 1995). The authors also argue that response strategies may differ on the part of participants, and that support from the model may be due to collapsing across subjects and finding the average when identifying the input of conscious and unconscious factors, whereas modeling the participants separately may lead to different conclusions. Wilson and Horton (2002) also provided evidence of a correlation with a response time task, due to what is termed "involuntary conscious awareness" meaning that the processes may be independent, but that a correlation will emerge due to conscious awareness stemming from the unconscious process. Schmitter-Edgecomb (1999) also discovered a highly significant negative correlation between controlled and automatic processes indicating the confluence of the two; as measurements of controlled processes decreased, measurements of automatic processes increased. If an instructional manipulation increases the rate at which a participant uses controlled processes, such as strategies to increase the levels of processing, the influence of implicit memory will be underestimated (Curran & Hintzman, 1995).

In response to Curran and Hintzman (1995), Rouder, Lu, Morey, Sun, and Speckman (2008) proposed a hierarchical process dissociation model. This model was based on the PDP but contains within it parameters accounting for participant and item variability. As with the process dissociation model, the processes of recollection and familiarity are assumed independent. This model allows for the estimation of recollection and familiarity for individual participants learning specific items during specific testing scenarios. Rather than agree with Curran and Hintzman (1995) that a relationship exists between recollection and familiarity, Rouder et al. (2008) tested the individuals separately and found that there was no longer a relationship between controlled and automatic influences. This supports the theory that the relationship between the processes in the PDP may be a sign of aggregating across participants, not an actual relationship itself.

Another major critique of the model is its reliance on the origin, or source, of learned information. In fact the PDP does not separate the memory for a specific item from the memory for the list from which that item was learned. It may be argued, however, that it is possible to have explicit memory for an item without having memory for that item's source. But what the PDP considers to be recollection relies on having not only item information but also memory for the source of the item. The value for automatic processes may be overestimated because participants may not exclude items when they have no memory for the source, but in fact they remember the item (Roediger & McDermott, 1994). The PDP does not discriminate recollection from what it is at its core: source memory. Furthermore, the interaction between item and source information may alter the "yes" rate. If a participant has an explicit memory of an item being presented, but does not remember the source of the item, the rate at which they respond "yes" in the inclusion and exclusion conditions may be altered. This would create a situation where a participant is less likely to respond positively in the exclusion condition.

Mulligan and Hirshman (1997) used a model that separates recollection of items with and without memory for source attributions to compare to the results attained from a standard PDP and discovered that conscious and unconscious processes in the PDP were affected by memory for the source of the item. In other words, familiarity was overvalued because recollection of an item without memory for the source of that item was considered as familiarity, not as recognition. Mulligan and Hirshman (1997) contend that the PDP is more a test of source memory than a separation of controlled and automatic processes.

Dodson and Johnson (1996) also conducted a study to test the assumptions of the PDP. Based on a number of experimental manipulations, they concluded that familiarity of an item is not automatic, as is an assumed of the process dissociation procedure. Furthermore, these researchers came to a similar conclusion as Mulligan and Hirshman (1997) such that recollection is not an all-or-none process, as implied by the model. Participants were able to use the experimental design to guess the source of information, affecting the inclusion and exclusion part of the paradigm. In accordance with Mulligan and Hirshman (1997), Dodson and Johnson (1996) suggested instead that process dissociation is a test for source information.

An inherent assumption of the PDP is that the instructions do not alter implicit and explicit processes used in both the inclusion and exclusion conditions. Although supportive of the model in general, Reingold and Toth (1996) reviewed the process dissociation assumptions and discussed the issue underlying the instructional manipulation. Reingold and Toth (1996) explain that memories may be consciously controlled, or unconsciously influenced. If participants see a cued recall stem, the cue may remind them of a learned item they had not consciously remembered. This implicit activation may lead to a conscious memory of a learned item, which would not have been consciously remembered initially. The type of instruction the participant receives may affect the amount to which unconscious activation leads to conscious awareness. This item will then be counted as conscious memory, and lead to an overestimate of the C parameter, and an underestimate of the U parameter. The instructions themselves might alter the response tendencies separate from the issue of explicit and implicit processes, alter the parameters of the model, and make the model ineffective. The instructional manipulation may alter the "overlap", or dependency, of conscious and unconscious information (Reingold & Toth, 1996).

For her dissertation work Chamberland (Chamberland & Chechile, 2007) provided an in depth description proving a case against the PDP. In this work, it was presented that the PD model is a saturated model, because it has as many parameters as degrees of freedom for model testing. To get around this limitation, the researchers added confidence ratings along with the standard inclusion and exclusion instructions. With this redefined model, Chamberland and Chechile were able to estimate similar conscious and unconscious processes within both the inclusion and exclusion conditions, which challenge the assumptions set forth by Jacoby (1991) that the unconscious and conscious estimates of memory are different in the two instructional conditions. Based on this finding, a model that does not depend on instructional manipulation is required.

The PDP meets further criticism when the results are compared across individuals and across patient groups. Roediger and McDermott (1994) argue that null results may be found when comparing older and younger adults because different subject groups have differing rates of false alarms. In response to a study conducted by Verfaeillie and Treadwell (1993), Roediger and McDermott (1994) stated that the conclusions maintained by Verfaeillie and Treadwell (1993) were due to the researchers not including rates of false alarms. The PDP attempts to remove false alarms in its calculations of controlled and automatic processes, but Roediger and McDermott (1994) state that when groups or individuals have variability within their respective levels of false alarms, the PDP may not be a valid model for measuring automatic processes. The researchers argue that when comparing different groups of people, as well as different experimental situations, the PDP may not accurately compare performance due to differing false alarm rates among groups. When a signal detection approach to the PDP's estimate of familiarity is utilized, there should be equal variances among groups. Ratcliff et al. (1995) found that this assumption was not true, but concluded that it was overall not a necessary assumption in the totality of the model, and still insisted that the model be the benchmark for all other models to come.

Buchner, Erdfelder, and Vaterrodt-Plünnecke (1995) argue that response biases are present in any psychological task, including process dissociation, and therefore must be addressed. In this case, Buchner et al. (1995) added a parameter for guessing (g_i and g_c for inclusion and exclusion, respectively). The addition of guessing is important, especially in light of the confounding nature of false alarm rates. When false alarm rates differ among conditions, or groups of participants, the extended model proposed by Buchner et al. (1995) can establish a means to correct for this.

One final point, developed by Chamberland and Chechile (2007) in the former's dissertation work is that the PDP does not account for the possibility that there may be some explicit, yet fractional, information about an item. In other words, the model does not correct for the facilitation that comes from conscious partial information (Chechile, Sloboda & Chamberland, 2012). Specifically, a person may remember seeing or hearing an item, but not the specific source of that item. Or, there may be some information about an item that leads a person to recognize it without having full explicit awareness of the item. This partial information would aid in recognition in the inclusion condition, but be less helpful in the exclusion condition. Therefore, the fractional explicit memory may be accounted for by the estimate of unconscious memory in the PDP; the estimate for *U* would be inflated because it is not only measuring implicit memory, but explicit fractional memory as well.

Finally, as outlined in Chechile et al. (2012), having partial item knowledge may dictate differently the criterion used to respond yes in the inclusion and exclusion conditions, and this may alter the explicit and implicit components in the two conditions. Buchner et al. (1995) further demonstrated this with a difference in response rates to foil trials in the exclusion and inclusion conditions. A response to a foil should be the same regardless of the instructional manipulation. In process dissociation, it is assumed that the implicit component, or familiarity, is the same in both conditions. However, as Chechile, et al. (2012) state, if familiarity is fixed, then there exists a change in the yes response rates as a direct result of the exclusion and inclusion instructions, and this adjusts the rates of explicit and implicit memory.

Based on these criticisms, the model forwarded in this thesis, the Implicit-Explicit Separation Model, contains within it parameters for not only explicit and implicit memory, but fractional memory and non-storage as well. The model does not depend on instructional manipulations or memory for an items source. It also includes within it confidence ratings as well as parameters for guessing rates that can address differences in false alarms across the groups being tested. Despite the various criticisms reviewed here, the PDP is still actively being used. Reingold and Toth (1996) rightfully assert that the benefit of the model is that it increased the awareness of the necessity to actively measure implicit and explicit processes in memory research. In our laboratory at Tufts University, we have developed another mathematical model that we call the Implicit/Explicit Separation (IES) model. The following section describes the IES model.

The Implicit Explicit Separation Model

The majority of research on implicit and explicit memory has been conducted in either the process pure, or process dissociation approach. A new approach utilizing multinomial processing tree (MPT) modeling has been forwarded, which separates the four fundamental underlying types of memory involved in a specific task. The Implicit-Explicit Separation (IES) model contains parameters, or probability measures, that allow for the measurement of explicit memory, implicit memory, fractional storage, and non-storage.

Any multinomial processing tree model has a specific task with which it is associated and thus the task must first be identified. The IES model and task is based on, and inspired by, the experimental task developed by Chechile and Soraci (1999) that provided for storage, fractional storage, and non-storage measurements. The IES model task is comprised of a yes/no recognition task and prompts for confidence ratings, followed by a forced-choice recognition task. A pictorial explanation of the task is provided in Figure 1, and the associated response cells are provided in Figure 2. The procedure is that participants are first shown study material, or stimuli, during a learning trial, and then tested on their ability to remember that material.

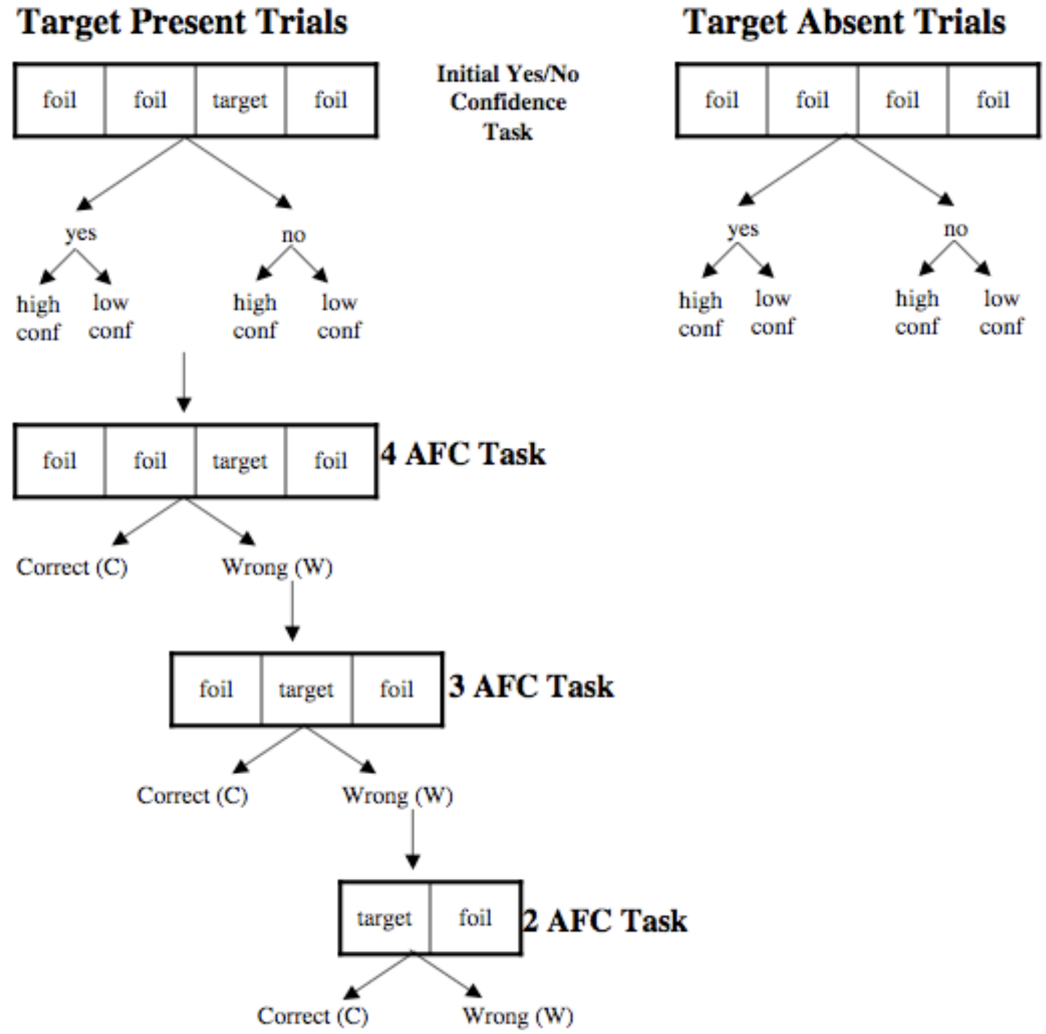
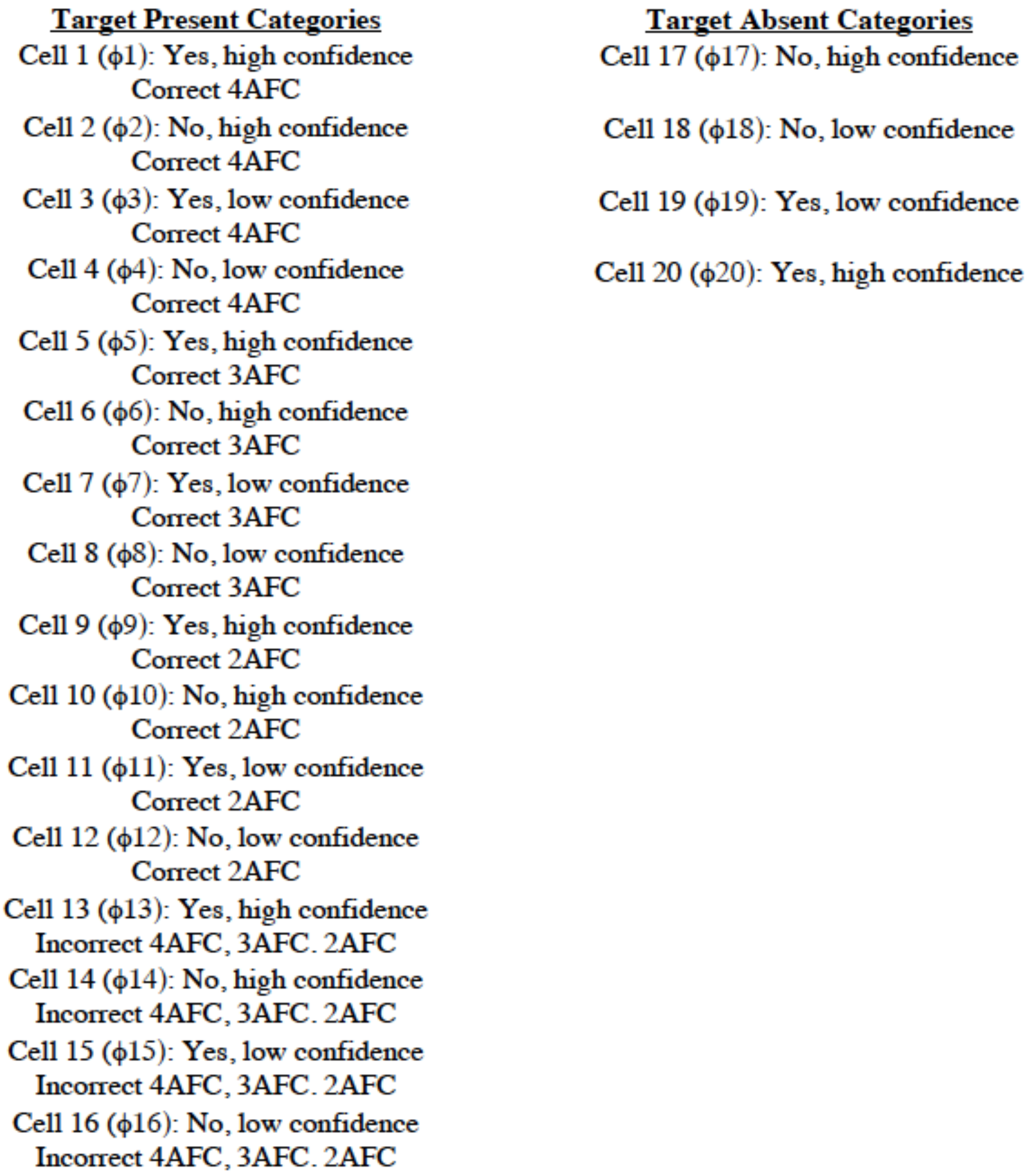


Figure 1. The figure includes the flowchart for the task associated with the IES paradigm. Trials begin with an initial Yes/No task with confidence ratings. Target-Present trials are followed by a 4-Alternative forced-choice task. If correct, the trial ends. If an incorrect response is logged, then the response is removed and 3-Alternative forced-choice task follows, and a 2-Alternative task, if need be. Target-Absent trials ended after the Yes/No Confidence Task.



Target Present Categories

Cell 1 (ϕ1): Yes, high confidence
Correct 4AFC
Cell 2 (ϕ2): No, high confidence
Correct 4AFC
Cell 3 (ϕ3): Yes, low confidence
Correct 4AFC
Cell 4 (ϕ4): No, low confidence
Correct 4AFC
Cell 5 (ϕ5): Yes, high confidence
Correct 3AFC
Cell 6 (ϕ6): No, high confidence
Correct 3AFC
Cell 7 (ϕ7): Yes, low confidence
Correct 3AFC
Cell 8 (ϕ8): No, low confidence
Correct 3AFC
Cell 9 (ϕ9): Yes, high confidence
Correct 2AFC
Cell 10 (ϕ10): No, high confidence
Correct 2AFC
Cell 11 (ϕ11): Yes, low confidence
Correct 2AFC
Cell 12 (ϕ12): No, low confidence
Correct 2AFC
Cell 13 (ϕ13): Yes, high confidence
Incorrect 4AFC, 3AFC. 2AFC
Cell 14 (ϕ14): No, high confidence
Incorrect 4AFC, 3AFC. 2AFC
Cell 15 (ϕ15): Yes, low confidence
Incorrect 4AFC, 3AFC. 2AFC
Cell 16 (ϕ16): No, low confidence
Incorrect 4AFC, 3AFC. 2AFC

Target Absent Categories

Cell 17 (ϕ17): No, high confidence

Cell 18 (ϕ18): No, low confidence

Cell 19 (ϕ19): Yes, low confidence

Cell 20 (ϕ20): Yes, high confidence

Figure 2. The figure contains the 16 response cells for target-present trials and the 4 response cells for target-absent trials. Each one of the response cells is described by the pattern of responses on the Yes/No Confidence Task, and whether the participant correctly chose an item on the 4-, 3-, or 2-Alternative Task. The four memory components are estimated on participants' responses in each of the cells.

Two types of trials are conducted: participants are presented with either a target present or a target absent trial. In both cases, participants are provided with four items and asked to make a yes/no recognition judgment as to whether or not they had seen any of the stimuli previously. This judgment is then followed by a confidence rating of 3, 2, or 1, where a 3 signifies high confidence, a 2 indicates that the participant is somewhat confident, and a 1 signifies a blind guess. For the purpose of estimating the parameters of the model, the 2 and 1 confidence ratings are combined such that there is essentially a high or low confidence rating.

In the target absent trials, four alternative test items are presented, none of which would have been previously presented to a participant. The participants would be correct in answering “no”, indicating none of the items had been previously presented. There are four response outcomes, indicated in cells 17 through 20 in Figure 2 based on whether participants were correct or incorrect and had high or low confidence in the initial yes/no recognition test.

In the target present trials, one of the four items is a target and the other three are foils. A participant would be correct in answering “yes”, indicating they believed the target was present. During target-present trials, regardless of whether or not the participant is correct on the yes/no recognition test, the yes/no recognition test is followed by a prompt to choose which of the four stimuli represents the target in a four-alternative forced-choice (4AFC) task. If the participant is correct the test of that specific trial is over and a response is recorded in one of the cell categories 1 to 4 from Figure 2, again depending on whether participants were correct or incorrect and had high or low confidence in the initial yes/no recognition test. If the participant is incorrect, however, their initial response is removed from the list of four stimuli and they are presented with the three remaining alternatives and prompted to identify which of the three stimuli had been previously presented. If the participant is correct, their response is recorded in cells 5 through 8 from Figure 2. Again, if they are wrong, they are presented with the two remaining alternatives. Responses are recorded in cells 9 to 12 if they are correct and 13 through 16 if they are incorrect.

The multinomial processing tree model can be found in Figures 3, 4, 5, and 6. Figure 3 demonstrates the model for the four fundamental memory states, explicit (θ_{se}), implicit (θ_{si}), fractional (θ_F), and non-storage (θ_N), for target-present trials. Figure 4 is an extension of the branch for fractional storage, and Figure 5 is an extension of the branch for non-storage. Finally, Figure 6 depicts those parameters estimated from target-absent trials.

Based on the task, it is easy to define the proportion of items explicitly stored. When a participant views the four alternatives, it is assumed that the presence of a target stimulus activates the explicit memory of the target. If an item is explicitly stored a participant would answer “yes” with high confidence, indicated by a response of a confidence rating of “3”. In the presence of explicit memory, a participant should then correctly chose the item on the 4AFC task, a cell 1 response. The estimated parameter denoting the proportion of explicitly remembered information is θ_{se}.

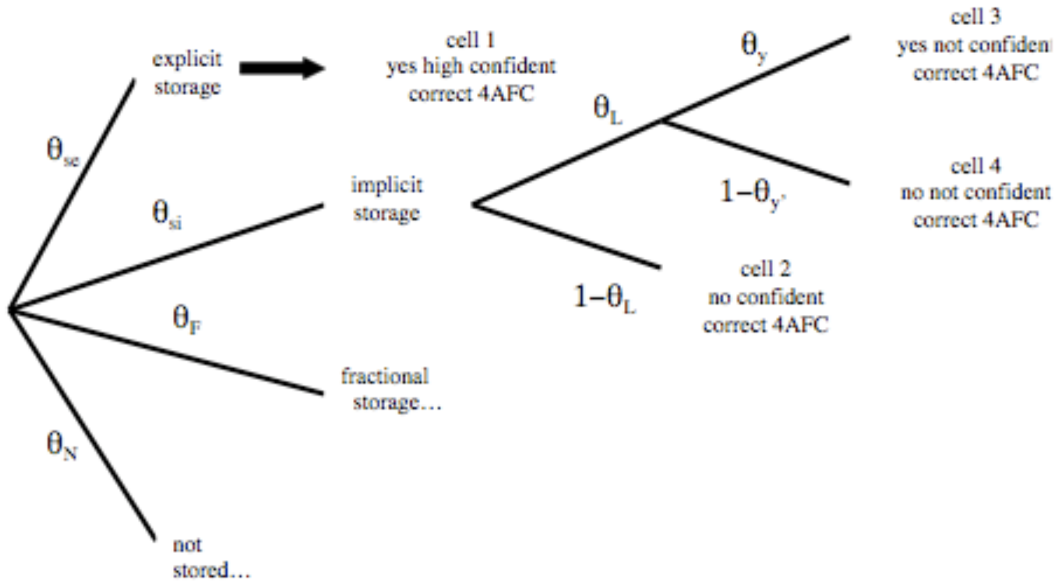


Figure 3. The figure contains IES model containing the four initial memory states. The model for non-storage continues in Figure 4, the model for fractional storage continues in Figure 5, and the model for target-absent trials can be found in Figure 6. There is one outcome when information is explicitly stored. It is assumed that when information is explicitly stored, a participant will say "yes" in the yes/no recognition trial, with high confidence, and then be able to correctly identify it on the 4AFC task, or Cell 1. There are three outcomes that may occur when an item is implicitly stored. These outcomes refer to cells 2, 3, and 4, which are the cases that occur after a "no" response to a target-present trial, or a "yes" response to a target-present trial followed by low confidence. The cases when cells 2, 3, and 4 occur due to fractional and non-storage have already been taken into account in Figures 4 and 5. If there is implicit storage of an item, the value for implicit storage (θ_{si}) will be higher than the predicted rates of either non-storage or fractional storage. The parameters θ_L and $\theta_{y'}$ are the probabilities associated with a "yes" response to a target-present trial followed by a low confidence rating.

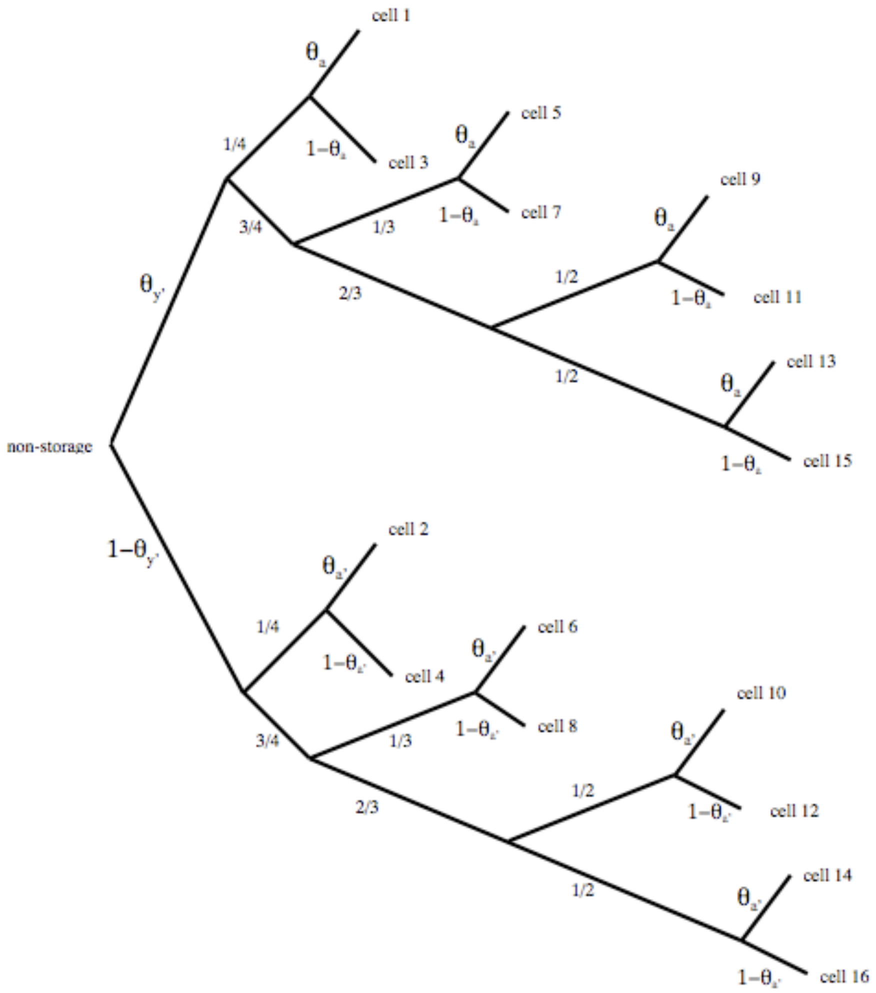


Figure 4. The IES model for non-storage is a continuation of the branch for non-storage θ_N in figure 3. The model for non-storage contains the parameter θ_{y*} which describes the guessing rate on target-present and target-absent trials (and thus is included in the tree for target-absent trials in Figure 6). The θ_a parameter is the probability of a highly confident rating on the yes/no recognition task. The $\theta_{a'}$ parameter corresponds to a "no" response when there is no item storage. The inclusion of these parameters in the IES model is for the assumption that there is a response bias from participants that do not always follow instructions and use high confidence ratings even when they are not highly confident.

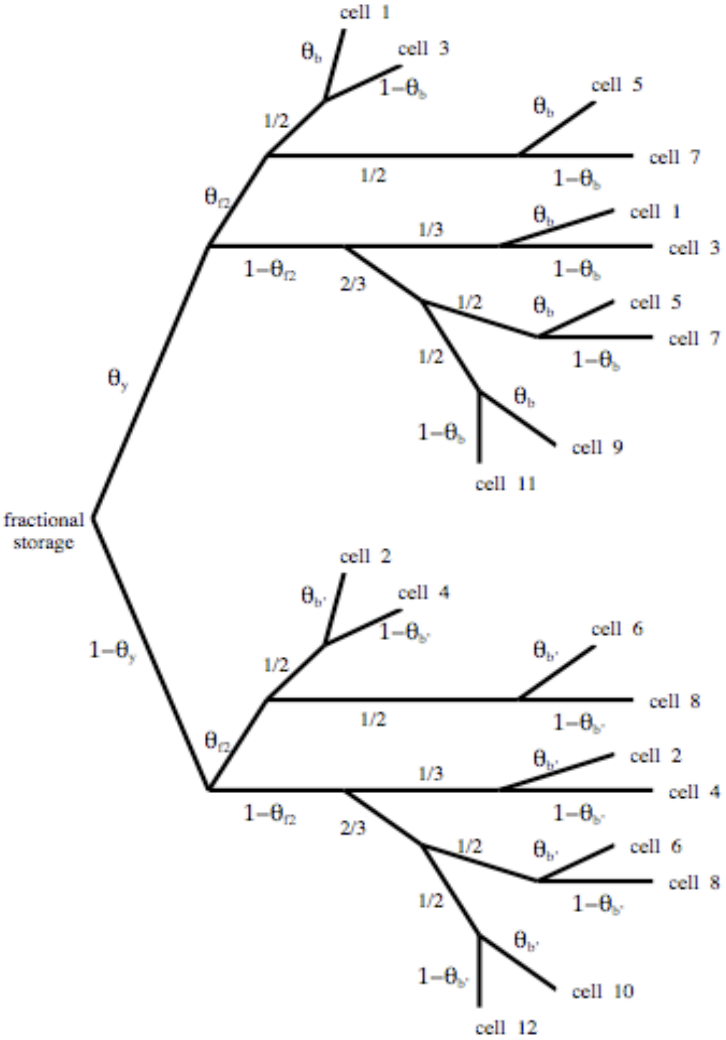


Figure 5. The IES model for fractional storage. The probability of a correct "yes" in target-present trials is represented by θ_y. Responses that may occur due to partial knowledge indicate that a participant may have some memory for an item that leads them to be able to reject one or two of the foils. Fractional storage differs from implicit storage in that it is not an actual memory trace for an item, but there is some information available to the participant to make a more educated guess during target-present trials. The tree for fractional storage has within it two parameters, θ_b and $\theta_{b'}$ that deal with the overconfidence of participants. These parameters differ from their non-storage counterparts θ_a and $\theta_{a'}$ because partial information may affect whether participants say yes or no, as well as their confidence ratings. There are two cases of fractional storage (1) when participants are able to reject one of the three foils ($1\text{-}\theta_{f2}$) and on the 4AFC and (2) when participants have enough information to reject two of the three foils (θ_{f2}) on the 4AFC. If the participant is unable to reject any foils, that is considered non-storage. If the participant can reject all three foils in a target-present trial, then that is considered either explicit or implicit memory storage.

Figure 4 depicts the tree for non-storage (θ_N), or the case when every trace of that information has been lost from memory in a target-present trial. Even if information is no longer stored, there is still a 0.25 chance that a participant can correctly guess the item on a 4AFC. The parameter θ_{y*} describes the guessing rate on target-present and target-absent trials. The θ_a parameter is the probability of a highly confident rating on the yes/no recognition task. The $\theta_{a'}$ parameter corresponds to a "no" response when there is no item storage. The inclusion of these parameters in the IES model is for the assumption that there is a response bias from participants that do not always follow instructions and use high confidence ratings even when they are not highly confident. This would be indicative of a response consistent with cells 1 through 4 when there is actually no storage of the item. With a $1/4$ chance of correctly guessing, there is a $3/4$ chance of incorrectly guessing in the case of nonstorage on the 4AFC, followed by a $2/3$ chance of guessing incorrectly on a 3AFC and a $1/2$ chance of guessing incorrectly on the 2AFC. The probabilities for each of the cells 5 through 8, 9 through 12, and 13 through 16 in the case of non-storage is $\left[\frac{1}{4}\theta_n\theta_{y^*}\theta_a\right]$, $\left[\frac{1}{4}\theta_n(1-\theta_{y^*})\theta_{a'}\right]$, $\left[\frac{1}{4}\theta_n\theta_{y^*}(1-\theta_{a'})\right]$, and $\left[\frac{1}{4}\theta_n(1-\theta_{y^*})(1-\theta_{a'})\right]$.

A participant may also have partial item storage, denoted by the parameter θ_{F}, or fractional storage indicated by a participant's ability to reject one or two foils based on some knowledge of the target. The section of the multinomial processing tree that extends the branch for fractional storage is in Figure 5. The probability of a correct "yes" in target-present trials is represented by θ_y. Fractional storage differs from implicit storage in that it is not an actual memory trace for an item, but there is some information available to the participant to make a more educated guess during target-present trials. The tree for fractional storage contains within it two parameters, θ_b and $\theta_{b'}$ that deal with the overconfidence of participants, that inaccurately inflate confidence. These parameters differ from their non-storage counterparts θ_a and $\theta_{a'}$ because partial information may affect whether participants say yes or no, as well as their confidence ratings. There are two cases of fractional storage (1) when participants are able to reject one of the three foils (1-θ_{f2}) and on the 4AFC and (2) when participants have enough information to reject two of the three foils (θ_{f2}) on the 4AFC. If the participant is unable to reject any foils, that is considered non-storage. If the participant can reject all three foils in a target-present trial, then that is considered either explicit or implicit memory storage. The probabilities for the responses in cells 1 through 4 and 5 through 8 are $\left[{}^{1}/_{6}\,\theta_F\theta_y\theta_b(2+\theta_{f2})\right]$, $\left[{}^{1}/_{6}\,\theta_F(1-\theta_y)\theta_{b'}(2+\theta_{f2})\right]$, $\left[{}^{1}/_{6}\,\theta_F\theta_y(1-\theta_b)(2+\theta_{f2})\right]$, and $\left[{}^{1}/_{6}\,\theta_F(1-\theta_y)(1-\theta_{b'})(2+\theta_{f2})\right]$. The respective probabilities for cells 9 through 12 in the case of partial storage are $\left[{}^{1}/_{3}\,\theta_F\theta_y\theta_b(1-\theta_{f2})\right]$, $\left[{}^{1}/_{3}\,\theta_F(1-\theta_y)\theta_{b'}(1-\theta_{f2})\right]$, $\left[{}^{1}/_{3}\,\theta_F\theta_y(1-\theta_b)(1-\theta_{f2})\right]$, and $\left[{}^{1}/_{3}\,\theta_F(1-\theta_y)(1-\theta_{b'})(1-\theta_{f2})\right]$. A response that would be categorized in cells 13 through 16 can only occur in the case of non-storage.

Referring again to Figure 3, there are three outcomes that may occur when an item is implicitly stored. These outcomes refer to cells 2, 3, and 4, which are the cases that occur after a “no” response to a target-present trial with either high or low confidence, or a “yes” response to a target-present trial followed by low confidence. If a response falls within category cells 2, 3, and 4 due to fractional or non-storage, this has already been taken into account through the equations stated above. Whatever remains, then, can be considered implicit storage. If there is implicit storage of an item, the value for implicit storage (θ_{si}) will be higher than the predicted rates of either non-storage or fractional storage. The parameters θ_L and $\theta_{y'}$ are the probabilities associated with a "yes" response to a target-present trial followed by a low confidence rating. This leads then to the probabilities in cells 2, 3, and 4, when there is implicit storage, to be $[\theta_{si}(1-\theta_L)]$, $[\theta_{si}\theta_L\theta_{y'}]$, and $[\theta_{si}\theta_L(1-\theta_{y'})]$.

Finally, there is one more section of the IES model left to address, and that is the tree for target-absent trials, depicted in Figure 6. Target absent trials are an important aspect of estimating the parameters for memory storage, because without target absent trials, a participant need only ever answer "yes" that a target is present. In target absent trials, participants are provided with four foils, and it is assumed that in answering "no" the participants have retrieved enough information about the learned information to reject correctly all four foils. The parameter θ_k is the probability that there is enough target information to notice a disparity in the four alternatives from any stored items. Chechile (2004; 2007) reviewed the process of rejecting foils. The participants would answer "no" with high confidence if the foils do not match the information they have of the target. The case of not having information available to reject correctly the foils is described with probability $1-\theta_k$. The rate for responding yes in this case is θ_{y*}, which is the same parameter as the yes-response when there is no storage for a target-present trial. Similarly, the target-absent tree contains parameters θ_a and $\theta_{a'}$, which describe high confidence ratings on the yes/no recognition task, and responding yes when there is no item recognition, respectively.

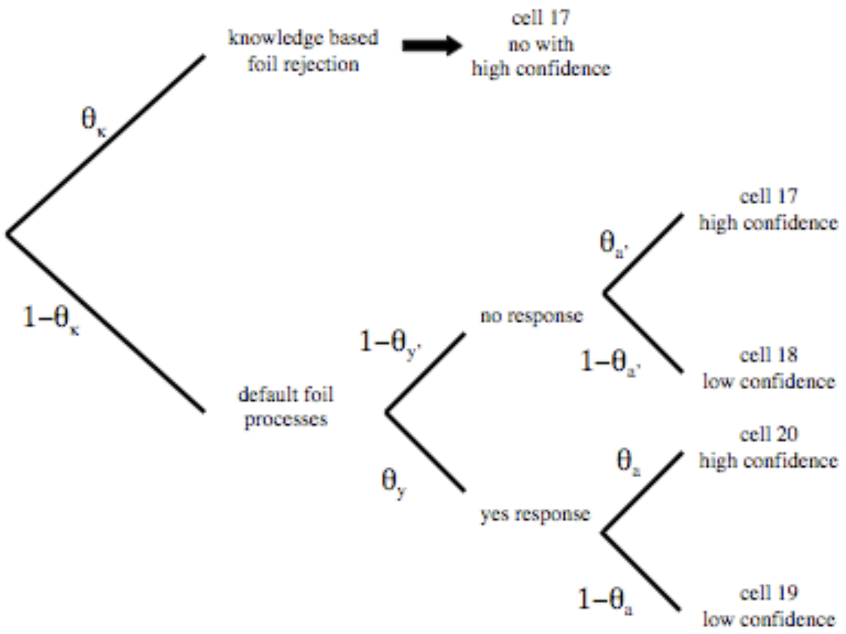


Figure 6. The IES model for target-absent trials. The parameter θ_k is the probability that there is enough target information to notice a disparity in the four alternatives from any stored items. The case of not having any information to reject correctly the foils is described with probability *1 -* θ_k. The rate for responding yes in this case is $\theta_{y*,}$ which is the same parameter as the yes-response when there is no storage for a target-present trial described in Figure 4. Similarly, the target-absent tree contains parameters θ_a and $\theta_{a'}$, which describe high confidence ratings on the yes/no recognition task, and responding yes when there is no item recognition, respectively

Parameters within any multinomial model are estimated through various means of parameter estimation. Population parameter mapping and maximum likelihood estimates are developed utilizing frequency counts in each cell of the model. The frequency counts in cells 1 through 20 are developed based on the responses of each individual participant. Population parameter mapping (PPM) (Chechile, 1998; 2004; 2009; 2010a, 2010b) is a means of estimating parameters based on Monte Carlo sampling of vectors from the posterior distribution for the population proportions for the various multinomial cells, 1 through 20. PPM provides a Bayesian distribution for each of the modeled parameters, and the mean of the distribution is provided as the point estimate. Table 1 provides the mean absolute value errors for θ_{se} and θ_{si} for both PPM and MLE estimates. Appendix A provides the equations for estimating these values. As can be seen from Table 1, P(coh) values are small for small sample sizes. The values increase as *n* increases. P(coh) is a measurement of the coherence of the model based on how successfully sampled vectors (ϕ) are mapped to a corresponding model space vector (θ).

In the case of the IES model, it is possible to estimate the parameters described herein. A set of equations can be examined to see how the four fundamental memory components change. The equations for finding both MLE and PPM estimates can be reviewed in Appendix A.

Table 1.
Mean absolute value errors for MLE and PPM estimates of θ_{se} *and* θ_{si} *as a function of sample size, n. Also Shown are the PPM P(coh) values.*

		$\left\|\theta_{se}-\overset{\frown}{\theta}_{se}\right\|$		$\left\|\theta_{si}-\overset{\frown}{\theta}_{si}\right\|$	
n	P(coh)	MLE	PPM	MLE	PPM
20	.083	.104	.166	.084	.050
30	.108	.082	.133	.065	.045
40	.134	.070	.107	.062	.045
50	.156	.062	.093	.054	.042
75	.205	.051	.071	.044	.037
100	.248	.042	.058	.038	.035
200	.340	.031	.037	.029	.027
300	.424	.025	.029	.025	.024
400	.487	.021	.023	.022	.021
500	.521	.019	.021	.019	.019
600	.561	.018	.018	.018	.018
700	.593	.016	.017	.016	.016
800	.624	.015	.016	.016	.016
900	.652	.014	.014	.015	.015
1000	.661	.014	.014	.013	.014
1100	.687	.012	.013	.014	.014
1200	.703	.012	.013	.013	.013
1300	.719	.012	.012	.012	.013
1400	.742	.011	.011	.012	.012
1500	.754	.011	.011	.011	.012
2000	.798	.010	.010	.010	.010

Validity of the IES Model

When developing models, it is important to provide supporting experimental results to validate the use of the model. The IES model has been used in a few instances since its development, including testing of implicit and explicit memory following differential exposure times as well as with addressing the generation effect the later indicates that dissociations among the four fundamental memory types exist (Chechile et al., 2012). Memory information, when stored, will be stored explicitly, implicitly, or in a fractional manner. In distinction to this, models should also be able to identify the amount of memories never stored, or lost all together, as non-storage. Previous models (Chechile 1998; Chechile & Soraci, 1999) have identified a separation between fractional storage and explicit storage. If a valid model can account for fractional storage, explicit storage, and non-storage, the proportion of remaining items would be considered implicitly stored. If the IES model were used to estimate the values for these distinct memory components, and the estimates for implicit memory were to remain 0 across all conditions and testing designs, then implicit memory would not be supported as a separable construct. Chechile and Soraci (1999) argued that the estimate of storage was likely inflated due to an implicit input. From this argument, it is likely that a valid model can assess implicit memory separately from explicit memory.

In order to validate the IES model, as well as each of the separate memory components a number of studies have been conducted. Chechile et al. (2012) reported three such studies, which identify a dissociation among the memory components. The third study is presented in this thesis as Experiment 4, but the first two, which are not part of the thesis will be briefly mentioned here for validation purposes. Chechile et al. manipulated encoding time, which should affect explicit memory, by presenting participants with lists of six words presented for 45 ms, 100 ms, or 1000 ms per word. The results from this experiment indicated that while encoding time reliably increased explicit memory, and decreased non-storage, there was no effect on implicit storage. While implicit memory did not change reliably with increased encoding time, at all conditions, the value for implicit memory was greater than 0, indicating that implicit memory is a valid, and separable construct to be measured. In terms of fractional storage, there was an effect of encoding time when comparing the 1000 ms condition to the 45 ms condition. Finally, the θ_k parameter increased reliably only when comparing the 1000 ms interval to the 45 and 100 ms conditions. It was only in the longest encoding condition that participants had enough knowledge of the presented list to reject correctly the available foils. This is an important point for validation of the θ_k parameter. If the to-be-remembered items are known, then the θ_k parameter has some value. If a participant cannot remember a list explicitly, then the θ_k parameter will not have much value, evidenced by the fact that the parameter was negligibly 0 in the 45 ms and 100 ms conditions.

The second experiment presented in Chechile et al. (2012) used a classic generative encoding task. The generation effect resulted in an interaction between explicit and implicit memory in the process dissociation procedure (Jacoby, 1991) where generation conditions lead to increased explicit memory and read conditions lead to increased implicit memory. Chechile et al. (2012) presented word-pairs to participants, and they had to type the response item that was either presented intact or missing a single letter. Generative encoding should increase the values for explicit storage, which was found to be the case. Explicit memory and fractional storage were greater in the generation condition, as opposed to the read condition. The non-storage values were lower in the generation condition than the read condition. There was a non-significant trend toward the read condition resulting in larger values for implicit storage. What is of importance in these results is that the generation and read conditions have opposing effects on fractional storage and implicit storage. While fractional storage is greater in the generation condition (similar to explicit storage), implicit storage is greater in the read condition. Because these two memory components are acting in opposition to one another, the study validates the assumption that these are two separate memory components.

The patterns in these two experiments were as expected: encoding time increased explicit memory, but had little effect on implicit memory, and generation affected explicit memory and fractional storage, whereas implicit memory was greater in the read condition. In both experiments, the four memory components vary independent of each of the other memory components. Additionally, the results of the two experiments are very similar: there exists a condition that leads to better encoding, increasing explicit memory and fractional storage. Non-storage increased with decreased explicit memory and implicit memory remained stable, and perhaps even rose as a function of the less deeply encoded conditions. These experiments indicate that the parameters change as expected with the design manipulations, and the results support the validation of the IES model.

Current Research

The current proposal addresses, and furthers the literature by using the IES model to test the changes in memory storage over the retention interval with both younger and older adults. The first two experiments examined the four fundamental memory states as they change across the retention interval in a list-learning paradigm. The third experiment examined explicit memory again in a list-learning paradigm over the long term and fit the storage values to a newly developed theory of memory storage (Chechile, 2006). The fourth experiment addressed the retention interval over the very short term in a Brown-Peterson paradigm. The fifth experiment compared the four fundamental memory states in a list-learning paradigm with healthy older adults to see if the decrease in the memory parameters in older adults was similar to that of younger adults.

Experiment 1

The first experiment was designed to analyze the changes in the four fundamental memory states over the retention interval. If there exists a unified memory system, then there should be an interaction of the four memory types. In this vein, as explicit memory degrades, it is possible that the insufficient memory traces are not lost all together, but instead degrade to another state of memory such as implicit memory or fractional storage, and then from there finally degrade to a state of non-storage. In this case, the degraded memories are not strong enough to be considered as explicit but may be available to aide in the memory tasks to a certain degree. A variable then that can easily manipulate the degradation of memory states is the retention interval.

Retention interval has been used to study memory loss. Memory storage in general decreases with increasing lag time (Chechile, 1987, 2004, 2006, 2010b). But the rate of loss of implicit memory is often slower, or not observed in general, likely perhaps because of the experimental paradigm or type of implicit test and stimuli used (Schacter, Chiu & Oschner, 1993). Implicit memory as indicated by priming has been shown to last in short and long intervals in normal subjects (Parkin, Reid, & Russo, 1990; Roediger, Weldon, Stadler, & Riegler, 1992; Mitchell & Brown, 1988, McAndrews & Moscovitch, 1990). Parkin et al. (1990) used recognition and fragment completion tasks to assess explicit and implicit memory of words after intervening short-term lags of zero and six.

Although lengthening the lag affected recognition memory, there was no affect on the fragment completion task indicating that the lag effect was only seen in explicit memory. Mitchell & Brown (1988) tested picture naming after one, four, and six-week intervals and found facilitation due to implicit memory in all three intervals despite a decline in explicit memory.

There seems to be little consensus in the literature as to the rate at which implicit memory is lost. While McKone (1998) discovered long-term stability in implicit memory, this stability only occurred after an initial fast decay in short-term implicit memory. Using stem completion and stem-cued recall McBride and Dosher (1997) found that the rates of loss of both types of memory were the same; both memory subtypes declined steadily over 15 minutes and then leveled asymptotically, which, they argued, was evidence for only one memory system. The rate of loss in the implicit system, however, is likely task dependent (Schacter, Chiu & Oschner, 1993) and thus results may not be generalized from one task to another (McBride & Dosher, 1997). This task dependency calls for the need for a model to examine the influences of the two types of memory regardless of the task at hand.

Researchers have used differential rates of loss as a means of arguing for separate explicit and implicit memory systems. It is possible, when examining the retention interval, that as explicit memory degrades the amount of implicit memory may increase or even level off as it is being fed by the explicit memory. This finding would be in direct competition with a theory involving multiple memory systems. With separate memory systems, there would only be stability or decay across the retention interval. However, a finding of an increase in a certain type of memory would indicate that that memory type is somehow being fed from another memory type. Even stable memory over the retention interval may still be fed into by explicit memory and indicate a unified memory system. If explicit memory decreases, and implicit memory increases, across the retention interval, a multiple systems framework could not easily support this finding.

Therefore a list-learning procedure was chosen to examine the retention interval. By providing participants with lists to be studied, and later tested, the retention interval can be easily manipulated. Participants saw a list of words separated by an interval during which they either learned a new list or were tested on a previous list. With this method, the retention interval can be defined, and results of the four memory states can be compared across various lags.

Another design consideration was made based on the Monte Carlo estimates for the process of population parameter mapping (PPM), which indicate that a large number of trials are required to get enough data so as to have an adequate model coherence defined as the P(coh) value. Each list presented to participants can contain any number of to-be-tested stimuli, and therefore a large amount of data for each participant can be collected. A list-learning paradigm clearly suits both these needs.

Finally, there is a great deal of interference provided in this study paradigm. The interference caused by learning new lists prior to being tested on the target list will decrease the amount of target information (θ_k) that participants will have throughout the testing period. The θ_k parameter is described by the amount of information about the target that exists in order to reject the foils in a target-absent trial. In a list learning paradigm, there are a large number of potential stimuli to be tested so that a participant cannot likely use this information to reject any foils. The list-learning paradigm should result in a θ_k parameter that is remarkably small.

Based on previous research, and what is known about explicit memory over the retention interval, it is hypothesized that the value for θ_{se} will decrease as the retention interval increases. With each interval, θ_{se} will become smaller. The input of implicit memory is less clear, but it is hypothesized that the parameter θ_{si} will decrease, however at a rate different than θ_{se}. With the decrease in both θ_{se} and θ_{si}, an increase in θ_F and θ_N is also hypothesized. Another purpose of using the list learning procedure is based on the assumption that with so much target information to be learned, participants will not have any information about the item to help reject foils and therefore will not have any way of knowing what the set of memory targets are. Thus, it is hypothesized that the θ_k parameter will be very small and invariant with respect to the retention interval

Methods

Participants

A total of 40 participants were tested in Experiment 1. Participants were all undergraduate students at Tufts University in Medford, Massachusetts registered in either the Introduction to Psychology or Psychological Statistics classes. Participants received partial course credit for their participation. Participants enrolled in the experiment online. All participants were native English speakers. Gender and age data were not collected.

Design and Materials

Experiment 1 followed the guidelines of the IES task described above. The specific design of Experiment 1 was a list-learning paradigm. Testing sessions followed one of three retention intervals. These retention intervals were measured in terms of the average number of intervening events between learning and testing of the list. The retention intervals were comprised of one, four, or nine other testing or learning sessions. A retention interval of one, therefore, was designed such that a participant would learn a list of words, then be presented with a second list of words, and finally be tested on the first list that they had learned. For each lag, the average time between testing and learning varied because the time to complete the items that separated learning and testing varied. The time between learning and test was also dependent on the participant's performance. The time required to finish a test trial is increased if a participant had to complete a three-alternative forced choice, or a two-alternative forced-choice, as opposed to being correct on the four-alternative forced-choice. Consequently, the average time for each lag differed slightly. The order of learning and testing sessions was as follows, with an "L" denoting the learning of a list and a "T" denoting the testing of a list: L1, L2, L3, L4, L5, T4, T2, L6, L7, T6, T1, L8, T3, T7, T5, L9, T8, T9.

The stimuli presented to the participants during the list learning sessions were presented once only. The stimuli were taken from the Kucera and Francis (1967) word norms. The complete list of words used in Experiment 1 is provided in Appendix B. The words from the Kucera-Francis norm all had a frequency rating of 50 and above, as higher scores indicate increased frequency. Word length was also limited to three to seven letters. After minimizing the Kucera-Francis list based on frequency ratings and word-length, the remaining stimuli were compared on the USF Word Association norm (Nelson, McEvoy & Schreiber, 1998) so that no words had a high association with any other words. The word norm provides a rate of association for a word and some of its highly associated counterparts. For instance, the word "ability" has an association rating of 280 to the word "capability", indicating a high association; but "ability" has a low association (a rating of 10) to the word "ease". For the purpose of this experiment, no word with an association value greater than 120 to the target word was used. This process was done to decrease the possibility of any semantic priming from highly associated words. Participants were exposed to nine lists of 20 words each. A total of 180 words were presented during learning sessions.

Each testing phase was comprised of 20 test items: 12 target-present and 8 target-absent trials. The word lists were presented in the same order to every participant, however, the design was such that there were three lists for each of the three lag intervals. For each lag interval, there were 36 target-present and 24 target-absent trials. An additional 612 words were taken from the Kucura-Francis norm to act as foils for both the target present and target absent trials. The foil items were all compared on the same frequency norm. The 612 words were separated such that 324 words were the foils for the target-present items (there were three foils for each of the 12 test items) and 288 words were the foils for the target-absent trials (there were four foils for each of the eight test items). The inclusion of target-absent trials is imperative so that participants were not presented with only repeated words and must therefore cast judgment on a word's previous appearance, as well as for calculating the parameters of the IES model

Learning and testing sessions were presented in the order stated above by use of a computer program written in QuickBasic for a Windows platform.

Procedure

Participants were assigned specific times for arrival at the computer testing site. All participants were tested in the same laboratory on the Tufts University campus. The number of participants attending each testing session was limited to three. Upon arrival, participants were asked to carefully read an informed consent and sign if they agreed with the terms set forth in the form. After the students' signed agreements were obtained, participants were given instructions for interacting with the computer program during the testing session. After reading the instructions, the experimenter affirmed that the participants understood the directions. The participants were then asked if she or he had any further questions and then if he or she was ready to begin the experiment. Upon the approval of the participant, the experimenter began the session by hitting the appropriate start command on the keyboard.

During learning sessions words were presented on the computer screen one at a time and participants were instructed to type the word into the keyboard and strike the "ENTER" key. On average, it took about one minute to present participants with each of the lists, or three seconds per word. The word remained on the computer screen until participants hit "ENTER". Upon completion of a learning session, the letter "X" appeared on the computer screen informing the participant that the learning session had ended. After seeing the "X", and hitting "ENTER" participants then completed the next learning or testing session.

During testing sessions, participants were presented with either target-present or target-absent trials. The computer program was written so that the order of presentation of words and test trials did not differ from subject to subject. In target absent trials, participants were presented with four words, none of which had been presented before. Above the target set, the computer provided the prompt "Have any of these words been previously presented?" The correct response in target-absent trials would be "no", and participants would indicate this by pressing "N" on the computer screen. Participants were then prompted to provide a confidence rating or "3", "2", or "1". A three indicated high confidence in their response. A two indicated an informed guess, whereas a one indicated a blind guess. Participants were reminded at each trial what each of the confidence ratings assigned for each of the trials were. Target-absent trials ended after the confidence rating. Target-present trials also started with a yes/no recognition task followed by a confidence rating. In the case of target-present trials, the correct response would be "yes", that one of the four stimuli had been previously presented. Striking the "Y" key on the keyboard would make this response. Again, a confidence rating followed the yes/no recognition task. Regardless of the accuracy of the participant's response, if the trial were target-present, the recognition and confidence rating prompts would be followed by a four-alternative forced-choice task. Consistent with the task described earlier, participants were asked to indicate which of the four words had been previously presented. If the participant chose correctly, the trial ended. If incorrect, participants saw the prompt "Incorrect response. Please choose again". If the participant chose incorrectly, their incorrect response was removed from the four choices, and they were prompted to again answer from the remaining three choices If the participant chose correctly from the three alternatives, the trial ended. If the participant chose incorrectly, their incorrect response was again removed from the three choices, and they were prompted to answer from the remaining two choices. Regardless of their accuracy, the trial would end after the two-alternative forced-choice test. There were 20 trials for each testing session comprised of 12 target-present and 8 target-absent trials

At the end of the experiment, the participants were thanked and offered an opportunity to ask any questions about the preceding experiment. The participants were then given a debriefing form describing the purpose of the study as well as the underlying ideas about the implicit and explicit distinction and the IES models. When all questions were answered, the students were thanked again and escorted out of the testing area.

Results

After completion of the experiment, raw data from each of the 40 individuals were collated for each of the 20 cells within the IES model. The pooled raw data for each of the 20 cells of the IES model can be found in Table 2. The experiment took, on average, 35 minutes for each individual to complete. The average time for each learning trial was 3 seconds, and each testing trial was 5.8 seconds, so that the average time between learning and testing was 1.93 minutes for a lag of 1, 7.72 minutes for a lag of 4, and 17.37 minutes for a lag of 9. The data for each individual participant can be found in Appendix C. As can be seen, there is complete data for every participant, except subject 3, who is missing data for one of the lag 9 conditions due to power outage issues.

Table 2.
The following lists the pooled number of responses for all 40 participants in Experiment 1. The data are sorted by the response in the Yes/No task and accompanying confidence rating. Each response pattern is then separated by whether the participant was correct on the 4-, 3-, or 2-AFC task. Finally, the 20 response cells are listed for each of the three retention intervals.

	4AFC				3AFC				2AFC				Incorrect				Foils			
	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
1	410	44	244	189	28	22	76	91	17	21	56	106	15	12	38	59	101	400	318	133
4	323	42	242	196	23	20	115	103	18	20	68	89	22	23	57	79	95	459	322	84
9	192	31	238	208	40	33	101	137	31	20	91	124	12	21	77	84	116	470	309	65

Table 3 provides the probabilities of having correctly said “yes” to a target-present trial with high confidence, as well as with low confidence. These data provide information about the tendencies of the respondents to use the high and low confidence ratings. The IES model is based on previous models (Chechile, 2004; Chechile &Soraci, 1999) that use both confidence ratings and the 4AFC choice procedure. Analyzing the conditional probabilities provides information about the use of the confidence ratings on the part of the participants. The MPT models that use confidence ratings make an assumption that people accurately use the confidence ratings. In this case, we can look at the accuracy of responding yes when a participant has high confidence, and again when they have low confidence. Participants have a higher rate of being correct with high confidence than with low confidence. The same pattern is seen when the participants respond to target-absent trials. Additionally, it is possible to analyze the accuracy of being correct on the 4AFC task after each possible response on the yes/no recognition trial: either saying yes or no with high or low confidence. The probabilities are in Table 4. These conditional probabilities tell us that people are most likely to be correct on a

4AFC task following a "yes" response made with high confidence. As their confidence decreases, so does their ability to correctly recognize the item during a 4AFC test trial.

Table 3.
The following are conditional responses for Experiment 1 for each of the three lag conditions. These are the probabilities of a correct responses to target-present or target-absent trials given either high or low confidence.

Retention	Target Present		Target Absent	
	P(hi conf correct)	P(lo conf correct)	P(hi conf correct)	P(lo conf correct)
1	.826	.482	.432	.557
4	.786	.508	.531	.588
9	.724	.478	.641	.603

Table 4.
Conditional probabilities for a correct response on the 4AFC following a high or low confidence for each of the lag conditions in Experiment 1.

Retention interval	P(4AFC, hi)	P(4AFC, lo)
1	.872	.589
4	.837	.502
9	.698	.469

The pooled values for each of the 20 cells of the IES model were input into a computer-modeling program, which then estimated the values for each of the parameters within the IES model. The estimates were conducted with two separate procedures, Population Parameter Mapping (PPM) and Maximum Likelihood Estimates (MLE). For a description of these two processes, see Appendix A. The PPM and MLE estimates for the IES model parameters are based on the pooled data. Chechile (2009) had previously analyzed whether data should be pooled prior to being input into processing tree models, or if individual data should be analyzed, and the subsequent parameters averaged. Based on Monte Carlo sampling, Chechile (2009) discovered that pooling raw data prior to parameter estimation resulted in more accurate estimates. Table 5 contains the values for all the parameters of the IES model for each of the three retention intervals, as well as the standard deviation of the posterior distribution and the P(coh) values. The values were estimated by means of population parameter mapping (Chechile, 2009), a method that estimates the parameters of mathematical models by comparing the parameters of the model to a statistical likelihood function. In this method, a value of coherence of the comparison is provided. The MLE estimates are also listed in Table 5. While the remainder of this dissertation lists both PPM and MLE estimates, only the PPM values were used for tests of significance. Although the MLE values provide valuable results, the PPM estimates provide a posterior distribution of the value, and a standard deviation for the parameter, as opposed to just a point estimate.

Table 5.

The following table provides the parameter estimates for each of the 14 parameters in the IES model in Experiment 1. The MLE and PPM estimates are provided. The standard deviation and the coherence values are also listed for the PPM estimates. The values are listed as a function of retention interval.

	Retention Interval					
Parameter	1		4		9	
	MLE	PPM(SD)	MLE	PPM(SD)	MLE	PPM(SD)
θ_{se}	.271	.267 (.013)	.208	.201 (.013)	.106	.104 (.010)
θ_{si}	.199	.197 (.017)	.168	.171 (.018)	.143	.142 (.019)
θ_N	.347	.354 (.030)	.121	.508 (.035)	.213	.544 (.036)
θ_F	.183	.181 (.032)	.503	.119 (.037)	.539	.210 (.040)
θ_K	.036	.016 (.018)	.001	.003 (.001)	.008	.009 (.013)
θ_{f2}	.130	.148 (.129)	.759	.745 (.220)	.294	.299 (.155)
θ_{v*}	.445	.430 (.042)	.426	.436 (.035)	.432	.457 (.033)
θ_v	.401	.428 (.088)	.759	.575 (.114)	.500	.456 (.096)
$\theta_{v'}$	.667	.663 (.048)	.573	.611 (.057)	.664	.657 (.066)
θ_L	.925	.932 (.031)	.916	.959 (.041)	.991	.989 (.019)
θ_a	.229	.235 (.012)	.229	.237 (.012)	.223	.220 (.011)
$\theta_{a'}$	.137	.177 (.044)	.192	.229 (.039)	.180	.204 (.038)
θ_b	.297	.325 (.102)	.087	.310 (.209)	.358	.419 (.132)
$\theta_{b'}$	.242	.261 (.156)	.093	.298 (.235)	.161	.195 (.114)
P(coh)		.980		.967		.964

Pair-wise comparisons of the three retention intervals were completed in order to ascertain the differences of each of the parameters across the retention interval. For the analyses, a Bayesian test of hypothesis was used. The PPM method provides a complete Bayesian posterior distribution for each model parameter. The mean of the distribution is used as the point estimate for each parameter (these are the values provided in Table 5). The means of the posterior distributions of any two parameters can indicate whether there is a difference between conditions. For a more in depth explanation, see Chechile (1998; 2004; 2007; 2010a; 2010b). The posterior distribution is represented as a probability over 100 intervals, [0, .01], [.01, .02], · · ·, [.98, .99], [.99, 1.0]. The probability that a parameter is in the i^{th} interval is $P_i(\theta_{se}| D)$. Based on this, we can compute the probability of a difference between two lag conditions, L_1 and L_2 using the following formula:

$$P\left\{\theta_{se}(L_1) > \theta_{se}(L_2) | D\right\} = \sum_{j=1}^{99} P_j\left\{\theta_{se}(L_2) | D\right\} \sum_{i=j+1}^{100} P_i\left\{\theta_{se}(L_1) | D\right\} \qquad (3)$$

If the posterior probability of the comparison is greater than 0.95, the difference can be considered a highly reliable effect. If the difference is less than 0.95, it is not considered a highly reliable effect. The Bayesian probabilities of a difference between retention intervals for each of the parameters in the IES model are listed in Table 6.

As can be seen from Table 6, the values for explicit storage, θ_{se} decrease with increasing retention interval, from .27 to .21 to .10. Furthermore, this difference is found when comparing the 1 and 4 retention interval (the probability of a difference exceeds .99), the 4 and 9 retention interval (the probability of a difference exceeds .99), and the 1 and 9 retention intervals (the probability of a difference exceeds .99). Implicit memory also decreases with increasing retention interval from .20 to .17 to .14. There is a high probability of a difference in the θ_{si} parameters when comparing the 1 and 9 retention intervals only (the probability of a difference is.98). In other words, the rate at which implicit memories are lost across the retention interval is systematically slower than the rate at which explicit memories are lost.

Table 6.

Table of Bayesian tests of differences for each parameter over all three lag conditions in Experiment 1. If the test of differences is above .95, then it is considered that there is a high probability of a difference. In these cases, the results are in bold.

			Lag	
Parameter			1	4
θ_{se}	1 = .267	1	---	
	4 = .201	4	**.999**	---
	9 = .104	9	**.999**	**.999**
θ_{si}	1 = .197	1	---	
	4 = .171	4	.801	---
	9 = .143	9	**.977**	.824
θ_N	1 = .354	1	---	
	4 = .508	4	**.999**	---
	9 = .544	9	**.999**	.727
θ_F	1 = .181	1	---	
	4 = .119	4	.875	---
	9 = .210	9	.688	.943
θ_K	1 = .016	1	---	
	4 = .003	4	.482	---
	9 = .009	9	.204	.305
θ_L	1 = .932	1	---	
	4 = .959	4	.670	---
	9 = .989	9	.909	.573
$\theta_{v'}$	1 = .663	1	---	
	4 = .611	4	.736	---
	9 = .657	9	.510	.122
θ_{v*}	1 = .430	1	---	
	4 = .436	4	.512	---
	9 = .457	9	.666	.634
θ_v	1 = .428	1	---	
	4 = .575	4	.854	---
	9 = .456	9	.569	.784
θ_{f2}	1 = .148	1	---	
	4 = .745	4	**.984**	---
	9 = .299	9	.765	**.940**
θ_a	1 = .235	1	---	

	4 = .237	4	.415	---
	9 = .223	9	.734	.756
$\theta_{a'}$	1 = .177	1	---	
	4 = .229	4	.786	---
	9 = .204	9	.651	.640
θ_b	1 = .325	1	---	
	4 = .310	4	.460	---
	9 = .419	9	.705	.563
$\theta_{b'}$	1 = .261	1	---	
	4 = .298	4	.539	---
	9 = .195	9	.617	.589

The values for non-storage increase with retention from .35 to .51 to 54. There is a high probability of a difference when comparing the values for non-storage in the 1 and 4 conditions (the probability of a difference exceeds.99) and 1 and 9 conditions (the probability of a difference exceeds.99), but not the 4 and 9 conditions (the probability of a difference is .73). The value for non-storage was already quite high with four intervening lists that the resulting probability of a difference could not be high.

Fractional storage remains consistent across the retention interval, and does not differ significantly as a function of retention. The values for the 1, 4, and 9 condition are .18, .12, and .21, respectively.

As hypothesized, the values for θ_k were very small in each of the lag conditions. This was hypothesized based on the assumption that there would be very little item information used by participants to reject the foils in target-absent trials. The differences between each of the conditions were negligible, as each of the 3 lag conditions had very small θ_k values. The changes of the four fundamental memory types as well as θ_k are provided in Figure 7.

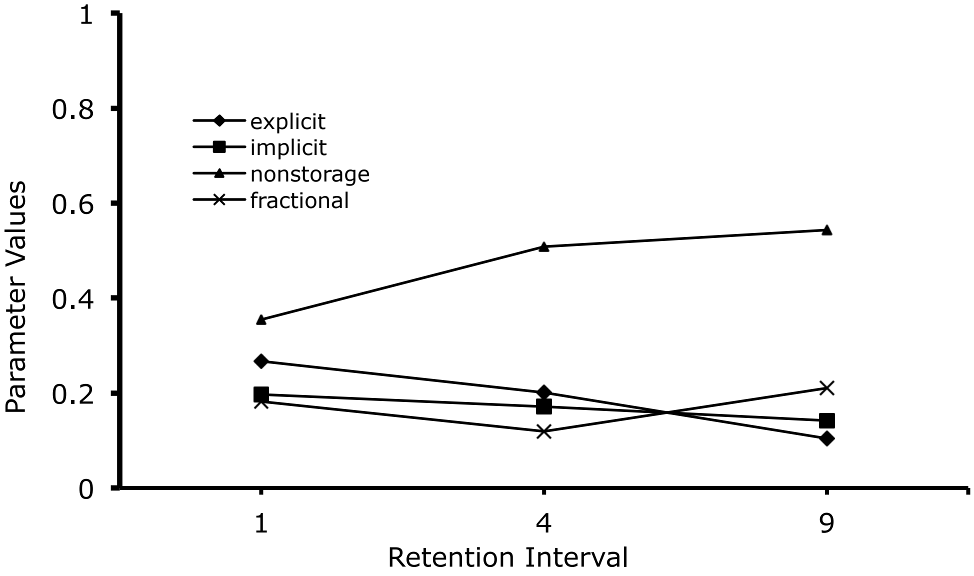


Figure 7. The four fundamental memory states as a function of retention interval in Experiment 1.

Pair-wise comparisons were made between the three lag conditions for the remaining IES model nuisance parameters. High probabilities of a difference were found only in the θ_{f2} parameter, which is likely just a chance effect. This parameter addresses the probability of rejecting one of the three foils in target-present trials, $(1-\theta_{f2})$, and two of the three foils, θ_{f2}, in target-present trials. This correct rejection of foils occurs when a participant has fractional information about a stimulus.

Discussion

Experiment 1 utilized a multinomial model that distinguishes implicit and explicit storage from fractional and non-storage and discovered consistent changes in explicit storage, implicit storage, and non-storage. There was a significant change across the retention interval in both explicit and implicit memory, however the rate of loss of implicit memory was slower than the rate of loss of explicit memory. It is likely that with increasing retention interval, some items that were explicitly stored transferred to implicit storage, and some items that were originally implicitly stored transferred to fractional or non-storage. These results are consistent with previous findings that show a decrease in explicit memory across retention interval (Chechile, 1998; 2004; 2009; 2010a, 2010b). However, they are not consistent with results that indicate a marked decrease in implicit memory at the onset of the retention interval or stability within the implicit retention interval (McKone, 1998). This could likely be due to the time-length between study and test and will be addressed in Experiment 2.

Unlike the process dissociation models, the IES model has made corrections for fractional storage, non-storage and the use of guessing strategies on the part of the participant. Overall, these data suggest that the IES model is able to successfully separate measures for explicit and implicit storage, and the utilization of the model is a more precise manner for doing so than the process purity or process dissociation approaches. Moreover, implicit memory is a viable construct because even after the estimates of explicit memory, fractional storage, and non-storage have been accounted for, there is still some memory left over, as described by and consistent with implicit memory.

The design of the experiment did not allow for a calculation of memory storage immediately after a learning session. The learning and testing sessions of the 1 retention interval was separated by another learning or testing session, which took only a short while, between one and three minutes, but did not allow for measuring immediate explicit and implicit storage. Additionally, the intervening list provided a great deal of interference for the learner, likely reducing the explicit memory for the first list. Although this design manipulation and allowance for interference was intentional, a second experiment was designed to examine storage in a more immediate fashion following learning. Thus, in Experiment 2, a zero retention interval was included, in which a learning session immediately preceded a testing session. In this new paradigm, it was hypothesized that the rate of loss of implicit and explicit memory would be similar to Experiment 1, however, there may be a possibility of a greater change in implicit memory from the 0 to 1 retention interval as the majority of loss in explicit memory would filter in to implicit memory. On the other hand, implicit memory may not change over the short time interval between the 0 and 1 lags, or there may be evidence of a quick decrease in the shorter retention interval, which would be consistent with McKone (1998).

Experiment 2

Experiment 2 was designed to replicate Experiment 1, with the exception of an additional retention interval. Experiment 2 estimated the parameters of the IES model immediately after learning a list of words, however the list length also changed. In Experiment 1, the average time between encoding words and testing in the lag 1 condition was between one and three minutes. The lag interval was comprised of a number of intervening items that were designed to lower the memory storage of the original target list. This was exposed in the low rates of explicit storage at all lag conditions. Thus, Experiment 2 will use the same paradigm with the addition of another learning and testing condition occurring after a lag of zero. It was assumed that the zero condition would have a higher level of both explicit and implicit memory, and the 1, 4, and 9 conditions would replicate those results from Experiment 1.

Methods

Participants

A total of 30 undergraduate students at Tufts University participated in Experiment 2. Participants received partial course credit for their classes in the Psychology Department at Tufts for participation. Participants enrolled in the experiment online. All participants were native English speakers. Gender and age data were not collected.

Design and Materials

The design of Experiment 2 was very similar to Experiment 1, with the exception of an additional retention interval. As in Experiment 1, Experiment 2 followed the rules of the task associated with the IES model. Words were presented one at a time, in list format, and remained on the screen until participants typed the word, and hit "ENTER". Lists were presented to participants and then separated by one of four retention intervals: 0, 1, 4, and 9. The zero retention intervals were added in order to assess the amount of explicit and implicit storage at a time interval as short as possible following the learning of a list. The order of the learning and testing sessions was as follows: L1, T1, L2, L3, T2, L4, L5, L6, L7, T7, T4, L8, T6, T3, L9, L10, T5, T10, L11, T9, T8, L12, T12.

As noted above, there were three iterations of each of the four retention intervals, therefore, there were 12 lists all together. To maintain the length of the experiment and keep consistent the number of words learned, the list length was shortened to 14 words in each list, 8 of the 14 words were later tested during the testing session. The lists used in Experiment 2 are available in Appendix B. During testing there were 14 test items, 8 of which were target present and 6 of which were target-absent trials. Otherwise, the design and materials of Experiment 2 were the same as Experiment 1.

Procedure

The procedure for Experiment 2 was similar to that of Experiment 1. Participants were assigned specific times for arrival at the computer testing site. All participants were tested in the same laboratory on the Tufts University campus. Upon approval of the consent form, the researcher started the computer program. Participants were presented with lists of 14 words, separated by an "X", and asked to enter the words on the keyboard as they appeared, followed by striking the "ENTER" key. During testing, participants were provided eight target-present and six target-absent trials, which followed the guidelines of the task of the IES model. Upon completion of the experiment, participants were thanked, and provided a debriefing form.

Results

The purpose of Experiment 2 was twofold: (1) to replicate the results of Experiment 1, and (2) to investigate the level of implicit and explicit memory immediately following the learning session.

After completion of the experiment, raw data from each of the 30 individuals were collated for each of the 20 cells within the IES model. The pooled raw data for each of the 20 cells of the IES model can be found in Table 7. The data for each individual participant can be found in Appendix C. The experiment took, on average, 42 minutes to complete. The average time for each learning trial was 3 seconds and each testing trial was 4.5 seconds, so that the average time between learning and testing was 42 seconds for a lag of 0, 1.13 minutes for a lag of 1, 4.52 minutes for a lag of 4, and 10.08 minutes for a lag of 9.

Table 7.

The following lists the pooled number of responses for all 30 participants in Experiment 2. The data are sorted by the response in the Yes/No task and accompanying confidence rating. Each response pattern is then separated by whether the participant was correct on the 4-, 3-, or 2-AFC task. Finally, the 20 response cells are listed for each of the three retention intervals.

	4AFC				3AFC				2AFC				Incorrect				Foils			
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
0	284	8	133	75	9	6	44	48	2	3	19	30	4	6	22	27	57	250	208	43
1	231	14	160	82	7	4	50	52	4	5	34	37	3	2	16	19	44	184	262	68
4	132	20	130	122	13	18	35	84	2	9	39	52	3	8	28	25	51	203	247	57
9	120	21	127	88	10	10	74	67	8	4	53	50	3	3	33	49	40	215	243	60

Table 8 provides the probabilities of having correctly said “yes” to a target-present trial with high confidence, as well as with low confidence. Similar to Experiment 1, participants have a higher accuracy of being correct with high confidence than with low confidence. The same pattern is seen when the participants respond to target-absent trials. Table 9 provides the accuracy of being correct on the 4AFC task after each possible response on the yes/no recognition trial: either saying yes or no with high or low confidence. Similar to Experiment 1, people are most likely to be correct on a 4AFC task following a “yes” response made with high confidence. As their confidence decreases, so does their ability to correctly recognize to-be-remembered item in a 4AFC task. These numbers all decrease monotonically with the lag intervals

Table 8.
The following are conditional responses for Experiment 2 for each of the four lag conditions. These are the probabilities of a correct responses to target-present or target-absent trials given either high or low confidence.

Retention	Target Present		Target Absent	
	P(hi conf correct)	P(lo conf correct)	P(hi conf correct)	P(lo conf correct)
0	.929	.548	.798	.633
1	.907	.578	.684	.573
4	.732	.450	.638	.585
9	.788	.583	.559	.564

Table 9.
Conditional probabilities for a correct response on the 4AFC following a high or low confidence for each of the lag conditions in Experiment 2.

Retention interval	P(4AFC, hi)	P(4AFC, lo)
0	.950	.610
1	.943	.615
4	.880	.560
9	.851	.443

Similar to Experiment 1, the pooled values for each of the 20 cells of the IES model were input into a computer-modeling program, which then estimated the values for each of the parameters within the IES model with both the PPM and MLE methods. Table 10 contains the parameter estimates based on the PPM and MLE methods as well as the P(coh) values and standard deviations for the PPM values.

Table 10.
The following table provides the parameter estimates for each of the 14 parameters in the IES model in Experiment 2. The MLE and PPM estimates are provided. The standard deviation and the coherence values are also listed for the PPM estimates. The values are listed as a function of retention interval.

	Retention Interval							
Parameter	0		1		4		9	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.380	.369 (.019)	.312	.304 (.018)	.169	.159 (.016)	.152	.143 (.016)
θ_{si}	.166	.165 (.022)	.208	.204 (.025)	.183	.187 (.027)	.119	.122 (.027)
θ_N	.328	.343 (.041)	.222	.239 (.035)	.356	.369 (.043)	.489	.500 (.048)
θ_F	.126	.123 (.042)	.258	.253 (.041)	.292	.285 (.049)	.240	.234 (.054)
θ_K	.029	.019 (.023)	.043	.052 (.031)	.014	.011 (.017)	.043	.073 (.022)
θ_{f2}	.999	.941 (.115)	.355	.355 (.147)	.457	.465 (.153)	.532	.543 (.201)
θ_{y*}	.408	.425 (.048)	.414	.447 (.053)	.401	.441 (.041)	.414	.415 (.046)
θ_y	.611	.507 (.044)	.549	.529 (.077)	.284	.283 (.092)	.697	.595 (.109)
$\theta_{y'}$	.762	.745 (.063)	.784	.792 (.069)	.698	.691 (.091)	.698	.747 (.133)
θ_L	.983	.998 (.010)	.938	.936 (.030)	.975	.974 (.030)	.843	.907 (.081)
θ_a	.130	.133 (.013)	.130	.133 (.013)	.124	.128 (.012)	.124	.126 (.012)
$\theta_{a'}$	.143	.185 (.056)	.130	.119 (.060)	.167	.217 (.053)	.130	.074 (.035)
θ_b	.204	.463 (.101)	.112	.139 (.076)	.278	.539 (.206)	.124	.285 (.189)
$\theta_{b'}$	.050	.443 (.150)	.050	.074 (.078)	.167	.181 (.103)	.038	.373 (.170)
P(coh)		.762		.71		.410		.957

Pair-wise comparisons of each parameter for all four retention intervals were completed in order to ascertain the differences of each of the parameters across the retention interval. The results can be found in Table 11. For the analyses, a Bayesian test of hypothesis was used. A high probability of a difference was found when comparing the parameter for explicit memory in each of the pairwise comparisons, except between the 4 and 9 conditions. The probability of a difference between 0 and 1 lag conditions exceeds .99. The probability of a difference between the 0 and 4 conditions exceeds .99. The probability of a difference between 0 and 9 conditions exceeds .99. The probability of a difference between 1 and 4 conditions exceeds .99. These results indicate that as retention interval increases, explicit memory decreases monotonically, and significantly.

Table 11.

Table of Bayesian tests of differences for each parameter over all three lag conditions in Experiment 2. If the test of differences is above .95, then it is considered that there is a high probability of a difference. In these cases, the results are in bold.

			Lag		
Parameter			0	1	4
θ_{se}	0 = .369	0	---		
	1 = .304	1	**.988**	---	
	4 = .159	4	**.999**	**.999**	---
	9 = .143	9	**.999**	**.999**	.686
θ_{si}	0 = .165	0	---		
	1 = .204	1	.839	---	
	4 = .187	4	.676	.628	---
	9 = .122	9	.865	**.982**	.940
θ_N	0 = .343	0	---		
	1 = .239	1	**.966**	---	
	4 = .369	4	.637	**.988**	---
	9 = .500	9	**.992**	**.999**	**.974**
θ_F	0 = .123	0	---		
	1 = .253	1	**.981**	---	
	4 = .285	4	**.991**	.665	---
	9 = .234	9	.938	.576	.734
θ_K	0 = .019	0	---		
	1 = .052	1	.709	---	
	4 = .011	4	.420	.790	---
	9 = .073	9	.917	.645	**.959**
θ_L	0 = .998	0	---		
	1 = .936	1	**.954**	---	
	4 = .974	4	.529	.789	---
	9 = .907	9	.758	.558	.687
$\theta_{V'}$	0 = .745	0	---		
	1 = .792	1	.678	---	
	4 = .691	4	.679	.808	---
	9 = .747	9	.502	.598	.633
θ_{V*}	0 = .425	0	---		
	1 = .447	1	.595	---	
	4 = .441	4	.565	.514	---

	9 = .415	9	.539	.654	.455
θ_v	0 = .507	0	---		
	1 = .529	1	.565	---	
	4 = .283	4	.943	**.967**	---
	9 = .595	9	.553	.644	**.972**
θ_{f2}	0 = .941	0	---		
	1 = .355	1	**.994**	---	
	4 = .465	4	**.981**	.689	---
	9 = .543	9	.933	**.981**	**.611**
θ_a	0 = .133	0	---		
	1 = .133	1	.392	---	
	4 = .128	4	.511	.508	---
	9 = .126	9	.553	.550	.425
$\Theta_{a'}$	0 = .185	0	---		
	1 = .119	1	.709	---	
	4 = .217	4	.634	.873	---
	9 = .074	9	.946	.704	**.982**
θ_b	0 = .463	0	---		
	1 = .139	1	**.959**	---	
	4 = .539	4	.523	**.983**	---
	9 = .285	9	.565	.678	.834
$\theta_{b'}$	0 = .443	0	---		
	1 = .074	1	.911	---	
	4 = .181	4	.841	.821	---
	9 = .373	9	.467	.935	.803

The parameters for implicit memory are only highly different when comparing the rate of implicit memory between the 1 and 9 conditions; in this case the probability of a difference is .98. The comparisons of explicit and implicit memory between the estimates of the 1, 4, and 9 conditions (.20, .19, .12, respectively) are similar to those from Experiment 1, which indicate that while both explicit and implicit memory decrease with increasing retention, they do so at differing rates. Interestingly, although there is a monotonic decrease in explicit memory across all four conditions, there is an increase in implicit memory between the 0 and 1 conditions, although this is not highly probable (the probability of a difference is 0.839, which is less than the cutoff of .95). The proportion of memories stored implicitly is .17 at a lag of 0 and increases to .20 at a lag of 1. This indicates that immediately after the learning session, participants have a good deal of explicit memory on which to rely in the testing paradigm, and thus few memories are actually stored as implicit storage. As the retention interval increases, explicit memories decrease. When these memories degrade, if they are not lost entirely, they must go somewhere, and are therefore transferred to either implicit memory, or fractional storage. This degradation of memories from explicit to some other state may explain the increase in the value of implicit storage from the 0 to the 1 condition. However, this result is not statistically reliable. Perhaps an experimental paradigm that leads to greater drops in explicit memory could further distinguish explicit and implicit memory in the very short term. A visual depiction of the four fundamental memory types are depicted in Figure 8.

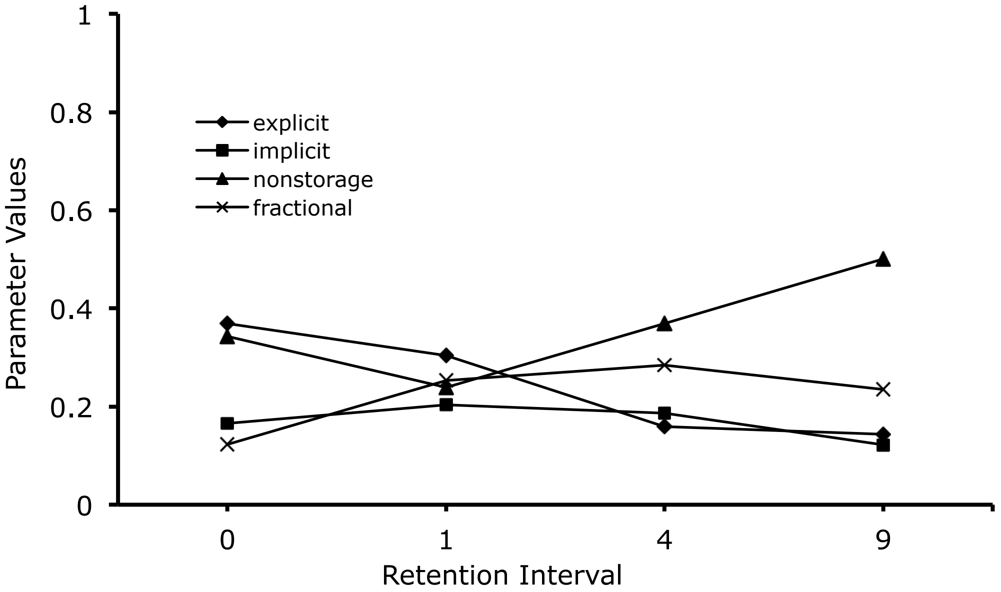


Figure 8. The four fundamental memory states as a function of retention interval in Experiment 2.

The remainder of the parameters in the IES model confirmed the results from Experiment 1. There was a difference in the rate of non-storage between all the conditions, except when comparing the 0 and 4 conditions. The probability of a difference between 0 and 1 conditions is .97. The probability of a difference between the 0 and 4 conditions is .64. The probability of a difference between 0 and 9 conditions exceeds .99. The probability of a difference between 1 and 4 conditions exceeds .99. The probability of a difference between 1 and 9 conditions exceeds .99. And finally, the probability of a difference between 4 and 9 conditions is .97. In this case, there was a decrease in non-storage from the 0 to the 1 conditions, which is hard to explain logically, because non-storage should only be increasing monotonically with the retention interval. In addition, an increase from the 1 to 4 conditions suggests this is due to a difference in the non-storage parameter.

Similar to Experiment 1, there were no differences in fractional storage among the 1, 4, and 9 conditions. However, there was a highly probably increase in fractional storage as the retention interval increased from 0 to 1 (the probability of a difference is .98) and 0 to 4 (the probability of a difference between exceeds .99), and a trend toward a highly probable decrease when comparing the 0 to 9 condition (0.94). The remainder of the nuisance parameters in the IES model replicated the results from Experiment 1. The only probable differences between all the pair-wise condition comparisons were discovered in the θ_{f2} parameter.

Discussion

Experiment 2 was designed to mirror the results of Experiment 1 with the addition of a new retention interval, such that participants were tested on their memory for the word lists directly following the presentation of the word list. The results from the zero retention interval provided a number of insights into the usefulness of the IES model in measuring the four fundamental memory states. When words were tested immediately following list presentation, the resulting explicit storage parameter was significantly higher than all the remaining retention intervals. When tested immediately, the grouped results indicated that participants remembered around 38% of the presented words. As discussed in Experiment 1, the words presented to participants were chosen from the Kucera-Francis word norm and measured on the association norm to ensure that no words were semantically related. However, the words chosen from the word norm were all of similar length and frequency of use, and thus the interference generated from learning each list was very high leading to a low percentage of words remembered even after a short period of time. This point will be raised again in Experiment 4, which used a Brown-Peterson paradigm to reduce the interference generated in the list-learning paradigm. Finally, there was a significant decrease in explicit memory from the 0 condition to the other three conditions, and changes in explicit memory across the 1, 4, and 9 conditions replicates that of Experiment 1. The only exception exists in comparing the 4 and 9 conditions. In the case of Experiment 2, there was not a significant difference between the 4 and 9 conditions whereas there was a significant difference in Experiment 1. In viewing the parameter estimates themselves, the estimates of explicit memory from the 4 and 9 conditions of the first experiment were 20% and 10% respectively, whereas the estimates in the second experiment were 15% and 14% respectively. These differences between experiments are likely due to the small changes in list-length. While the lists in Experiment 2 were shorter than Experiment 1, which may lead to higher rates of storage, and lower rates of non-storage, there were more lists in Experiment 2 than in Experiment 1. The decrease in list length reduces the length of the retention interval and this may have resulted in the increased amount of explicit memory in the 9 condition in Experiment 2 as opposed to Experiment 1. In Experiment 2 the lists were shorter than Experiment 1, however, the overall number of words to be learned was greater, increasing the overall interference.

An interesting result was noted in Experiment 2 in regards to implicit memory between the 0 and 1 condition. Implicit memory decreased as a function of retention interval between 1 and 9, only. When this is compared to explicit memory, it can be seen that the decrease in implicit memory is slower than that of explicit memory. Thus, the IES model is able to measure separately the two types of memory, and that there is an interaction between the two. This result is similar to that of the first experiment indicating, again, a replication of Experiment 1. An interesting additional point relates to what is occurring in implicit memory between the zero and one condition. In this case, implicit memory is rising between the state of immediate testing and one intervening session. Although this result is non-significant, there is a rise from 16% to 20% of items remembered implicitly. The probability of a difference, based on the Bayesian tests performed in this experiment, was .84. Although this is not a significant rise, it seems important to note that there is a trend of rising implicit memory detected between the 0 and 1 conditions.

In Experiment 1 it was discussed that there is an interaction between the four fundamental states of memory such that as memory degrades it will change from one state to another. In some instances, memories degrade from explicit memory to implicit memory, which would cause an increase in implicit memory. Another experimental paradigm may further elucidate these results, which are in contradiction to the results of McKone (1998) who found long-term stability in implicit memory after an initial fast decay in short-term implicit memory. More particularly, the design of the study may limit the extent to which we can examine how much implicit memory may actually be rising. An experiment narrowing the time differential present in a list-learning paradigm would lead to insights in the dynamics of memory in the immediacy of the retention interval. Additionally, testing participant groups who may rely more naturally on implicit memory may alter the shape of the implicit retention curve. Experiment 4 and Experiment 5 were designed to examine these theories. If it is the case that explicit memory and implicit memory are interacting in a manner such that explicit memories degrade to the state of implicit memory, this would be strong evidence supporting a single memory system.

Experiment 3

Experiment 1 and 2 modeled the four fundamental memory states as they changed across retention intervals. The data were modeled based on pooled memory data, due to the proof explained in Chechile (2009) which indicated that pooling raw data prior to parameter estimation resulted in more accurate estimates than averaging the data after the estimation procedures. However, it was of interest to see how well the IES model could measure the four fundamental estimates with individual data. Additionally, Experiment 3 intended to use the storage estimates to model the parameters of a memory theory developed by Chechile (2006), which describes memory as two separate traces, a short-term and a long-term memory trace. In previous work the Two-Trace Hazard Model was used to model differences in memory storage as a result of repeated and spaced memory learning scenarios (Sloboda, Masters Thesis, 2008) and the current experiment will act similarly while looking at memory information over the very long term.

Experiment 3 was designed to once again employ the list-learning paradigm, but provided participants with a large amount of data to remember over a very long retention interval. The third experiment analyzed the rate of loss in implicit and explicit memory over the very long term. McKone (1995) has identified a different retention interval for short-term implicit memory and long-term implicit memory. This data indicated that implicit memory follows two separate traces, while short-term implicit memory degrades immediately following stimulus presentation. Long-term implicit memory lasts for 45 seconds and then begins to degrade (McKone, 1995). In a similar vein, Chechile (2006) also suggested that memory storage exists in the form of two separate traces.

Chechile (2006) proposed the Two-Trace Hazard Model of memory storage that describes changes in memory in terms of hazard functions. Hazard is the instantaneous risk of an event occurring, given that it has not yet occurred (Chechile, 2006). In the real world, hazard has a number of applications. In product reliability, hazard relates to the risk of product failure. In the health services, hazard can be related to the risk of disease onset or patient death. In memory, hazard has also been described as the instantaneous risk of memory loss at a particular time, conditioned by the fact that memory loss has not yet occurred (Chechile, 2006). Hazard portrays the dynamics of the risk that a memory trace will be lost as it changes over time, and may be utilized to estimate any stochastic function. Hazard is particularly useful to describe memory, which may be considered a subprobability function. Whereas probability functions are theorized on the assumption that the resulting cumulative function rises to a value of 1.0, subprobability functions instead result in a cumulative function of some value less than 1.0 over the domain of support. In terms of memory as a subprobability function, this could describe the idea that not all memories are lost over a lifetime, which is the case in memory theory (Chechile, 2006).

The development of the Two-Trace Hazard Model arose from a review conducted by Chechile (2006) examining the hazard of 15 existing memory theories as well as their corresponding retention functions to determine which memory theory best described existing memory data. Each memory theory had an associated, distinct, hazard curve. In his review, Chechile (2006) demonstrated that the hazard shape of memory must be in the form of a peak where the hazard curve begins at some lower point, rises to a peak and then decreases. This biphasic shape leads to an increasing susceptibility to memory loss, up to a point, and then decreasing susceptibility to memory loss.

Chechile (2006) indicated that most of the theories in the available literature are described by monotonically decreasing hazard functions, which would make those theories mathematically incapable of describing memory loss. With the memory theories that did have a peak-shaped hazard function, Chechile (2006) performed additional analyses with experimental memory data to see which theory was best able to describe existing data. These data were linearized logarithmically to analyze them and then fit them to the hazard function. The remaining theories were unable to provide a good fit to existing memory data with very short and very long retention intervals. With no remaining theories capable of describing memory, Chechile (2006) developed a new theory, the Two-Trace Hazard Model, which hypothesizes that memory is formed by two distinct traces that have rather different hazard characteristics.

As the name implies, the Two-Trace Hazard Model postulates that the formation of a memory consists of the simultaneous creation of two individual memory traces. The first trace (Trace 1) is described by monotonically increasing hazard, making it analogous to a short-term memory trace. Because the hazard of Trace 1 is increasing, the susceptibility to loss of this trace amplifies quickly over time. Both time and intervening items affect the loss of Trace 1. As time passes, and a greater number of items are placed into memory (which act as intervening items), it becomes likely that this first trace will be lost (Chechile, 2006). The second trace (Trace 2) is described by monotonically decreasing hazard. Over time, the risk of loss of this second trace becomes less. Trace 2 is analogous to long-term memory and is susceptible to time only. The seemingly unlimited storage theorized for long-term memory is explained by the fact that Trace 2 is only susceptible to time and not to intervening items (Chechile, 2006).

Correct recall is supported if either one of the two traces is still available. The conjunction of the Two-Trace Hazard Model has a peak-shaped hazard function, as described by $u(t)$ (Chechile, 2006). If the peak occurs at $t = 0$, then the hazard is monotonically decreasing. If the peak of the $u(t)$ function is greater than 0, then only those memory functions with a peak-shaped associated hazard function may accurately describe the data. However, if the point at which this peak in the biphasic function occurs is very early in terms of the temporal-lifetime of the function, it is impossible to measure in experimental cases that employ designs like the list-learning procedures and may only be analyzed with short-term data. Experiment 4 will address this point in more detail. Further, as described by Chechile (2006) to prove whether or not the peak is actually at 0, indicating a monotonically decreasing hazard function, the existence of the peak can only be found by testing memory immediately following learning, at a point as close to $t = 0$. The hazard of Trace 1 and Trace 2 as well as the peak-shaped conjunction of both traces are shown in Figure 9.

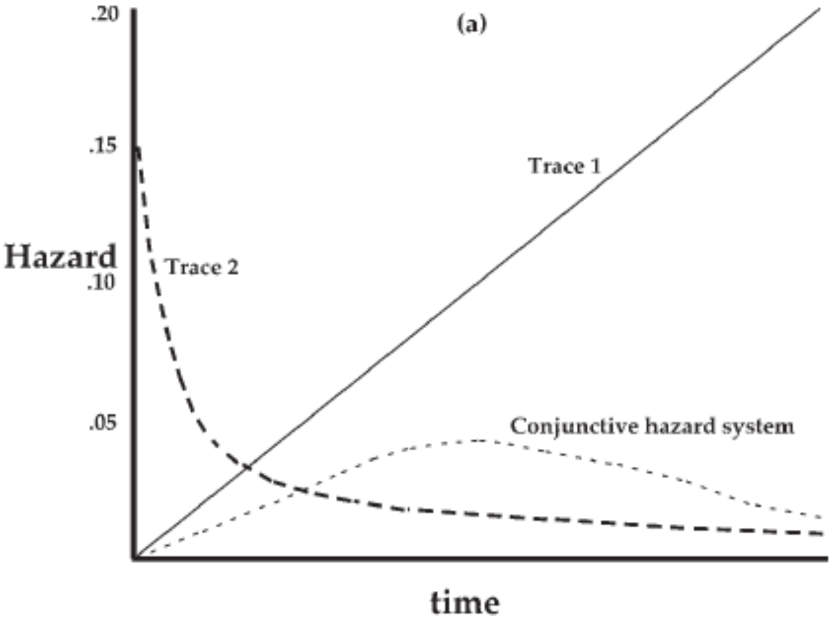


Figure 9. Hazard function of Trace 1 and Trace 2, and the conjunction of the two traces (taken from Chechile, 2006).

The Multiple Store Model of Atkinson and Shiffrin (1968) is considered by many researchers the modal model. This model has monotonically decreasing hazard and so is thus not able to model correctly memory functions (Chechile, 2006). The Two-Trace Hazard Model differs from the Multiple Store Model (Atkinson & Shiffrin, 1968) in several distinct ways. The Multiple Store Model is defined as having one memory trace that is transferred from sensory memory to short-term, or working memory. Once in short-term memory, the memory trace can either be transferred to long-term memory or can be lost. Memories can be lost between the transference from sensory registry to short-term memory and from short-term memory to long-term memory. If the memory trace is transferred to long-term memory, then it becomes permanent. By comparison, the Two-Trace Hazard Model states that two individual memory traces are generated simultaneously and both of these traces are subject to loss. While the Two-Trace Hazard

Model allows for memories to become permanent, it also allows for memories to be lost completely over a lifetime. Thus, the Two-Trace Hazard Model allows for and is able to model instances of super memory as well as near total memory such as in cases of traumatic brain injury or dementia (Chechile, 2006).

Two-Trace Hazard Model Parameters

The Two-Trace Hazard Model includes four different parameters that will be reviewed here. Trace 1 is a function of the *d* parameter, which is based on the rate of loss of this first trace. If we denote θ_{s1} as the probability of storage for Trace 1, then storage loss for this trace is

$$F_1(t) = 1 - \theta_{s1} = 1 - \exp(-dt_2). \tag{4}$$

Because this trace has a monotonically increasing hazard function, the rate of loss of Trace 1 increases as *d* increases in value.

The function for Trace 2 includes three parameters: *b, c,* and *a*. The *b* parameter of Trace 2 is related to the proportion of loss of memory traces over time (Chechile, 2006). If *b* is equal to 1, then all memory traces have been lost. If *b* is equal to 0.5, then 50% of traces have been lost. The *a* and *c* parameters direct the rate at which Trace 2 is lost. These two parameters describe the rate of approach to the asymptote of Trace 2 (see Figure 9). As the *a* and *c* parameters increase, the rate of loss of Trace 2 increases. Figure 10 contains two curves depicting the *a* and *c* parameters. As the curves show, all three functions will eventually reach the same asymptote, however, the rate at which this asymptote is reached is dependent on the value of the rate parameters.

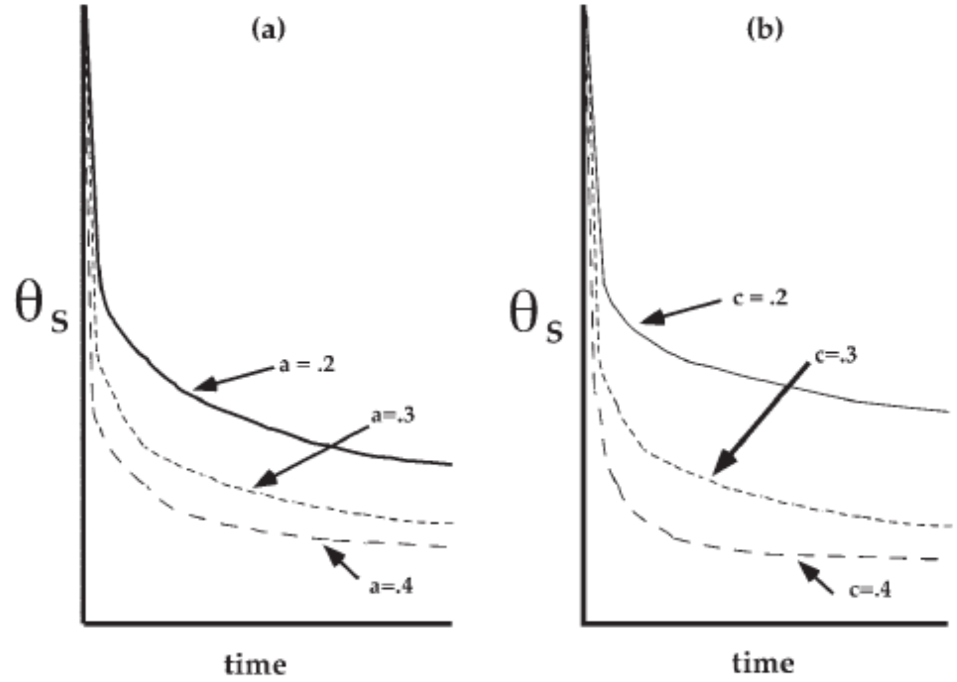


Figure 10. The rate of loss of memory traces with various values of the *a* and *c* parameter (taken from Chechile, 2006).

The second trace is the more durable of the two traces present in the Two-Trace Hazard Model. The probability of storage for Trace 2 is denoted by θ_{s2}. This equation has a decreasing hazard function. Trace 2 is represented by the function

$$F_2(t) = 1 - \theta_{s2} = b[1 - \exp(-at_c)]. \quad (5)$$

The Two-Trace Hazard Model, as described by Chechile (2006), is a result of two individual traces, working in conjunction with one another. Memories can be retrieved if either trace is available and both traces must be erased for memory loss to occur. The conjunction of the two memory traces is a peak-shaped hazard function. When both traces are lost, the probability of loss is

$$F(t) = 1 - \theta_s(t) = F_1(t)F_2(t). \tag{6}$$

Experiment 3 and 4 were designed to address the ability of the Two-Trace Hazard Model to measure memory data in the short and long term as well as to ascertain if the IES model parameters result in a peak-shaped conjunctive system by using a list-learning paradigm and a Brown-Peterson paradigm. In Experiment 3, word-lists were presented to participants, and the IES model was used to estimate values for explicit and implicit memory, as well as the remaining parameters. The values for explicit storage, and an explicit/implicit storage value, or total storage, estimated the parameters *a, b, c,* and *d*. In Experiment 4, consonant triads were used with the Brown-Peterson Paradigm to gather group data, and estimate the storage values as a function of time to locate the peak of the hazard function, described by *u(t)*.

Previously, the values for *a, b, c,* and *d* of the Two-Trace Hazard Model were estimated as a function of the repetition using memory storage (Sloboda, Masters Thesis, 2008) and discovered that when information is repeated, memory traces become more durable, and degrade more slowly. The third experiment will evaluate both the short-term and long-term memory traces in terms of explicit and implicit memory, as opposed to just memory storage, as a function of the retention interval. Any memory theory should be able to describe the dynamics of memory loss in the very short and very long term. Experiment 3 is the to use novel data to test the fit of the Two-Trace Hazard Model over such a long retention interval. The current Experiment used retention intervals from 15 seconds to 6 days. A large amount of information was collected on a small number of participants.

Methods

Participants

The third experiment enrolled nine participants. All nine participants were members of the Psychology Department at Tufts University, either as undergraduate researchers in the Memory and Cognition Laboratory or as graduate students in the Psychology Department. All participants chose to participate on a purely voluntary basis, and received no monetary payment for their participation.

Design and Materials

The third experiment presented 30 lists of 20 words to participants. The words were chosen from the Kucera-Francis (1969) word norms and were reviewed to ensure that no word held any high association to any other word, to the degree possible with so many words. Because of the large number of words used in Experiment 3, only words with a frequency value of 50 or higher were used. Participants were told that they were to remember each word for a later memory test. Words were presented one at a time, and remained on the computer screen for 3 seconds each. Participants were instructed to read each word and try to remember for a later testing session. List presentations and testing sessions were completed on a windows based computer and written in the program E-Prime.

The purpose of the study was to compare the memory of words over a wide range of retention intervals, and thus 10 retention intervals were tested, including 15 seconds, 5 minutes 15 minutes, 30 minutes, 1 hour, 3 hours, 9 hours, 1 day, 3 days, and 6 days after list presentation. Every retention interval test contained two words from each of the 30 lists. Participants were presented with all 30 lists during the initial learning session. The total presentation time for each list lasted only one minute.

After beginning the experiment, each list was presented, one at a time. The experiment was split into two identical halves, with 15 lists presented in each half. After the first list was presented, a 15 second break followed. Participants were presented with two target-present items from the immediately preceding list, as well as two target-absent items. This occurred for all 15 lists in each half. Thus, four test items (of 120 test items total) were presented after each list to test the participants' memory after a 15-second retention interval. After the first test trial finished, the second list was presented, as well as another 15-second break followed by two target-present and two target-absent test items.

Starting at the fourth test, and continuing throughout the remainder of the first 15 list presentations, participants were provided eight test items. The additional four test items were comprised of two target-present and two target-absent test items from three lists prior (a 3-back task). Starting on the fourth list, there were eight test items; four test items were presented to test the 15 second retention interval of the immediately preceding list (list three) and four test items tested the 5 minute retention interval (from list one). This timing was approximate, but the list presentations were timed such that the retention interval was as close to five minutes as possible. This manner of list presentation and testing continued for the remainder of the first half of the experiment, for all 15 lists. After 15 of the lists were presented, participants were given a 10-minute break. The participants were then tested on 60 items from the first 15 lists, comprising the 15-minute retention interval. Of the test items, there were 30 target-present items from all of the 15 lists and 30 target-absent trials presented in the first half.

Upon completion of the first 15 lists, participants were given a brief break, and began the process again for lists 16 through 30. The procedure for the second 15 lists was identical to the first 15 lists. Although lists were not counter-balanced, the words within the lists were presented randomly. Together, the list presentations and testing sessions for the 15-second, 5-minute, and 15-minute retention intervals were completed in around 90 minutes. Upon completion of the second half, participants had another 30-minute break and then began the 30-minute test, which was comprised of 120 test-items (60 target-present and 60 target-absent) from all 30 lists. At this point, the time for each follow-up test was set so that the 1-hour, 3-hour, and so on, retention intervals started one hour and three hours after the completion of the second learning session.

After another 45-minute break, the participants were then tested with another 120 test items. This was approximately one hour after the end of the learning session, and thus tested the one-hour retention interval. Finally, participants were given a 1 hour and 45 minute break, and tested on 120 items to test the 3-hour retention interval.

Participants were then asked to return after the appropriate retention interval for the last four testing sessions, each of which lasted 17 minutes. Participants returned 9 hours after the end of the learning session, and then 1, 3, and 6 days following the end of the initial learning session.

There were 120 test items for each of the 10 retention intervals. Of the 120 test items, 60 test items were target-present trials and 60 items were target-absent trials. Altogether, participants were expose to 600 words (30 lists of 20 words each) and completed 1200 test items (600 target present trials and 600 target absent trials), providing a large amount of data to be tested individually. Based on the Monte Carlo sampling provided in Table 1, an *n* of 600 would result in a P(coh) value of .561, and divergence from the mean of .018 for both MLE and PPM methods.

Procedure

At the first meeting, which commenced at approximately 9AM on the initial day of testing, participants arrived at the testing location, and were consented by the experimenter. They were assured that they could stop their participation in the experiment at any time. Because all the participants were members of the Memory and Cognition lab at Tufts University they were compensated for their time by working less hours in the laboratory for two weeks of their choice. They were seated at a computer, at which point the instructions for the experiment were presented on the computer screen. Participants were then allowed to ask any questions. The experimenter started the computer program. The first session lasted approximately four hours, of which two hours were break time and the participants were allowed to do anything of their choice. Participants learned all 30 lists in this first session, as well as completed all test items for the 15-second, 5-minute, 15-minute, 30-minute, 60-minute, and 3-hour testing sessions. Participants were then asked to return around 6 PM (five hours later) for the 9-hour retention interval testing session. Participants were asked to return one, three, and six days later, starting at the hour that the initial testing session ended. For instance, if a participant started at 9, they were generally done with learning at 10:45, and so were asked to return each day at 10:45 AM. During each testing session, participants answered

120 test items, which took no more than 20 minutes to complete, such that the total time that participants were actively involved in the study was a total of seven hours. At the six-day retention interval testing session, participants were given a debriefing form. Again, participants were given a chance to ask any questions they may have had, and they were then thanked profusely for all their effort and time.

The testing phases were each comprised of 60 target-present and 60 target-absent trials. In target-present trials participants were presented with four different words, one of which was presented earlier in one of the 30 lists, along with three foils. There were two words from each list tested at all 10 retention intervals so that all 600 words were eventually tested. The target absent and target present trials followed the IES task described above.

Results

Experiment 3 analyzed the results in a different manner than the other experiments. In Experiment 3, the parameters of the IES model were analyzed on an individual subject basis, as opposed to the group aggregate manner used in each of the other experiments. Additionally, the storage parameters were then used to address and model the *a, b, c,* and *d* parameters of the Two-Trace Hazard Model.

After completion of the experiment, raw data from each of the nine individuals were collated for each of the 20 cells within the IES model. The pooled raw data for each of the 20 cells of the IES model for each individual participant can be found in Appendix C.

The individual subject values for each of the 20 cells of the IES model were input into a computer-modeling program, which then estimated the values for each of the parameters within the IES model using both PPM and MLE methods. Because these analyses were conducted on an individual subjects basis, the results for each participant are listed in Appendix C. The tables provide maximum likelihood estimates for each parameter, as well as the standard deviation of the PPM estimates and the P(coh) values for each parameter at each condition, listed in Tables 12-15. The storage parameters indicate that there was a drastic loss of memory over the entire retention interval. The average storage values for each participant went from .638 at a 15 seconds to an average of .011 at the one-week lag.

Again, the purpose of Experiment 3 was to model the Two-Trace Hazard Model parameters using the long-term memory storage data estimated with the IES model. For the purpose of estimating the parameters of the Two-Trace Hazard Model, only the estimates for explicit and implicit storage will be used. The storage values for each of the 10 retention intervals for each of the 9 subjects are available in Table 12 through 15. The values for explicit storage and for implicit storage are listed, as well as a combined storage value (θ_{tot}), which was calculated by adding explicit and implicit storage.

Table 12.

The following table contains storage values based on PPM estimates of $\theta_{se,}$ θ_{si} *and* θ_{tot} *for participants 1 through 5 for each of the 10 lag conditions in Experiment 3. The* $\theta_{se,}$ *and* θ_{si} *values are listed in the first row for each retention interval and the combined* θ_{tot} *value is written below the individual implicit and explicit storage parameters.*

	Participant									
	PPM Values									
	1		2		3		4		5	
Ret	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}
30sec	.594	.102	.471	.123	.340	.046	.752	.041	.170	.101
	.696		.594		.386		.793		.271	
5min	.487	.100	.348	.081	.206	.058	.681	.075	.068	.118
	.587		.429		.264		.756		.186	
15min	.401	.058	.155	.072	.140	.081	.639	.075	.054	.068
	.459		.227		.221		.714		.122	
30min	.334	.078	.183	.057	.107	.126	.515	.128	.024	.105
	.412		.240		.233		.643		.129	
1hr	.235	.091	.240	.052	.130	.131	.493	.134	.013	.090
	.326		.292		.261		.627		.103	
3hr	.142	.044	.021	.050	.042	.053	.417	.117	.047	.046
	.186		.071		.095		.534		.093	
9hr	.065	.146	.052	.066	.021	.066	.312	.102	.022	.065
	.211		.118		.087		.414		.087	
24hr	.053	.058	.014	.073	.014	.066	.236	.153	.013	.061
	.111		.087		.080		.389		.074	
72hr	.013	.081	.013	.096	.014	.047	.094	.184	.014	.055
	.094		.109		.061		.278		.069	
144hr	.036	.111	.021	.047	.011	.041	.065	.049	.012	.037
	.147		.068		.052		.114		.049	

Table 13.

The following table contains storage values based on PPM estimates of $\theta_{se,}$ θ_{si} and θ_{tot} for participants 6 through 9 for each of the 10 lag conditions in Experiment 3. The $\theta_{se,}$ and θ_{si} values are listed in the first row for each retention interval and the combined θ_{tot} value is written below the individual implicit and explicit storage parameters.

	Participant							
	PPM Values							
	6		7		8		9	
Ret Tot	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}
30sec	.700	.043	.633	.099	.497	.026	.426	.096
	.743		.732		.523		.522	
5min	.577	.046	.662	.074	.379	.178	.238	.082
	.623		.736		.557		.320	
15min	.475	.064	.532	.100	.462	.117	.140	.075
	.539		.632		.579		.215	
30min	.407	.086	.389	.202	.282	.083	.059	.058
	.493		.591		.365		.117	
1hr	.309	.169	.349	.207	.179	.183	0	0
	.478		.556		.362		0	
3hr	.309	.076	.259	.083	.130	.192	.051	.067
	.385		.342		.322		.118	
9hr	.237	.106	.153	.092	.129	.120	.047	.025
	.343		.245		.249		.072	
24hr	.131	.088	.089	.066	.166	.075	.056	.130
	.219		.155		.241		.186	
72hr	.019	.091	.058	.080	.061	.072	.014	.054
	.110		.138		.133		.068	
144hr	.014	.001	.023	.079	.060	.052	.022	.102
	.015		.102		.112		.124	

Table 14.

The following table contains storage values based on MLE estimates of $\theta_{se,}$ θ_{si} *and* θ_{tot} *for participants 1 through 5 for each of the 10 lag conditions in Experiment 3. The* $\theta_{se,}$ *and* θ_{si} *values are listed in the first row for each retention interval and the combined* θ_{tot} *value is written below the individual implicit and explicit storage parameters.*

	Participant									
	MLE Values									
	1		2		3		4		5	
Ret	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}
30 sec	.750	.150	.612	.138	.416	.001	.950	.050	.251	.065
	.900		.750		.417		1.0		.316	
5 min	.619	.114	.427	.106	.262	.005	.850	.117	.087	.146
	.733		.533		.267		.967		.233	
15 min	.502	.048	.200	.050	.199	.051	.776	.124	.036	.047
	.550		.250		.250		.900		.083	
30 min	.426	.074	.193	.006	.128	.189	.652	.165	.017	.083
	.500		.199		.317		.817		.100	
1 hr	.301	.099	.282	.001	.130	.187	.620	.197	.001	.099
	.400		.283		.317		.817		.100	
3 hr	.173	.044	0	.001	.032	.001	.531	.135	0	.001
	.217		.001		.033		.666		.001	
9 hr	.087	.146	.063	.037	.017	.033	.405	.095	0	.001
	.233		.100		.050		.500		.001	
24 hr	0	.001	0	.001	0	.001	.305	.195	0	.001
	.001		.001		.001		.500		.001	
72 hr	.001	.016	0	.001	0	.001	.135	.215	0	.001
	.017		.001		.001		.350		.001	
144 hr	.042	.141	0	.001	0	.001	.001	.016	0	.001
	.183		.001		.001		.017		.001	

Table 15.

The following table contains storage values based on MLE estimates of $\theta_{se,}$ θ_{si} *and* θ_{tot} *for participants 6 through 9 for each of the 10 lag conditions in Experiment 3. The* $\theta_{se,}$ *and* θ_{si} *values are listed in the first row for each retention interval and the combined* θ_{tot} *value is written below the individual implicit and explicit storage parameters.*

	Participant							
	MLE Values							
	6		7		8		9	
Ret	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}	θ_{se}	θ_{si}
30 sec	.883	.033	.800	.133	.532	.001	.549	.101
	.916		.933		.533		.650	
5 min	.691	.059	.818	.114	.486	.231	.311	.073
	.750		.932		.717		.384	
15 min	.602	.065	.651	.149	.566	.166	.166	.050
	.667		.800		.732		.216	
30 min	.497	.103	.492	.258	.365	.085	.058	.009
	.600		.750		.450		.067	
1 hr	.399	.200	.421	.313	.214	.253	0	0
	.599		.734		.467		0	
3 hr	.398	.018	.332	.067	.173	.277	.054	.011
	.416		.399		.450		.065	
9 hr	.300	.150	.214	.069	.176	.158	0	.001
	.450		.283		.334		.001	
24 hr	.175	.075	.089	.028	.214	.053	0	.194
	.250		.117		.267		.194	
72 hr	.006	.060	.050	.083	.080	.037	0	.001
	.066		.133		.117		.001	
144 hr	0	.001	.007	.043	.049	.001	0	.001
	.001		.050		.050		.001	

As a means of measuring the *a, b, c,* and *d* parameters, the θ_{se} and θ_{tot} parameters were input into a computer program to estimate the parameters of the Two-Trace Hazard Model. This was done for both the MLE and PPM estimates. The implicit memory parameter alone was not analyzed in the Two-Trace Hazard Model parameter fit program for two reasons: first, because the implicit memory parameter remained low throughout the retention intervals, and second, because the Two-Trace Hazard Model is a model of memory storage in general and could not account for implicit memory alone. The *a, b, c,* and *d* parameters for each participant form MLE and PPM are listed in Table 16.

Table 16.
The a, b, and c parameters for all 9 participants in Experiment 3 for the PPM and MLE methods. Both estimates based on $\theta_{se,}$ *and* θ_{tot} *parameters are available. The d parameter is not listed, as it was not measured in the long retention interval.*

	a				*b*				*c*			
	MLE		PPM		MLE		PPM		MLE		PPM	
p	θ_{se}	θ_{tot}	θ_{se}	θ_{tot}	θ_{se}	θ_{tot}	θ_{se}	θ_{tot}	θ_{se}	θ_{tot}	θ_{se}	θ_{tot}
1	1.2	.9	1.4	1.3	1.0	1.0	.99	.96	.35	.43	.27	.33
2	2.0	2.2	2	1.7	1.0	1.0	.99	.94	.29	.43	.2	.23
3	2.4	2.0	2.6	2.1	1.0	1.0	.99	.96	.23	.18	.19	.15
4	.4	.2	.7	.5	1.0	1.0	1.0	.98	.37	.56	.27	.23
5	4.8	2.7	4.2	2.5	1.0	1.0	1.0	.96	.26	.18	.18	.12
6	.8	.6	1.0	.8	1.0	1.0	1.0	1.0	.33	.34	.22	.21
7	.8	.4	1.0	.8	1.0	.96	.99	.91	.34	.58	.29	.35
8	1.2	.7	1.6	1.0	.99	1.0	.97	.99	.19	.26	.29	.16
9	3.7	4.0	2.6	2.3	1.0	1.0	.99	.94	.38	.57	.23	.24

What can be seen from the results is that the *b* parameter is at or near one for all nine participants. As presented in the review of the Two-Trace Hazard Model, the *b* parameter is the proportion of memory items lost, asymptotically, over time. The Two-Trace Hazard Model was able to describe the total loss of memory after one week's time in all of the nine participants. The *b* parameter is a subprobability. If *b* is equal to 1, then all memories have been lost. If *b* is less than 1, then some memories still remain in explicit memory. Two participants (participant 7 and 8) had values for parameter *b* that did not reach 1.0 (based on the MLE estimates). These participants had θ_{se} values greater than zero after one week, which indicates that they retained some explicit memories from the learned items even after 1 week. While the MLE method allows for estimates of zero, the PPM method does not. Since every participant had a value for the PPM estimates greater than 0 (even if that value were .001), the *b* estimates based on θ_{tot} for the PPM estimates were all less than 1.

An interesting point based on the Two-Trace Hazard Model estimates is that of the *a* parameter. What can be seen here is the *a* parameter is rather high, indicating a quick drop toward the asymptote in the Two-Trace Hazard Model. The *a* parameter describes loss in the immediacy of encoding, or how much memory is lost from Trace 2 from 0 to 1 seconds. This means that as *a* increases, the speed at which memories are lost in the first second after encoding also increases. This will be addressed more directly in Experiment 5.

Weibull distributions are probability distributions that can describe data based on a shape parameter and a rate parameter. Among other uses, Weibull distributions are used in product reliability. If the shape parameter, *c,* is greater than one, the function has monotonically increasing hazard; if *c* is less than one, the function has decreasing hazard, and if *c* is equal to one, the Weibull distribution mimics the exponential distribution (Chechile, 2003). In terms of subprobabilities, the Weibull function is peak-shaped when *c* is greater than one (Chechile, 2006). The following analysis is to determine, with the data from Experiment 3, the ability of the Two-Trace Hazard Model to fit long-term data.

By using data from the Strong (1913) experiment, Chechile (2006) described a means of transforming, logarithmically, memory data to fit a Weibull subprobability model. If the Weibull subprobability model, which is the basis for Trace 2, fits the data from Experiment 3, then the Two-Trace Hazard Model can describe these data in the long term. The transformation was performed based on each of the time intervals (plotted on the x-axis), and a log transformation of the storage value for each time interval and the resulting *b* parameter (plotted on the y-axis). More specifically, the x-axis is plotted as a natural log of the time, t, in minutes of each of the ten retention intervals. The y-axis was linearized by inputting the storage values and the resulting *b* parameter for each of the ten retention intervals into the following formula:

$$\ln\left[\ln\left(b/(b-1+\theta_s)\right)\right] \qquad (7)$$

The consequential linearized data supported the notion that the data results fit a Weibull subprobability function, and therefore the Two-Trace Hazard Model.

The θ_{se} and θ_{tot} estimates are plotted for each participant. The resulting graphs for each participant are in Figures 11-19. Each of the plots contains the equations for the line of best fit as well as the resulting r^2 values. In viewing the graphs for each participant based on the θ_{se} and θ_{tot} values, it can be seen that the data fit the function quite well. The θ_{se}, a more precise value of storage, has an even better fit to the model. With this in mind, the long-term memory data are described well by a Weibull subprobability function, indicating that Trace 2, which is based on the subprobability function, can model the data over the long term. The r^2 values are within the range of .73 - .97 for explicit storage and .64 - .94 for total storage. The slopes are all within the range of 0.08 - 0.25 for explicit storage and 0.10 - 0.27 for total storage.

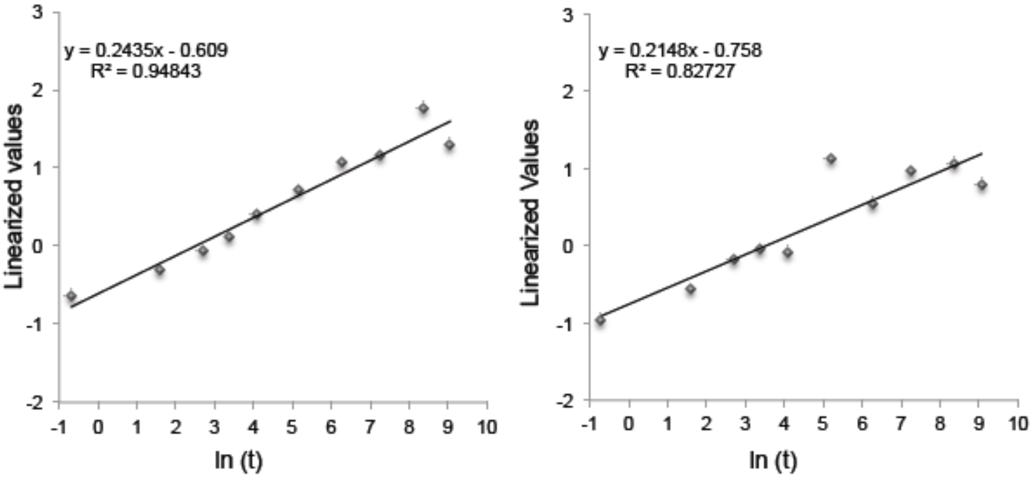


Figure 11. The two graphs display the linearized data values for Participant 1. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

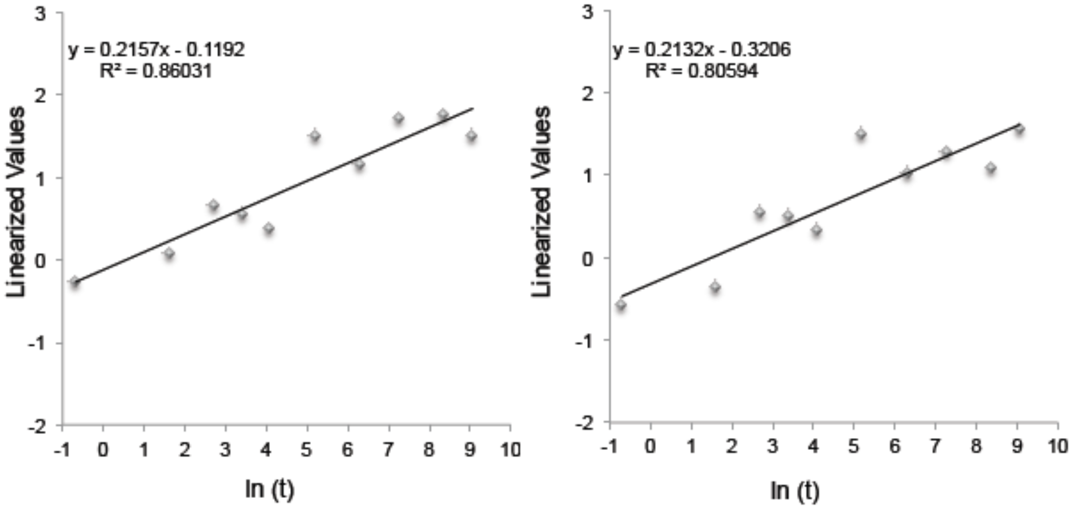


Figure 12. The two graphs display the linearized data values for Participant 2. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

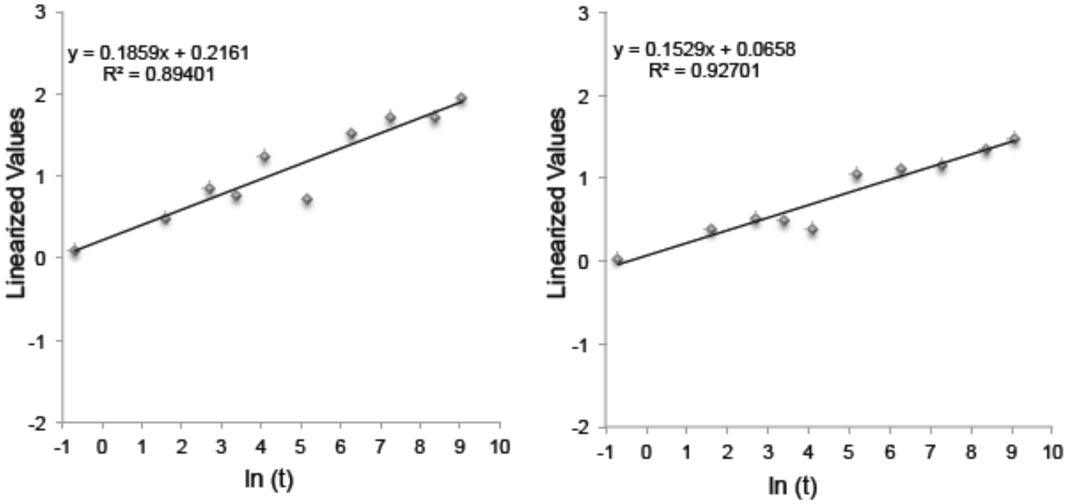


Figure 13. The two graphs display the linearized data values for Participant 3. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

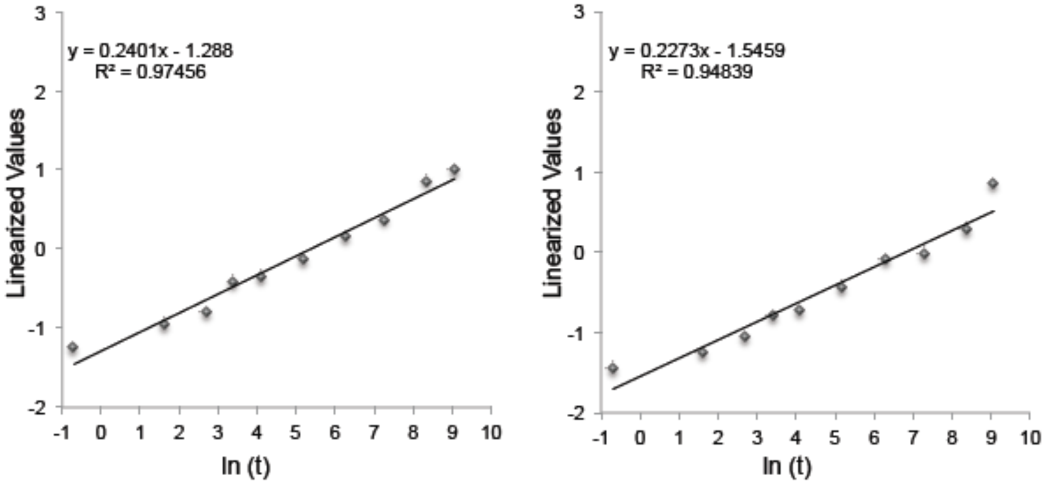


Figure 14. The two graphs display the linearized data values for Participant 4. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

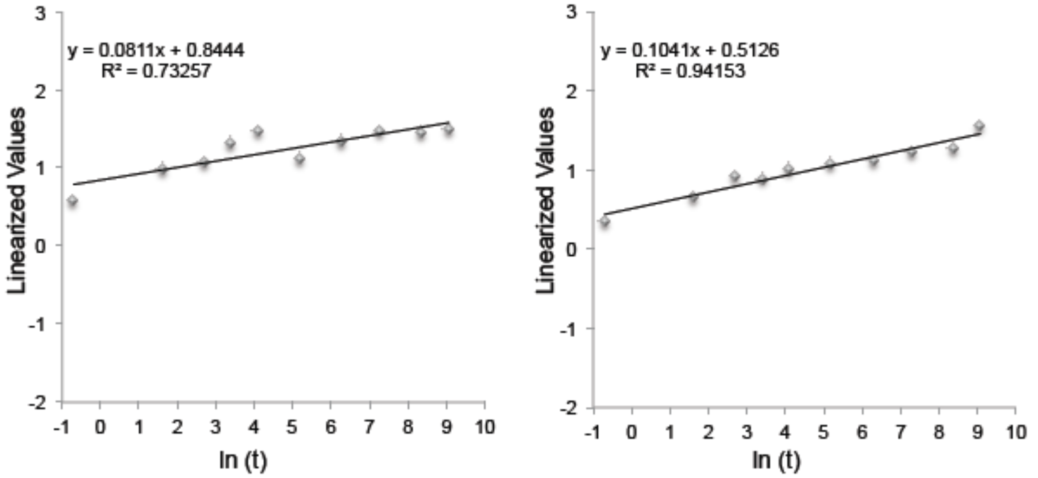


Figure 15. The two graphs display the linearized data values for Participant 5. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

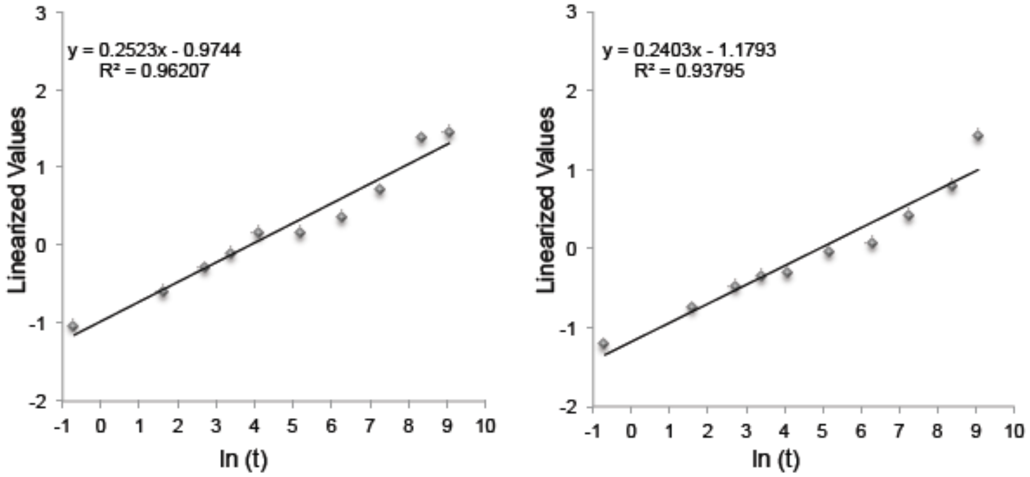


Figure 16. The two graphs display the linearized data values for Participant 6. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

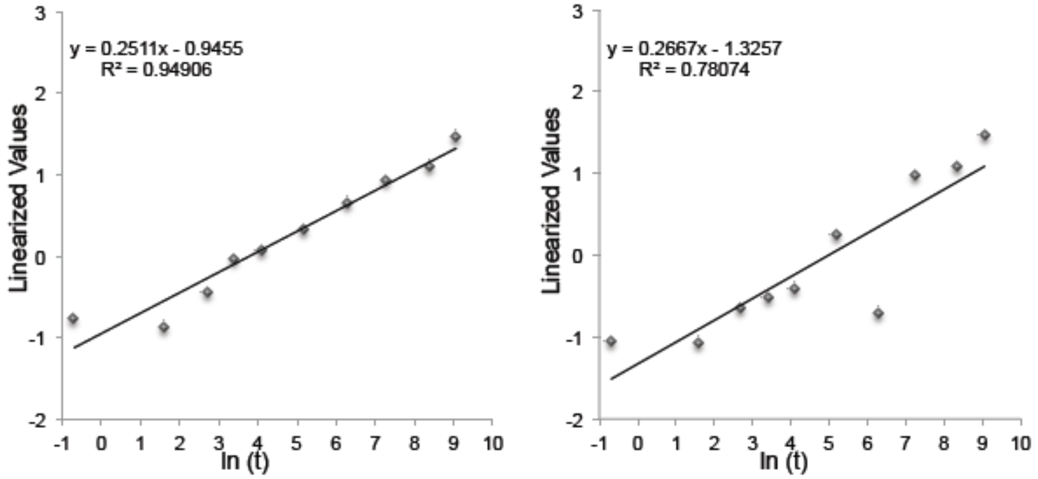


Figure 17. The two graphs display the linearized data values for Participant 7. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

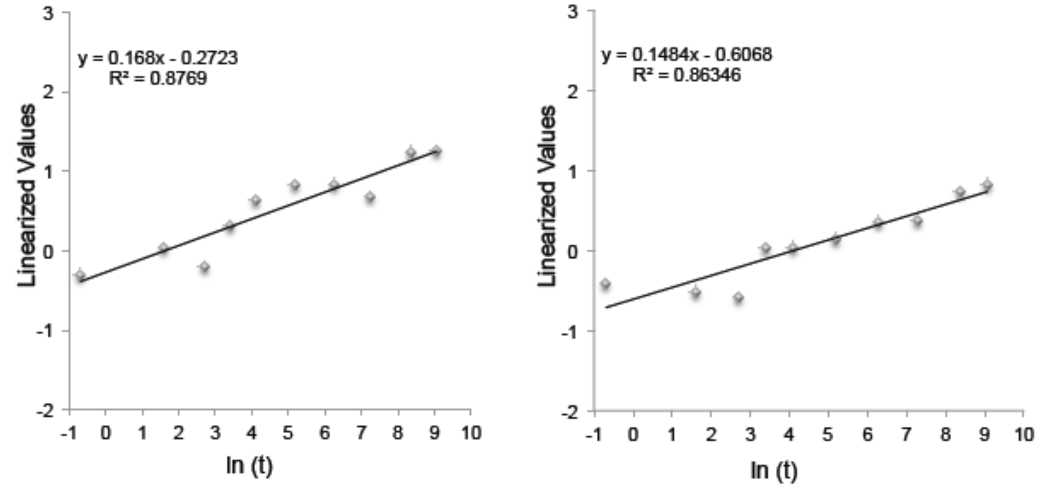


Figure 18. The two graphs display the linearized data values for Participant 8. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

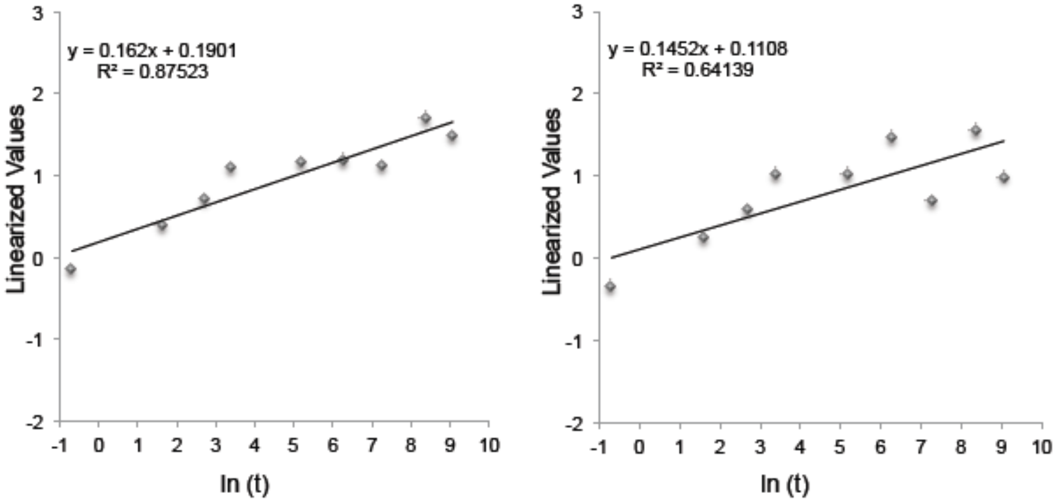


Figure 19. The two graphs display the linearized data values for Participant 9. The graph on the left is the linearized data points for each of the 10 retention intervals for the explicit storage value while the graph on the left is the linearized data points for each of the 10 retention intervals for the total (explicit and implicit) storage value.

Discussion

Experiment 3 was designed similar to some of the most preliminary memory experiments in the literature (Ebbinghaus, 1885; Strong 1913) that tested a small number of individuals on a large amount of data over a long period of time. In Experiment 3, nine participants were presented, and subsequently tested, on 600 words in order to assess the long-term storage and loss of memory items. As in the other experiments presented thus far, the results from the testing sessions were input into the IES model to measure the fundamental memory states. Each individual acted, as individuals do, in a very different manner, but the overall conclusion was that most, if not all, memories were lost at a similar rate and to a similar extent by each participant over the week of testing. Explicit memory was close to 0 for each individual. Implicit memory remained low throughout the experiment, and non-storage rose to almost 100 percent after a week of testing.

The storage values for explicit memory, as well as a value for total storage (explicit and implicit memory combined) were input into the fit parameters for the Two-Trace Hazard Model. For each participant, a value for each of the *a, b,* and *c* parameters were estimated. In a discussion of the Two-Trace Hazard Model, Chechile (2006) argued for the development of the model, as existing models were unable to describe memory data over the long-term. Chechile (2006) argued that a Weibull subprobability model was the best type of model to describe memory data in the long-term, and used such a model of memory retention to describe Trace 2 of the Two-Trace Hazard Model. More evidence in support of the Weibull subprobability distribution was discovered in this experiment, because data from each of the individuals was linearized with a logarithmic function based on the probability function. The slope of each line provides the shape distribution for each person. In all cases, whether explicit storage alone, or total storage estimates were used, slope values, or shape parameters for the participants were less than

1, indicating that these data are supported by the Trace 2 function, which has decreasing hazard.

In terms of fitting the Two-Trace Hazard Model parameters to the storage values estimated from the IES model, each storage value was input into a fit program. In the case of Experiment 3, the first term memory trace was likely lost even at the shortest retention intervals. Since the long-term memory data fit the Weibull subprobability model on which the TTHM was developed, this model adequately fit the data.

As described earlier a second conclusion grounded in hazard theory to analyze memory is that any function must have a peak-shape, and the conjunction of the two traces in the Two-Trace Hazard Model is peak-shaped. The data provided in Experiment 3 are unable to express this peak as they are only descriptions of the shape of the Trace 2 function since the first trace is no longer available in memory. The next experiment, however, was designed to analyze data in the short term to discover if and where this peak exists.

Experiment 4

The list-learning paradigm has a few associated limitations, one of which is the inability to determine precisely the interval between encoding and testing. A more advantageous procedure to analyze exact time differences is the Brown-Peterson paradigm. This paradigm presents participants with a to-be-learned target item. The presentation of the target is then followed by a distraction task, which is administered as a means of limiting rehearsal of the target item. A test item, or in the case of the IES model task, a target-present or target-absent test trial immediately follows the distraction task. The longer the retention interval, the more weakened the memory trace of the initial target item becomes. With this paradigm, we can precisely control for each item the time and events between encoding and testing.

The Brown-Peterson paradigm also provides the ability to examine the θ_k parameter in a manner different than that was used in the first three experiments. In all three experiments, θ_k was very small due to lack of knowledge of the target information in the list-learning paradigm. In Experiment 3, it was expected that the participant would have some information about the target item, especially after the very short retention intervals. If a participant can identify foils as foils, then the value for θ_k should be large. It is assumed that this value will decrease as a function of retention interval.

Experiments 1 and 2 provided some information about the possibility of an increase in implicit memory over the retention interval. Previous research has identified either a decrease from lags of zero to longer lags (Bentin & Moscovitch, 1988; Kersteen-Tucker, 1991) or a stable amount of implicit memory as lag increases (Scarborough, Cortese, & Scarborough, 1977, exp. 1). However, research with non-word stimuli may lead to differing results. McKone (1995) found an immediate decrease in implicit memory of non-words, but a longer retention of implicit memory in words as tested by a lexical decision task. The following experiment will not only identify the changes in implicit and explicit memory with a Brown-Peterson paradigm, but with consonant-triads as stimuli as well.

An additional purpose of the fourth experiment was to try to find the location of the peak of the conjunction of the two memory traces as modeled by the Two-Trace Hazard Model. As discussed in Experiment 3, the conjunction of the Two-Trace Hazard Model has a peak-shaped hazard function, as described by $u(t)$ (Chechile, 2006). The $u(t)$

function provides a statistically stable means of allowing us to assess if the peak of the hazard function is at a non-zero time. An analysis to find the location of the peak in the *u(t)* function was performed to see if the Two-Trace Hazard Model could adequately fit the data. As discussed in Experiment 3, the Two-Trace Hazard Model was developed based on the assumptions that any memory model must be able to fit data in the short term and in the long term, and also must be described by a peak-shaped hazard function. Experiment 3 provided long-term results that were easily fit by the model, and Experiment 4 will assess whether the data in the short term have a peak at a non-zero time, as opposed to a peak at a time equal to zero. The two individual memory traces as well as the conjunction of the two is detailed in Figure 10. Because it is likely that the peak exists at a time close to zero, it is impossible to measure in experimental cases that employ designs like the list-learning procedures and was thus not calculated in Experiment 3. In this study, immediate memory, tested after 333ms and up to intervals of 30s were tested in order to assess the dynamic changes in implicit memory as well as if the peak of the *u(t)* function exists at time equal to 0 or at a point in the lifetime function later than 0 seconds.

Methods

Participants

A total of 58 undergraduate students at Tufts University participated in Experiment 4. Participants received partial course credit for their enrollment in the experiment. Participants enrolled in the experiment online. All participants were native English speakers. Gender and age data were not collected.

Design and Materials

This experiment followed the Brown-Peterson paradigm; a stimulus was presented, followed by a distracter task, and then participants were tested on the previously presented stimulus. The computer program was written in E-Prime, for a Windows based computer platform.

A single consonant triad (such as BXT or TJX) was presented aurally to participants through headphones. The triads were taken from the Witmer (1935) three-place consonant norm. The norm provides consonant triads formed from 19 consonants with a frequency rating of 0 to 100. The current experiment limited triads to a range of 0 to 45 so that triads with high frequencies were not used. The triads were chosen randomly. Any triad with a common association, such as BMW, was not used. The three consonants were presented at a rate of precisely one-third of a second per letter, such that a single presentation lasted one second in total. The auditory presentations were presented in stereo as a .wav file at an audio sample rate of 44 kHz, 705 kbs/sec, and a sample size of 16 bits.

The experiment measured memory for the consonant triads while varying the temporal separation of the initial presentation of the consonant triad and the test. There were five retention intervals, 1/3 of a second, 1 and 1/3 seconds, 4 seconds, 12 seconds, and 30 seconds. Participants were presented with a string of random numbers (from 1 to 9) at a rate of 333 ms per digit. Because each number in the shadowing task was presented at a rate of one-third of a second, the five retention intervals were comprised of the presentation of 1, 4, 12, 36, and 90 intervening randomly presented numbers, respectively. The number sequences were randomly generated by a program written in QuickBasic.

There were 24 consonant triads presented for each of the 5 retention intervals. Therefore, there were 120 separate test trials. Of the 24 test items, 12 test items were a target present trial and 12 items were a target absent trial. The foil presentations in the target-present trials had some similarity to the previously presented triad. If BXT were the to-be-remembered stimulus, the foil triads would have been BML, FXG, and HDT such that each foil shares a similar letter in the same placement location with the to-be-remembered stimuli. This was designed so that participants could not judge the existence of an item based on fractional storage alone. Half of the consonant triads were presented in a male voice, and half were presented with a female voice. Half of the shadowing tasks were presented with a male voice, and half with a female voice. The consonant triads presented with a male voice were followed by a shadowing task in a female voice, and vice versa. The computer program randomly presented the 120 test items.

Procedure

During the experiment, participants arrived at the testing location, and provided their informed consent to the experimenter. Once settled at the computer, the instructions for the experiment were presented on the computer screen. Participants were then allowed to ask any questions they may have had. The experimenter provided participants with a test trial to see if the participant could adequately hear the test stimuli, as well as understand the procedure of the test trial. They were instructed that they would hear letters and they were to remember them for a later memory test. They were also instructed they were to repeat the numbers aloud, as they heard them through the headphones. After a test trial, the researcher began the experiment. Participants first heard three consonants through a set of headphones. Following the presentation of the to-be-remembered stimuli, participants engaged in the shadowing task. The numbers were presented in the same fashion as the three letters. The purpose of the distracter task was simply to keep the participants from rehearsing the triads. Immediately following the distracter task, participants were provided the IES task. On average, it took participants 45 minutes to complete the experiment. Once all 120 consonant triads had been presented and tested, the computer program ended, and the participants were given a debriefing form. Again, participants were given a chance to ask any questions they may have had.

Results

Experiment 4 examined implicit and explicit memory over a very short retention interval using consonant triads in a Brown-Peterson paradigm. Despite the addition of the zero-interval in Experiment 2, the design of that experiment, using lengthy lists of words, was incapable of measuring memory components in the very immediate time frame following stimulus presentation. Thus, it was assumed that a more distinct picture of the changes in implicit and explicit memory would emerge with a Brown-Peterson paradigm. Particularly, it was hypothesized that there would be a monotonic decrease in explicit memory across the retention interval, but implicit memory would have a different rate of loss, if any loss occurred at all.

After completion of the experiment, raw data from each of the 58 individuals were collated for each of the 20 cells within the IES model. The pooled raw data for each of the 20 cells of the IES model can be found in Table 17. The data for each individual participant can be found in Appendix C.

Table 17.
The following lists the pooled number of responses for all 58 participants in Experiment 4. The data are sorted by the response in the Yes/No task and accompanying confidence rating. Each response pattern is then separated by whether the participant was correct on the 4-, 3-, or 2-AFC task. Finally, the 20 response cells are listed for each of the three retention intervals.

	4AFC				3AFC				2AFC				Incorrect				Foils			
	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
1/3	667	12	9	2	3	1	0	1	0	0	0	0	0	0	0	1	658	28	4	6
11/3	597	28	36	14	4	5	2	5	1	0	1	2	1	0	0	0	610	69	6	11
4	361	61	141	38	9	13	19	22	1	6	4	14	0	1	1	5	378	223	76	19
12	175	27	195	94	9	7	54	52	0	4	20	37	1	4	6	11	163	341	177	15
30	94	21	149	130	4	7	83	70	2	5	23	56	1	3	10	38	123	369	188	16

Table 18 provides the probabilities of having correctly said "yes" to a target-present trial with high confidence, as well as with low confidence. Similar to the results of Experiment 1 and 2, the tendency to answer yes with high confidence in a target present trial is higher than with low confidence. This indicates that participants were correctly using the confidence ratings. The same pattern is seen when the participants respond to target-absent trials. Table 19 provides the accuracy of being correct on the 4AFC task after each possible response on the yes/no recognition trial: either saying yes or no with high or low confidence. Similar to Experiments 1 and 2, participants are most likely to be correct on a 4AFC task following a "yes" response made with high confidence. As their confidence decreases, so does their ability to recognize correctly the item on a 4AFC.

Table 18.
The following are conditional responses for Experiment 4 for each of the five lag conditions. These are the probabilities of a correct responses to target-present or target-absent trials given either high or low confidence.

Retention	Target Present		Target Absent	
	P(hi conf correct)	P(lo conf correct)	P(hi conf correct)	P(lo conf correct)
1/3	.982	.692	.991	.875
1 1/3	.954	.644	.984	.803
4	.885	.614	.952	.718
12	.849	.588	.916	.651
30	.773	.477	.885	.661

Table 19.
Conditional probabilities for a correct response on the 4AFC following a high or low confidence for each of the lag conditions in Experiment 4.

Retention interval	P(4AFC, hi)	P(4AFC, lo)
1/3	.997	1.00
1 1/3	.990	.921
4	.973	.860
12	.946	.703
30	.922	.560

The pooled values for each of the 20 cells of the IES model were input into a computer-modeling program, which then estimated the values for each of the parameters within the IES model using both PPM and MLE methods. The results for each lag condition are listed in Table 20. The table provides estimates for each parameter conducted with MLE and PPM estimation procedures, as well as the standard deviation of the PPM estimates and the P(coh) values for each condition.

Table 20.
The following table provides the parameter estimates for each of the 14 parameters in the IES model in Experiment 4. The MLE and PPM estimates are provided. The standard deviation and the coherence values are also listed for the PPM estimates. The values are listed as a function of retention interval.

	Retention Interval									
Parameter	1/3		1 1/3		4		12		30	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.954	.935 (.010)	.852	.832 (.015)	.508	.495 (.020)	.242	.235 (.017)	.130	.126 (.014)
θ_{si}	.031	.025 (.008)	.095	.094 (.013)	.265	.260 (.022)	.288	.284 (.027)	.201	.197 (.030)
θ_N	.006	.028 (.012)	.006	.028 (.013)	.040	.062 (.018)	.126	.146 (.028)	.299	.314 (.040)
θ_F	.010	.012 (.010)	.047	.046 (.016)	.187	.183 (.272)	.343	.336 (.037)	.371	.363 (.048)
θ_K	.940	.922 (.031)	.869	.832 (.059)	.404	.429 (.093)	.030	.072 (.059)	.122	.113 (.037)
θ_{f2}	.999	.693 (.400)	.727	.709 (.246)	.585	.586 (.132)	.510	.511 (.103)	.605	.608 (.118)
θ_{y*}	.241	.401 (.200)	.186	.584 (.195)	.229	.249 (.097)	.284	.315 (.061)	.334	.268 (.042)
θ_y	.716	.508 (.069)	.426	.440 (.111)	.414	.435 (.073)	.512	.510 (.057)	.562	.591 (.074)
$\theta_{y'}$	.888	.908 (.135)	.793	.776 (.086)	.903	.798 (.051)	.800	.800 (.056)	.575	.582 (.086)
θ_L	.474	.474 (.184)	.639	.646 (.069)	.743	.748 (.041)	.898	.905 (.030)	.902	.909 (.043)
θ_a	.605	.608 (.142)	.666	.676 (.117)	.198	.217 (.048)	.081	.091 (.021)	.081	.089 (.020)
$\theta_{a'}$	.093	.332 (.235)	.093	.474 (.281)	.297	.238 (.135)	.297	.261 (.084)	.087	.097 (.045)
θ_b	.999	.543 (.134)	.623	.551 (.188)	.315	.355 (.098)	.081	.164 (.053)	.038	.063 (.081)
$\theta_{b'}$	.808	.512 (.127)	.475	.503 (.132)	.364	.426 (.114)	.107	.081 (.068)	.087	.123 (.107)
P(coh)		.994		.911		.850		.640		.571

The results from Experiment 4 indicate changes in the four fundamental memory states as a function of the five retention intervals. The dynamics of the parameters as a function of the retention interval are shown in Figure 20.

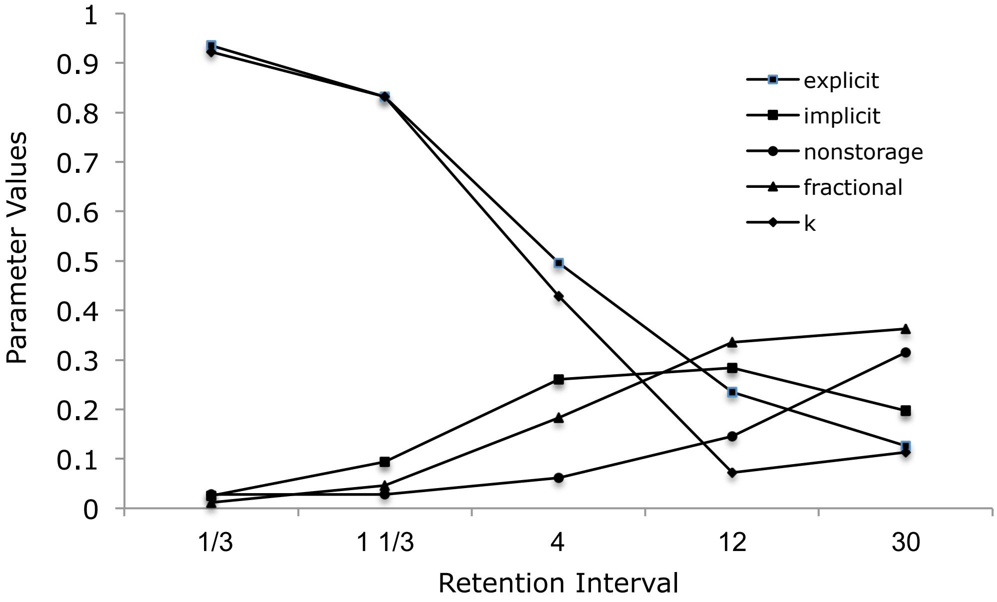


Figure 20. The four fundamental memory states as well as the θ_k parameter as a function of retention interval in Experiment 4.

The results of the Bayesian test of differences are listed in Table 21. There is a highly reliable difference between each of the retention intervals for the explicit memory parameter, θ_{se}. In fact, the posterior probability distributions are non-overlapping, for any of the retention intervals, which means that the probability of a difference exceeds .99. As would be expected, there is also an increase in fractional storage and non-storage across the retention interval. In both cases, there is no overlap when comparing the Bayesian posterior distributions between the shortest and longest retention interval, indicating a highly reliable probability of a difference in fractional storage as well as non-storage as a function of retention interval.

Table 21.

Table of Bayesian tests of differences for each parameter over all three lag conditions in Experiment 4. If the test of differences is above .95, then it is considered that there is a high probability of a difference. In these cases, the results are in bold.

			Lag			
Parameter			1/3	1-1/3	4	12
θ_{se}	1/3 = .935	1/3	---			
	1-1/3 = .832	1-1/3	**.999**	---		
	4 = .495	4	**.999**	**.999**	---	
	12 = .235	12	**.999**	**.999**	**.999**	---
	30 = .126	30	**.999**	**.999**	**.999**	**.999**
θ_{si}	1/3 = .025	1/3	---			
	1-1/3 = .094	1-1/3	**.999**	---		
	4 = .260	4	**.999**	**.999**	---	
	12 = .284	12	**.999**	**.999**	.701	---
	30 = .197	30	**.999**	**.999**	.940	**.999**
θ_N	1/3 = .028	1/3	---			
	1-1/3 = 028	1-1/3	.380	---		
	4 = .062	4	.909	.907	---	
	12 = .146	12	**.999**	**.999**	**.992**	---
	30 = .314	30	**.999**	**.999**	**.999**	**.999**
θ_F	1/3 = .012	1/3	---			
	1-1/3 = .046	1-1/3	.936	---		
	4 = .183	4	**.999**	**.999**	---	
	12 = .336	12	**.999**	**.999**	**.999**	---
	30 = .363	30	**.999**	**.999**	**.999**	.646
θ_K	1/3 = .922	1/3	---			
	1-1/3 = .832	1-1/3	**.966**	---		
	4 = .429	4	**.999**	**.992**	---	
	12 = .072	12	**.999**	**.999**	**.989**	---
	30 = .113	30	**.999**	**.999**	**.986**	.690
θ_L	1/3 = .474	1/3	---			
	1-1/3 = .646	1-1/3	.929	---		
	4 = .748	4	.927	.886	---	
	12 = .905	12	**.968**	**.999**	**.998**	---
	30 = .909	30	**.968**	**.998**	**.994**	.491
$\theta_{v'}$	1/3 = .908	1/3	---			
	1-1/3 = .776	1-1/3	.809	---		
	4 = .789	4	.636	.877	---	
	12 = .800	12	.795	.575	.886	---
	30 = .582	30	**.952**	.941	**.998**	**.981**
θ_{v*}	1/3 = .401	1/3	---			
	1-1/3 = .584	1-1/3	.736	---		
	4 = .249	4	.723	.925	---	

	12 = .315	12	.618	.886	.697	---
	30 = .268	30	.699	.927	.560	.712
θ_v	1/3 = .508	1/3	---			
	1-1/3 = .440	1-1/3	.463	---		
	4 = .435	4	.774	.556	---	
	12 = .510	12	.468	.307	.771	---
	30 = .591	30	.813	.882	.928	.793
θ_{f2}	1/3 = .693	1/3	---			
	1-1/3 = .709	1-1/3	.372	---		
	4 = .586	4	.676	.681	---	
	12 = .511	12	.705	.770	.666	---
	30 = .608	30	.669	.659	.534	.720
θ_a	1/3 = .608	1/3	---			
	1-1/3 = .676	1-1/3	.631	---		
	4 = .217	4	**.995**	**.999**	---	
	12 = .091	12	**.999**	**.999**	**.996**	---
	30 = .089	30	**.999**	**.999**	**.997**	.453
$\theta_{a'}$	1/3 = .332	1/3	---			
	1-1/3 = .474	1-1/3	.641	---		
	4 = .238	4	.590	.739	---	
	12 = .261	12	.544	.713	.575	---
	30 = .097	30	.808	.891	.824	**.951**
θ_b	1/3 = .543	1/3	---			
	1-1/3 = .551	1-1/3	.324	---		
	4 = .355	4	.893	.845	---	
	12 = .164	12	**.996**	**.963**	**.957**	---
	30 = .063	30	**.973**	**.961**	**.971**	.944
$\theta_{b'}$	1/3 = .512	1/3	---			
	1-1/3 = .503	1-1/3	.303	---		
	4 = .426	4	.709	.674	---	
	12 = .081	12	**.983**	**.989**	**.993**	---
	30 = .123	30	**.955**	**.962**	**.959**	.588

There is also a reliable difference between each of the retention intervals for implicit memory. Rather than being a monotonically decreasing retention interval, however, the shape of the retention interval for implicit memory rises to a point, and then decreases, following an inverted-u shape. In this case, implicit memory increases as retention interval increases from a lag of 1/3 of a second to 12 seconds. Implicit memory peaks at 12 seconds and then decreases again at 30 seconds.

In the first two experiments, θ_k was estimated to be a very small value. In the Brown-Peterson design, a single to-be-remembered item was presented followed by a shadowing distracter task to limit rehearsal. Additionally, the foils in the target-present trials shared some information with the target item. Despite these two experimental features, it was still assumed that participants had some item information to be able to reject correctly one or two of the foil items. Supporting this assumption, the value for θ_k was close to 1 in the shortest retention interval indicating that participants could easily reject one or two of the foil items. The value for θ_k decreased reliably across the retention interval. At the shortest interval θ_k was equal to 0.922, and decreased to 0.072 at the lag 12 condition. There was an increase at the lag of 30 condition, however this increase is not reliable.

Finally, the data were analyzed in terms of the Two-Trace Hazard Model (Chechile, 2006) to address if the inverted-u function exists, and if so, where in the memory function hazard peaks before it begins to decrease. For this analysis, the explicit storage parameters for each of the five retention intervals were input into the following equation:

$$u(t) = \frac{1-\theta_{se}}{t} \tag{8}$$

In equation 8, *t* is equal to the time at which the testing occurred, inclusive of the presentation time of the prompt. Thus, for the 1/3-second retention interval, *t* would be equal to one second plus 1/3 of a second, or 1333 ms. The results for the 1/3, 1 1/3, 4, 12, and 30 second retention intervals are 0.049, 0.072, 0.101, 0.059, and 0.028, respectively. As can be clearly seen from this analysis, there is a peak in the function, at the 4-second retention interval.

If the function were monotonically decreasing, it would peak at a time equal to 0, but instead we see the function peaking at a time of 5 seconds (equal to the 4-second retention interval, plus 1 second for the test-probe presentation). As with the other evidence in the Chechile (2006) paper, these reults indicate that the memory hazard for the explicit memory component cannot be monotonically decreasing.

Discussion

Experiment 4 provided valuable insight into both the function of implicit memory over the very short term, and provided evidence for the Two-Trace Hazard Function based on the existence of a biphasic, inverted-U hazard memory function. Perhaps the most exciting result in this experiment is that implicit memory increased across the retention interval. It seems implausible, that after learning a memory item, it would appear at a later time in the implicit system, without a method of entering the substorage space. Thus, the implicit memory store must be being fed from somewhere else, and the most likely, if not the only explanation, is that the measurement of implicit memory rises because of degradation in the quality, or strength, of the memories housed in the explicit subsystem. As was addressed in Experiments 1 and 2, there is a constant interaction of the four memory types and each lower-strength encoded memory type is being fed by one of the other higher-order memory types. It is likely that memories are not lost all together when they exit the state of explicit memory, but instead degrade down to a less encoded state. This hypothesis is supported by the findings that implicit memory rose over the retention interval.

A very important implication of these results is on the dual-process theory of memory purported by Yonelinas (1994). If the memory systems were separate, how might it be explained that the proportion of memories stored implicitly increases within the first few seconds of the experiment. In past experiments, the sparing of the implicit system even in the presence of loss in the explicit system supported the separate memory system theories. The multiple systems theory, however, cannot account for why there exists an increase in implicit memory. Instead, a single memory system approach whereby a memory degrades from being more strongly encoded in the explicit state to a more weakly encoded memory in an implicit or fractional state can account for these results. This explains why explicit memory degrades across the lifetime of the retention interval, why implicit memory rises, and then falls, and why there is a monotonic increase in non-storage and fractional storage. Furthermore, increasing implicit memory is not likely due to design flaws within the experiment, as the design of the study mitigates any possible confounds. The triads used as study materials were carefully examined to be within a small range of frequency on the norm from which they came, and every trial was randomly presented to participants. Thus, the implicit memory increase may not be accounted for by the items being tested, or the order of items presented to participants.

Unlike experiments 1 and 2, an interesting pattern of results emerged with the θ_k parameter. In distinction from the first two experiments, the third experiment presented participants with one to-be-remembered item, and then tested that single item. Thus, if participants remembered the item, they should have an easy time rejecting any foil that was not the to-be-remembered stimulus, as θ_k is a measurement of the item knowledge in target-absent trials. In fact, if a participant has explicit knowledge of an item, and thus is able to reject foil items, then the θ_k parameter would be similar to the explicit parameter. This is precisely what was observed in Experiment 4. The θ_k parameter decreased with increasing retention interval, which provides another reason to use the Brown-Peterson paradigm to test the IES model.

Finally, Experiment 4 provided proof that the Two-Trace Hazard Model (Chechile, 2006) has peak-shaped hazard. This analysis was done on the grouped data, as opposed to an individual subject analysis of the retention interval, because Chechile (2006) argued that accuracy increases when performing the analysis on the group data, as opposed to individual data. Because there existed a peak in the hazard function, any memory model described by decreasing or constant hazard cannot accurately describe these data. Instead, only memory models with peaked-hazard can describe the data. In combination with the results of the long-term memory analysis from Experiment 3, these combined data sets support the Two-Trace Hazard Model as it can adequately describe data in the very long-term, as well as be described by data with a peaked-shape hazard function. In addition, the IES model accurately computes the values for the four fundamental memory states, and these storage estimates fit the Two-Trace Hazard Model parameters.

Experiment 5

It is a general belief that memory performance decreases with age. Our memory faculties worsen, and people perform less well on tasks directed at memory assessment. The common belief is that the major detriment to memory in healthy older adults occurs in explicit memory (Nilsson, 2003). Craik and McDowd (1987) concluded that recall failure is more pronounced in the elderly because it requires more cognitive resources. Furthermore, this trend may worsen with age. When testing the task of three-letter recall Chandler, Lacritz, Cicerello, Chapman, Honig, Weiner, and Callum (2004) discovered that although memory-impaired participants performed the worst of the groups tested, younger healthy elderly adults (below 75 years of age) performed significantly better than older healthy elderly adults (those adults over 75 years of age). Hultsch, Hertzog, Small, McDonald-Miszczak, and Dixon (1992) conducted a longitudinal study that tested elderly participants over a period of three years. They measured an overall significant decrease in verbal working memory, general knowledge and verbal fluency scores.

An interesting dissociation within the explicit system exists in the elderly. Although the elderly perform worse at tests of recall than younger adults, memory recognition remains relatively more stable across the lifespan (Zelinski & Burnight, 1997). This discrepancy between recall and recognition tasks may be explained by task complexity, such that as the complexity of a task rises, the processing demands rise resulting in a greater age difference (Craik & McDowd, 1987; Hess, 2005). In a 16-year longitudinal study, Zelinski and Burnight (1997) discovered that recall of lists as well as text recall decreased with age, however the researchers found little difference in performance on recognition tasks. Craik and McDowd (1987) also discovered older adults performed less well on cued recall. Subjects enrolled in the Craik and McDowd (1987) study also completed a reaction time task, and as the complexity of the secondary task increased, the performance on cued-recall decreased. An opposing pattern of results occurred with recognition memory indicating that older adults performed equally well as younger adults when assessed in this manner. An interaction effect between the age of participants and recall and recognition test types existed; younger adults performed better than older adults on recall, and older adults performed better when compared to younger adults on recognition (Craik & McDowd, 1987). Although recognition is considered a task of explicit memory because it requires active searching of material presented during encoding, direct tests of recognition may be highly contaminated by implicit processes, as discussed earlier in this introduction in the critique of the process-purity literature. Although both types of memory are considered explicit, the conclusions drawn from the elderly population are that recognition memory is invariant to aging in comparison to recall memory.

Implicit memory tends to remain stable throughout the lifespan (Nilsson, 2003), although not all empirical evidence and researchers support this conclusion. It may be possible that age-related invariance, when present, is likely due to the simplicity of stimuli within the experimental design (Toth & Parks, 2006). The majority of implicit memory tests conducted on the elderly have dealt with priming, and these results suggest priming does not differ significantly from younger subjects (Schugens, Daum, Spindler, & Birbaumer, 1997). Non-priming indirect tasks, or non-priming tests of implicit memory, do not show the same pattern. Hasher and Zacks (1998) discovered that older adults had similarly primed responses as younger adults when the targets, in this case sentences in working memory, were short and easily accessible. Schugens et al. (1997) tested differences in implicit memory by employing a word-stem completion task and a mirror-reading test. Although the results indicated a decline in word-stem completion as a function of age, this difference was not significant. Furthermore, there was no difference in skill acquisition across the age groups.

In healthy younger adults the effect of retention on implicit memory differs based on the approach taken, be it a process-purity approach, or process dissociation approach. In general, task-specific implicit tests indicate that implicit memory would decrease across the retention interval (Roediger, Weldon, Stadler, & Riegler, 1992; Sloman, Hayman, Ohta, Law, & Tulving, 1988). McBride & Dosher (1999) and Stolz and Merikle (2000) used the process-dissociation procedure to analyze retention interval on explicit and implicit processes. While the retention intervals used in these two studies differed temporally, the researcher's conclusions differed. McBride and Dosher (1999) found that automatic processes decreased across lag, whereas Stolz and Merikle (2000) tested participants from 2 minutes to 2 weeks and found an increase in the implicit component from 2 minutes to 2 days, but then a stable amount of implicit involvement.

Two theories of the detriment in recollection in older adults are posited. The dual-process view of memory, as described by Yonelinas (1994), suggests that older adults do not use available contextual information, and thus do not encode information as deeply. When the contextual information is used, older adults have an increase in their values of recollection (Hay & Jacoby, 1999). On the other hand, Hasher and Zacks (1988) forward the inhibitory hypothesis that suggests older adults have trouble inhibiting unimportant information.

The process dissociation procedure has been used in a number of experiments with the elderly. Overall, the results indicate that in aging populations, controlled processes decrease while the implicit component is invariant to age and experimental manipulation. Jennings and Jacoby (1993) utilized a false fame procedure by asking participants to identify names as either famous or non-famous. In the inclusion condition participants were told the names on an original learning list were famous and on the exclusion condition researchers informed participants that all names on the list were non-famous. The results from this experimental paradigm indicated that older adults had lower rates of conscious processes, but equal levels of familiarity as the younger adults.

In a study by Jacoby and Jennings (1997), the researchers presented lists of words to participants and performed a standard task dissociation recognition test and analyzed memory through the process dissociation procedure. Participants studied a list of words and then were given a test where they had to deem words as new or old. The words on the test were either presented once, or repeated with various intervening lags. Participants were instructed to say an item was "old" only if it was on the original list. Any words repeated during testing were considered a repetition error if the participants answered that they were "old" when in fact they were not on the first list. Jacoby and Jennings (1997) analyzed what they deemed repetition errors, or saying "yes" to an item as being "old" when it did not qualify as "old". The results showed that recollection in both standard tests as well as process dissociation tests was markedly worse in older adults; however the rates of automatic processes, or familiarity, remained the same between older and younger adults. In fact, the results indicated that younger and older adults had an equal estimated proportion of familiarity at the shorter retention interval

(.64 and .67, respectively) and only a slight difference in the proportion of familiarity at longer retention intervals (.66 and .74, respectively). Thus, Jennings and Jacoby (1997) concluded that familiarity, or unconscious processes are invariant with age. Furthermore, elderly participants had decreased recollection in every lag condition, and this decrease emerged immediately (after only four repetitions) so that participants declined maximally at the shortest lags (Jennings & Jacoby, 1997). These results showed that memory impairment occurred in the older adults almost immediately after encoding.

Similar to Jennings and Jacoby (1997), Hay and Jacoby (1999) used homographs paired with more or less common word associations (e.g., organ-music and organ-heart). While age was invariant to automatic processes, or the implicit component, age negatively affected recollection. Based on practice trials, Hay and Jacoby (1999) commented on the speed by which younger adults, as opposed to older adults, may learn habit or implicit responses. Because there was an increase in the ability of younger adults to use the contextual information from the uncommon response, Hay and Jacoby (1999) concluded that the recollection of older adults is worsened due to an inability to use richer encoding strategies to support recollection.

If the controlled processes of recollection as well as a faster support process of familiarity boost explicit memory, older adults may have trouble suppressing the automatic process of familiarity. Age related differences could clearly be detected on tasks that rely solely on recollection when familiarity leads to incorrect responses, as compared to scenarios where familiarity and recollective processes lead to the same response (Hay & Jacoby, 1997).

A story has emerged about the depletion of the explicit memory system with aging as well as the invariance of the implicit system. To date, research has been conducted with techniques that have not allowed for the testing of the four fundamental memory types used in the IES model. Testing of memory changes in the elderly would be more appropriate with the use of the IES model. Experiment 5 will replicate Experiment 2 but with elderly participants in order to measure the involvement of the underlying processes of explicit and implicit memory.

Methods

Participants

Experiment 5 was a replication of Experiment 2, with a different study population. Instead of undergraduate psychology students, Experiment 5 enrolled 31 participants from an elderly subject pool in order to compare the memory retention of older and younger adults. The average age of the participants was 75.7 years (sd = 7.3) Of the 31 participants, 24 were female and 7 were male. The average MMSE score was 28.3 (see Results for further details). With the exception of the one participant who scored a 24, all participants had MMSE scores considered within the normal range, which is between 25 and 30. Participants were compensated for their time at a rate of 15 dollars per hour. The participants were chosen from a participant pool of elderly adults who have previously agreed to be involved in research at Tufts University. The participant pool from which the older adults were recruited is overseen by Dr. Ayanna Thomas and is updated through targeted mailings and newspaper advertisements. The pool is comprised of community dwelling senior citizens. Each member of the pool has completed a battery of cognitive tests as well as provided medical and medication histories. Members of the pool have no cognitive or health disorders which would affect their participation. All participants are able to provide informed consent and all must be able to travel to the testing site on their own. Age and medication history are available for every participant who is a member of the pool, although this information was not used for analysis.

Design and Materials

The design and materials of Experiment 5 were the same as Experiment 2, with a few minor changes. Instead of instructing participants to enter the words on the keyboard as they appeared, participants were asked to read the word aloud. The participants were instructed to remember the words for future memory tests, and to use whatever encoding strategies they thought fit in order to best remember the target information.

Procedure

The procedure of Experiment 5 was similar to Experiment 2, as well. Participants were assigned specific times for arrival at the computer testing site. All participants were tested in the same laboratory on the Tufts University campus. Upon arrival, participants were seated at a computer and provided a consent form. After signing the consent, participants were given the Mini-Mental Status Examination (Folstein, Folstein, & McHugh, 1975), which is a 30-point assessment of general global funtioning such as memory, orientation, and language. The test is a quick means of assessing cognitive abilities, and any score over 25 is constituted as cognitively unimpaired. Once the participants were ready, and had a chance to ask any questions they may have had, the researchers began the computer program. Participants were presented with 12 lists of 14 words, separated by an "X" and asked to read aloud the words presented on the computer screen as they appeared. During testing, participants were provided eight target-present and six target-absent trials, which followed the guidelines of the task of the IES model. Upon completion of the experiment, participants were thanked, and paid for their time.

Results

Before running the experiment, each of the participants enrolled in Experiment 5 completed a brief cognitive inventory, the Mini-Mental Status Exam (Folstein, et al., 1975), the results of which can be found in Table 22. The average score on the MMSE of 28.29 (*SD* = 1.68) was well within the normal range. In fact, any score over 25 is considered to be within the normal age. The maximum score was 30 out of a total possible score of 30. Every participant scored in the normal range, with the exception of one participant who scored 24. For this participant, three out of six of the points missed on the MMSE were memory-related. This individual remembered zero of the three words presented in the MMSE.

Table 22.
MMSE and age results for participants enrolled in Experiment 5.

	Male	Female	Total
N	7	24	31
MMSE (*SD)*	28.14 (1.68)	28.33 (1.71)	28.29 (1.68)
Age (*SD)*	78 (6.90)	75.04 (7.35)	75.71 (7.25)

After completion of the experiment, raw data from each of the 31 individuals were collated for each of the 20 cells within the IES model. The pooled raw data for each of the 20 cells of the IES model can be found in Table 23, and the data for each individual participant can be found in Appendix C. Each individual took, on average, 47 minutes to complete the experiment. The average time for each item presentation was 3 seconds, and each testing trial was 12.5 seconds, so that the average time between learning and testing was 60 seconds for a lag of 0, 3.91 minutes for a lag of 1, 15.64 minutes for a lag of 4, and 35.19 minutes for a lag of 9.

Table 23.
The following lists the pooled number of responses for all 31 participants in Experiment 5. The data are sorted by the response in the Yes/No task and accompanying confidence rating. Each response pattern is then separated by whether the participant was correct on the 4-, 3-, or 2-AFC task. Finally, the 20 response cells are listed for each of the three retention intervals. In addition, the pooled values for the $0^{(-)}$ *condition is listed.*

	4AFC				3AFC				2AFC				Incorrect				Foils			
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
0	168	15	158	59	21	8	66	70	10	7	48	45	11	4	22	31	57	250	208	43
1	163	7	169	73	18	9	65	46	10	9	48	39	6	5	36	41	44	184	262	68
4	116	19	146	100	22	13	69	56	12	7	50	41	9	12	31	41	51	203	247	57
9	81	15	154	82	14	19	72	50	10	11	67	61	4	9	55	40	40	215	243	60
$0^{(-)}$	109	7	104	42	14	5	51	44	6	4	30	29	10	3	15	23	21	175	149	27

Table 24 provides the probabilities of having correctly said "yes" to a target-present trial with high confidence, as well as with low confidence. Similar to Experiment 1, 2, and 3, participants have a higher accuracy of being correct with high confidence than with low confidence; as confidence lowers, so does the probability of providing a correct response. The same pattern is seen when the participants respond to target-absent trials. Table 25 provides the accuracy of being correct on the 4AFC task after each possible response on the yes/no recognition trial: either saying yes or no with high or low confidence. Similar to Experiments 1, 2, and 3, older adults are most likely to be correct on a 4AFC task following a "yes" response made with high confidence, then with low confidence. As their confidence decreases, so does their ability to recognize correctly a to-be-remembered item in a 4AFC task. Furthermore, this tendency decreases as the retention interval increases. Unlike younger adults, older adults were more likely to be correct after a high confidence response in the 1 retention than the 0 retention interval. This may be a product of older adults' lower than expected performance in the 0 condition as will be explained later.

Table 24.
The following are conditional responses for Experiment 5 for each of the four lag conditions. These are the probabilities of a correct responses to target-present or target-absent trials given either high or low confidence.

Retention	Target Present		Target Absent	
	P(hi conf correct)	P(lo conf correct)	P(hi conf correct)	P(lo conf correct)
0	0.861	0.588	0.570	0.546
1	0.868	0.615	0.393	0.413
4	0.757	0.554	0.472	0.451
9	0.669	0.599	0.400	0.469

Table 25.
Conditional probabilities for a correct response on the 4AFC following a high or low confidence for each of the lag conditions in Experiment 5.

Retention interval	P(4AFC, hi)	P(4AFC, lo)
0	0.800	0.537
1	0.827	0.531
4	0.730	0.493
9	0.743	0.443

The pooled values for each of the 20 cells of the IES model were input into a computer-modeling program, which then estimated the values for each of the parameters of the IES model. Table 26 contains the parameter estimates based on the PPM and MLE methods as well as the P(coh) values and standard deviations for the PPM values.

Table 26.
The following table provides the parameter estimates for each of the 14 parameters in the IES model in Experiment 1. The MLE and PPM estimates are provided. The standard deviation and the coherence values are also listed for the PPM estimates. The values are listed as a function of retention interval. The results for the $0^{(-)}$ *interval are also listed.*

	Retention Interval									
Parameter	$0^{(-)}$		0		1		4		9	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.193	.184 (.021)	.199	.193 (.017)	.196	.191 (.016)	.127	.122 (.146)	.092	.088 (.012)
θ_{si}	.106	.105 (.031)	.117	.116 (.025)	.172	.170 (.024)	.170	.169 (.025)	.145	.145 (.026)
θ_N	.411	.429 (.054)	.371	.384 (.043)	.473	.484 (.047)	.500	.511 (.048)	.581	.590 (.051)
θ_F	.290	.282 (.062)	.313	.306 (.049)	.159	.156 (.505)	.203	.199 (.053)	.181	.177 (.055)
θ_K	.020	.024 (.022)	.020	.025 (.021)	.020	.026 (.021)	.001	.116 (.005)	.009	.010 (.014)
θ_{f2}	.625	.635 (.191)	.472	.476 (.143)	.542	.557 (.266)	.662	.670 (.218)	.089	.160 (.195)
θ_{y*}	.543	.514 (.049)	.543	.503 (.044)	.543	.498 (.040)	.531	.462 (.035)	.537	.542 (.044)
θ_y	.599	.573 (.094)	.555	.549 (.077)	.709	.620 (.135)	.636	.581 (.053)	.555	.516 (.133)
$\theta_{y'}$	.999	.954 (.071)	.999	.988 (.032)	.793	.831 (.072)	.622	.663 (.077)	.752	.742 (.082)
θ_L	.963	.964 (.055)	.928	.922 (.055)	.999	.997 (.009)	.962	.981 (.032)	.999	.989 (.024)
θ_a	.198	.221 (.197)	.198	.209 (.015)	.192	.190 (.012)	.192	.198 (.013)	.186	.180 (.011)
$\theta_{a'}$	.149	.146 (.063)	.149	.135 (.054)	.149	.129 (.048)	.180	.233 (.049)	.167	.194 (.053)
θ_b	.210	.283 (.138)	.241	.282 (.089)	.229	.366 (.141)	.291	.419 (.115)	.056	.200 (.172)
$\theta_{b'}$	.063	.188 (.186)	.093	.110 (.100)	.204	.432 (.234)	.260	.364 (.199)	.371	.530 (.254)
P(coh)		.768		.752		.767		.410		.957

Pair-wise comparisons of each parameter for all four retention intervals were completed in order to ascertain the differences of each of the parameters across the retention interval. The results can be found in Table 27. The same Bayesian test of hypothesis was used for all of the following analyses.

Table 27.

Table of Bayesian tests of differences for each parameter over all three lag conditions in Experiment 5. If the test of differences is above .95, then it is considered that there is a high probability of a difference. In these cases, the results are in bold.

			Lag		
Parameter			0	1	4
θ_{se}	0 = .193	0	---		
	1 = .191	1	.451	---	
	4 = .122	4	**.997**	**.998**	---
	9 = .088	9	**.999**	**.999**	**.961**
θ_{si}	0 = .116	0	---		
	1 = .170	1	.934	---	
	4 = .169	4	.922	.465	---
	9 = .145	9	.794	.695	.672
θ_N	0 = .384	0	---		
	1 = .484	1	.924	---	
	4 = .511	4	.943	.532	---
	9 = .590	9	**.997**	.903	.875
θ_F	0 = .306	0	---		
	1 = .156	1	**.982**	---	
	4 = .199	4	.883	.779	---
	9 = .177	9	.940	.644	.622
θ_K	0 = .025	0	---		
	1 = .026	1	.645	---	
	4 = .116	4	.807	.587	---
	9 = .010	9	.786	.557	.190
θ_L	0 = .922	0	---		
	1 = .997	1	.858	---	
	4 = .981	4	.756	.429	---
	9 = .989	9	.827	.218	.398
$\theta_{y'}$	0 = .988	0	---		
	1 = .831	1	.949	---	
	4 = .663	4	**.999**	**.955**	---
	9 = .742	9	.987	.802	.759
θ_{y*}	0 = .503	0	---		
	1 = .498	1	.771	---	
	4 = .462	4	.498	.845	---
	9 = .542	9	.822	.584	.876
θ_y	0 = .549	0	---		
	1 = .620	1	.548	---	

	4 = .581	4	.508	.443	---
	9 = .516	9	.663	686	.657
θ_{f2}	0 = .476	0	---		
	1 = .557	1	.560	---	
	4 = .67	4	.753	.625	---
	9 = .160	9	.845	.813	.923
θ_a	0 = .209	0	---		
	1 = .190	1	.576	---	
	4 = .198	4	.473	.544	---
	9 = .180	9	.509	.653	.546
$\theta_{a'}$	0 = .135	0	---		
	1 = .129	1	.543	---	
	4 = .233	4	.932	.916	---
	9 = .194	9	.806	.761	.726
θ_b	0 = .282	0	---		
	1 = .366	1	.569	---	
	4 = .419	4	.699	.320	---
	9 = .200	9	.732	.729	.796
$\theta_{b'}$	0 = .110	0	---		
	1 = .432	1	.846	---	
	4 = .364	4	.703	.540	---
	9 = .530	9	.920	.510	.649

Explicit memory decreased monotonically across the retention interval. The values of explicit storage for the 0, 1, 4, and 9 retention intervals were .19, .10, .12, and .09, respectively. By the retention interval of 9, participants remembered half as many items than what was explicitly stored in the immediate retention interval. The difference between the 0 and 1 retention intervals was not significant (the probability of a difference was .45), however all other comparisons were significant. The probability of a difference between 0 and 4 exceeds .99. The probability of a difference between 0 and 9 exceeds .99. The probability of a difference between 1 and 4 exceeds .99. The probability of a difference between 1 and 9 exceeds .99. Finally, the probability of a difference between 4 and 9 is .96. These significant differences mean that after an initial lack of change in the shorter retention intervals, explicit memory degrades as a function of the longer retention intervals.

By comparison, implicit memory remained much more stable than explicit memory. In fact, none of the pair-wise comparisons were significantly different from any other. Over the retention interval, the values for the 0, 1, 4, and 9 retention intervals were .12, .17, .15, and .11, respectively. There was a trend toward an increase in implicit memory between the 0 and 1 condition. In fact, the probability of an increase from the 0 condition to the 1 condition is .93. The percent of memories stored implicitly were 11.7% at the 0 interval versus 17.2% at the retention interval of 1. After this initial rise, implicit memory remained relatively stable for the remainder of the domain of support.

Similarly, non-storage also remained relatively stable. The only probability of a difference existed in comparing the shortest and the longest retention intervals (.38 to .59

between the 0 and 9 retention intervals, respectively), with a probability of an increase exceeding .99. With that said, non-storage was relatively high even at the onset of the experiment, rising from 37% to 58% of all memories lost throughout the experiment.

The overall pattern in fractional storage was one of loss. Fractional storage fluctuated across the 0, 1, 4, and 9 retention intervals from.31, .16, .20 to .18, respectively, over the retention interval. There was only one comparison with a significant difference, found when comparing the 0 and 1 condition, which had a probability of a difference of .98. There was another probable trend between the 0 and 9 condition, with a probability of a difference of .94. Although this retention interval is not monotonically decreasing due to a non-statistically reliable bounce in the data, fractional storage seemed to begin high, and had an initial drop, after which it remained stable.

Finally, the θ_k parameter, as in Experiments 1 and 2, lacked any significant changes across the retention interval, as it was a negligibly zero at all four intervals. The θ_k parameters for the 0, 1, 4, and 9 retention intervals were .03, .03, .12, and .01, respectively, which indicates that participants were unable to reject any foils based on knowledge about the target item.

The estimates for the 0 and 1 conditions of explicit memory were exactly the same. While we would anticipate a low value even in the zero condition, it is surprising that the zero condition is as low as the one condition. Again, this was surprising based on the design of the study. The experiment was designed, as explained in Experiment 2 so that the first list learned was also the first list tested. Participants saw 14 words and then were immediately tested with 14 test items. Even with degraded explicit storage, it would be assumed that participants would perform better in the 0 condition. During testing observation of participants suggested the experiment was harder than they had expected it to be. Many participants even made post-test comments to the experimenter as to the surprising difficulty. It may be possible that participants performed less well than expected on the first learning/testing trial, which would drive down performance on the overall level of performance in the zero condition. As a result, a separate analysis was performed to estimate the parameters of the IES model with 2, as opposed to 3 iterations of the 0 condition. Based on the outcome the results from the very first list learning/testing session were disregarded, and the new results are listed in the Table 26 as $0^{(-)}$. New comparisons between the parameters were then conducted comparing the $0^{(-)}$ condition and the 1, 4, and 9 conditions. The results are listed in Table 28.

Table 28.
Bayesian comparisons between lags 1, 4, and 9 and the 0’ results for each parameter estimate in Experiment 5.

Parameters		Lag	
Theta	1	4	9
θ_{se}	.638	**.979**	**.999**
θ_{si}	**.955**	.940	.789
θ_{N}	.533	.850	**.965**
θ_{f}	.887	.853	.842
θ_{k}	.444	.599	.550
θ_{L}	.463	.802	.415
$\theta_{y'}$	.907	**.992**	**.965**
θ_{y*}	.483	.787	.517
θ_{y}	.535	.535	.574
θ_{f2}	.623	.646	**.980**
θ_{a}	.862	.790	.947
$\theta_{a'}$	.531	.832	.736
θ_{b}	.600	.757	.584
$\theta_{b'}$	.596	.695	.855

When comparing $0^{(-)}$ to the remainder of the retention intervals, the same pattern of results occurred as with the 0 comparisons; there was no significant difference between $0^{(-)}$ and 1, but there was a significant decrease in explicit memory between $0^{(-)}$ and the 4 and 9 retention intervals. The probabilities of a difference equal .98 and .99, respectively. There were no significant differences in fractional storage, and there was only a difference in non-storage when comparing the $0^{(-)}$ and 9 retention intervals. The probability of a difference is .97. Similarly, the θ_k parameter was non-significant in all the pair-wise comparisons.

While comparing the $0^{(-)}$ retention interval for implicit memory to the other retention intervals, it seems that there was a significant increase in implicit memory from the $0^{(-)}$ condition to the 1 condition, with a probability of a difference of .96, and then a non-significant drop in implicit memory as time increased to the 4 and 9 intervals, indicating a significant rise in implicit memory followed by stability in the implicit parameter across the remainder of the retention interval.

After comparing the results of each retention interval within the older adult population, a Bayesian posterior distribution analysis was conducted to compare older adults to younger adults. The results of all of these pairwise comparisons are listed in Table 29. As a general rule, the values for explicit memory were lower in older adults than in younger adults. The probability of a difference for each retention interval exceeded .99 for the 0, 1, and 9 conditions but was only .89 for the 4 condition. Obviously, the comparison of young and old did not differ at the 4 retention interval. A possible explanation for this result will be discussed shortly.

Table 29.

Comparisons of model estimates between older adults and younger adults. The Bayesian probabilities of a difference, as a function of lag, are listed for each of the 14 parameters. If the Bayesian test proved there was a highly reliable difference between old and young, the numbers (shown in bold) are above .950. For those values that are significant, a + indicates that the younger adults had a significantly higher parameter estimate, whereas a – indicates the younger adults had a significantly lower parameter estimate.

Theta	0	1	4	9
θ_{se}	**.999 +**	**.999 +**	.891	**.989 +**
θ_{si}	**.950 +**	.844	.698	.634
θ_{N}	.765	**.999 -**	**.973 -**	.880
θ_{f}	**.998 -**	.931	.830	.724
θ_{k}	.661	.721	.314	**.979 +**
θ_{L}	.861	**.954**	.333	.729
$\theta_{y'}$	**.997 -**	.708	.575	.493
θ_{y*}	.776	.919	.723	**.979 -**
θ_{y}	.761	.686	**.972 -**	.644
θ_{f2}	**.985 +**	.660	.725	.888
θ_{a}	**.984 -**	**.997 -**	**.997 -**	.456
$\theta_{a'}$	.732	.619	.659	**.973 -**
θ_{b}	.859	.864	.682	.614
$\theta_{b'}$	.873	.891	.642	.608

There was a significant difference in implicit memory only in the zero condition with a probability of a difference of .95. The older adults had a significantly lower implicit memory score at the 0 condition. This is easily explained because memory rose from 0 to 1 in the older adults, more so than it did in the younger adults, and then remained stable (whereas it dropped in younger adults).

Similar to implicit memory, significant differences in fractional storage are only found in the 0 interval. The probability that older adults have a greater level of fractional storage at the 0 retention interval is .99. There is an interaction of age and retention interval. The older adults decrease across the retention interval and younger adults have an increased amount of fractional storage across the retention interval. The quality of encoded information in the two populations will be discussed later.

There was only a significant difference in non-storage in the 1 and 4 retention intervals when comparing younger and older adults. The probability of a difference is .99 and .97, respectively. These results are suggestive of each individual group's rate of memory loss. The dynamics of the parameters as a function of the retention interval are shown in Figure 21.

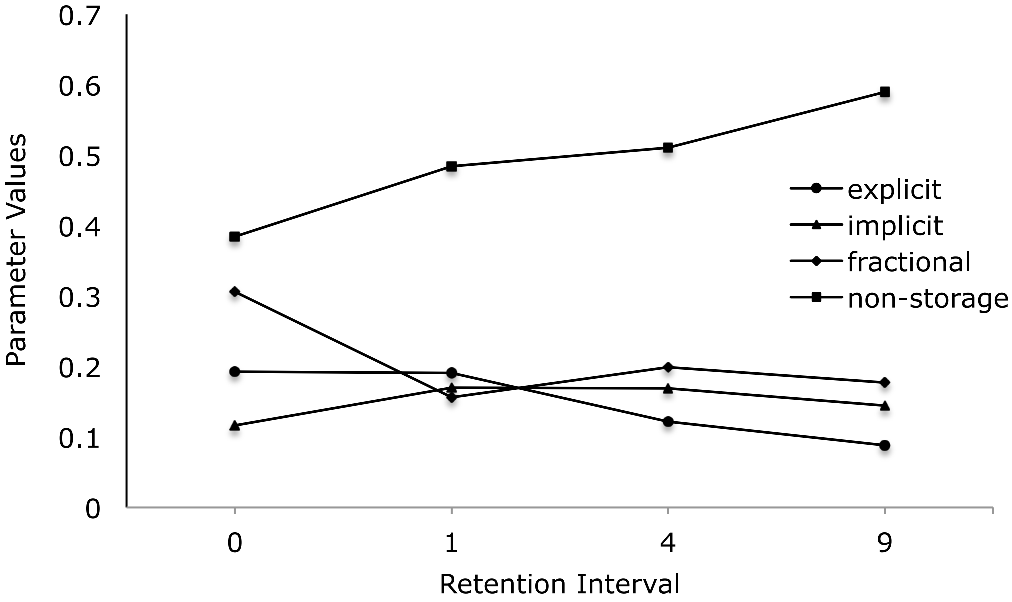


Figure 21. The four fundamental memory states as a function of retention interval in Experiment 5.

In general, older adults are a harder population to study, as there is possibly less consistency among the group members, as opposed to younger group members. Mixtures of subjects (those subjects that do not behave similarly) are not only found in older adults, but in other clinical populations. Chechile (2010) indicated a bonus in coherence when pooling data, even in clinical populations; however, he also described an approach to identify mixtures within groups of clinical populations. If there are sub-groups within the pooled data of participants who act differently in any of the storage parameters, these differences will not be detected when the data are pooled. Additionally, the pooled results will be pulled in a possible abnormal direction as a result of a sub-group of individuals who perform differently than the group. In both these cases, the mean may not be representative of the group as a whole. Thus, in the current experiment a method for analyzing outliers in data, developed off of the jackknife method (Quenouille, 1956; Tukey, 1958), and described in Chechile (2010) was used to identify individual differences in the group data. In this manner, a pseudoscore for each participant (and each parameter) is calculated based on the group score. The pseudoscore was calculated with the following formula:

$$\theta_x^{*i} = N\theta_x(all) - (N-1)\theta_x(without\ i) \tag{9}$$

where x is the parameter of interest, i is the participant for whom the pseudoscore is calculated, and N is the total number of participants in the study. Additionally, $\theta_x(all)$ is the pooled estimates for all the participants, and $\theta_x(without\ i)$ is the pooled estimate for all participants, except for the participant for whom the pseudoscore is being calculated. If and when the pseudoscores are outside of the possible range of 0 to 1, the following steps are applied:

$$\theta_{xi}^{*} = \begin{cases} 1 & \text{if } \theta_{xi}^{*} \geq 1, \\ 0 & \text{if } \theta_{xi}^{*} \leq 0, \\ \theta_{xi}^{*} & \text{otherwise} \end{cases} \tag{10}$$

Once each of the pseudoscores was calculated, frequencies for each parameter were counted, and frequency distributions were generated. The figures for the PPM and MLE estimates for each retention interval of each of the four fundamental memory states, including the θ_k parameter, are all available in Appendix D. From frequency tables, it is possible to see what parameters have participants who behave differently than the majority of the group.

Possible signs of mixtures within the group would be described by a great deal of variability within the distribution, or bimodal distributions, or evidence of any outliers. A bimodal distribution might exist if there were no participants with a pseudoscore equal to the mean of the distribution. Viewing the explicit storage figures, it can be seen that a strange pattern of results may only exist in the 4 retention interval of the MLE data. In this case, there are two participants (participant 15 and participant 21) who were deemed possible outliers as a result of the jackknife method; however these outliers were not present in the PPM method. In the explicit old-young comparisons, the 4 condition was the only non-significant comparison. Perhaps the outliers led to a slightly higher estimate of explicit storage in older adults creating less of a difference among these groups.

If there is any general pattern that can be used to describe explicit memory, it is that the distribution of pseudoscores of the participants is positively skewed. There tends to be a clustering with some variability about the mean, but the mean of all of the scores is in the lower end of the distribution (between .19 and .09 for each condition). The tail to the distribution indicates that not all participants are performing to the point that can be described by the mean.

In the implicit measures, there also existed outliers in the 4 condition in both the MLE and PPM methods of parameter estimation. Again, these pseudoscore outliers were participants 21 and 15, as well as participant 27. For some reason, these participants had high implicit and explicit scores. Perhaps there was a personal response to the word lists that led to deeper encoding. Participants 15 and 21 performed the best of all participants on all measures of explicit memory with the MLE estimates and had close to the lowest scores of implicit memory on all the MLE estimates. Oddly, these same participants scored high on measures of implicit memory with the PPM method of estimation.

In some cases, it seems that the group value is not evidence of any individual differences, which may be indicative of a bimodal distribution. For instance, in the PPM distribution for the 4 retention interval of the non-storage parameter, the actual mean is .5, but only four individuals have pseudoscores around .5, indicating that the mean score may not be indicative of the actual distribution, instead there seems to be two groups whose means are .25 and .75.

The mixture in non-storage becomes more evident with increasing retention. In the case of both the PPM and MLE estimates, there are participants whose pseudoscores are both 0 and 1, which would mean some subjects have 0 items in non-storage and some subjects have 100% of items in non-storage. The figures in Appendix D for non-storage do seem to identify bi-modality in the distribution, indicating that participants are either performing well, or quite poorly, and there are very few participants who perform close to the mean. Remember, the values of non-storage for most of the retention interval remained around 50% of items totally lost to non-storage.

Fractional storage is also an important construct to view with the jackknife method. Younger adults started at a low point and gained fractional storage, whereas older adults started with a higher amount of fractional memories, and lost them with retention. Both the PPM and MLE estimates had a wide range of results in fractional storage similar to that of non-storage. The PPM estimates indicate that the majority of pseudoscores are low with a positive skew. As retention interval increases, the spread of the results becomes greater. In the 4 and 9 conditions, participants have pseudscores in the range of 0 to 1, indicating that the variability in fractional storage increases as the time between presentation and test increases. This is a similar picture as in the MLE estimates.

Participant 24 was the only participant to not score within the normal range on the MMSE. The jackknife method provides a means of discerning this individual's performance throughout the experiment. This participant performed very close to the mean for all retention conditions in explicit memory, and had lower than the average scores on implicit memory. For this participant, fractional storage was again close to the mean for the participant with the lowest MMSE score, and non-storage scores were higher than the average. Because this participant was not constituted as an outlier in any condition, it does not seem necessary to disregard his or her scores based on the low MMSE score. Although the jackknife procedure led to insight about the heterogeneity in the behavior of older participants, there were no participants who were not included in the research based on their results. Instead, this observation confirms what is known about the elderly: they do not perform in a similar fashion to one another, and that there is not necessarily a similar detriment in every participant's memory profile.

Finally, the results for the pooled younger and older adults were analyzed by the Two-Trace Hazard Model to estimate the rate parameters in order to compare the rate of loss of explicit memory for older and younger adults. Based on the assumption that all memories will eventually be lost, and thus setting the *b* parameter to 1, the following equation was used to estimate *c* and consequently *a:*

$$F(t) = [1 - exp(-at^c)] \tag{11}$$

The younger adults had an estimated *c* parameter of 0.22 and the older adults had an estimated *c* parameter of .19. These numbers are essentially the same and indicate that at least one of the two rate parameters was invariant to age. However, the *a* parameter was then calculated for each of the groups, resulting in an estimate of 0.37 for the younger adults and 0.61 for the older adults. A larger *a* parameter indicates a steeper drop to the asymptote as defined by the *b* parameter. Thus, the rate of loss of memories, or the approach to all memories being lost over time is almost twice as fast in the older adults as it is in younger adults. The major difference in the younger and older adults is the rate of loss described by the *a* parameter which describes loss within the first second after encoding. Thus, if memories remain despite this initial first few moments of susceptibility to loss they very likely will result in a more durable memory trace.

Experiment 5 indicates that while older adults store a smaller amount of memories, overall, those memories that do become encoded, either through increased encoding strategies, or due to better semantic encoding, are more likely to stay encoded. In older adults it appears that it is more difficult to encode information, but once that information is thoroughly encoded, it remains more stable to future loss.

Discussion

Experiment 5 was an exact replication of Experiment 2 but involved a normal elderly population as opposed to college-aged students. In general, the older adults tended to perform less well in regards to the four fundamental memory states. There was a difference in performance with explicit memory. Of interest, however, is how the older adults perform in terms of implicit memory.

A general thought based on research in the process-purity and process-dissociation areas is that implicit memory is spared in older adults, even when explicit memory begins to degrade. The results from Experiment 5, in general, are in agreement with this notion. Although performance was lower in explicit memory in the elderly population in Experiment 5 than the college-aged students in Experiment 2, what was seen was a more stable level of performance, at least at the shorter retention intervals. Older adults performed more similarly across the retention intervals, whereas the younger adults had a greater decrease in explicit and implicit memory. It can be concluded from these results that when to-be-remembered information makes it past the first chance for loss, it does so because it is encoded more strongly, and thus the information remains stored explicitly. This conclusion supports previous results that suggest that older adults try harder on tasks when they are explicitly directed to take advantage of available encoding techniques, and when this happens the recollective component is invariant with respect to age (Hay & Jacoby, 1999).

Explicit memory in older adults degrades quite fast in the immediate time after encoding. This finding concurs with previous research (Jennings & Jacoby, 1997), which found the largest changes in memory retention in recollection to be at the shorter retention intervals. Whereas Jennings and Jacoby (1997) concluded that after an initial drop, explicit memory seemed to level out, the results from Experiment 5 indicate there is still a level of loss that is statistically reliable when comparing the longer retention intervals. Additionally, the larger *a* parameter supports the initial first drop in explicit memory observed by Hay and Jacoby (1999). There were reliable differences in explicit memory between older and younger adults, and the proportion of items lost was equal to the proportion of items lost in younger adults. Both younger and older adults lost about half of the explicit memories as a function of retention interval. The younger adults initially retained 38% of items and after a retention interval of 9, remembered only 17% of them explicitly. Older adults started with a lower level of explicit memory, at 19% but after a retention interval of 9 remembered less than 9% of items.

With this pattern of results in explicit memory in older adults, it is impressive that there was not a substantial difference in implicit memory. As has been discussed in this research so far, as explicit memories are lost, they are feeding into the lower memory systems including implicit memory. This initial loss may lead to increased implicit memory between the 0 and 1 condition. While implicit memory degrades, those items that were initially stored within it degrade to fractional or non-storage, while at the same time implicit memory is also being fed by the explicit system. This interaction between the four memory sub-systems supports a unified memory system. The younger adults start with a much higher level of explicit memory at 37% whereas the older adults begin with only 19% of items explicitly stored. The younger adults have a more drastic rate of loss from the 0 to 4 intervals to the point where they no longer retain a significantly different number of items stored explicitly between intervals 4 and 9. The younger adults continue to lose explicit memories. By the 9 interval younger and older adults have lost a proportionally similar amount of items, although the younger adults still remember a reliably larger number of items. In both the younger and older adults, the proportion of loss is about the same, but the base rate from which the older adults have to work is lower, and the rate of loss in the older adults is slower. The younger adults change from .37 to .14 whereas the older adults change from 0.19 to 0.09.

These results indicate that there really is a savings of implicit memory, which is in agreement with the previous literature (Nilsson, 2003). With that said that there is a fairly substantial gain of implicit memories in the very early stages of implicit memory in older adults, which refutes the data of McBride and Dosher (1999) and supports that of Stolz and Merikle (2000). And while this loss may not be statistically reliable, it certainly does indicate a trend as there is a 93% chance of a reliable difference. In fact, there is an initial gain in implicit memory in the older adults, and then the amount of implicit memories remains at a consistent level throughout the remaining retention intervals. In the younger adults there is a slight increase from the 0 to the 1 retention intervals and then a significantly reliable loss from intervals 1 to 9.

In older adults, non-storage began high and remained reliably stable, only increasing significantly between intervals 0 and 9. This observation is supportive of Hay and Jacoby (1999) who discovered that recollective inputs in older adults were drastically lower even at the shortest retention intervals. With respect to the non-storage parameters, the major difference between younger and older adults is the obviously slower accumulation of non-storage items on the part of the older adults. While most of the comparisons between retention intervals are close to significance, the only significant change in older adults is between the 0 and 9 retention intervals. Both younger and older adults have a statistically similar rate of non-storage by the time they have received nine intervening lists. So while adults start with a high non-storage parameter, there is more stability across the retention interval, and the younger adults eventually loose the same amount of items after 9 intervening lists.

An interesting story emerges in fractional storage, however. There is an interaction between age and fractional storage. In the younger adults, fractional storage began at a low percentage (.12) and increased by a factor of two (.23). The older adults showed the opposite pattern of results, whereby the rate of fractional storage started higher (.31) and decreased to roughly half of its original state (.18). How can this pattern describe what actually generates this difference between younger and older adults? Why does explicit memory degrade so differently in the two groups? One answer may come from the modeling of the Two-Trace Hazard Model parameters. The rate parameters of the Two-Trace Hazard Model differed only in the a parameter, not the c parameter. Since the proportion of loss in explicit storage and again in non-storage did not differ when comparing the young and old adults at the 9 retention interval, the b parameter is likely not different among these groups. Instead, the differences emerge in the rate parameters, a and c. While both parameters reflect the rate of loss over the domain of support, what both rate parameters describe is how fast memories are lost. A larger rate parameter indicates a steeper decline, or a faster rate of loss. If we think about the rate in terms of time, the *a* parameter describes the rate of loss immediately following storage from 0 to 1 second. In effect, it is the rate of loss from learning to the first retention interval test. This cannot simply be tested, however, as Trace 1 from the Two-Trace Hazard Model would be available at this time as well. But the higher *a* parameter in older adults would account for the lower rate of explicit memory at the 0 retention interval in the older participants. The *c* parameter, however, describes the rate of loss after this initial first few seconds. This parameter would measure the relative time that it would take participant data to reach the asymptote of the *b* parameter, or the equal amount of memory loss in older and younger adults. Since the proportion of loss is similar, the rate parameter *c* is similar.

The interaction present in fractional storage is very interesting in terms of its implications relative to previous studies. In most of the available research, fractional storage has not been measured as a separate construct. Instead, fractional storage has been grouped with implicit memory. If the current results are viewed in this light, by grouping implicit memory and fractional storage, such that they are considered a degraded memory in comparison to explicit memory, the interaction of age between older and younger adults is still present. The results comparing implicit memory and fractional storage together are provided in Table 30. Older adults have more of this degraded memory state at the beginning of the retention interval, and it decreases over time, while the younger adults have less of the degraded memory state at the beginning of the retention interval and this middle state gets fed into over time; thus the degraded state grows over the retention interval. In the older adults, of the 21% change in non-storage from the 0 to 9 conditions, approximately 10% can be accounted for by the trickling down effect of explicit memory, and approximately 10% can come from the degraded items leaving the implicit state. Instead of an invariant implicit measure, it seems that implicit memory remains stable due to a feeding in and degrading out of a relatively dynamic system.

Table 30.
Combined scores for fractional and implicit storage of older and younger adults.

Theta	0	1	4	9
Young	.288	.457	.472	.356
Old	.422	.331	.373	.326

In younger adults, there are fewer memories in the degraded middle state. As retention increases there is a big drop in explicit memory and non-storage increases by 16%, but there is still a lot of information left over in this middle degraded system of implicit and fractional storage. If any age group has a spared middle-system, it is the younger adults. What this may describe is that rather than implicit memory being spared, *per se*, in older adults, it is instead an artifact of the degrading of explicit memory. This is described by the large difference in the *a* parameter of the Two-Trace Hazard Model.

It is important to keep in mind the demand characteristics associated with any research conducted on the elderly. Elderly participants are perhaps more likely to fall victims to the stereotype that older adults do not perform as well (Thomas & Dubois, 2010). They may think the design of this experiment is very hard. Stimuli were chosen to be similar and to have a great deal of interference. While the stimuli are not associated with each other they were chosen to promote interference. In the design of Experiment 5, words were presented for three seconds, the participants were encouraged to read the word aloud, and use whatever encoding strategy they saw fit. The participants, in communication with researchers after the end of the experiment, explained that they would try to find connections among the words, or create sentences with the words. This was especially the case at the onset of the second list, after the participants realized how hard the experiment was after the test of list one. In contrast, younger adults were presented the word, and rather than passively encoding were asked to retype the word and hit enter. The word remained presented on the screen not for three seconds, but for as long as the participant deemed appropriate in order to encode. Based on the differences in average completion time, it is apparent that the words were presented on the screen for perhaps less than three seconds in the case of Experiment 2.

Lack of familiarity with keyboards may have increased the time spent answering test items in the older adults. Also, it may be possible that valuable cognitive resources were placed into using the keyboard as opposed to putting all the available processing capabilities into remembering the stimuli. Since the experiment is not timed does not have a forced-response schedule, computer skills, or lack thereof, may lead participants to put more time into trying to use the keyboard, increasing the lag time in the retention interval.

It is likely that the students, in an attempt to obtain credit for their class in the least amount of time possible, rushed through the experiment without employing the encoding strategies similar to the older adults, and thus decreased the lag time in the retention interval. Also, the college students participating in studies at Tufts University are a homogeneously educated group of achieving students. They are familiar with scenarios where they have to follow instructions, and all the participants must undergo a number of experiments a semester. Additionally, college students use computers far more often, and thus would have a much easier time using keystroke responses, freeing up cognitive resources. The older adults may differ in their ability to follow instructions as well as differ in their educational histories. There are a number of problems associated with research in older adults including mixtures within the group of participants, as described by the jackknife procedure, as well as differences even in their conscious perception.

The results in Experiment 5 may be contrasted to all the work that has occurred in the task dissociation and process-dissociation literature. Craik and Bialystock (2006) assert that older adults have a lack of access, not an encoding difficulty, which leads to poor memory performance. But these results indicate there is a detriment to encoding itself. The majority of results using the process dissociation procedure have indicated that implicit memory is invariant to age. Age invariance has been found with retention interval (Jennings & Jacoby, 1997); the false fame task (Jennings & Jacoby, 1993); repetition errors (Hay & Jacoby, 1999); stem completion (Hudson, 2008); and divided attention (Schmitter-Edgecomb & Woo, 2007). Thus, an explanation of the differing effects is warranted.

Researchers suggest the estimated rates of conscious and unconscious influences may be affected by the inability of older adults to correctly follow the complicated task manipulations. Older adults perform less well on more complicated tasks (Hess, 2005) to a greater degree than younger adults (Craik & McDowd, 1987). If a task is made easier then the unconscious process for older adults would be uncontaminated, but then the conscious process for younger adults may be equal to 1. When *C* is equal to 1, *U* cannot be estimated, and thus *U* may possibly be deflated in older adults and inflated in younger adults (Rybash, Santoro & Hoyer, 1998). The process dissociation literature indicates that implicit memory is invariant to age, but the invariance is more an artifact of decreasing recollection as a result of the drastic decrease in explicit memory and source memory. This is supported by the meta-analysis conducted by LaVoie and Light (1994). When making tasks easier to deal with source impairments in the elderly, unconscious processes are lowered. When Rybash, et al. (1998) measured recollection and familiarity for only those participants that made errors (and thus had a *C* less than 1), unconscious processes were greater in younger adults. With this in mind, it is likely that the process-dissociation results of age invariance in familiarity reflects how hard tasks are for older adults to complete. Also, in the current research we conclude that while the numbers show stability in implicit memory across the retention interval, the interaction among memory types is what is causing the seemingly consistent implicit memory system. If source errors lead to inflated unconscious processes, then a means of not relying on the source of memory gives a far more appropriate means of testing implicit and explicit memory. If implicit memory is increased due to source errors, then a model that relies on proper source information gives inflated measures of implicit memory. Thus, the age invariance may not exist at all, and may be an artifact of inflated estimates of unconscious processes due to an inability to accurately use source memory.

General Discussion

Five experiments were designed to test the efficacy of the Implicit-Explicit Separation (IES) model, as well as support the concept that memory can be separated into the distinct fundamental states of explicit memory, implicit memory, fractional storage, and non-storage. Explicit memories are easily described phenomena in terms of the task of the model. If knowledge of a target, assumed by a yes response, followed by high confidence and a correct 4AFC task indicates explicit memory, then implicit memory is described by a non-confident yes response, or a no response followed by a correct 4AFC response. These two patterns are separable when we estimate model parameters, and indicate an interaction, regardless of the experimental design used to measure retention interval. The IES model advances the available psychometric models by adding another memory component, fractional storage. If, in terms of the task associated with the IES model, explicit memory is characterized by the ability to remember, correctly, an item on a 4-AFC test after correctly saying that it is present with high confidence, then fractional storage is the ability to eliminate one or two of the foil items, in the absence of explicit storage for the to-be-remembered stimulus. Implicit memory is the special case of a residue leftover from explicit memory. If fractional storage and implicit memory were unimportant phenomena, then the value for these estimates would be zero. However, in all five experiments fractional storage and implicit memory appeared to play a critical role in the memory estimates, regardless of the population age and independent variable manipulations. Non-storage, on the other hand, would be characterized with the inability to reject any of the foils.

Further, fractional storage is differentiated even more from implicit storage. When fractional storage, non-storage and explicit storage were all estimated, based on the performance of the participants, there was a final integral phenomenon of implicit storage. Again, implicit memory is characterized by choosing correctly an item on the 4-AFC task followed by an "no" on the yes/no recognition task or a "yes" response with low confidence. The fact that we have corrected for the other memory states, and for guessing, and there is still a representation described as implicit memory lends credence to the existence of this memory type in general and its separation from explicit memory and fractional storage in particular. Whereas the IES model allows for four memory states, the process dissociation models (Jacoby, 1991) only allow for three states: implicit and explicit memory and non-storage.

The first two experiments used a list-learning paradigm to test normal, young adults over various retention intervals. These experiments indicated that the IES model was able to describe memory loss over the retention interval, including being able to model separately the differing rates of loss in implicit and explicit memory. Implicit and explicit memory decreased at different rates, indicating separable measured phenomena. Additionally, the values for fractional storage and non-storage were not equal to zero indicating they were both measurable phenomena as well. If fractional storage were equal to zero, then it would not be considered important in the model. Thus, any model measuring memory states should include a measurement of fractional storage. The IES model exceeds the modeling capabilities of the process dissociation procedure by including a measure of fractional storage, which the process dissociation procedure does not. The primary conclusions from Experiment 1 and 2 were that as retention interval increases, memories degrade from a more strongly encoded state, to a more damaged state of encoding. Implicit memory should be considered as a degraded construct that is neither explicit nor fractional. This new definition indicates that implicit memory is a residue of a memory trace that has been weakened (Chechile et al., 2012) as opposed to the definition provided by Jacoby (1991) that implicit memory is a limit to conscious control. Explicit memories may be lost from the explicit store, to a state of implicit or fractional store, or even lost all together, and considered no longer stored. This description of memory loss supports a single-system theory of memory. In support of this idea, there was a non-significant trend toward a rise in implicit memory after the shortest retention interval. Thus, in Experiment 2, implicit memory rose as a result of memory loss from the explicit store.

The third experiment utilized the results from the explicit and implicit storage parameters to estimate the probability of memory items being lost over time, as well as the rate of that memory loss in the Two-Trace Hazard Model. The Two-Trace Hazard Model parameters were estimated using both explicit storage and a combination of explicit and implicit storage. Previously, these model parameters were only estimated using memory storage as measured by multinomial models that did not separate implicit from fractional memory. In removing the estimates of fractional storage, a more appropriate value for storage was used. The values were input into the fit program for the Two-Trace Hazard Model for each individual participant. The data proved to be a good fit for the Two-Trace Hazard Model as defined by the r^2 statistic. The Two-Trace Hazard Model is based on Weibull sub-probability theory as it allows for a cumulative probability that is less than one. In terms of memory, this means that not all memory traces are lost over the lifetime. The Two-Trace Hazard Model allowed for conditions both when the *b* parameter was equal to one and less than one. The storage values were then linearized with a logarithmic function, and graphed as a function of retention interval. The graphs proved that the Two-Trace Hazard Model could fit the storage values from the IES model.

The fourth experiment used the IES model to analyze data over the very short term. In this experiment, the most important results came in the form of the implicit retention interval. Implicit memory had a highly reliable rise after the shortest retention interval. The stimuli tested in the fourth experiment were designed, and randomly presented, such that it is hard to explain the increase of implicit memory on design flaws. Instead, the most likely explanation is that the implicit memory store must be fed from some other state, likely explicit memory. As explicit memory decreases, the memories are not lost all together, but rather degrade to a lower memory state, causing an increase in implicit memory. These results are not explained by the dual-process theory of memory (Yonelinas, 1994), which suggests a deliberate recollective component and a separate, speedy, familiarity component. If there exists multiple, non-interacting memory systems, then the implicit system would only decrease, not increase. Instead, the implicit system interacts with the explicit as it increases with decreasing explicit memory.

Another feature of the fourth experiment is the importance of the θ_k parameter. In the first three experiments, the θ_k parameter remained relatively close to zero. The θ_k parameter describes the ability to reject foils when there is some knowledge of the to-be-remembered stimulus. In Experiments 1, 2, and 3 there was a large amount of to-be-remembered information, leading to participants' difficulty in having a knowledge-based rejection of foil items upon testing. In Experiment 4, there was only one stimulus to remember, and thus the θ_k parameter was quite high at shorter intervals and decreased with increasing retention. Thus, the fourth experiment not only provided great evidence for the single-store memory system, but also provided validity for the integrity of the θ_k parameter.

Experiments 3 and 4 used the estimates from the IES model to fit and find evidence to support the Two-Trace Hazard Model. Both experiments supported the Two-Trace Hazard Model by proving the model can describe data in both the short and long-term. The data set in Experiment 4 was fit to the $u(t)$ function to find the point of the hazard function. Chechile (2006) proved that any memory function must be able to describe memory in the short- and long-term and must be described by a peaked-hazard function. These data support this memory theory by proving that the Two-Trace model can describe the data and has an appropriate hazard shape.

Finally, the last experiment used the IES model with a different study population. In this experiment, older, healthy adults were enrolled and tested on a replication of the second experiment. The major finding in Experiment 5 was that the IES model could adeptly model data from older adults, leading to the implications of its importance with clinical populations. The results indicated that older adults had a lower level of memory retention in general. While older adults overall had less memories stored explicitly, explicit memory dropped in a proportionately similar amount in both older adults and younger adults. Further, although implicit memory was lower in older adults than in younger adults, it remained more stable throughout the lifetime of the retention function, supporting the results from the process-purity and process-dissociation research. These latter results suggest that implicit memories are retained in healthy older adults. This stability only occurred after an initial increase from intervals 0 to 1. When the possible muddled first learning/testing was removed from the results, there was a highly reliable rise of implicit memory from the first to the second retention interval. This can be described by the fast rate of loss in explicit memory degrading into the implicit memory system, which occurred before even the time of the 0 condition test. The Two-Trace Hazard Model parameters were again used to describe the rate of loss in younger and older adults. Because of the larger (by a factor of 2) value in the *a* parameter it was shown that the older adults have a much larger rate of loss in the first second after encoding.

A far-reaching implication of this experiment is that the model could be used to discriminate between different memory disorders, or different clinical populations. There is a possibility that memory disorders differ in what types of memory are lost and when. The IES model could be used to distinguish between different types of memory disorders such that treatments could be modified accordingly. The IES model suggests where the changes in the memory systems are as a result of aging and under what conditions memory can be enhanced. In particular, memory performance may be made more supportive by increasing motivation or skills at encoding. This may be a possible direction for the clinical approach for treating memory deficits (Hay & Jacoby, 1999; Hudson, 2008; Tse, Balota, Moynan, Duchek, & Jacoby, 2010).

Taking the entirety of this research together, it is clear that each experiment describes the changes in the four fundamental memory states as a function of the design manipulation. The overall pattern suggests that explicit memory decreased with retention interval, whereas implicit memory either decreased, had an inverted-u shaped function, or remained relatively stable after an initial increase with retention interval. The non-storage measure increased with retention interval, regardless of the independent variables or participant populations. And fractional storage increased in younger adults and decreased in older adults, indicating the initial encoding of older adults was more likely a non-durable memory store.

Based on the results from the five experiments, the IES model has proven its ability to describe data in both the short term and the long term in younger as well as older adults. Furthermore, the model supports the notion of a single memory system. Each experiment on its own has a different pattern of loss in the four fundamental memory states, and the models' coherence remained consistent across the experiments.

In the general corpus of implicit and explicit memory, a task has been used to measure one or the other type of memory, considered the process purity approach. The IES task extends beyond this approach by employing one single task and comparing the resultant measures on the one task. The belief is that in the process purity manipulation (one task to describe one memory type), it is likely true that multiple types of memory or cognitive processes are supporting the single task. It is not likely that a researcher can rule out any other cognitive support process in the task dissociation findings. This was the basis for the conception of models, like the process dissociation and multinomial processing tree models to disentangle these underlying processes. When measuring an implicit phenomenon, the IES model is able to remove the possibilities that other underlying memory types like explicit memory, fractional memory, or even just guessing, alter performance on a task. Thus, an important next step in the use of this model is to employ other classic implicit tasks such as priming and stem and fragment completion, and monitor the changes in the implicit memory with these task manipulations.

In this discussion, an argument has been made that implicit and explicit memory are two memory types located within a unitary memory system. This argument does not support separate memory systems, although it acknowledges that qualitative differences in memory exist. A common separation is between episodic and semantic memory. While semantic memory was certainly acquired from specific episodes in a learner's life, the memory type behaves in a different dynamic that is not tied to episodes. There are certainly examples in the brain where there are separate networks for separate systems such as the differing visual and auditory pathways. The argument set forth here is not that explicit and implicit memory are quantitatively different, rather there exist qualitative differences between implicit and explicit memory that do not arise from separate systems. Instead, the qualitative differences in implicit memory come from degraded representations of explicit memories.

There are a number of future directions that can be taken with this paradigm. A large number of experiments could be designed as long as they can be tested using the task associated with the IES model. Currently, the model is being used to test the four fundamental memory states of visual data. An experiment similar to the fourth experiment is designed using kaleidoscopic images in place of aurally presented triads so that comparisons can be made between memory for letter triads and the visual memory for images, in order to see if the four memory states interact in the same way. Additionally, the DRM procedure is being used to see how the implicit estimates differ in this false-memory task. A most exciting future direction would be to replicate

Experiment 4 with older adults and to develop a design that could be conducted with healthy older adults as well as clinical populations.

Another design difference in upcoming experiments, of note, is currently being conducted where the model is conceived with a three, as opposed to four, alternative choice procedure. The IES model need not have a four alternative procedure, and the experiments presented in this work will be repeated with three alternatives instead of four. When there are only three choices available, the number of multinomial cells decreases from 20 to 16, and the parameter estimates differ. In this vein, all the experiments described above will be rerun with three alternatives as opposed to four. If the results with the three alternatives have similar coherence values, and similar estimates as the four alternatives, then the three alternative version will prove to be an easier way of estimating the parameters both for the participant, as well as the user of the model.

Overall, these five experiments have added to the vast amount of research done on implicit and explicit memory. The traditional approach of testing memory, using the process-purity methods, was limited in its ability to accurately separate and test implicit and explicit memory. The process dissociation approach, albeit a good first step in separating memory measurements, is limited due to its reliance on instructional manipulations and its exclusion of fractional storage, which has been proven to be a viable type of memory storage. Additionally, the reliance of the process dissociation procedure on source memory may be a major limitation to the results that can be obtained from aging groups. The IES model, instead, is able to separately test explicit and implicit memory, using one procedure, does not rely on instructional manipulation, and includes estimates for fractional storage.

Appendix A

Obtaining MLE values for the IES Model.

For the purpose of this paper, MLE and PPM estimates were calculated via a method described in Chechile, Sloboda, and Chamberland (2012). To begin, a search procedure is found to estimate the best values for six parameters. The candidate values for θ_a, $\theta_{a'}$, θ_b, $\theta_{b'}$, θ_{y*}, and θ_y can be denoted *as* $\theta^{(c)}{}_a$, $\theta^{(c)}{}_{a'}$, $\theta^{(c)}{}_b$, $\theta^{(c)}{}_{b'}$, $\theta^{(c)}{}_{y*}$, and $\theta^{(c)}{}_y$. Seven values on the interval from 0 to 1 are considered as candidates for each of the six parameters, leading to 7^6, or 117,649 possible combinations. Estimated values for other parameters are based on the maximization of the likelihood function for each one of the combinations. The parameters are then used to calculate a likelihood value, $L^{(c)}$. The largest of the possible combinations provides an MLE for the first pass, each consecutive pass refines this original estimate.

The MLE estimates for θ_N, θ_F, and θ_{f2} can be calculated the following ways, based on the likelihood function in (1).

$$L = C\prod_{i=1}^{20}\phi_i^{n_i}(\Theta) \tag{1}$$

$$L_n = K\left(1-\frac{\theta_N}{4}\right)^{n_1+\ldots+n_{12}}\left(\frac{\theta_N}{4}\right)^{n_{13}+\ldots+n_{16}} \tag{2}$$

For the purpose of the θ_N parameter, we can use a section of the likelihood function that is only dependent on θ_N and is a binomial formed from cells 13, 14, 15, and 16 in one section, and cells 1 to 12 in another section. This equation is found in (2) where K is a constant for fixed frequencies. To maximize L_n so that θ_N is on the interval from 0 to 1

$$\hat{\theta}_N = \begin{cases} \dfrac{4\left(n_{13}+n_{14}+n_{15}+n_{16}\right)}{n_t} & \text{when } n_{13}+n_{14}+n_{15}+n_{16} \le 4n_t \\ 1 & \text{otherwise, } n_t = \sum_{i=1}^{16} n_i \end{cases}$$

The MLE values for θ_F and θ_{f2} can be calculated in a similar manner with a different partition of the likelihood function, using different groupings of cells, 1 to 4, 5 to 8, and 9 to 16. Thus,

$$L_* = K_* \phi_a^{n_a} \phi_b^{n_b} \phi_c^{n_c}$$

where $n_a = n_1 + n_2 + n_3 + n_4$, $n_b = n_5 + n_6 + n_7 + n_8$, $n_c = n_9 + \ldots + n_{16}$,

$$\phi_a = 1 - \frac{3}{4}\hat{\theta}_N - \frac{2}{3}\theta_F + \frac{1}{6}\theta_F\theta_{f2},$$
$$\phi_b = \frac{\hat{\theta}_N}{4} + \frac{1}{3}\theta_F + \frac{1}{6}\theta_F\theta_{f2},$$
$$\phi_c = 1 - \phi_a - \phi_{b,}$$

and where K_* is a constant for a fixed set of frequencies. To maximize L_* in terms of θ_F and θ_{f2} on the interval from 0 to 1

$$\frac{\partial L_*}{\partial \theta_F} = \frac{\partial L_*}{\partial \phi_a}\frac{\partial \phi_a}{\partial \theta_F} = 0$$

and

$$\frac{\partial L_*}{\partial \theta_{f2}} = \frac{\partial L_*}{\partial \phi_b}\frac{\partial \phi_b}{\partial \theta_{f2}} = 0$$

Following some restrictions, it can be seen that

$$\phi_a = \frac{n_a}{n_t}$$

and

$$\phi_b = \frac{n_b}{n_t}$$

$$\hat{\theta}_F = \begin{cases} 1 - \hat{\theta}_N - \left(\dfrac{n_a - n_b}{n_t}\right) & \text{when } n_a \ge n_b, \\ 1 - \hat{\theta}_N & \text{otherwise,} \end{cases}$$

$$\hat{\theta}_{f2} = \begin{cases} 1 & \text{when } n_c \le 2n_d, \\ 0 & \text{when } n_c \ge n_b + n_d \\ \dfrac{n_b - n_c + n_d}{n_b + \dfrac{n_c}{2} - 2n_d} & \text{otherwise,} \end{cases}$$

$$n_d = n_{13} + n_{14} + n_{15} + n_{16}.$$

With the parameters calculated thus far, the candidate value for θ_{se} can be calculated by combining cells 2 and 4 resulting in the following maximization:

$$\theta_{se}^{(c)} = \frac{n_1}{n_a}\left(1 - \hat{\theta}_N - \hat{\theta}_F + B_s^{(c)}\right) - \frac{\left(n_a - n_1\right)}{n_a} A_s^{(c)},$$

where

$$A_s^{(c)} = \frac{\hat{\theta}_N}{4}\theta_{y*}^{(c)}\theta_a^{(c)} + \frac{\hat{\theta}_F}{3}\theta_y^{(c)}\theta_b^{(c)}\left(1 + \frac{\hat{\theta}_{f2}}{2}\right)$$

$$B_s^{(c)} = \frac{\hat{\theta}_N}{4}\left(1 - \theta_{y*}^{(c)}\theta_a^{(c)}\right) + \frac{\hat{\theta}_F}{3}\left(1 + \frac{\hat{\theta}_{f2}}{2}\right)\left(1 - \theta_y^{(c)}\theta_b^{(c)}\right).$$

The candidate value for implicit storage is

$$\theta_{si}^{(c)} = \left(1 - \hat{\theta}_N - \hat{\theta}_F - \theta_{se}^{(c)}\right).$$

If either the candidate values for implicit or explicit storage are outside of the interval [0,1] then the specific combination of search parameters is disregarded and a new combination is calculated.

For θ_L and $\theta_{y'}$ the cells 3 and 4 are grouped together resulting in

$$\theta_L^{(c)} = \frac{\left(n_3 + n_4\right) A_L^{(c)} - n_2 B_L^{(c)}}{\left(n_2 + n_3 + n_4\right)\theta_{si}^{(c)}},$$

where

$$A_L^{(c)} = \theta_{si}^{(c)} + \frac{\hat{\theta}_N}{4}\left(1 - \theta_{y*}^{(c)}\right)\theta_{a'}^{(c)} + \frac{\hat{\theta}_F}{3}\left(1 - \theta_y^{(c)}\right)\theta_{b'}^{(c)}\left(1 + \frac{\hat{\theta}_{f2}}{2}\right)$$

$$B_L^{(c)} = \frac{\hat{\theta}_N}{4}\left[\theta_{y*}^{(c)}\left(1 - \theta_a^{(c)}\right) + \left(1 - \theta_{y*}^{(c)}\right)\left(1 - \theta_{a'}^{(c)}\right)\right].$$

Again, if the candidate value is outside of the interval [0,1] then another combination of candidate values will be tried. With the candidate value $\theta_L^{(c)}$ $\theta_{y'}$ can be calculated as

$$\theta_{y'}^{(c)} = \frac{n_3}{n_3 + n_4}\frac{n_3 A_{y'}^{(c)} - n_4 B_{y'}^{(c)}}{\left(n_3 + n_4\right)\theta_{si}^{(c)}\theta_L^{(c)}},$$

where

$$A_{y'}^{(c)} = \frac{\hat{\theta}_N}{4}\left(1 - \theta_{y*}^{(c)}\right)\left(1 - \theta_{a'}^{(c)}\right) + \frac{\hat{\theta}_F}{3}\left(1 - \theta_y^{(c)}\right)\left(1 - \theta_{b'}^{(c)}\right)\left(1 + \frac{\hat{\theta}_{f2}}{2}\right)$$

$$B_{y'}^{(c)} = \frac{\hat{\theta}_N}{4}\theta_{y*}^{(c)}\left(1 - \theta_a^{(c)}\right) + \frac{\hat{\theta}_F}{3}\theta_y^{(c)}\left(1 - \theta_b^{(c)}\right)\left(1 + \frac{\hat{\theta}_{f2}}{2}\right).$$

If the candidate parameter is outside of the interval [0,1] the process is repeated. The final parameter, the θ_k parameter can be calculated with:

$$\theta_k^{(c)} = 1 - \frac{n_{19} + n_{20}}{n_f \theta_{y*}},$$

where

$$n_f = n_{17} + n_{18} + n_{19} + n_{20}.$$

If the candidate value is outside the [0,1] range, it is rejected and a new candidate is found. Once all candidates have been found, the values are used to form the joint likelihood in (1). The MLE values chosen are those that, in combination, result in the largest $L^{(c)}$ value.

Obtaining the PPM estimates for the IES model

Population parameter mapping (PPM) (Chechile, 1998; 2004; 2009; 2010a, 2010b) is a means of estimating parameters based on Monte Carlo sampling of vectors from the posterior distribution for the population proportions for the various multinomial cells, 1 through 20. The parameters which come from the exact posterior distribution from statistical population parameters are then mapped unto the parameters of the IES model. The population proportion for the observation categories are represented with a prior and a posterior distribution. The statistical model parameters are the population proportions for the target-present multinomial, and the target-absent multinomial, e.g, $\phi_1, \ldots, \phi_{16}$ and $\phi_{17}, \ldots, \phi_{20}$ where

$$\sum_{i=1}^{16} \phi_i = 1$$

and

$$\sum_{i=17}^{20} \phi_i = 1$$

Random vectors from the posterior distribution in terms of ϕ are sampled, and each vector is mapped to a corresponding vector for the scientific model parameters. The vectors mapped to the parameter space is used to obtain the point estimates and the probability distributions of each parameter.

With $k + 1$ multinomial cells, Chechile (1998) drew a random ϕ–space vector $<\phi>$ $= (\phi_1, \ldots, \phi_{k+1})$ from the joint posterior distribution from a random set of k values from a beta distribution, $b_1, \ldots, b_k$. The random $<\phi>$ is

$$
\begin{aligned}
&\phi_1 = b_1, \\
&\phi_2 = (1 - b_1)b_2, \\
&\phi_3 = (1 - b_1)(1 - b_2)b_3, \\
&\vdots \\
&\phi_{k+1} = \prod_{i=1}^{k} (1 - b_1).
\end{aligned}
$$

For a prior distribution with no information, the b_i values are random numbers sampled from the following beta distributions:

$$
\begin{aligned}
&b_1 \sim beta(n_1 + 1, n - n_1 + k), \\
&b_2 \sim beta(n_2 + 1, n - n_1 - n_2 + k - 1), \\
&\vdots \\
&b_k \sim beta(n_k + 1, n_{k+1} + 1),
\end{aligned}
$$

where n is the total sample size for the multinomial. The Cheng (1978) algorithm for generating random values from the beta distribution is used to calculate the b_i values. There are two multinomials with $k = 15$ for the target-present multinomial and $k = 3$ for the target-absent multinomial.

For the IES model, 30,000 random vectors $<\phi>$ were generated from the posterior distribution for each condition. Each vector was mapped to a $<\theta>$ vector. This was accomplished with the following equations:

$$\theta_N = 4(\phi_{13} + \phi_{14} + \phi_{15} + \phi_{16}) \tag{A1}$$

If θ_N exceeds 1, then another $<\phi>$ vector is sampled, as no IES parameter may exceed the value of 1. If $\phi_a = \phi_1 + \phi_2 + \phi_3 + \phi_4$, $\phi_b = \phi_5 + \phi_6 + \phi_7 + \phi_8$ and $\phi_d = \phi_{13} + \phi_{14} + \phi_{15} + \phi_{16}$, then

$$\theta_F = \begin{cases} 1 & \text{if } \phi_b \geq \phi_a + 4\phi_d, \\ 0 & \text{if } \phi_a + 4\phi_d \geq 1 + \phi_b, \\ 1 - 4\phi_d - \phi_a + \phi_b & \text{otherwise,} \end{cases} \tag{A2}$$

$$\theta_{f2} = \begin{cases} 1 & \text{if } \phi_d \geq \phi_r, \\ 0 & \text{if } \phi_b \leq \phi_r, \\ \dfrac{4\phi_b + 2\phi_d + 2\phi_a - 2}{1 - 4\phi_d - \phi_a + \phi_b} & \text{otherwise,} \end{cases} \tag{A3}$$

where $\phi_r = \phi_9 + \phi_{10} + \phi_{11} + \phi_{12}$.

$$\theta_{a'} = \frac{\phi_{14}}{\phi_{14} + \phi_{16}}, \tag{A4}$$

$$\theta_{y*} = \frac{\phi_{13} + \phi_{15}}{\phi_d}, \tag{A5}$$

$$\theta_a = \frac{\omega_a}{\omega_a + 1}, \tag{A6}$$

where

$$\omega_a = \frac{\dfrac{\phi_{20}}{\phi_{19}}\left(\phi_{19} + \phi_{20}\right) + \dfrac{\phi_{13}}{\phi_{15}}\left(\phi_{13} + \phi_{15}\right)}{\phi_{19} + \phi_{20} + \phi_{13} + \phi_{15}}$$

$$\theta_k = \frac{\phi_{17} - \left(1 - \theta_{y*}\right)\theta_{a'}}{1 - \left(1 - \theta_{y*}\right)\theta_{a'}}, \tag{A7}$$

where θ_{y*} and $\theta_{a'}$ parameters in (A7) are obtained from (A5) and (A4), respectively.

Because θ_y is a conditional process parameter, it is unaffected when θ_F is close to zero.

There are four conditions that imply that θ_y is unimportant, and if any condition is met, θ_y is set to 0.5. These conditions are

$$\phi_6 + \phi_8 < \phi_{14} + \phi_{16},$$
$$\phi_{10} + \phi_{12} < \phi_{14} + \phi_{16}.$$
$$\phi_5 + \phi_7 < \phi_{13} + \phi_{15},$$
$$\phi_9 + \phi_{11} < \phi_{13} + \phi_{15}.$$

If none of these conditions occurs, then

$$\theta_y = \frac{\phi_5 + \phi_7 + \phi_9 + \phi_{11} - 2(\phi_{13} + \phi_{15})}{\phi_b + \phi_r - 2\phi_d} \tag{A8}$$

If the value for θ_y from (A8) exceeds 1, then it is considered inconsistent with the IES model and another <ϕ> vector is sampled. If the IES parameters are consistent with the model then

$$\theta_{b'} = \begin{cases} 1 & \text{if } \phi_8 \le \phi_{16}, \\ 0 & \text{if } \phi_6 \le \phi_{14}, \\ \dfrac{\phi_6 - \phi_{14}}{\phi_6 + \phi_8 - \phi_{14} - \phi_{16}} & \text{otherwise.} \end{cases} \tag{A9}$$

With that in mind it follows that

$$\theta_{\mathrm{b}} = \begin{cases} 1 & \text{if } \phi_7 \le (\phi_{13} + \phi_{15})(1 - \theta_a), \\ 0 & \text{if } \phi_5 \le (\phi_{13} + \phi_{15})\theta_a, \\ \dfrac{\phi_6 - \theta_a(\phi_{13} + \phi_{15})}{\phi_5 + \phi_7 - \phi_{13} - \phi_{15}} & \text{otherwise,} \end{cases} \tag{A10}$$

where θ_a in (A10) is the value from (A6). Given the values from (A6), (A2), (A8), (A10), and (A9)

$$\theta_{se} = \phi_1 - \theta_a\left(\phi_{13} + \phi_{15}\right) - \frac{\theta_F \theta_y \theta_b \left(2 + \theta_{f2}\right)}{6} \qquad \text{(A11)}$$

If the value for θ_{se} is less than zero, then the entirety of the mapping is incoherent and another $<\phi>$ vector is sampled. However, if it is positive, the implicit component may be calculated with

$$\theta_{si} = 1 - \theta_{se} - \theta_F - \theta_N .$$

If the value for θ_{si} is negative, another $<\phi>$ vector is sampled. The conditional parameter θ_L is

$$\theta_L = \begin{cases} 1 & \text{if } \phi_3 + \phi_4 \geq G_1 - G_2, \\ .5 & \text{if } \theta_{\text{si}} = 0, \\ 0 & \text{if } \phi_3 + \phi_4 \leq G_1 - G_2, \\ \dfrac{\phi_3 + \phi_4 - G_1 - G_2}{\theta_{\text{si}}} & \text{otherwise,} \end{cases} \qquad \text{(A12)}$$

where

$$G_1 = \theta_F\left(2 + \theta_{f2}\right)\left[\theta_y\left(1 - \theta_b\right) + \left(1 - \theta_y\right)\left(1 - \theta_{b'}\right)\right],$$

$$G_2 = \frac{\theta_N\left[\theta_{y*}\left(1 - \theta_a\right) + \left(1 - \theta_{y*}\right)\left(1 - \theta_{a'}\right)\right]}{4}.$$

$$\theta_{y'} = \begin{cases} 1 & \text{if } \phi_4 + H_1 + H_2 \leq G_1 - G_2, \\ .5 & \text{if } \phi_3 + \phi_4 \leq G_1 - G_2 \text{ i.e., if } \theta_{\text{L}} = 0, \\ 0 & \text{if } \phi_3 \leq H_1 + H_2, \\ \dfrac{\phi_3 - H_1 + H_2}{\phi_3 + \phi_4 - G_1 - G_2} & \text{otherwise,} \end{cases} \qquad \text{(A13)}$$

where

$$H_1 = \frac{\theta_F\left(2+\theta_{f2}\right)\theta_y\left(1-\theta_b\right)}{6},$$

$$H_2 = \frac{\theta_N\theta_{y*}\left(1-\theta_a\right)}{4}.$$

The equations, (A1) through (A13) can result in incoherent values in four situations. Parameters inconsistent with the IES model occur when $\theta_N > 1$, $\theta_y > 1$, $\theta_{se} < 0$, or when $\theta_{si} < 0$. There is one more condition resulting in an incoherent $<\phi>$ vector. When a model contains a number of parameters that is less than the degree of freedom for the ϕ-space, the model has a probability measure of zero in ϕ. A more in depth review of this can be found in Chechile (1998; 2004). The IES model has 18 degrees of freedom. Modeling error is allowed (Chechile, 1998; 2004; 2009). Given a successfully mapped vector $<\phi>$, the parameters of the IES model are mapped via the following equations

$$\phi_1 = \theta_{se} + \frac{\theta_N \theta_{y*} \theta_a}{4} + \frac{\theta_F \theta_y \theta_b \left(2 + \theta_{f2}\right)}{6}$$

$$\phi_2 = \theta_{si}\left(1 - \theta_L\right) + \frac{\theta_N \left(1 - \theta_{y*}\right)\theta_{a'}}{4} + \frac{\theta_F \left(1 - \theta_y\right)\theta_{b'}\left(2 + \theta_{f2}\right)}{6}$$

$$\phi_3 = \theta_{si}\theta_L\theta_{y'} + \frac{\theta_N \theta_{y*}\left(1 - \theta_a\right)}{4} + \frac{\theta_F \theta_y \left(1 - \theta_b\right)\left(2 + \theta_{f2}\right)}{6}$$

$$\phi_4 = \theta_{si}\theta_L\left(1 - \theta_{y'}\right) + \frac{\theta_N \left(1 - \theta_{y*}\right)\left(1 - \theta_{a'}\right)}{4} + \frac{\theta_F \left(1 - \theta_y\right)\left(1 - \theta_{b'}\right)\left(2 + \theta_{f2}\right)}{6}$$

$$\phi_5 = \frac{\theta_N \theta_{y*} \theta_a}{4} + \frac{\theta_F \theta_y \theta_b \left(2 + \theta_{f2}\right)}{6}$$

$$\phi_6 = \frac{\theta_N \left(1 - \theta_{y*}\right)\theta_{a'}}{4} + \frac{\theta_F \left(1 - \theta_y\right)\theta_{b'}\left(2 + \theta_{f2}\right)}{6}$$

$$\phi_7 = \frac{\theta_N \theta_{y*}\left(1 - \theta_a\right)}{4} + \frac{\theta_F \theta_y \left(1 - \theta_b\right)\left(2 + \theta_{f2}\right)}{6}$$

$$\phi_8 = \frac{\theta_N \left(1 - \theta_{y*}\right)\left(1 - \theta_{a'}\right)}{4} + \frac{\theta_F \left(1 - \theta_y\right)\left(1 - \theta_{b'}\right)\left(2 + \theta_{f2}\right)}{6}$$

$$\phi_9 = \frac{\theta_N \theta_{y*} \theta_a}{4} + \frac{\theta_F \theta_y \theta_b \left(1 - \theta_{f2}\right)}{3}$$

$$\phi_{10} = \frac{\theta_N \left(1 - \theta_{y*}\right)\theta_{a'}}{4} + \frac{\theta_F \left(1 - \theta_y\right)\theta_{b'}\left(1 - \theta_{f2}\right)}{3}$$

$$\phi_{11} = \frac{\theta_N \theta_{y*}\left(1 - \theta_a\right)}{4} + \frac{\theta_F \theta_y \left(1 - \theta_b\right)\left(1 - \theta_{f2}\right)}{3}$$

$$\phi_{12} = \frac{\theta_N \left(1 - \theta_{y*}\right)\left(1 - \theta_{a'}\right)}{4} + \frac{\theta_F \left(1 - \theta_y\right)\left(1 - \theta_{b'}\right)\left(1 - \theta_{f2}\right)}{3}$$

$$\phi_{13} = \frac{\theta_N \theta_{y*} \theta_a}{4}$$

$$\phi_{14} = \frac{\theta_N \left(1 - \theta_{y*}\right)\theta_{a'}}{4}$$

$$\phi_{15} = \frac{\theta_N \left(1 - \theta_{y*}\right)\theta_a}{4}$$

$$\phi_{16} = \frac{\theta_N \left(1 - \theta_{y*}\right)\left(1 - \theta_{a'}\right)}{4}$$

$$\phi_{17} = \theta_k + \left(1 - \theta_k\right)\left(1 - \theta_{y*}\right)\theta_{a'}$$

$$\phi_{18} = \left(1 - \theta_k\right)\left(1 - \theta_{y*}\right)\left(1 - \theta_{a'}\right)$$

$$\phi_{19} = \left(1 - \theta_k\right)\theta_{y*}\left(1 - \theta_{a'}\right)$$

$$\phi_{20} = \left(1 - \theta_k\right)\theta_{y*}\theta_{a'}$$

The values can be denoted as $\phi^{(t)}{}_i$, $i = 1, \ldots , 20$. Chechile (2004; 2007; 2009) measured modeling error with $\delta = max(|\phi^{(c)}{}_i - \phi_i|)$, $i = 1, \ldots , 20$. We define Δ^* as the largest modeling error that is allowable. Thus, $<\phi>$ is considered inconsistent with the IES model if $\delta > \Delta^*$. The largest allowable error was set to 0.1

The proportion of acceptable $<\phi>$ out of the total sampled is the sampled estimate of model coherence, *P(coh)*. If *P(coh)* is measured in the absence of data, with $n_i = 0$, $i = 1, \ldots , 20$. If *P(coh)* is high for the measurement in the absence of data, then the IES model is not highly testable by means of *P(coh)*. However, if *P(coh)* is low with no data, the posterior value is high, the IES model has withstood a test. Given this final criteria, as well as the four listed previously, the prior value for *P(coh)* is .008 for the IES model. The five criteria result in a low no-data *P(coh)* value, and indicates a testable model via the *P(coh)* measure.

Appendix B

The following lists in Appendix B include the stimuli for the list-learning experiments. The following are the nine word lists from Experiment 1.

LIST 1	LIST 2	LIST 3	LIST 4	LIST 5
ABILITY	ACTION	AGAIN	ALIVE	AMOUNT
CLASSES	BEGINS	CAUSES	CELLS	CHEST
DEVELOP	DROPPED	EMPTY	ENTER	EVIDENT
FOREST	FRONT	GETTING	GUESS	HANDLE
KEEPING	LARGELY	LIGHT	LOOSE	LISTEN
MONEY	MOTOR	ANGLE	VOLUME	GOODS
NEARLY	ADVANCE	CLEAN	SOUND	UNION
ACHIEVE	OCTOBER	USEFUL	OFFICER	SMALLER
EFFECT	TABLE	VIEWS	ANODE	PUSHED
TOWNS	CAREER	AFFAIRS	NOTED	TODAY
WAGON	FREEDOM	ANOTHER	SITTING	ANNUAL
NEITHER	CARRIED	ANIMAL	UNITED	VICTORY
GROUP	AGENCY	UNIQUE	RADIO	SHORT
FRANK	PROJECT	DOORS	DIVIDED	KITCHEN
SIGHT	AFTER	ACTIVE	NAMES	DRINK
SHARE	TAKEN	EASILY	STYLE	DROVE
WELFARE	USUAL	LEGAL	SILENCE	BROWN
BEAUTY	KNOWING	PRIVATE	TRYING	MOUTH
PARTS	JURIES	UNABLE	TREATED	RATHER
RELATED	NATURAL	THING	LEADER	REALIZE

LIST 6	**LIST 7**	**LIST 8**	**LIST 9**
APART	AROUND	ATTEMPT	BALANCE
CHAIN	CHAIR	CLASS	CLOTHES
FAMOUS	FISCAL	FLOWERS	FOLLOW
HOLDING	HOWEVER	INITIAL	JANUARY
MARINE	MANAGER	MERELY	MIDDLE
WEAPONS	STARED	GROSS	MISSION
EDITOR	BEGIN	ALREADY	BECAUSE
EIGHT	CHAPTER	BECAME	CLEAR
NUCLEAR	COLUMN	BEFORE	STEPS
REDUCE	LIBRARY	CIVIL	STOCK
EXTREME	MAJOR	THEATER	WHEEL
PICKED	REMOVE	TASTE	USING
BELOW	RUNNING	RECEIVE	SPEECH
ARTICLE	TESTS	GLASS	NORMAL
PAPER	WAITED	EVERY	NOTICE
ESTATE	WILLING	LONDON	REPORT
FACULTY	HEARING	ENJOYED	ENOUGH
ARRIVED	ASIDE	REQUIRE	CHECK
MAYBE	CLAIM	ENERGY	AMONG
WINDOWS	GREEN	ANCIENT	ASKED

The following are the 12 lists of words from Experiment 2 and Experiment 5.

LIST 1	**LIST 2**	**LIST 3**	**LIST 4**	**LIST 5**	**LIST 6**
FRANK	TAKEN	ANIMAL	OFFICER	HANDLE	WEAPONS
NEARLY	TABLE	UNIQUE	ANODE	SMALLER	ESTATE
ABILITY	CARRIED	DOORS	UNITED	PUSHED	PAPER
CLASSES	AFTER	ACTIVE	RADIO	TODAY	ARTICLE
KEEPING	USUAL	EASILY	DIVIDED	DRINK	PICKED
GROUP	KNOWING	CLEAN	NAMES	FISCAL	BELOW
PARTS	JURIES	USEFUL	STYLE	KITCHEN	HOLDING
BEAUTY	NATURAL	THING	VOLUME	AMOUNT	EXTREME
NEITHER	FRONT	LEGAL	SOUND	BROWN	REDUCE
DEVELOP	LARGELY	PRIVATE	ALIVE	MOUTH	FACULTY
EFFECT	ACTION	EMPTY	CELLS	CHEST	ARRIVED
WAGON	BEGINS	GETTING	NOTED	EVIDENT	MAYBE
SIGHT	AGENCY	LIGHT	TRYING	REALIZE	WINDOWS
SHARE	PROJECT	ANGLE	SITTING	GOODS	FAMOUS

LIST 7	**LIST 8**	**LIST 9**	**LIST 10**	**LIST 11**	**LIST 12**
MANAGER	FLOWERS	AMONG	FOREST	AGAIN	CLAIM
STARED	THEATER	JANUARY	WELFARE	AFFAIRS	STOCK
RUNNING	MERELY	MIDDLE	RELATED	VIEWS	BALANCE
COLUMN	TASTE	NORMAL	ACHIEVE	ANOTHER	ENTER
WAITED	RECEIVE	CLEAR	MONEY	UNABLE	GUESS
HEARING	GLASS	STEPS	TOWNS	VICTORY	LOOSE
ASIDE	EVERY	NOTICE	DROPPED	SHORT	TREATED
LIBRARY	LONDON	REPORT	OCTOBER	UNION	EDITOR
CHAPTER	ENJOYED	ENOUGH	ADVANCE	BECAUSE	BEGIN
REMOVE	REQUIRE	CLOTHES	MOTOR	SILENCE	CHAIR
MAJOR	ENERGY	FOLLOW	CAREER	CHECK	DROVE
TESTS	ANCIENT	USING	FREEDOM	SOVIET	HOWEVER
GREEN	ATTEMPT	WHEEL	CAUSES	CIVIL	MARINE
AROUND	CLASS	ASKED	MISSION	GROSS	BEFORE

The following are the 30 lists of words used in Experiment 3.

List 1	**List 2**	**List 3**	**List 4**
AGGRESSIVE	AMOUNT	ADOLESCENCE	BADLY
ARRIVAL	BACKWARD	AMPLE	CHORUS
BEER	CAMPUS	ASSOCIATED	COMPREHENSIVE
BURMA	CORRESPONDENCE	BASS	DAIRY
CELLAR	DESTRUCTIVE	BLOOD	DEADLY
CLASS	DOCUMENTS	CAN	EXTRAORDINARY
COMPOSITE	ENABLE	COLUMBIA	FILING
HUMOR	EXPECTATIONS	COWBOY	FORMULATION
INSTRUMENT	MESS	DEPEND	GOD
LOVING	OAK	DISEASES	INTEGRATION
MEANWHILE	PARTNER	DRANK	LOYALTY
MOTHER	PONT	ENCOUNTERED	MOTORS
OUTPUT	RANCHER	HAPPENING	SKILLS
PROMISED	ROUND	HONORS	SPEAKING
REGULARLY	SHARING	LOCKED	SUFFERING
RIGID	SKETCH	MARSHALL	SYMBOL
SAVAGE	VICIOUS	PLEASED	THOUSAND
SELDOM	WHOM	REHABILITATION	VOLUNTARY
SIZE	WORST	ROURKE	WHY
SPANISH	YOURSELF	SMILED	WORTHY

List 5

BOWL
CARRYING
CLASSIFICATION
CONGRESSIONAL
DEALER
DOING
EXCEPT
FOLLOWING
GENTLY
HIDE
INITIATIVE
LEANED
MAKING
NARRATIVE
PARTY
RANGE
RENT
SAW
SPEAKS
STARTING

List 6

AGRICULTURE
EXTREMELY
FLASHED
GOING
IMAGINE
LEANING
MECHANICAL
NEUTRAL
PEN
PROBLEM
QUESTIONING
RITUAL
SHE
SMOKE
STARTLED
SYMPATHETIC
TRANSPORT
VARIATION
WAS
WOUND

List 7

BEHALF
CEREAL
COMPARABLE
CONVERSATION
DEFINITION
ENTRANCE
FILM
GRAVE
HORIZON
INVESTMENT
JAPANESE
LOGICAL
MECHANICS
OVERHEAD
PHENOMENON
TRYING
UNDERSTANDING
VARIATIONS
WASHED
WITHOUT

List 8

BUSINESSMEN
DEALT
DEPUTY
DISPLAYS
EDUCATION
EXPENSE
FOOLISH
GEOMETRIC
HEAVEN
JAR
LIBERALISM
LONDON
MASSACHUSETTS
NATIONALISM
PAN
POPULATION
PROOF
REFERENCES
SALEM
SHOUTED

List 9

AIM
DINNER
EUROPE
FINALLY
GOLF
HORRIBLE
JUDGED
LEARNING
LUNCHEON
OBSERVATION
PANEL
PHILADELPHIA
PROCEEDINGS
RELATIVELY
SAYS
SETTING
SNAPPED
SUBJECTED
THERE
URBAN

List 10

AREA
BILLION
CAST
COAST
CONVICTION
DANCE
DEAR
DISPOSED
EDWARD
EXPERIENCED
FOOTBALL
KILLING
MASSIVE
MONTHLY
ONLY
PENNY
PROCEEDS
TERRIBLE
VOYAGE
WOMAN

List 11

ACTIVE
ATE
BRANNON
COAT
CONVINCED
DIPLOMATIC
DREW
EXCITED
FARMING
FOR
GAINING
GREATEST
HIMSELF
INPUT
JUDGING
LEATHER
LISTENING
REALIZED
SCARCELY
SPECIFICALLY

List 12

ABSURD
ALSO
AUTO
CASUAL
COMING
CREAM
DISSOLVED
ORGANIZATION
OWEN
PODGER
QUITE
REFLECTED
SINCERE
SPECIFIED
STOLEN
SURRENDER
THEREFORE
TREASURY
VAST
WET

List 13

AEGEAN
APPARENT
BRUSH
CREATED
DEVELOPMENT
EQUALLY
LYRICS
NAVY
OPENED
PARADE
PORTLAND
PROCUREMENT
REALM
REVISED
SEVENTEEN
SOPHISTICATED
STRIKING
SUITCASE
TEST
UNEMPLOYMENT

List 14

LECTURE
NEAR
OWNER
PHOTOGRAPHS
PORTRAIT
PROPOSALS
REALTORS
ROD
SCENE
SHERMAN
SORRY
SQUARE
STRING
SUITE
TAIL
THROWING
TURNPIKE
USEFUL
WATSON
WROTE

List 15

ACTUAL
ATMOSPHERE
BUDGET
CHALLENGE
COMMENTED
COUNTED
DELIGHTFUL
DEVIL
DISTINCT
EMERGED
FACULTY
FLIGHT
GAMES
HAIL
HISTORIC
INDICATING
LAST
MACHINERY
MELODY
NEARBY

List 16

ACCELERATION
ALARM
ATOM
BREAKFAST
CLEVELAND
COOLIDGE
CREATIVE
DESERVES
DRINKS
EMERGENCY
EXPLAINS
MORALE
NICE
PATHOLOGY
PRIDE
SAMPLES
SINK
SUM
UNHAPPY
YARD

List 17

ADAMS
ATOMIC
BEARING
BREAKING
BUFFER
CHEST
DELIVERY
DISTINCTIVE
ENGINE
FENCE
FOUNTAIN
GOVERNMENT
HISTORY
NOTING
PATIENCE
POETS
PRIEST
RACING
RESPONSIBLE
SECTION

List 18

ALBERT
ATTACHED
BOOK
CHANCE
CITED
COFFEE
COMPETING
IDEA
INSIST
JESUS
LIGHTED
MATURE
OCCUPIED
PERFORMED
PRELIMINARY
RADAR
RELIGIOUS
RUNNING
SEWAGE
SOCIETIES

List 19

APPLICATION
BOOST
COMMISSION
CURIOSITY
DOUBLE
EXECUTIVE
FEVER
FRONTIER
HAM
INSISTENCE
JET
LATTER
LIVED
MEMORIAL
MORELAND
OCCURRED
PATROL
PHYSIOLOGICAL
POINTING
PRIMARY

List 20

ARMIES
CAPTURED
COLLAGE
COP
CURIOUS
DESIRABLE
DOUBTFUL
EMOTIONS
EXPLOSION
MARBLE
NECESSITY
OCCURRENCE
PIANO
PROFESSIONAL
RICH
SHIPS
SPENCER
STAYING
UTILITY
WIND

List 21

ADDITIONAL
ANNOUNCEMENT
BARREL
BITTER
BRIDE
COLLAR
COUPLE
DEMOCRATIC
DISTRIBUTION
EASIER
ERROR
EXPLOSIVE
FATS
FLOWING
MEN
POLAND
POSSIBILITIES
PROFESSORS
REFUSED
SANG

List 22

AWAKE
CARBON
COLLEAGUES
DECLARED
DROPPING
EXPOSED
FAULKNER
MARCHING
NOW
PERMANENT
PRINCE
REGARDED
ROMANTIC
SENTIMENTAL
SHADOW
SOLAR
STRUCK
SUSTAINED
TRAIL
VISITED

List 23

AFTERNOON
ASSERT
CALLED
CONTOURS
DEMONSTRATED
EMPHASIZE
EVIDENCE
FIRM
PAULA
POST
PROTESTANT
REMARK
SANTA
SITTING
SOUTHEAST
STOVE
SWEAT
TRAILS
WANTING
WORKING

List 24

DROVE
EASTERN
ELABORATE
FAVORABLE
GAVE
GRADUAL
HOWEVER
JOE
LIZZIE
MEADOW
MERCER
ODD
PAUSE
PROFOUND
RECOGNITION
RUTH
SHAKESPEARE
SOUTHERN
SWEEP
VACATION

List 25

ANOTHER
BENSON
CLAIMED
CONSPIRACY
DEDICATED
DOWNWARD
EXISTED
FIFTEEN
FULLY
HAY
JOHN
LOUIS
MORTGAGE
SHAKING
SOLE
STEIN
SUCCESSES
TIGHTLY
WEATHER
WORKSHOP

List 26

AGAINST
AMEN
ASSESSORS
BOTH
CAVALRY
COLLEGE
CONSTANTLY
CONTRAST
DEDICATION
DRUMS
FISCAL
FOAM
GRADUATE
HEADED
HUGE
INTIMATE
LAWN
MUTTERED
NOISE
TYPICALLY

List 27

ANSWERED
GROWS
ILL
INTO
IVORY
MERE
NONE
OPPOSED
PAYNE
POTTERY
QUALIFICATIONS
REGIONAL
ROOTS
SHAME
SPITE
TAP
TILL
UNLESS
VITAL
WORN

List 28

AMERICA
AXIS
CEILING
EXISTS
FIGHTERS
GENERALLY
HUMAN
JOINED
LESSER
MAILED
MEREDITH
NUMEROUS
OUTER
PILED
SAD
SHAPED
SOVIET
SWIFTLY
TIM
WARM

List 29

AMERICANS
ATTRACT
COMMUNICATION
ELECTRIC
GLORIOUS
HUMANITY
LAWYER
MERELY
NEITHER
OUTFIT
POURED
RECORDED
ROSE
SHAPES
SPLIT
STRATEGIC
TAPPET
TRANSFORMED
VALIDITY
WORRY

List 30

ADMIRED
APPROPRIATE
BASICALLY
CLOTHING
COVERED
DIFFERENTIAL
DUE
ECONOMY
EMPLOYMENT
FITTED
FUNDAMENTAL
HONEST
LOCATED
MERGER
PARTISAN
RAN
ROUGH
SERIOUSLY
TOTAL
VOCATIONAL

Appendix C

Table C1.

The following table includes the raw data for each of the 40 individual participants in Experiment 1. The participant number is listed on the left, and the data is separated by the yes/no response with high and low confidence, and whether or not participants chose the correct word on the 4-, 3-, or 2-alernative response, or were incorrect. The yes/no response and confidence is listed for foil trials as well.

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
1	Short	17	1	8	6	0	2	0	0	1	0	0	0	1	0	0	0	2	13	5	4
	Med	15	2	4	4	1	1	4	1	1	2	0	0	0	0	0	1	9	6	5	4
	Long	9	4	8	9	0	0	0	2	0	0	1	1	0	1	0	1	2	12	7	3

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
2	Short	8	1	6	9	1	0	2	3	0	0	1	5	0	0	0	0	3	17	3	1
	Med	8	0	6	7	0	0	2	5	0	0	2	2	0	0	1	3	0	17	6	1
	Long	2	1	3	9	1	0	1	7	9	9	2	4	0	1	3	2	1	12	11	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
3	1	10	3	5	1	1	1	0	1	0	0	1	0	0	0	0	1	2	5	7	2
	4	12	0	9	3	1	0	3	1	0	0	1	5	0	0	1	0	2	8	12	2
	9	1	2	0	9	0	1	2	5	4	0	2	0	0	1	5	4	1	10	11	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
4	1	4	2	6	6	1	0	1	0	0	1	4	4	1	0	4	2	1	5	12	6
	4	0	1	4	2	0	0	5	4	2	0	5	1	2	0	6	4	1	12	8	3
	9	1	0	5	7	0	0	2	1	2	0	4	6	1	1	4	2	3	9	10	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
5	1	15	2	5	4	1	0	1	1	2	0	0	3	1	0	0	1	4	8	12	0
	4	8	2	9	3	1	0	2	2	1	0	3	3	0	0	1	1	3	7	12	2
	9	2	0	9	7	1	0	4	3	0	0	3	3	0	0	3	1	1	15	8	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
6	1	16	0	8	6	0	0	1	3	0	0	0	1	0	0	0	1	0	12	12	0
	4	8	0	10	10	0	0	3	2	0	0	0	3	0	0	0	0	0	17	7	0
	9	2	0	7	10	0	0	0	3	0	0	5	2	0	0	3	4	0	15	9	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
7	1	8	4	4	5	0	4	1	1	0	1	1	3	0	2	1	1	10	5	4	5
	4	9	1	5	6	1	0	1	5	0	1	3	2	0	1	1	0	2	16	5	1
	9	6	2	7	2	2	1	2	5	1	0	0	1	2	3	1	1	6	10	6	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
8	1	4	0	9	7	0	0	0	6	0	0	5	3	0	0	1	1	0	19	5	0
	4	3	0	7	8	0	0	1	3	0	0	1	8	0	0	1	4	0	17	7	0
	9	2	0	5	6	0	0	2	4	0	0	2	6	1	0	5	3	0	15	9	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
9	1	12	3	4	1	1	4	1	0	1	2	1	4	0	0	0	2	4	10	6	4
	4	11	3	3	4	0	3	1	0	1	4	1	3	2	0	0	0	7	11	4	2
	9	6	1	6	2	5	1	0	4	1	1	2	3	0	0	1	3	3	13	6	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
10	1	10	1	5	4	0	1	2	2	0	0	4	3	0	1	0	3	2	12	9	1
	4	3	0	12	6	0	0	1	3	0	0	0	3	0	1	2	5	2	15	7	0
	9	2	0	9	8	0	0	1	1	1	1	1	3	0	0	2	7	1	19	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
11	1	13	2	3	5	1	2	0	2	0	1	1	0	0	2	2	2	4	12	6	2
	4	12	4	5	6	0	1	1	3	0	0	1	0	0	3	0	0	4	11	7	2
	9	8	4	2	7	1	2	1	0	1	1	0	3	0	2	1	3	6	12	5	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
12	1	9	0	4	6	2	0	2	3	1	0	2	4	0	0	0	3	0	16	5	3
	4	8	0	10	4	0	0	1	4	0	0	0	3	1	1	2	2	0	15	9	0
	9	7	0	6	6	1	0	2	5	0	0	4	2	0	0	1	2	0	16	8	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
13	1	11	0	8	4	0	0	3	6	0	0	0	2	0	0	0	2	0	13	8	3
	4	11	1	9	6	0	0	1	4	0	0	1	1	0	0	0	2	0	20	3	1
	9	2	0	10	8	0	0	0	8	0	0	2	3	0	0	1	2	0	21	3	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
14	1	8	1	5	7	0	0	0	3	0	0	4	3	1	0	4	0	1	10	11	2
	4	0	1	4	9	0	1	1	4	0	0	3	4	2	0	5	2	1	12	11	0
	9	0	0	8	2	1	1	6	7	1	0	2	4	0	0	3	1	2	11	11	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
15	1	5	0	5	7	1	1	1	3	2	1	1	2	1	1	3	2	1	8	13	2
	4	8	0	5	3	2	0	7	1	1	0	3	2	0	0	1	3	2	9	11	2
	9	3	0	8	2	0	0	4	4	2	0	3	5	0	0	2	3	2	10	11	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
16	1	10	0	8	2	0	0	1	5	1	0	1	4	0	0	1	3	0	12	9	3
	4	10	1	8	7	0	0	2	3	0	0	2	0	0	0	0	3	1	14	9	0
	9	3	1	9	8	0	0	3	4	0	0	0	2	0	0	2	4	0	10	13	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
17	1	11	1	4	9	1	0	4	2	0	0	0	1	0	0	1	2	2	15	4	3
	4	11	6	6	2	1	1	0	1	1	1	1	1	0	0	1	3	4	9	9	2
	9	4	0	5	3	1	0	3	5	3	0	2	3	0	4	2	1	6	10	6	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
18	1	10	0	10	4	0	0	2	1	1	0	1	1	1	0	3	2	0	7	15	2
	4	7	0	10	7	0	0	2	2	0	0	3	2	0	0	1	2	0	14	10	0
	9	4	0	9	4	0	0	6	3	0	0	4	4	0	0	0	2	1	12	10	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
19	1	27	2	2	3	0	1	0	0	0	0	0	1	0	0	0	0	8	11	2	3
	4	25	1	4	3	0	0	0	1	0	2	2	2	0	0	0	0	11	8	3	2
	9	21	1	1	5	1	0	0	1	0	2	2	2	0	0	0	0	11	8	3	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
20	1	22	0	3	2	0	1	1	2	0	1	0	3	0	0	1	0	6	7	3	8
	4	13	2	3	3	2	3	5	1	2	0	1	0	0	0	0	1	7	4	7	6
	9	7	2	4	2	2	3	1	2	1	3	3	0	2	2	1	1	4	9	3	8

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
21	1	5	0	9	9	0	0	1	4	0	0	0	5	0	1	0	2	0	19	5	0
	4	13	0	10	6	0	0	1	1	0	0	1	2	0	0	1	1	0	13	11	0
	9	2	0	8	8	0	0	1	5	1	0	4	3	0	0	2	2	0	18	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
22	1	2	0	7	5	1	0	5	4	1	0	2	1	0	0	4	4	0	9	11	4
	4	2	0	6	4	0	0	6	4	0	0	5	2	0	0	4	3	0	5	19	0
	9	4	0	6	6	0	0	5	2	0	0	3	4	1	0	3	2	1	7	14	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
23	1	8	3	5	11	0	0	1	3	0	0	0	3	0	0	0	2	5	10	4	5
	4	10	1	3	2	1	1	6	2	1	0	1	6	0	2	0	0	0	9	8	7
	9	2	3	2	6	1	3	3	3	1	1	5	2	0	0	3	1	6	11	6	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
24	1	8	1	6	1	1	0	5	2	0	0	4	4	0	0	0	4	1	9	13	1
	4	11	1	8	4	0	0	4	3	0	0	1	2	0	0	1	1	3	4	12	5
	9	7	0	9	3	0	0	6	4	2	0	1	2	0	0	2	0	0	10	13	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
25	1	21	2	3	1	1	1	0	1	1	1	0	1	1	2	0	0	8	1	2	13
	4	14	4	1	2	3	3	0	1	1	3	0	0	2	2	0	0	8	3	1	12
	9	19	2	2	3	2	3	0	1	1	2	0	0	1	0	0	0	16	1	4	3

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
26	1	10	0	7	8	0	0	5	4	0	0	1	1	0	0	0	0	0	14	10	0
	4	6	0	12	4	0	0	3	2	0	0	1	2	0	0	1	5	0	17	7	0
	9	2	0	8	5	0	0	6	5	0	0	4	3	0	0	1	2	0	16	8	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
27	1	6	0	8	5	2	0	1	4	0	0	4	4	0	0	0	2	0	9	15	0
	4	11	0	2	5	3	0	8	2	0	1	0	2	0	0	2	0	0	17	7	0
	9	10	0	4	4	3	0	1	8	0	0	1	3	0	0	1	1	0	18	5	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
28	1	5	0	10	6	0	0	4	5	0	0	1	2	0	0	0	3	0	13	11	0
	4	3	0	3	9	0	0	4	4	0	0	2	7	0	0	2	2	0	17	7	0
	9	3	0	4	5	0	0	6	6	1	0	2	4	0	0	0	5	0	18	5	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
29	1	3	0	10	5	1	0	3	1	0	0	4	5	0	0	1	3	0	11	12	1
	4	4	0	10	4	0	0	6	1	0	0	5	1	0	0	1	4	0	12	12	0
	9	0	0	10	6	0	0	6	3	0	0	4	1	0	0	4	2	0	10	14	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30	1	7	2	11	0	1	0	4	1	1	1	1	3	2	0	2	0	0	4	11	9
	4	6	0	5	4	0	0	6	3	0	0	6	1	0	0	3	2	0	10	12	2
	9	2	1	13	4	1	1	3	3	0	0	4	3	0	0	1	0	0	4	19	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
31	1	11	3	0	1	1	4	1	0	1	7	0	1	2	3	0	1	14	0	4	6
	4	4	2	2	0	2	3	0	1	3	6	1	1	3	6	1	1	12	6	1	5
	9	5	1	1	1	5	9	2	1	1	5	0	2	2	1	0	0	15	2	1	6

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
32	1	14	1	3	3	2	0	4	2	2	0	0	0	1	0	2	2	0	7	11	6
	4	6	1	3	1	2	2	3	2	1	1	4	2	4	1	0	3	4	5	10	5
	9	6	2	4	4	2	1	4	1	3	0	1	2	1	3	1	1	8	3	4	9

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
33	1	7	2	6	3	3	0	4	0	1	3	3	2	1	0	1	0	8	1	8	7
	4	3	0	5	7	0	0	6	2	0	0	2	1	0	1	3	6	2	7	12	3
	9	4	1	7	1	0	1	6	1	0	0	3	5	0	0	5	2	0	6	16	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
34	1	19	1	4	2	1	0	0	3	0	0	1	4	1	0	0	0	4	6	7	7
	4	12	0	5	3	3	1	0	2	0	0	0	4	2	2	2	0	1	14	6	3
	9	5	3	6	2	7	2	2	2	1	1	2	1	0	1	0	1	9	6	4	5

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
35	1	6	1	5	5	0	0	5	3	1	1	1	4	0	0	0	4	5	11	7	1
	4	3	1	6	11	0	0	0	6	0	0	0	3	0	2	1	2	0	17	6	1
	9	1	0	7	7	0	1	1	4	0	1	0	8	0	0	2	4	4	17	3	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
36	1	12	1	3	6	1	0	1	5	0	0	0	6	0	0	1	0	2	13	4	5
	4	4	4	4	5	0	0	3	8	0	0	0	0	2	1	1	4	5	12	7	0
	9	11	0	5	1	1	3	0	2	0	1	3	3	0	0	2	4	2	18	3	1

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
37	1	17	0	6	4	0	0	2	2	0	0	1	2	0	0	1	1	0	13	6	5
	4	12	2	5	4	0	0	3	3	1	0	2	2	0	0	1	1	4	13	4	3
	9	9	0	4	7	1	0	2	4	0	1	3	2	0	0	1	2	1	15	5	3

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
38	1	10	0	8	7	1	0	3	1	0	0	0	5	0	0	1	0	0	15	8	1
	4	9	0	6	6	0	0	4	2	0	1	1	2	0	0	3	2	1	11	12	0
	9	6	0	8	3	1	0	3	2	0	0	1	6	0	0	3	3	1	16	7	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
39	1	5	2	15	3	1	0	3	2	0	0	2	2	0	0	0	1	3	13	6	2
	4	8	0	8	9	0	0	4	1	0	0	2	2	0	0	1	1	0	14	9	1
	9	1	0	4	9	0	0	2	5	1	0	3	8	0	0	1	2	0	16	8	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
40	1	4	2	6	6	1	0	1	0	0	1	4	4	1	0	4	2	1	5	12	6
	4	0	1	5	3	0	0	5	2	2	0	3	3	2	0	6	4	1	12	8	3
	9	1	0	5	7	0	0	2	1	2	0	3	5	1	1	5	3	3	9	10	2

Table C2.

The following table includes the raw data for each of the 30 individual participants in Experiment 2. The participant number is listed on the left, and the data is separated by the yes/no response with high and low confidence, and whether or not participants chose the correct word on the 4-, 3-, or 2-alernative response, or were incorrect. The yes/no response and confidence is listed for foil trials as well.

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
1	0	2	2	4	3	0	0	2	3	0	1	2	2	0	0	0	3	2	9	6	1
	1	7	0	5	3	1	0	1	0	0	0	2	4	0	0	0	1	2	10	5	1
	4	4	0	2	4	0	2	0	7	0	0	2	0	0	1	0	2	0	11	7	0
	9	3	0	4	5	0	1	4	2	0	0	0	2	0	0	0	3	0	8	8	2

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
2	0	5	0	6	2	0	0	2	4	0	0	0	1	0	0	3	1	0	10	7	1
	1	4	0	8	4	0	0	3	2	0	0	1	2	0	0	0	0	0	8	10	0
	4	1	0	4	4	0	0	1	5	0	0	2	3	0	0	3	1	0	6	12	0
	9	0	0	5	1	0	0	8	5	0	0	1	1	0	0	2	1	0	8	8	2

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
3	0	6	0	6	3	2	0	2	2	0	0	0	1	0	0	1	1	6	5	7	0
	1	6	0	8	2	0	0	2	2	0	0	1	3	0	0	0	0	0	10	7	1
	4	4	0	3	4	0	0	4	1	0	1	1	4	0	0	2	0	0	10	8	0
	9	7	0	4	3	0	0	1	2	0	0	3	2	0	0	0	2	1	6	11	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
4	0	11	0	1	4	1	1	0	2	0	2	0	1	0	0	0	1	2	10	6	0
	1	6	2	2	3	0	1	2	2	0	1	2	2	0	1	0	0	3	8	6	1
	4	7	0	6	2	0	2	1	2	1	0	0	0	0	0	1	2	4	11	2	1
	9	3	1	2	6	1	1	2	3	0	0	0	2	0	0	1	2	2	11	5	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
5	0	16	0	3	1	0	0	2	0	0	0	0	1	0	1	0	0	7	5	6	0
	1	16	2	2	2	1	0	1	0	0	0	0	0	0	0	0	0	4	8	6	0
	4	7	1	5	2	1	0	2	1	0	0	1	2	1	1	0	0	5	7	4	2
	9	13	0	0	1	1	1	1	0	1	0	3	1	0	0	2	0	2	3	9	4

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
6	0	17	0	2	1	0	0	0	2	0	0	0	0	2	0	0	0	9	5	1	3
	1	15	1	1	0	2	0	0	2	0	1	0	1	1	0	0	0	6	6	3	3
	4	4	3	6	1	1	1	0	0	0	1	1	0	0	2	3	1	6	5	4	3
	9	3	2	2	1	1	1	2	4	1	1	0	2	0	2	0	2	9	4	0	5

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
7	0	7	0	11	1	0	0	1	0	0	0	0	2	0	0	1	1	0	12	6	0
	1	9	0	7	5	0	0	0	1	0	0	1	0	0	0	1	0	0	9	9	0
	4	6	0	9	4	0	0	0	1	0	0	0	3	0	0	1	0	0	11	6	1
	9	1	0	9	0	0	0	5	5	0	0	1	1	0	0	0	2	0	13	4	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
8	0	8	0	8	1	0	1	1	1	0	0	2	1	0	0	1	0	2	8	7	1
	1	6	0	7	4	0	0	0	3	0	0	3	1	0	0	0	0	0	11	7	0
	4	2	1	5	4	1	0	1	3	0	0	2	2	0	0	0	3	1	8	8	1
	9	3	1	9	2	0	0	2	2	0	0	1	1	0	0	2	1	0	12	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
9	0	4	0	3	5	0	0	0	2	0	0	2	6	0	0	0	2	3	11	4	0
	1	2	0	4	1	0	0	3	5	0	0	9	0	0	0	0	0	0	7	11	0
	4	7	0	4	2	0	1	1	2	0	0	3	2	0	0	2	0	2	8	7	1
	9	2	0	1	4	1	0	3	6	0	0	3	2	0	0	1	1	0	10	7	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
10	0	10	0	3	2	0	0	2	4	0	0	0	3	0	0	0	0	0	14	4	0
	1	12	0	6	2	0	0	0	3	0	0	1	0	0	0	0	0	2	11	5	0
	4	2	0	4	7	0	1	1	5	0	1	1	1	0	0	0	1	1	10	5	2
	9	6	2	4	4	1	0	1	1	0	0	1	4	0	0	0	0	2	8	8	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
11	0	8	1	6	3	0	0	1	2	0	0	1	1	0	0	0	1	3	9	6	0
	1	6	0	2	9	0	2	3	0	0	0	0	2	0	0	0	0	2	9	5	2
	4	1	1	4	3	0	0	2	3	0	0	1	4	0	1	2	2	1	10	6	1
	9	2	0	3	3	0	0	2	4	1	0	3	5	0	0	0	1	1	11	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
12	0	8	0	4	4	0	0	1	3	1	0	1	2	0	0	0	0	2	10	6	0
	1	8	0	6	4	0	0	1	1	0	0	0	2	0	0	0	2	1	14	3	0
	4	3	1	3	10	0	1	0	1	0	0	0	3	0	1	0	1	2	10	6	0
	9	0	2	5	8	0	0	1	1	0	0	2	1	0	0	0	4	0	13	5	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
13	0	14	0	3	1	0	0	4	1	0	0	0	0	1	0	0	0	2	9	6	1
	1	6	0	7	1	0	0	5	1	0	0	1	1	0	0	2	0	0	8	10	0
	4	3	1	4	2	0	1	2	2	1	1	3	0	0	0	1	3	1	7	8	2
	9	3	0	5	3	0	0	9	1	0	0	1	1	0	0	0	1	0	7	11	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
14	0	11	1	1	4	0	2	0	1	0	0	0	0	0	1	1	2	13	5	0	0
	1	7	2	2	4	2	0	0	4	0	0	1	1	0	0	0	1	9	4	4	1
	4	1	4	1	3	0	5	2	2	0	1	0	4	0	0	0	1	10	7	1	0
	9	1	4	3	1	0	3	1	2	0	2	0	4	0	0	1	2	3	9	3	3

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
15	0	9	0	3	2	2	1	2	0	0	0	1	0	0	2	2	0	5	7	5	1
	1	9	0	7	0	1	0	0	0	0	1	1	1	0	0	2	2	2	5	8	3
	4	6	1	4	1	2	1	3	2	0	0	3	0	1	0	0	0	0	10	5	3
	9	5	0	6	3	0	1	1	0	1	0	3	1	1	0	2	0	1	6	10	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
16	0	13	1	4	2	0	0	0	1	0	0	0	1	0	1	1	0	7	5	6	0
	1	16	0	3	0	0	0	2	1	0	0	0	2	0	0	0	0	8	7	3	0
	4	6	1	3	3	0	0	2	4	0	0	1	4	0	0	0	0	1	14	2	1
	9	4	2	2	2	0	0	0	2	0	1	3	3	0	1	0	4	5	10	3	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
17	0	8	0	4	3	0	0	3	3	0	0	0	0	0	0	3	0	2	7	5	4
	1	4	1	3	3	0	1	2	1	2	1	1	1	2	0	2	0	1	9	6	2
	4	3	0	2	5	2	2	0	0	0	2	2	3	0	1	1	1	2	7	8	1
	9	3	1	2	3	0	0	2	2	2	0	5	1	1	0	1	1	0	11	5	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
18	0	13	0	6	0	0	0	0	3	0	0	0	0	0	0	1	1	2	6	10	0
	1	3	0	6	6	0	0	1	3	0	0	1	0	0	1	2	1	0	11	7	0
	4	5	0	4	5	0	0	1	4	0	0	2	2	1	0	0	0	0	12	6	0
	9	2	0	3	2	0	0	3	3	0	0	4	0	0	0	5	2	0	5	12	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
19	0	7	0	11	2	0	0	2	0	0	0	0	0	0	0	1	1	0	13	3	2
	1	6	0	8	2	0	0	2	2	0	0	2	0	0	0	0	2	0	10	8	0
	4	5	0	1	4	1	0	3	5	0	0	2	2	0	0	0	1	0	9	9	0
	9	3	0	8	2	0	0	3	2	0	0	1	3	0	0	1	1	0	10	8	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
20	0	8	0	3	4	0	0	3	1	0	0	0	1	0	0	3	1	1	11	5	1
	1	10	0	8	1	0	0	1	1	0	0	0	3	0	0	0	0	0	7	11	0
	4	2	0	10	4	0	0	0	4	0	0	3	0	0	0	1	0	0	7	10	1
	9	6	0	6	3	0	0	2	1	0	0	3	0	0	0	2	1	0	4	14	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
21	0	5	1	5	1	2	1	5	0	0	0	1	0	0	0	1	2	4	6	5	3
	1	7	0	8	2	0	0	2	0	0	0	0	2	0	0	2	1	0	6	10	2
	4	4	0	7	4	0	0	1	2	0	0	1	3	0	0	2	0	0	4	14	0
	9	1	0	4	4	1	0	3	3	0	0	3	1	0	0	3	1	0	9	8	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
22	0	20	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	13	5	0	0
	1	16	2	2	3	0	0	0	1	0	0	0	0	0	0	0	0	8	8	1	1
	4	12	4	1	3	0	1	0	2	0	0	0	0	0	0	0	1	8	9	0	1
	9	11	2	4	4	0	1	0	0	0	0	0	0	0	0	0	2	5	10	2	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
23	0	5	0	9	3	0	0	0	1	0	0	1	0	0	0	1	4	0	10	7	1
	1	2	0	6	4	0	0	2	4	0	0	2	0	0	0	1	3	0	10	8	0
	4	3	0	2	9	0	0	1	2	0	0	2	3	0	0	1	1	0	11	7	0
	9	2	0	2	3	0	0	5	2	0	0	4	1	0	0	2	3	0	14	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
24	0	17	0	1	1	0	0	1	1	0	0	1	1	0	0	0	1	5	7	5	1
	1	19	1	1	1	0	0	0	0	1	0	0	1	0	0	0	0	1	10	5	2
	4	9	1	5	3	1	0	2	2	0	0	1	0	0	0	0	0	4	8	3	3
	9	9	2	4	0	0	1	3	1	0	0	1	1	0	0	2	0	4	5	7	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
25	0	18	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	4	12	2	0
	1	8	1	7	4	0	0	1	1	0	0	0	1	0	0	0	1	1	14	2	1
	4	14	0	5	2	0	0	0	1	0	1	0	0	0	1	0	0	3	13	2	0
	9	12	2	1	3	0	0	0	2	0	0	1	1	0	0	1	1	2	14	1	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
26	0	9	0	3	6	1	0	0	1	1	0	1	0	0	0	0	2	2	10	5	1
	1	6	1	10	1	0	0	0	1	1	0	2	0	0	0	1	1	1	11	6	0
	4	1	0	7	3	2	0	0	5	0	0	2	3	0	0	1	0	0	7	9	2
	9	3	0	4	5	0	0	2	3	1	0	1	3	1	0	1	0	0	8	9	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
27	0	7	0	2	3	1	0	2	4	0	0	0	2	0	1	0	2	3	10	4	1
	1	4	1	4	6	0	0	3	2	0	1	0	1	0	0	0	2	0	10	6	2
	4	2	0	5	6	0	0	2	4	0	0	0	2	0	0	3	0	0	12	6	0
	9	3	0	7	1	0	0	4	4	0	0	1	0	0	0	0	4	0	12	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
28	0	10	1	2	2	0	0	1	3	0	0	1	2	1	0	1	0	3	9	6	0
	1	4	0	8	2	0	0	3	4	0	0	0	2	0	0	0	1	0	8	10	0
	4	1	1	3	9	0	0	0	5	0	1	0	0	0	0	2	2	0	11	7	0
	9	0	0	4	7	1	0	0	2	0	0	1	2	0	0	2	5	0	9	9	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
29	0	1	0	8	5	0	0	4	1	0	0	4	1	0	0	0	0	1	11	6	0
	1	0	0	8	1	0	0	6	3	0	0	1	2	0	0	2	1	0	8	10	0
	4	1	0	5	5	0	0	2	4	0	0	3	0	0	0	2	2	0	6	11	1
	9	1	0	10	2	0	0	2	1	0	0	2	3	0	0	2	1	0	9	9	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
30	0	7	0	5	3	0	0	3	2	0	0	1	1	0	0	1	1	0	9	5	4
	1	7	0	4	2	0	0	4	2	0	0	2	2	0	0	1	0	1	9	6	2
	4	6	0	6	4	2	0	1	3	0	0	0	2	0	0	0	0	0	8	8	2
	9	8	0	4	2	3	0	2	1	1	0	1	1	0	0	0	1	1	7	8	2

Table C3.

The following table includes the raw data for each of the 9 individual participants in Experiment 3. The participant number is listed on the left, and the data is separated by the yes/no response with high and low confidence, and whether or not participants chose the correct word on the 4-, 3-, or 2-alernative response, or were incorrect. The yes/no response and confidence is listed for foil trials as well.

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 1	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	45	7	1	3	0	1	0	1	0	0	0	1	0	1	0	0	31	23	5	1
5 min	38	6	5	2	1	2	1	3	0	1	0	1	0	0	0	0	36	17	5	2
15 min	31	3	1	6	1	2	3	2	0	1	2	3	0	4	0	1	21	27	8	4
30 min	26	1	2	10	0	4	2	3	1	1	0	5	0	2	1	2	21	26	8	5
1 hr	19	5	3	7	2	2	2	4	0	3	2	5	0	4	0	2	27	21	8	4
3 hr	13	3	6	6	2	2	2	9	2	2	3	3	0	0	1	6	13	28	13	6
9 hr	5	0	8	11	0	1	3	6	0	0	5	10	0	0	6	5	0	37	22	1
24 hr	4	2	6	7	1	0	2	9	0	0	5	8	0	2	5	9	3	39	17	1
72 hr	0	0	13	6	1	0	7	10	0	0	5	8	0	0	6	4	0	32	27	1
144 hr	3	0	11	8	0	2	5	4	1	2	5	8	0	1	3	7	3	29	23	5

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 2	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	36	3	4	6	0	0	1	3	0	1	2	4	0	0	0	0	19	25	13	3
5 min	26	3	8	2	0	1	1	5	1	0	1	6	1	2	2	1	17	33	10	0
15 min	12	0	7	7	0	1	6	4	1	0	4	9	0	2	4	3	2	37	18	3
30 min	15	0	5	8	2	0	2	8	0	0	3	5	1	0	4	7	1	32	21	6
1 hr	19	0	6	7	1	0	5	9	0	0	4	2	0	0	4	3	0	29	30	1
3 hr	1	1	6	9	0	0	11	11	0	0	5	6	0	0	5	5	0	31	29	0
9 hr	4	0	4	13	0	0	4	11	0	0	4	7	0	0	5	8	0	39	21	0
24 hr	0	0	8	10	0	0	6	8	0	0	8	5	0	0	4	11	0	40	20	0
72 hr	0	0	11	10	0	0	6	5	0	0	6	7	0	0	9	6	0	32	28	0
144 hr	1	0	8	6	0	0	7	11	0	0	4	9	0	0	3	11	0	36	24	0

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 3	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	27	4	3	1	3	1	6	0	1	5	1	4	0	3	0	1	34	16	6	4
5 min	18	8	2	2	3	5	3	3	1	8	2	1	0	3	0	1	39	11	5	5
15 min	15	6	0	7	6	4	0	3	0	7	1	5	1	2	0	3	33	8	2	17
30 min	10	12	0	8	3	3	3	2	2	7	0	0	1	6	0	3	41	7	4	8
1 hr	10	18	1	2	4	7	0	1	0	6	0	1	1	8	0	1	47	4	3	6
3 hr	5	9	2	0	0	12	2	0	1	12	3	4	1	8	1	0	36	3	9	12
9 hr	1	1	6	9	0	0	2	12	0	0	8	8	0	0	4	9	0	45	15	0
24 hr	0	0	4	12	0	0	4	6	0	0	3	11	0	0	4	16	0	51	9	0
72 hr	0	0	2	13	0	0	7	13	0	0	4	9	0	0	2	10	0	50	10	0
144 hr	0	0	2	9	0	0	3	14	0	0	1	18	0	0	3	10	0	58	2	0

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 4	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	57	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	43	12	4	1
5 min	52	4	3	0	1	0	0	0	0	0	0	0	0	0	0	0	50	5	4	1
15 min	49	3	5	0	2	0	0	1	0	0	0	0	0	0	0	0	29	17	11	3
30 min	40	8	4	2	1	0	1	3	0	1	0	0	0	0	0	0	33	15	8	4
1 hr	38	6	5	3	1	1	1	0	1	2	0	0	0	1	0	1	25	18	10	7
3 hr	32	0	13	2	0	0	6	1	0	0	1	3	0	1	1	0	18	25	14	3
9 hr	25	2	11	3	1	1	6	3	0	2	3	1	0	2	0	0	37	7	10	6
24 hr	19	6	11	3	1	2	5	1	0	3	2	2	0	2	2	1	32	12	11	5
72 hr	9	6	17	2	1	2	8	2	0	3	1	3	1	0	3	2	26	14	16	4
144 hr	6	2	9	4	5	6	5	4	2	3	2	1	1	5	4	1	25	15	20	0

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 5	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	17	1	10	4	1	1	6	5	0	1	0	7	0	1	4	2	15	27	0	18
5 min	6	2	10	8	2	1	5	4	0	4	4	4	0	0	3	7	15	29	13	3
15 min	5	1	12	3	2	4	4	6	1	1	3	8	1	0	4	5	7	26	26	1
30 min	2	2	11	8	1	2	5	9	0	0	6	4	2	1	1	6	8	19	29	4
1 hr	0	0	7	11	0	4	3	5	1	0	6	12	0	2	3	6	13	23	24	0
3 hr	4	0	4	9	0	2	8	7	0	2	8	5	0	2	6	3	2	37	19	2
9 hr	1	0	8	9	0	1	4	10	0	1	4	7	0	0	3	12	3	40	17	0
24 hr	0	0	5	11	0	0	5	11	0	0	5	12	0	0	6	5	0	36	23	1
72 hr	0	0	9	6	0	0	6	12	0	0	5	11	1	0	3	7	0	43	16	1
144 hr	0	0	4	6	0	0	4	12	0	0	6	9	0	0	7	12	0	45	13	2

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 6	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	53	1	1	2	0	0	1	1	0	0	1	0	0	0	0	0	27	21	10	2
5 min	45	1	3	2	4	1	1	0	0	1	0	1	0	0	0	1	24	24	9	3
15 min	37	0	3	5	1	1	1	2	2	0	2	3	0	0	0	3	5	39	6	10
30 min	33	0	8	5	3	0	2	5	1	0	0	2	0	1	0	0	6	35	15	4
1 hr	25	2	13	7	1	1	6	3	0	0	1	0	0	0	0	1	10	26	20	4
3 hr	24	0	11	3	0	1	1	11	0	0	2	4	0	0	1	2	1	33	24	2
9 hr	19	0	10	7	0	0	5	4	0	0	5	2	1	0	3	4	1	34	18	7
24 hr	12	0	12	5	2	0	5	7	0	0	5	5	3	0	4	0	0	33	22	5
72 hr	1	0	13	9	0	0	7	9	0	0	6	1	0	0	10	4	2	27	28	3
144 hr	0	2	10	5	0	1	10	7	0	1	5	9	0	1	4	5	0	33	27	0

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 7	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	48	0	7	3	0	1	1	0	0	0	0	0	0	0	0	0	23	33	3	1
5 min	50	1	4	3	0	0	0	1	0	0	0	0	0	0	0	1	20	32	7	1
15 min	41	0	6	6	2	0	1	2	0	1	0	0	0	1	0	0	11	37	8	4
30 min	30	2	10	8	1	0	2	2	0	0	0	5	0	0	0	0	8	39	12	1
1 hr	27	3	7	12	2	0	0	3	0	0	1	2	0	1	0	2	1	47	10	2
3 hr	21	0	8	9	1	1	4	8	0	0	0	4	0	1	1	2	3	44	12	1
9 hr	14	1	6	8	2	1	1	8	1	0	7	6	1	0	2	2	1	33	21	5
24 hr	10	2	8	6	4	5	6	4	2	2	4	1	2	1	2	1	13	22	19	6
72 hr	6	0	9	8	4	1	4	6	0	1	6	5	0	1	1	8	1	28	24	7
144 hr	2	0	13	4	2	1	7	6	1	0	8	9	0	0	2	5	0	23	29	8

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 8	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	39	1	0	4	0	0	5	7	0	0	1	1	0	0	2	0	6	37	15	2
5 min	29	2	6	10	1	0	1	2	0	1	0	6	0	0	0	2	7	45	5	3
15 min	35	0	7	7	0	0	2	1	1	0	2	1	0	0	1	3	1	46	8	5
30 min	23	1	6	8	1	1	4	5	1	2	1	2	1	1	1	2	2	45	7	6
1 hr	14	2	8	14	1	0	0	9	0	0	1	4	1	0	4	2	8	43	7	2
3 hr	10	2	7	14	1	1	0	4	0	3	4	6	0	1	1	6	12	37	10	1
9 hr	11	0	6	13	0	4	1	5	0	1	1	9	1	0	5	3	13	34	9	4
24 hr	13	0	7	9	0	0	4	9	0	0	2	8	1	0	2	5	2	46	11	1
72 hr	5	0	9	9	0	0	5	11	0	0	1	9	0	0	4	7	1	47	11	1
144 hr	5	0	8	6	1	0	6	9	0	0	3	11	0	0	1	10	2	38	19	1

	4AFC				3AFC				2AFC				Incorrect				Foils			
S 9	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30 sec	33	1	4	8	0	1	0	6	0	1	1	4	0	0	1	0	10	42	6	2
5 min	19	1	7	7	0	0	1	10	0	0	1	7	0	0	2	5	7	47	2	4
15 min	12	1	7	8	2	0	4	9	1	0	1	11	0	0	0	4	5	45	10	0
30 min	5	1	3	12	1	2	1	13	0	2	2	6	0	2	5	5	14	39	7	0
1 hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 hr	4	8	7	3	0	7	1	8	0	2	2	4	0	4	4	6	25	28	7	0
9 hr	4	1	3	5	0	1	8	13	1	1	3	5	0	5	5	5	14	27	17	2
24 hr	4	2	7	12	0	2	1	6	0	1	0	14	0	0	2	9	6	45	9	0
72 hr	0	0	2	12	0	0	4	9	0	0	3	15	0	1	2	12	5	41	14	0
144 hr	1	1	5	15	0	0	2	9	0	2	3	7	0	1	1	13	13	40	7	0

Table C4.

The following table has the MLE and PPM estimates, as well as the standard deviation of the PPM estimates for each of the 9 participants in Experiment 3

	S1 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.750	.594	.619	.487	.502	.401	.426	.334	.301	.235
		(.058)		(.614)		(.058)		(.057)		(.055)
θ_{si}	.150	.102	.114	.100	.048	.058	.074	.078	.099	.091
		(.054)		(.547)		(.041)		(.051)		(.056)
θ_N	.067	.238	0	.207	.117	.417	.333	.446	.400	.497
		(.086)		(.098)		(.104)		(.115)		(.128)
θ_F	.033	.067	.267	.206	.333	.124	.167	.142	.200	.177
		(.072)		(.106)		(.100)		(.108)		(.127)
θ_K	.054	.250	.372	.439	.001	.055	.027	.124	.001	.103
		(.163)		(.165)		(.081)		(.110)		(.118)
θ_{f2}	.999	.377	.625	.578	.571	.377	.400	.382	.001	.234
		(.434)		(.354)		(.418)		(.408)		(.346)
θ_{y*}	.106	.218	.186	.319	.186	.213	.223	.279	.186	.219
		(.097)		(.138)		(.080)		(.089)		(.089)
θ_y	.001	.491	.247	.454	.722	.522	.204	.466	.445	.497
		(.088)		(.119)		(.093)		(.108)		(.106)
$\theta_{y'}$	.307	.419	.999	.805	.001	.219	.063	.149	.287	.405
		(.325)		(.248)		(.281)		(.191)		(.314)
θ_L	.329	.331	.510	.428	.688	.721	.999	.954	.627	.673
		(.279)		(.302)		(.339)		(.130)		(.328)
θ_a	.167	.324	.284	.392	.315	.410	.377	.407	.334	.412
		(.163)		(.159)		(.134)		(.120)		(.136)
$\theta_{a'}$	.537	.415	.445	.324	.463	.461	.204	.369	.568	.518
		(.167)		(.213)		(.103)		(.129)		(.116)
θ_b	.260	.514	.5	.522	.272	.470	.001	.422	.334	.522
		(.164)		(.206)		(.133)		(.200)		(.177)
$\theta_{b'}$	.469	.509	.5	.488	.260	.503	.192	.559	.001	.404
		(.163)		(.192)		(.191)		(.189)		(.238)
P(coh)		.135		.273		.054		.238		.255

	S1 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.173	.142	.087	.065	0	.053	.001	.013	.042	.036
		(.049)		(.032)		(.029)		(.013)		(.026)
θ_{si}	.044	.070	.146	.107	.001	.058	.016	.081	.141	.111
		(.050)		(.065)		(.045)		(.053)		(.064)
θ_N	.467	.548	.733	.730	.999	.825	.667	.735	.733	.734
		(.134)		(.126)		(.092)		(.151)		(.133)
θ_F	.317	.240	.033	.098	.001	.064	.317	.171	.083	.119
		(.139)		(.109)		(.080)		(.148)		(.119)
θ_K	.211	.149	.001	.004	.001	.008	.001	.005	.001	.012
		(.808)		(.010)		(.019)		(.012)		(.024)
θ_{f2}	.526	.437	.001	.087	.001	.208	.526	.394	.001	.078
		(.383)		(.245)		(.374)		(.424)		(.234)
θ_{y*}	.401	.345	.383	.423	.297	.320	.463	.488	.426	.419
		(.086)		(.069		(.063)		(.070)		(.071)
θ_y	.303	.483	.204	.484	.999	.500	.617	.466	.759	.491
		(.102)		(.079)		(.053)		(.109)		(.085)
$\theta_{y'}$	.999	.745	.477	.456	.999	.682	.999	.875	.704	.742
		(.295)		(.308)		(.318)		(.215)		(.258)
θ_L	.999	.589	.999	.847	.001	.576	.999	.882	.999	.881
		(.365)		(.222)		(.397)		(.224)		(.192)
θ_a	.297	.350	.026	.089	.007	.114	.026	.070	.149	.204
		(.099)		(.051)		(.064)		(.038)		(.068)
$\theta_{a'}$	.001	.127	.001	.067	.087	.145	.001	.075	.106	.148
		(.102)		(.051)		(.057)		(.056)		(.071)
θ_b	.734	.562	.001	.493	.999	.524	.063	.410	.001	.416
		(.213)		(.157)		(.119)		(.202)		(.191)
$\theta_{b'}$	.537	.451	592	.501	.001	.465	.001	.381	.999	.552
		(.180)		(.137)		(.132)		(.212)		(.186)
P(coh)		.245		.122		.051		.027		.159

	S2 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.612	.471	.427	.348	.200	.155	.193	.183	.282	.240
		(.061)		(.057)		(.047)		(.050)		(.055)
θ_{si}	.138	.123	.106	.809	.050	.072	.006	.057	.001	.052
		(.057)		(.050)		(.052)		(.044)		(.042)
θ_N	0	.206	.400	.478	.600	.635	.800	.680	.467	.525
		(.097)		(.110)		(.124)		(.101)		(.119)
θ_F	.250	.200	.067	.093	.150	.138	.001	.080	.250	.183
		(.103)		(.093)		(.117)		(.089)		(.123)
θ_K	.304	.177	.067	.103	.001	.004	.015	.011	.001	.004
		(.118)		(.093)		(.012)		(.019)		(.010)
θ_{f2}	.001	.076	.001	.203	.001	.105	.001	.518	.999	.728
		(.192)		(.354)		(.264)		(.461)		(.350)
θ_{y*}	.383	.360	.106	.285	.346	.372	.457	.444	.512	.519
		(.104)		(.072)		(.069)		(.073)		(.074)
θ_y	.272	.436	.500	.482	.722	.501	.759	.494	.389	.492
		(.137)		(.083)		(.082)		(.059)		(.072)
$\theta_{y'}$	.481	.486	.999	.933	.739	.642	.130	.435	.999	.424
		(.304)		(.161)		(.322)		(.347)		(.351)
θ_L	.684	.582	.724	.653	.999	.803	.999	.896	.999	.923
		(.263)		(.329)		(.292)		(.232)		(.212)
θ_a	.186	.268	.075	.174	.118	.180	.229	.259	.026	.080
		(.108)		(.097)		(.075)		(.075)		(.045)
$\theta_{a'}$	.032	.259	.260	.310	.081	.159	.001	.077	.001	.089
		(.163)		(.111)		(.060)		(.058)		(.064)
θ_b	.001	.435	.765	.508	.050	.421	.999	.528	.328	.510
		(.287)		(.164)		(.190)		(.122)		(.140)
$\theta_{b'}$	.124	.315	.001	.448	.001	.518	.001	.473	.001	.434
		(.262)		(.179)		(.192)		(.120)		(.160)
P(coh)		.166		.020		.022		.132		.091

	S2 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	0	.021 (.017)	.063	.052 (.029)	0	.014 (.014)	0	.013 (.013)	0	.021 (.018)
θ_{si}	.001	.050 (.043)	.037	.066 (.050)	.001	.073 (.053)	.001	.096 (.066)	.001	.047 (.038)
θ_N	.667	.706 (.150)	.867	.773 (.112)	.999	.856 (.099)	.999	.858 (.095)	.933	.830 (.105)
θ_F	.417	.224 (.149)	.033	.110 (.110)	.001	.058 (.084)	.001	.033 (.062)	.017	.102 (.100)
θ_K	.001	.004 (.010)	.001	.004 (.010)	.001	.005 (.011)	.001	.005 (.011)	.001	.004 (.010)
θ_{f2}	.880	.571 (.389)	.999	.477 (.448)	.001	.284 (.424)	.001	.171 (.361)	.999	.385 (.442)
θ_{y*}	.482	.482 (.072)	.340	.368 (.068)	.334	.333 (.064)	.463	.502 (.068)	.358	.356 (.068)
θ_y	.420	.498 (.114)	.001	.486 (.078)	.999	.508 (.052)	.999	.500 (.045)	.925	.497 (.084)
$\theta_{y'}$	.001	.315 (.342)	.001	.163 (.258)	.999	.660 (.327)	.999	.542 (.301)	.999	.848 (.261)
θ_L	.001	.697 (.388)	.999	.888 (.237)	.999	.872 (.239)	.999	.906 (.192)	.999	.762 (.344)
θ_a	.001	.050 (.034)	.001	.067 (.047)	.001	.061 (.042)	.001	.039 (.029)	.001	.067 (.047)
$\theta_{a'}$	.001	.077 .056	.001	.058 (.045)	.001	.053 (.042)	.001	.070 (.056)	.001	.057 (.043)
θ_b	.001	.337 (.220)	.001	.489 (.146)	.001	.477 (.102)	.001	.484 (.097)	.001	.440 (.169)
$\theta_{b'}$	.069	.357 (.226)	.001	.451 (.149)	.001	.487 (.097)	.001	.496 (.095)	.001	.440 (.177)
P(coh)		.030		.133		.057		.068		.026

	S3 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.416	.340	.262	.206	.199	.140	.128	.107	.130	.107
		(.058)		(.056)		(.053)		(.045)		(.045)
θ_{si}	.001	.046	.005	.058	.051	.081	.189	.126	.187	.131
		(.036)		(.043)		(.053)		(.069)		(.069)
θ_{N}	.267	.396	.267	.413	.400	.516	.667	.670	.667	.660
		(.118)		(.129)		(.142)		(.126)		(.122)
θ_{F}	.317	.217	.467	.323	.350	.262	.017	.097	.017	.102
		(.120)		(.136)		(.147)		(.107)		(.108)
θ_{K}	.001	.206	.001	.284	.297	.330	.265	.316	.069	.303
		(.164)		(.193)		(.151)		(.183)		(.212)
θ_{f2}	.001	.090	.143	.194	.001	.198	.999	.432	.999	.629
		(.217)		(.268)		(.299)		(.449)		(.437)
θ_{y*}	.155	.243	.155	.262	.451	.413	.272	.258	.161	.231
		(.103)		(.118)		(.111)		(.095)		(.100)
θ_{y}	.746	.505	.414	.492	.100	.459	.999	.507	.999	.497
		(.042)		(.131)		(.100)		(.057)		(.057)
$\theta_{y'}$	.999	.717	.001	.541	.001	.153	.001	.093	.349	.460
		(.280)		(.282)		(.234)		(.182)		(.310)
θ_{L}	.001	.371	.001	.213	.538	.505	.400	.492	.146	.189
		(.393)		(.319)		(.359)		(.320)		(.250)
θ_{a}	.401	.470	.500	.538	.900	.860	.722	.690	.765	.691
		(.147)		(.145)		(.073)		(.126)		(.135)
$\theta_{a'}$	.685	.579	.777	.633	.599	.493	.765	.663	.900	.824
		(.142)		(.157)		(.169)		(.123)		(.101)
θ_{b}	.371	.492	.475	.519	.907	.598	.426	.491	.999	.530
		(.057)		(.207)		(.191)		(.084)		(.116)
$\theta_{b'}$	.623	.513	.771	.542	.518	.523	.001	.494	.759	.513
		(.057)		(.287)		(.186)		(.127)		(.114)
P(coh)		.181		.301		.260		.440		.580

	S3 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.032	.042	.017	.021	0	.014	0	.014	0	.011
		(.030)		(.018)		(.014)		(.014)		(.012)
θ_{si}	.001	.053	.033	.066	.001	.066	.001	.047	.001	.041
		(.041)		(.048)		(.051)		(.038)		(.033)
θ_{N}	.667	.712	.867	.812	.999	.893	.800	.768	.867	.813
		(.140)		(.113)		(.071)		(.142)		(.137)
θ_{F}	.300	.193	.017	.101	.001	.027	.283	.171	.233	.135
		(.135)		(.105)		(.045)		(.141)		(.129)
θ_{K}	.001	.064	.001	.004	.001	.004	.001	.004	.001	.006
		(.118)		(.011)		(.009)		(.010)		(.013)
θ_{f2}	.001	.025	.001	.137	.001	.091	.823	.370	.001	.091
		(.127)		(.304)		(.275)		(.410)		(.226)
θ_{y*}	.309	.349	.247	.288	.149	.201	.161	.190	.032	.132
		(.088)		(.063)		(.054)		(.057)		(.040)
θ_{y}	.137	.452	.999	.504	.999	.501	.432	.515	.426	.449
		(.115)		(.058)		(.037)		(.110)		(.117)
$\theta_{y'}$	.999	.595	.999	.644	.999	.501	.001	.207	.999	.566
		(.269)		(.338)		(.349)		(.310)		(.351)
θ_{L}	.182	.207	.476	.564	.999	.765	.999	.779	.999	.467
		(.332)		(.373)		(.344)		(.339)		(.398)
θ_{a}	.531	.571	.001	.080	.001	.100	.001	.111	.001	.214
		(.097)		(.056)		(.071)		(.078)		(.170)
$\theta_{a'}$	.937	.901	.001	.051	.001	.039	.001	.046	.001	.035
		(.073)		(.040)		(.031)		(.034)		(.031)
θ_{b}	.001	.426	.001	.481	.001	.490	.001	.339	.001	.405
		(.189)		(.131)		(.072)		(.217)		(.178)
$\theta_{b'}$	.833	.578	.001	.470	.001	.498	.001	.383	.001	.446
		(.179)		(.131)		(.075)		(.233)		(.210)
P(coh)		.130		.080		.015		.023		.002

	S4 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.950	.752	.850	.681	.776	.639	.652	.515	.620	.493
		(.052)		(.056)		(.060)		(.061)		(.060)
θ_{si}	.050	.041	.117	.754	.124	.075	.165	.128	.197	.134
		(.030)		(.043)		(.044)		(.058)		(.062)
θ_N	0	.160	0	.183	0	.186	0	.204	.133	.295
		(.062)		(.056)		(.080)		(.093)		(.103)
θ_F	.001	.046	.033	.061	.100	.100	.183	.153	.05	.078
		(.050)		(.063)		(.080)		(.098)		(.082)
θ_K	.615	.574	.833	.711	.288	.316	.486	.381	.001	.188
		(.161)		(.138)		(.156)		(.165)		(.140)
θ_{f2}	.001	.269	.999	.390	.999	.566	.727	.593	.001	.273
		(.402)		(.436)		(.419)		(.382)		(.394)
θ_{y*}	.217	.371	.500	.492	.328	.401	.389	.400	.278	.359
		(.169)		(.214)		(.134)		(.146)		(.113)
θ_y	.999	.504	.999	.508	.820	.517	.358	.487	.654	.508
		(.078)		(.083)		(.093)		(.106)		(.083)
$\theta_{y'}$	.999	.680	.999	.817	.999	.926	.999	.731	.655	.718
		(.305)		(.251)		(.168)		(.276)		(.250)
θ_L	.333	.347	.429	.425	.625	.586	.284	.296	.594	.588
		(.360)		(.315)		(.314)		(.239)		(.253)
θ_a	.198	.369	.198	.387	.217	.299	.334	.401	.414	.452
		(.177)		(.188)		(.118)		(.132)		(.117)
$\theta_{a'}$	.334	.363	.001	.483	.408	.337	.204	.357	.599	.419
		(.237)		(.282)		(.209)		(.222)		(.169)
θ_b	.925	.514	.999	.542	.999	.581	.500	.518	.882	.507
		(.141)		(.154)		(.178)		(.181)		(.142)
$\theta_{b'}$	.999	.512	.999	.502	.001	.469	.284	.387	.999	.552
		(.163)		(.162)		(.185)		(.207)		(.180)
P(coh)		.249		.720		.264		.348		.337

	S4 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.531	.417	.405	.312	.305	.236	.135	.094	.001	.065
		(.058)		(.059)		(.054)		(.042)		(.037)
θ_{si}	.135	.117	.095	.102	.195	.153	.215	.184	.016	.049
		(.059)		(.059)		(.070)		(.075)		(.040)
θ_{N}	.133	.302	.133	.309	.333	.457	.400	.512	.733	.699
		(.107)		(.117)		(.130)		(.139)		(.120)
θ_{F}	.200	.164	.367	.277	.167	.154	.250	.210	.250	.187
		(.108)		(.126)		(.122)		(.142)		(.128)
θ_{K}	.195	.115	.001	.263	.170	.285	.290	.358	.115	.120
		(.103)		(.192)		(.156)		(.100)		(.114)
θ_{f2}	.500	.444	.455	.446	.400	.385	.800	.613	.999	.799
		(.399)		(.347)		(.409)		(.384)		(.318)
θ_{y*}	.352	.369	.254	.398	.321	.431	.469	.573	.377	.444
		(.099)		(.145)		(.123)		(.111)		(.092)
θ_{y}	.839	.532	.709	.563	.888	.510	.796	.503	.913	.511
		(.094)		(.127)		(.087)		(.056)		(.069)
$\theta_{y'}$	.984	.946	.951	.838	.803	.853	.999	.970	.999	.691
		(.110)		(.205)		(.180)		(.085)		(.287)
θ_{L}	.999	.974	.887	.891	.695	.741	.730	.723	.999	.967
		(.096)		(.211)		(.227)		(.205)		(.145)
θ_{a}	.155	.234	.371	.425	.272	.331	.204	.255	.106	.112
		(.092)		(.121)		(.103)		(.084)		(.063)
$\theta_{a'}$	.204	.349	.851	.731	.642	.545	.364	.222	.593	.627
		(.145)		(.172)		(.175)		(.169)		(.124)
θ_{b}	.001	.414	.081	.330	.069	.437	.056	.459	.740	.539
		(.173)		(.204)		(.160)		(.127)		(.127)
$\theta_{b'}$	.001	.471	.032	.313	.592	.525	.950	.525	.001	.502
		(.199)		(.242)		(.194)		(.130)		(.132)
P(coh)		.085		.437		.549		.541		.056

	S5 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.251	.170	.087	.068	.036	.054	.017	.024	.001	.013
		(.054)		(.035)		(.032)		(.020)		(.013)
θ_{si}	.065	.101	.146	.118	.047	.068	.083	.105	.099	.090
		(.058)		(.066)		(.049)		(.062)		(.061)
θ_N	.467	.543	.667	.675	.667	.691	.667	.696	.733	.789
		(.126)		(.131)		(.131)		(.148)		(.134)
θ_F	.217	.186	.100	.138	.250	.188	.233	.174	.167	.108
		(.129)		(.123)		(.132)		(.146)		(.124)
θ_K	.117	.128	.229	.192	.111	.077	.072	.051	.075	.084
		(.089)		(.080)		(.054)		(.054)		(.076)
θ_{f2}	.769	.547	.001	.273	.400	.323	.999	.583	.001	.038
		(.400)		(.385)		(.389)		(.414)		(.164)
θ_{y*}	.340	.417	.346	.354	.506	.499	.592	.507	.432	.390
		(.085)		(.082)		(.078)		(.076)		(.075)
θ_y	.814	.496	.371	.510	.543	.469	.075	.476	.118	.483
		(.048)		(.079)		(.095)		(.087)		(.083)
$\theta_{y'}$	.999	.936	.771	.785	.999	.936	.999	.671	.392	.327
		(.120)		(.242)		(.159)		(.268)		(.298)
θ_L	.999	.955	.971	.811	.999	.809	.999	.886	.999	.899
		(.115)		(.234)		(.298)		(.217)		(.198)
θ_a	.808	.940	.161	.225	.063	.116	.143	.216	.001	.061
		(.055)		(.089)		(.056)		(.064)		(.044)
$\theta_{a'}$	.217	.252	.075	.109	.001	.115	.124	.233	.241	.268
		(.125)		(.091)		(.092)		(.112)		(.108)
θ_b	.001	.462	.260	.486	.771	.554	.241	.442	.740	.448
		(.129)		(.128)		(.174)		(.184)		(.182)
$\theta_{b'}$	.001	.483	.001	.529	.888	.552	.235	.441	.001	.525
		(.115)		(.172)		(.159)		(.150)		(.167)
P(coh)		.129		.425		.196		.030		.063

	S5 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	0	.047	0	.022	0	.013	0	.014	0	.012
		(.026)		(.018)		(.012)		(.014)		(.011)
θ_{si}	.001	.046	.001	.065	.001	.061	.001	.055	.001	.037
		(.034)		(.048)		(.047)		(.043)		(.034)
θ_N	.733	.732	.999	.838	.733	.740	.733	.732	.999	.908
		(.120)		(.100)		(.155)		(.149)		(.075)
θ_F	.267	.174	.001	.076	.267	.175	.317	.198	.101	.044
		(.115)		(.090)		(.151)		(.147)		(.064)
θ_K	.001	.003	.025	.030	.001	.042	.001	.004	.001	.007
		(.014)		(.033)		(.010)		(.010)		(.013)
θ_{f2}	.250	.199	.001	.377	.001	.132	.211	.187	.001	.235
		(.356)		(.452)		(.289)		(.320)		(.407)
θ_{y*}	.346	.410	.291	.283	.395	.423	.278	.308	.247	.328
		(.070)		(.066)		(.071)		(.063)		(.066)
θ_y	.623	.516	.371	.495	.137	.428	.666	.476	.999	.490
		(.099)		(.072)		(.131)		(.126)		(.045)
$\theta_{y'}$	.001	.217	.999	.781	.999	.283	.999	.872	.999	.670
		(.317)		(.281)		(.330)		(.230)		(.285)
θ_L	.999	.807	.999	.874	.999	.692	.999	.696	.999	.523
		(.319)		(.252)		(.358)		(.362)		(.440)
θ_a	.013	.139	.001	.082	.026	.078	.069	.140	.063	.131
		(.065)		(.056)		(.045)		(.069)		(.054)
$\theta_{a'}$	.093	.156	.044	.061	.001	.068	.001	.057	.001	.048
		(.059)		(.050)		(.052)		(.044)		(.037)
θ_b	.001	.404	.001	.470	.001	.380	.001	.279	.001	.461
		(.209)		(.140)		(.240)		(.240)		(.136)
$\theta_{b'}$	.358	.513	.999	.496	.001	.359	.001	.337	.001	.457
		(.208)		(.134)		(.229)		(.258)		(.135)
P(coh)		.005		.106		.026		.020		.002

	S6 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.883	.700	.691	.577	.602	.475	.497	.407	.399	.309
		(.054)		(.064)		(.061)		(.066)		(.058)
θ_{si}	.033	.043	.059	.046	.065	.064	.103	.086	.200	.169
		(.032)		(.035)		(.043)		(.054)		(.072)
θ_N	0	.176	.067	.229	.200	.335	.067	.253	.067	.256
		(.070)		(.088)		(.103)		(.104)		(.107)
θ_F	.083	.083	.183	.148	.133	.127	.333	.254	.333	.266
		(.067)		(.096)		(.098)		(.122)		(.124)
θ_K	.211	.291	.126	.262	.062	.037	.001	.019	.147	.081
		(.149)		(.132)		(.042)		(.034)		(.072)
θ_{f2}	.400	.323	.727	.503	.001	.121	.700	.621	.999	.834
		(.402)		(.392)		(.271)		(.322)		(.235)
θ_{y*}	.254	.344	.229	.312	.284	.271	.309	.324	.469	.433
		(.121)		(.108)		(.082)		(.081)		(.092)
θ_y	.617	.523	.833	.540	.759	.535	.500	.525	.654	.530
		(.101)		(.105)		(.105)		(.105)		(.087)
$\theta_{y'}$	.001	.430	.579	.714	.384	.591	.999	.805	.636	.728
		(.344)		(.307)		(.332)		(.227)		(.197)
θ_L	.501	.590	.999	.767	.999	.782	.999	.954	.917	.942
		(.377)		(.325)		(.287)		(.130)		(.110)
θ_a	.167	.273	.247	.341	.623	.623	.210	.283	.161	.232
		(.122)		(.131)		(.113)		(.100)		(.085)
$\theta_{a'}$	.408	.293	.408	.239	.038	.107	.161	.201	.038	.196
		(.190)		(.165)		(.073)		(.083)		(.127)
θ_b	.001	.485	.833	.583	.451	.489	.691	.582	.143	.437
		(.175)		(.162)		(.183)		(.172)		(.140)
$\theta_{b'}$	.001	.473	.999	.598	.352	.566	.001	.334	.284	.479
		(.196)		(.213)		(.209)		(.226)		(.141)
P(coh)		.137		.207		.220		.023		.065

	S6 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.398	.309	.300	.237	.175	.131	.006	.019	0	.014
		(.057)		(.052)		(.045)		(.017)		(.014)
θ_{si}	.018	.076	.150	.106	.075	.088	.060	.091	.001	.063
		(.050)		(.062)		(.059)		(.062)		(.048)
θ_{N}	.200	.371	.533	.569	.467	.568	.933	.834	.667	.700
		(.117)		(.116)		(.144)		(.106)		(.160)
θ_{F}	.383	.245	.017	.088	.283	.213	.001	.056	.350	.224
		(.114)		(.098)		(.142)		(.083)		(.157)
θ_{K}	.012	.009	.022	.009	.002	.003	.038	.021	.001	.001
		(.018)		(.018)		(.007)		(.027)		(.005)
θ_{f2}	.609	.518	.999	.427	.471	.449	.999	.725	.286	.225
		(.362)		(.449)		(.395)		(.429)		(.346)
θ_{y*}	.438	.430	.426	.436	.451	.538	.537	.575	.414	.439
		(.079)		(.076)		(.069)		(.069)		(.066)
θ_{y}	.383	.449	.000	.511	.679	.483	.001	.500	.740	.488
		(.111)		(.066)		(.115)		(.030)		(.120)
$\theta_{y'}$	.999	.960	.743	.760	.999	.901	.854	.580	.999	.794
		(.103)		(.227)		(.190)		(.263)		(.271)
θ_{L}	.999	.951	.999	.957	.999	.930	.999	.989	.001	.576
		(.141)		(.108)		(.168)		(.052)		(.390)
θ_{a}	.069	.137	.210	.312	.223	.259	.056	.107	.001	.053
		(.067)		(.081)		(.067)		(.045)		(.036)
$\theta_{a'}$	.007	.093	.001	.084	.001	.091	.001	.098	.026	.114
		(.064)		(.061)		(.060)		(.077)		(.055)
θ_{b}	.001	.521	.001	.462	.173	.466	.001	.487	.001	.292
		(.194)		(.132)		(.189)		(.078)		(.238)
$\theta_{b'}$	.069	.420	.001	.487	.001	.381	.001	.490	.759	.446
		(.156)		(.119)		(.227)		(.068)		(.262)
P(coh)		.084		.202		.004		.057		.022

	S7 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.800	.633	.818	.662	.651	.532	.492	.389	.421	.349
		(.055)		(.055)		(.060)		(.060)		(.058)
θ_{si}	.133	.099	.114	.074	.149	.100	.258	.202	.313	.207
		(.051)		(.045)		(.054)		(.065)		(.075)
θ_N	0	.192	.067	.218	.067	.245	0	.208	.200	.354
		(.081)		(.076)		(.098)		(.097)		(.115)
θ_F	.067	.076	.001	.046	.133	.122	.250	.201	.067	.090
		(.072)		(.057)		(.095)		(.107)		(.091)
θ_K	.369	.232	.282	.206	.001	.048	.001	.058	.001	.003
		(.133)		(.117)		(.061)		(.058)		(.010)
θ_{f2}	.999	.491	.001	.395	.999	.622	.001	.210	.999	.425
		(.440)		(.453)		(.402)		(.292)		(.440)
θ_{y*}	.106	.177	.186	.225	.192	.237	.217	.261	.192	.198
		(.079)		(.088)		(.082)		(.082)		(.070)
θ_y	.716	.511	.001	.503	.672	.523	.303	.470	.839	.510
		(.073)		(.065)		(.090)		(.118)		(.081)
$\theta_{y'}$	.646	.823	.632	.748	.553	.622	.666	.666	.411	.479
		(.181)		(.246)		(.231)		(.184)		(.185)
θ_L	.999	.966	.868	.854	.999	.970	.871	.865	.845	.868
		(.089)		(.213)		(.086)		(.129)		(.124)
θ_a	.247	.398	.124	.271	.334	.396	.075	.186	.161	.272
		(.184)		(.145)		(.130)		(.104)		(.123)
$\theta_{a'}$	.026	.222	.093	.197	.254	.236	.167	.144	.038	.104
		(.148)		(.136)		(.098)		(.092)		(.046)
θ_b	.001	.478	.260	.509	.691	.536	.334	.485	.999	.558
		(.129)		(.117)		(.127)		(.185)		(.155)
$\theta_{b'}$	.999	.554	.001	.500	.001	. 459	.001	.441	.001	.482
		(.165)		(.131)		(.188)		(.266)		(.153)
P(coh)		.072		.187		.037		.061		.043

	S7 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.332	.259	.214	.153	.089	.089	.050	.058	.007	.023
		(.057)		(.508)		(.045)		(.033)		(.019)
θ_{si}	.067	.083	.069	.092	.028	.066	.083	.080	.043	.079
		(.055)		(.057)		(.048)		(.058)		(.055)
θ_N	.267	.406	.333	.469	.400	.505	.667	.698	.467	.570
		(.122)		(.135)		(.139)		(.131)		(.151)
θ_F	.333	.252	.383	.286	.483	.340	.200	.163	.483	.328
		(.133)		(.145)		(.148)		(.130)		(.154)
θ_K	.001	.010	.012	.009	.036	.090	.001	.003	.001	.003
		(.022)		(.017)		(.080)		(.010)		(.009)
θ_{f2}	.999	.298	.001	.102	.690	.594	.500	.369	.001	.074
		(.273)		(.209)		(.331)		(.404)		(.183)
θ_{y*}	.204	.246	.438	.456	.432	.507	.463	.413	.580	.536
		(.070)		(.078)		(.091)		(.073)		(.075)
θ_y	.438	.487	.414	.473	.703	.529	.703	.518	.611	.505
		(.076)		(.107)		(.103)		(.094)		(.128)
$\theta_{y'}$	.894	.654	.620	.556	.044	.584	.700	.719	.999	.906
		(.271)		(.336)		(.329)		(.281)		(.194)
θ_L	.999	.981	.873	.732	.999	.909	.999	.938	.999	.807
		(.098)		(.291)		(.212)		(.162)		(.291)
θ_a	.069	.170	.204	.248	.272	.312	.198	.267	.204	.238
		(.092)		(.076)		(.082)		(.078)		(.067)
$\theta_{a'}$	.075	.129	.007	.093	.358	.311	.056	.129	.001	.099
		(.058)		(.064)		(.139)		(.058)		(.068)
θ_b	.223	.465	.321	.679	.432	.510	.592	.544	.143	.293
		(.126)		(.251)		(.159)		(.163)		(.241)
$\theta_{b'}$	.044	.435	.106	.381	.586	.583	.247	.483	.087	.421
		(.163)		(.202)		(.188)		(.187)		(.276)
P(coh)		.042		.112		.098		.025		.037

	S8 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.532	.497	.486	.379	.566	.462	.365	.282	.214	.179
		(.057)		(.057)		(.058)		(.055)		(.049)
θ_{si}	.001	.026	.231	.178	.166	.117	.085	.083	.253	.183
		(.020)		(.066)		(.062)		(.054)		(.075)
θ_N	.133	.292	.133	.313	.267	.370	.333	.456	.467	.530
		(.092)		(.113)		(.097)		(.122)		(.121)
θ_F	.333	.185	.150	.131	.001	.051	.217	.179	.067	.108
		(.093)		(.103)		(.069)		(.118)		(.109)
θ_K	.101	.043	.023	.056	.027	.009	.001	.006	.135	.083
		(.045)		(.054)		(.017)		(.016)		(.060)
θ_{f2}	.999	.800	.001	.100	.001	.204	.769	.550	.999	.607
		(.303)		(.239)		(.370)		(.408)		(.437)
θ_{y*}	.315	.352	.137	.176	.223	.245	.217	.260	.173	.296
		(.078)		(.071)		(.072)		(.071)		(.061)
θ_y	.297	.510	.210	.473	.999	.508	.629	.525	.272	.473
		(.082)		(.098)		(.050)		(.096)		(.091)
$\theta_{y'}$	.001	.209	.463	.523	.624	.705	.418	.616	.517	.466
		(.282)		(.218)		(.215)		(.305)		(.203)
θ_L	.800	.566	.885	.820	.999	.940	.999	.910	.872	.937
		(.488)		(.154)		(.109)		(.189)		(.090)
θ_a	.100	.174	.377	.441	.315	.409	.475	.487	.217	.272
		(.095)		(.152)		(.118)		(.117)		(.113)
$\theta_{a'}$	.001	.114	.112	.106	.001	.068	.081	.114	.001	.101
		(.076)		(.073)		(.048)		(.053)		(.073)
θ_b	.001	.453	.555	.504	.001	.488	.149	.421	.999	.538
		(.130)		(.149)		(.078)		(.168)		(.137)
$\theta_{b'}$	.100	.426	.112	.501	.001	.507	.408	.512	.001	.457
		(.171)		(.212)		(.087)		(.197)		(.134)
P(coh)		.002		.188		.135		.022		.007

	S8 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.173	.130 (.043)	.176	.129 (.045)	.214	.166 (.047)	.080	.061 (.033)	.049	.060 (.032)
θ_{si}	.277	.192 (.082)	.158	.120 (.066)	.053	.075 (.051)	.037	.072 (.052)	.001	.052 (.041)
θ_{N}	.533	.597 (.132)	.600	.647 .123	.533	.590 (.125)	.733	.714 (.128)	.733	.716 (.126)
θ_{F}	.167	.081 (.099)	.067	.104 (.110)	.200	.169 (.122)	.150	.153 (.125)	.217	.172 (.127)
θ_{K}	.013	.088 (.075)	.221	.165 (.076)	.021	.018 (.025)	.021	.011 (.019)	.001	.018 (.025)
θ_{f2}	.001	.037 (.161)	.001	.234 (.374)	.500	.405 (.417)	.999	.584 (.417)	.308	.265 (.372)
θ_{y*}	.186	.223 (.073)	.278	.389 (.074)	.204	.265 (.065)	.204	.268 (.063)	.291	.295 (.069)
θ_{y}	.907	.493 (.069)	.001	.484 (.075)	.457	.481 (.107)	.771	.485 (.078)	.802	.498 (.092)
$\theta_{y'}$	.375	.453 (.207)	.394	.334 (.239)	.999	.706 (.296)	.999	.822 (.240)	.999	.873 (.229)
θ_{L}	.965	.853 (.151)	.999	.945 (.127)	.999	.890 (.223)	.999	.936 (.170)	.999	.779 (.332)
θ_{a}	.087	.202 (.108)	.235	.332 (.107)	.112	.208 (.096)	.050	.148 (.081)	.044	.140 (.077)
$\theta_{a'}$	.235	.177 (.091)	.001	.116 (.095)	.001	.065 (.049)	.001	.055 (.043)	.026	.068 (.053)
θ_{b}	.574	.553 (.163)	.001	.493 (.110)	.001	.407 (.200)	.001	.453 (.150)	.173	.457 (.159)
$\theta_{b'}$	.999	.503 (.158)	.999	.514 (.089)	.001	.411 (.212)	.001	.449 (.155)	.001	.430 (.211)
P(coh)		.403		.040		.095		.084		.067

	S9 Retention Interval									
Parameter	30 sec		5 min		15 min		30 min		1 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.549	.426	.311	.238	.166	.140	.058	.059	0	0
		(.062)		(.053)		(.047)		(.033)		
θ_{si}	.101	.096	.073	.082	.050	.075	.009	.058	0	0
		(.055)		(.053)		(.053)		(.047)		
θ_N	.067	.253	.467	.542	.267	.410	.800	.737	0	0
		(.104)		(.119)		(.133)		(.117)		
θ_F	.283	.225	.150	.138	.517	.375	.133	.146	0	0
		(.117)		(.112)		(.141)		(.117)		
θ_K	.104	.088	.106	.074	.072	.041	.105	.109	0	0
		(.073)		(.056)		(.044)		(.080)		
θ_{f2}	.118	.227	.667	.458	.129	.190	.999	.591	0	0
		(.299)		(.431)		(.255)		(.424)		
θ_{y*}	.149	.228	.112	.195	.180	.188	.130	.253	0	0
		(.074)		(.059)		(.071)		(.058)		
θ_y	.069	.393	.358	.460	.420	.458	.321	.472	0	0
		(.152)		(.112)		(.128)		(.089)		
$\theta_{y'}$	.574	.529	.999	.871	.999	.784	.999	.222	0	0
		(.292)		(.198)		(.271)		(.289)		
θ_L	.999	.833	.773	.830	.673	.684	.999	.920	0	0
		(.229)		(.254)		(.344)		(.207)		
θ_a	.217	.316	.457	.604	.001	.173	.001	.134	0	0
		(.131)		(.159)		(.125)		(.094)		
$\theta_{a'}$	.081	.136	.001	.082	.001	.090	.180	.208	0	0
		(.094)		(.063)		(.064)		(.087)		
θ_b	.001	.563	.001	.439	.438	.465	.999	.552	0	0
		(.285)		(.198)		(.188)		(.157)		
$\theta_{b'}$	.173	.388	.001	.411	.001	.226	.001	.461	0	0
		(.218)		(.191)		(.247)		(.134)		
P(coh)		.019		.108		.194		.016		

	S9 Retention Interval									
Parameter	3 hr		9 hr		24 hr		72 hr		144 hr	
	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)	MLE	PPM (SD)
θ_{se}	.054	.051	0	.047	0	.056	0	.014	0	.022
		(.030)		(.023)		(.029)		(.014)		(.018)
θ_{si}	.011	.067	.001	.025	.194	.130	.001	.054	.001	.102
		(.050)		(.026)		(.072)		(.044)		(.066)
θ_N	.933	.786	.999	.803	.733	.074	.999	.860	.999	.829
		(.104)		(.107)		(.119)		(.102)		(.101)
θ_F	.001	.096	.151	.125	.001	.078	.001	.071	.001	.047
		(.098)		(.103)		(.097)		(.093)		(.074)
θ_K	.012	.195	.085	.045	.001	.064	.057	.031	.182	.129
		(.116)		(.068)		(.049)		(.038)		(.077)
θ_{f2}	.999	.736	.999	.669	.001	.085	.001	.069	.001	.213
		(.403)		(.392)		(.244)		(.235)		(.385)
θ_{y*}	.118	.252	.346	.336	.124	.205	.247	.217	.143	.151
		(.067)		(.075)		(.063)		(.062)		(.061)
θ_y	.001	.494	.340	.496	.001	.481	.759	.481	.999	.499
		(.045)		(.045)		(.077)		(.077)		(.053)
$\theta_{y'}$	.001	.812	.001	.465	.589	.661	.001	.207	.999	.480
		(.241)		(.377)		(.276)		(.317)		(.286)
θ_L	.960	.416	.999	.884	.903	.757	.999	.675	.999	.906
		(.391)		(.286)		(.248)		(.383)		(.187)
θ_a	.001	.135	.081	.149	.001	.137	.001	.098	.001	.173
		(.093)		(.062)		(.092)		(.066)		(.119)
$\theta_{a'}$	.525	.363	.254	.350	.106	.069	.026	.106	.075	.123
		(.108)		(.079)		(.056)		(.059)		(.072)
θ_b	.001	.506	.001	.463	.001	.501	.001	.457	.001	.480
		(.083)		(.128)		(.107)		(.151)		(.108)
$\theta_{b'}$	.999	.505	.001	.468	.408	.514	.001	.454	.406	.477
		(.063)		(.124)		(.107)		(.163)		(.119)
P(coh)		.097		.002		.267		.047		.225

Table C5.

The following table includes the raw data for each of the 58 individual participants in Experiment 4. The participant number is listed on the left, and the data is separated by the yes/no response with high and low confidence, and whether or not participants chose the correct triad on the 4-, 3-, or 2-alernative response, or were incorrect. The yes/no response and confidence is listed for foils trials as well.

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
1	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	12	9	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	7	3	2	0
	30	2	1	4	3	0	0	1	1	0	0	0	0	0	0	0	0	2	7	3	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
2	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	9	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	9	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	10	2	0	0
	12	4	0	3	1	0	0	2	1	0	0	0	0	0	1	0	0	8	0	4	0
	30	5	1	1	2	0	0	1	1	0	0	0	1	0	0	0	0	3	3	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
3	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	4	1	0
	4	1	1	3	2	2	1	1	1	0	0	0	0	0	0	0	0	2	4	4	2
	12	0	1	0	1	1	1	2	1	0	0	2	1	1	1	0	0	0	10	2	0
	30	0	0	1	2	0	0	2	2	0	0	0	2	1	1	0	1	1	10	1	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
4	⅓	11	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	8	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	8	0	2	1	0	0	0	0	0	0	0	0	0	0	0	1	7	4	1	0
	12	0	0	3	1	0	0	4	1	0	1	0	2	0	0	0	0	0	8	4	0
	30	0	0	1	2	0	0	2	2	0	0	2	1	0	1	0	1	3	3	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
5	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	5	1	4	2	0	0	0	0	0	0	0	0	0	0	0	0	3	9	0	0
	12	1	0	4	2	0	0	3	2	0	0	0	0	0	0	0	0	2	5	5	0
	30	0	0	4	3	0	0	2	2	0	0	0	1	0	0	0	0	1	5	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
6	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	7	0	3	0	0	0	0	1	0	0	1	0	0	0	0	0	9	3	0	0
	4	5	0	4	0	0	1	0	1	0	0	0	1	0	0	0	0	2	5	4	1
	12	1	0	5	2	0	0	3	0	0	0	1	0	0	0	0	0	0	4	8	0
	30	1	0	3	3	0	0	1	1	0	0	0	2	0	0	0	1	1	4	6	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
7	⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	1	1	1
	1⅓	8	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	11	0	0	1
	4	9	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	4	4	2	2
	12	3	1	3	0	1	0	2	1	0	0	1	0	0	0	0	0	0	7	5	0
	30	3	1	1	3	0	0	3	1	0	0	0	0	0	0	0	0	2	8	2	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
8	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	2	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	3	0	1
	4	4	0	3	3	1	0	1	0	0	0	0	0	0	0	0	0	0	9	3	0
	12	3	0	2	1	1	0	0	2	0	0	2	1	0	0	0	0	0	7	5	0
	30	1	0	4	1	0	0	2	1	0	0	0	1	0	0	1	1	0	5	7	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
9	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	4	2	2	2	0	0	1	1	0	0	0	0	0	0	0	0	9	3	0	0
	4	2	0	2	2	0	0	3	3	0	0	0	0	0	0	0	0	4	3	4	1
	12	0	0	2	3	1	0	4	2	0	0	0	0	0	0	0	0	2	5	5	0
	30	0	0	3	2	1	0	4	1	0	0	0	1	0	0	0	0	1	9	2	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
10	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3	0	0
	4	7	0	2	2	0	0	0	0	0	0	0	1	0	0	0	0	1	7	4	0
	12	0	0	6	2	0	0	2	1	0	0	0	1	0	0	0	0	0	1	10	1
	30	0	0	6	0	0	0	3	1	0	0	2	0	0	0	0	0	0	4	8	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
11	⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	2
	4	8	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	12	4	4	1	1	0	1	0	1	0	0	0	0	0	0	0	0	6	4	2	0
	30	3	3	3	2	0	0	0	1	0	0	0	0	0	0	0	0	5	4	2	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
12	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	2	1	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	4	11	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	11	0	0	1
	12	6	1	1	0	2	0	1	1	0	0	0	0	0	0	0	0	7	2	1	2
	30	4	2	0	0	1	2	0	1	0	1	1	0	0	0	0	0	3	5	3	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
13	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	7	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	0	2	5	3	0	0	0	1	0	0	0	1	0	0	0	0	6	3	3	0
	12	0	0	7	1	0	0	2	0	0	0	0	2	0	0	0	0	0	6	6	0
	30	1	0	2	1	0	0	4	2	0	0	0	2	0	0	0	0	0	8	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
14	⅓	10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	4	2	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0	5	7	0	0
	12	0	0	6	4	0	0	0	1	0	0	0	1	0	0	0	0	2	8	2	0
	30	0	0	1	5	0	0	0	0	0	0	3	3	0	0	0	0	0	8	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
15	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	6	0	5	0	0	0	0	1	0	0	0	0	0	0	0	0	8	4	0	0
	12	4	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	2	8	2	0
	30	4	0	1	6	0	0	0	0	0	0	1	0	0	0	0	0	4	5	2	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
16	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	6	1	2	2	0	1	0	0	0	0	0	0	0	0	0	0	9	2	1	0
	12	4	2	2	2	0	0	0	2	0	0	0	0	0	0	0	0	3	5	4	0
	30	0	1	2	7	0	0	0	0	0	0	0	1	0	0	1	0	4	5	3	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
17	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1
	1⅓	9	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	11	1	0	0
	4	9	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	9	2	1	0
	12	5	1	1	2	0	0	0	0	0	0	0	3	0	0	0	0	3	6	3	0
	30	3	0	1	2	0	0	2	2	0	0	0	1	0	0	0	1	2	6	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
18	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	11	0	1	0
	4	5	1	2	1	0	2	0	0	0	0	0	1	0	0	0	0	3	6	3	0
	12	1	0	4	3	0	1	1	2	0	0	0	0	0	0	0	0	0	3	8	1
	30	0	0	2	0	0	0	5	1	0	0	0	1	0	0	2	1	2	4	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
19	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	4	7	1	1	1	0	0	2	0	0	0	0	0	0	0	0	0	7	1	3	1
	12	2	0	7	1	0	0	1	0	0	0	0	0	0	0	1	0	1	3	8	0
	30	4	0	2	1	0	0	1	2	0	0	2	0	0	0	0	0	0	5	6	1

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
20	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	4	6	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	0	0
	12	2	0	8	2	0	0	0	0	0	0	0	0	0	0	0	0	5	6	1	0
	30	2	0	5	4	0	0	1	0	0	0	0	0	0	0	0	0	2	8	2	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
21	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	10	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	10	0	1	1
	12	4	0	1	1	2	0	2	1	0	0	0	0	0	0	0	1	4	3	3	2
	30	2	0	1	1	1	0	2	2	0	0	1	1	0	0	0	1	1	5	3	3

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
22	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	10	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	9	1	1	1
	12	4	1	5	1	0	0	1	0	0	0	0	0	0	0	0	0	7	3	1	1
	30	2	0	5	0	0	0	1	2	0	0	0	0	0	0	0	2	1	6	5	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
23	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	10	1	1	0
	4	8	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	7	4	1	0
	12	2	0	7	2	0	0	0	0	0	0	0	1	0	0	0	0	2	8	2	0
	30	1	0	1	3	0	0	3	2	0	0	0	2	0	0	0	0	1	9	2	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
24	⅓	11	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	4	7	1	1	0	0	1	0	0	1	0	0	0	0	1	0	0	11	1	0	0
	12	1	0	5	1	0	0	0	2	0	0	0	1	0	0	1	1	3	8	1	0
	30	1	1	4	2	0	1	0	2	0	0	0	1	0	0	0	0	8	4	0	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
25	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	9	1	2	0
	4	3	1	3	2	0	0	1	1	0	0	0	1	0	0	0	0	3	4	3	2
	12	2	0	4	0	1	1	3	0	0	0	1	0	0	0	0	0	5	1	2	4
	30	2	2	3	3	0	0	1	0	0	0	0	0	0	0	0	1	2	5	3	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
26	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	9	2	0	1
	4	4	0	4	1	1	0	1	1	0	0	0	0	0	0	0	0	2	9	1	0
	12	5	0	3	1	0	0	1	1	0	0	0	1	0	0	0	0	3	5	4	0
	30	3	0	1	2	1	0	3	0	0	0	0	1	0	0	1	0	1	6	4	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
27	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	10	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	9	3	0	0
	12	5	1	1	3	0	0	0	1	0	0	0	0	0	0	0	1	3	8	1	0
	30	1	0	1	4	0	0	0	3	0	0	0	1	0	0	0	2	6	6	0	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
28	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	4	4	4	1	0	0	1	0	1	0	1	0	0	0	0	0	0	12	0	0	0
	12	2	0	4	4	0	0	1	0	0	0	1	0	0	0	0	0	2	6	4	0
	30	1	0	2	4	0	0	0	2	0	0	0	3	0	0	0	0	1	7	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
29	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	6	0	4	1	1	0	0	0	0	0	0	0	0	0	0	0	7	2	3	0
	12	4	2	1	1	0	0	0	1	0	0	2	1	0	0	0	0	0	5	6	1
	30	0	0	5	1	0	0	4	0	0	0	1	0	0	0	0	1	0	4	8	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	1	0
	4	7	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	8	2	2	0
	12	8	0	1	1	0	0	0	1	0	0	0	1	0	0	0	0	4	7	1	0
	30	6	1	1	0	0	1	2	1	0	0	0	0	0	0	0	0	5	3	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
31	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	2	1	4	1	1	0	0	1	0	0	0	1	0	0	1	0	4	5	3	0
	12	2	0	3	3	0	0	0	2	0	0	0	1	0	0	1	0	0	7	5	0
	30	2	0	2	1	0	0	1	2	0	0	2	2	0	0	0	0	0	8	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
32	⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	1	0	1
	4	7	2	0	0	0	0	0	2	0	1	0	0	0	0	0	0	9	0	1	2
	12	7	2	1	0	0	0	1	0	0	0	0	1	0	0	0	0	8	3	1	0
	30	6	0	1	0	0	0	0	0	1	2	0	0	0	1	1	0	6	4	0	2

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
33	⅓	11	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	8	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	12	6	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	5	6	1	0
	30	3	0	2	4	0	0	1	2	0	0	0	0	0	0	0	0	3	5	4	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
34	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	4	2	0	6	3	0	0	0	0	0	0	0	1	0	0	0	0	3	6	2	1
	12	3	0	2	1	0	0	0	1	0	0	3	1	0	0	0	1	0	7	5	0
	30	0	0	0	3	0	0	1	3	0	0	1	2	0	0	0	2	1	10	1	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
35	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	9	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	4	7	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	3	8	1	0
	12	3	0	3	3	0	0	2	1	0	0	0	0	0	0	0	0	1	4	6	1
	30	1	0	3	3	0	0	0	1	0	0	0	3	0	0	0	1	1	5	6	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
36	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1
	4	9	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	7	2	2	1
	12	5	1	3	1	0	0	1	0	0	0	1	0	0	0	0	0	5	4	3	0
	30	0	0	4	3	0	0	0	2	0	0	0	1	0	0	1	1	0	11	1	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
37	⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	9	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	11	0	0	1
	4	3	0	2	2	0	0	2	0	0	0	1	2	0	0	0	0	4	4	4	0
	12	0	0	6	1	0	0	2	0	0	0	1	0	0	0	0	2	1	8	3	0
	30	1	0	3	1	0	0	3	1	0	0	2	0	0	0	0	1	0	4	8	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
38	⅓	11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	4	7	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	9	3	0	0
	12	4	0	6	0	0	0	1	0	0	0	0	1	0	0	0	0	5	7	0	0
	30	3	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	1	1

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
39	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	9	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	11	1	0	0
	12	8	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	7	3	2	0
	30	6	0	1	3	0	0	1	0	0	0	0	1	0	0	0	0	4	6	2	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
40	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	4	7	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	8	4	0	0
	12	0	0	4	4	0	0	1	2	0	0	0	1	0	0	0	0	6	4	2	0
	30	0	0	4	3	0	1	2	0	0	0	0	0	0	0	0	2	2	8	2	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
41	⅓	10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	0	1
	1⅓	11	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	4	7	0	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0	3	9	0
	12	1	0	6	2	0	0	1	2	0	0	0	0	0	0	0	0	0	9	3	0
	30	0	0	6	0	0	0	4	2	0	0	0	0	0	0	0	0	2	7	3	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
42	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	4	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	2	2	0
	12	5	1	1	3	0	1	0	1	0	0	0	0	0	0	0	0	5	6	1	0
	30	1	2	2	2	0	0	0	2	0	0	0	0	0	0	0	3	2	7	3	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
43	⅓	10	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7	5	0	0
	4	3	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11	0	0
	12	1	0	8	1	0	0	0	1	0	0	0	1	0	0	0	0	1	10	1	0
	30	0	0	5	0	0	0	5	2	0	0	0	0	0	0	0	0	1	9	2	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
44	⅓	11	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	4	8	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	1	0
	12	2	1	3	2	0	0	0	1	0	0	0	2	0	0	0	1	3	8	1	0
	30	0	0	4	0	0	0	1	1	0	0	2	0	0	0	1	3	0	9	3	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
45	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	12	4	0	5	1	0	1	0	0	0	1	0	0	0	0	0	0	4	6	2	0
	30	5	0	4	2	0	0	0	1	0	0	0	0	0	0	0	0	7	4	1	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
46	⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	1⅓	10	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1
	4	3	1	5	1	0	0	1	1	0	0	0	0	0	0	0	0	6	4	1	1
	12	5	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	1	8	3	0
	30	1	0	3	1	0	1	4	1	0	0	0	1	0	0	0	0	2	8	2	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
47	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	4	7	0	2	0	0	0	0	1	0	0	1	1	0	0	0	0	3	6	3	0
	12	2	0	3	2	0	0	3	0	0	0	1	1	0	0	0	0	1	7	4	0
	30	1	0	3	1	0	0	0	1	0	0	1	3	0	0	0	2	0	10	2	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
48	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	10	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	12	9	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	30	7	0	1	2	0	1	0	1	0	0	0	0	0	0	0	0	8	4	0	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
49	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1
	1⅓	10	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	2	5	2	3	0	0	0	0	0	0	0	0	0	0	0	0	9	1	2	0
	12	4	1	3	1	0	1	0	0	0	1	1	0	0	0	0	0	2	6	4	0
	30	1	0	0	5	0	0	0	1	0	0	0	3	0	0	0	2	1	8	3	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
50	⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	12	0	0	0
	4	3	1	4	0	1	0	1	0	0	1	0	1	0	0	0	0	5	7	0	0
	12	2	1	1	0	0	0	1	1	0	0	2	1	0	0	3	0	1	7	4	0
	30	1	0	2	1	0	0	1	2	0	0	3	0	0	0	0	2	3	2	7	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
51	⅓	9	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0
	1⅓	11	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5	7	0	0
	4	2	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0	4	8	0	0
	12	1	2	3	2	0	0	0	2	0	0	0	2	0	0	0	0	0	11	1	0
	30	0	2	1	6	0	0	0	0	0	0	0	3	0	0	0	0	2	9	0	1

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
52	⅓	7	1	2	1	0	0	0	0	0	0	0	0	0	0	0	1	9	3	0	0
	1⅓	6	0	4	1	0	0	0	0	0	0	0	1	0	0	0	0	4	0	7	1
	4	3	0	2	1	0	0	1	0	0	0	0	2	0	0	0	3	0	11	0	1
	12	0	0	1	1	0	0	0	4	0	0	1	1	0	0	0	4	0	10	1	1
	30	0	0	0	3	0	0	0	2	1	0	0	2	1	0	0	3	0	9	3	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
53	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	10	1	1	0
	4	9	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	4	5	3	0
	12	5	0	1	1	0	0	3	0	0	0	0	2	0	0	0	0	2	2	8	0
	30	0	0	3	1	0	0	1	2	0	0	1	2	0	0	0	2	0	6	6	0

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
54	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	7	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	9	3	0	0
	12	0	0	4	3	0	0	1	2	0	0	0	1	0	0	0	1	1	10	1	0
	30	0	0	5	4	0	0	2	1	0	0	0	0	0	0	0	0	0	11	1	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
55	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0
	4	6	0	2	0	0	1	1	1	0	1	0	0	0	0	0	0	3	5	4	0
	12	2	0	3	2	0	0	0	2	0	1	0	0	0	2	0	0	2	7	2	1
	30	1	2	0	4	0	0	4	1	0	0	0	0	0	0	0	0	0	8	3	1

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
56	⅓	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	0	1
	1⅓	9	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	8	3	1	0
	4	3	2	2	0	0	0	2	1	0	1	0	0	0	0	0	1	2	7	2	1
	12	1	0	3	3	0	0	3	1	0	0	0	1	0	0	0	0	1	9	2	0
	30	0	0	4	3	0	0	1	0	0	0	0	2	0	0	1	1	0	8	4	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
57	⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	8	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	9	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	12	4	2	1	2	0	0	1	1	0	0	0	1	0	0	0	0	6	5	1	0
	30	2	2	2	0	0	0	0	1	0	2	0	3	0	0	0	0	9	3	0	0

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
58	⅓	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	1⅓	10	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	4	5	0	4	1	0	0	0	2	0	0	0	0	0	0	0	0	8	4	0	0
	12	3	0	6	2	0	0	0	0	0	0	0	1	0	0	0	0	3	7	2	0
	30	0	0	4	5	0	0	1	1	0	0	0	1	0	0	0	0	2	9	1	0

Table C6.

The following table includes the raw data for each of the 31 individual participants in Experiment 5. The participant number is listed on the left, and the data is separated by the yes/no response with high and low confidence, and whether or not participants chose the correct word on the 4-, 3-, or 2-alernative response, or were incorrect. The yes/no response and confidence is listed for foil trials as well. The MMSE score is also provided

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
1	0	6	0	4	3	0	0	1	1	0	3	2	2	0	0	0	2	0	15	2	1
	1	8	3	2	2	3	3	0	0	1	0	0	0	2	0	0	0	5	4	2	7
	4	3	1	3	2	2	4	0	0	2	2	1	0	0	3	1	0	12	1	1	4
	9	2	4	2	0	3	5	0	0	1	2	1	0	1	1	1	1	10	1	0	7
	MMSE	27																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
2	0	6	4	1	2	3	1	1	2	1	1	1	0	0	0	0	1	8	5	2	3
	1	7	1	6	1	1	0	5	1	0	0	0	0	0	0	0	2	2	6	7	3
	4	4	2	3	5	1	1	2	2	0	0	1	1	0	1	1	0	3	5	5	5
	9	3	3	2	1	0	3	2	2	0	1	3	1	0	0	0	3	5	5	6	2
	MMSE	29																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
3	0	5	0	7	0	0	0	2	2	0	0	3	0	0	0	0	5	0	0	13	5
	1	3	0	14	4	0	0	0	0	0	0	0	1	0	0	0	2	0	7	10	1
	4	1	0	11	3	0	0	2	2	0	0	0	4	0	0	1	0	0	12	6	0
	9	2	0	10	4	0	0	2	2	0	0	1	1	0	0	0	2	0	10	7	1
	MMSE	30																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
4	0	7	0	1	0	1	2	1	2	3	0	2	0	2	3	0	0	5	4	4	5
	1	12	2	0	2	2	0	0	2	1	1	0	0	0	1	1	0	7	5	5	1
	4	6	1	0	1	1	3	0	1	2	3	0	0	3	1	1	1	6	1	3	8
	9	2	2	1	4	2	0	0	1	1	1	0	2	2	3	2	1	7	1	4	6
	MMSE	26																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
5	0	10	0	5	0	1	1	0	0	0	0	1	2	2	0	1	1	1	10	5	2
	1	12	0	1	1	2	1	1	0	1	1	1	2	0	0	1	0	1	3	12	2
	4	9	0	3	2	0	0	5	0	2	1	2	0	0	0	0	0	1	6	8	3
	9	3	0	4	1	1	0	5	1	2	0	2	3	0	0	2	0	0	4	10	4
	MMSE	30																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
6	0	2	0	4	4	0	0	4	5	0	0	2	2	0	0	0	1	1	9	8	0
	1	5	0	7	3	0	0	1	3	0	0	2	1	0	0	0	2	0	8	9	1
	4	4	0	5	5	0	0	1	4	0	0	2	1	0	0	1	1	0	9	9	0
	9	5	0	7	1	0	1	1	1	0	0	2	1	0	0	3	2	0	11	7	0
	MMSE	30																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
7	0	3	1	3	2	5	2	2	1	3	1	0	0	1	0	0	0	4	4	2	8
	1	4	0	2	0	4	2	0	0	6	2	1	0	2	1	0	0	6	0	0	12
	4	5	5	0	0	4	1	0	0	4	1	0	0	2	2	0	0	10	0	0	8
	9	4	2	0	0	3	3	4	1	1	2	2	0	0	1	1	0	4	1	5	8
	MMSE	28																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
8	0	2	1	7	5	0	0	2	2	0	0	2	1	0	0	0	2	2	8	8	0
	1	9	0	5	0	0	0	3	2	0	0	1	1	0	0	3	0	0	8	8	2
	4	6	0	4	2	0	1	4	1	1	0	1	0	0	0	2	2	1	2	13	2
	9	3	0	5	3	1	0	2	3	0	0	5	1	0	0	0	1	0	3	12	3
	MMSE	27																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
9	0	20	0	1	0	0	0	1	0	0	0	1	1	0	0	0	0	6	9	3	0
	1	11	0	7	2	0	0	0	2	0	0	0	1	0	0	0	1	2	9	6	1
	4	9	0	7	2	1	2	1	2	0	0	0	0	0	0	0	0	4	12	1	1
	9	5	0	2	6	1	0	2	1	0	0	3	2	0	0	1	1	4	11	3	0
	MMSE	29																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
10	0	8	0	2	4	0	0	1	3	0	0	2	2	0	0	1	1	0	8	8	2
	1	6	0	8	4	0	0	2	1	0	0	0	3	0	0	0	0	0	12	6	0
	4	4	0	4	7	0	0	1	3	0	0	0	2	1	0	1	1	0	11	5	2
	9	6	0	3	1	0	0	1	1	0	0	3	6	0	0	0	3	0	12	5	1
	MMSE	30																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
11	0	9	0	5	1	1	0	1	4	0	0	1	1	0	0	0	1	0	5	9	4
	1	9	0	5	0	1	0	5	0	0	0	1	1	0	0	0	2	0	1	6	11
	4	3	0	5	4	1	0	6	0	0	0	2	0	0	0	1	2	0	6	8	4
	9	6	0	5	2	1	0	3	1	0	0	4	1	0	0	0	1	0	13	3	2
	MMSE	29																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
12	0	1	0	4	5	1	0	0	3	0	0	1	6	0	0	1	2	1	11	6	0
	1	1	0	5	8	0	0	2	0	0	0	2	3	0	0	1	2	0	15	3	0
	4	0	0	4	8	0	0	1	3	0	0	0	2	0	0	0	6	0	11	7	0
	9	0	0	4	3	0	0	2	5	0	0	2	6	0	0	1	1	0	13	5	0
	MMSE	29																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
13	0	0	0	12	0	0	0	5	4	0	0	2	0	0	0	1	0	0	4	13	1
	1	1	0	11	0	0	0	7	0	0	0	3	0	0	0	2	0	0	3	15	0
	4	1	0	7	1	0	0	9	2	0	0	2	0	0	0	2	0	0	1	17	0
	9	0	0	11	3	0	0	5	0	0	0	3	1	0	0	1	0	0	4	14	0
	MMSE	30																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
14	0	9	3	4	1	1	0	0	2	1	0	0	0	1	1	0	1	9	2	6	1
	1	12	1	1	1	1	0	2	2	0	2	2	0	0	0	0	0	10	3	1	4
	4	11	4	2	1	1	0	1	1	0	0	1	0	0	1	0	1	4	7	7	0
	9	10	1	1	1	0	1	2	1	0	2	0	1	0	2	1	1	6	4	5	3
	MMSE	28																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
15	0	10	0	2	1	2	1	0	1	0	0	2	1	2	0	0	2	5	8	3	2
	1	11	0	4	2	1	0	0	4	0	2	0	0	0	0	0	0	4	5	5	4
	4	3	5	1	2	3	0	1	3	0	0	1	1	1	0	3	0	7	4	2	5
	9	3	2	4	6	0	1	2	1	0	1	0	2	0	0	0	2	0	6	6	6
	MMSE	27																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
16	0	6	1	3	0	2	1	1	1	2	1	1	0	3	0	2	0	6	5	4	3
	1	5	0	3	1	2	1	2	2	0	1	2	2	2	0	0	1	4	3	7	4
	4	5	0	3	2	2	0	3	1	1	0	1	1	1	1	1	2	0	7	5	6
	9	2	1	3	3	0	0	2	2	2	2	2	2	0	1	1	1	1	5	9	3
	MMSE	28																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
17	0	13	0	4	1	1	0	2	1	0	0	0	2	0	0	0	0	3	10	4	1
	1	11	0	5	0	0	0	0	2	0	0	1	4	0	0	0	1	1	7	9	1
	4	9	0	4	3	1	1	0	2	0	0	2	1	0	1	0	0	1	5	9	3
	9	9	0	7	3	0	0	0	2	0	0	1	0	0	0	0	2	0	5	8	5
	MMSE	26																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
18	0	8	0	8	1	0	0	2	1	0	0	1	1	0	0	0	2	0	12	5	1
	1	4	0	12	2	0	0	1	1	0	0	2	0	0	0	1	1	0	6	12	0
	4	3	0	7	3	0	0	4	3	0	0	2	1	0	0	1	0	0	6	12	0
	9	2	0	7	3	0	0	3	2	0	0	3	1	0	0	2	1	0	6	12	0
	MMSE	28																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
19	0	1	0	7	2	0	0	4	0	0	0	4	2	0	0	3	1	0	11	7	0
	1	6	0	4	4	0	0	5	3	0	0	0	1	0	0	0	1	0	5	10	3
	4	4	0	8	3	0	0	1	1	0	0	3	2	0	0	0	2	0	7	9	2
	9	0	0	6	4	0	0	3	2	0	0	4	0	0	0	3	2	0	8	7	3
	MMSE	26																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
20	0	4	0	4	3	0	0	5	0	0	0	4	3	0	0	1	0	0	6	11	1
	1	1	0	5	2	0	0	5	1	0	0	3	0	0	0	5	2	0	9	9	0
	4	4	0	4	6	0	0	4	1	0	0	1	0	0	0	2	2	0	8	10	0
	9	2	0	7	4	0	0	2	2	0	0	0	2	0	0	4	1	0	6	12	0
	MMSE	28																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
21	0	0	0	11	1	0	0	1	5	0	0	2	1	0	0	2	1	0	10	8	0
	1	0	0	5	3	0	0	4	3	0	0	2	2	0	0	3	2	0	7	11	0
	4	0	0	7	3	0	0	2	3	0	0	4	2	0	0	1	2	0	8	10	0
	9	0	0	3	3	0	0	2	2	0	0	4	3	0	0	4	3	0	8	10	0
	MMSE	30																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
22	0	4	4	1	2	1	0	3	2	0	1	2	2	0	0	1	1	2	6	8	2
	1	4	0	4	2	1	1	4	0	1	0	1	2	0	3	1	0	1	1	12	4
	4	1	1	2	4	1	0	1	0	0	0	6	2	0	1	3	2	2	5	11	0
	9	0	0	2	0	1	5	2	2	1	0	4	4	0	1	2	0	3	4	7	4
	MMSE	25																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
23	0	3	0	7	1	0	0	3	4	0	0	3	1	0	0	1	1	2	7	9	0
	1	1	0	6	3	0	0	2	1	0	0	2	6	0	0	1	2	0	5	13	0
	4	1	0	8	4	0	0	0	3	0	0	1	3	0	0	1	3	0	5	13	0
	9	0	0	5	4	0	0	2	3	0	0	3	4	0	0	2	1	0	7	11	0
	MMSE	29																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
24	0	4	0	7	0	1	0	3	3	0	0	1	2	0	0	3	0	0	6	11	1
	1	6	0	7	2	0	0	2	0	0	0	6	0	0	0	0	1	0	1	14	3
	4	7	0	6	2	2	0	1	2	0	0	2	1	0	0	0	1	0	6	9	3
	9	5	0	7	2	0	0	3	0	1	0	3	0	0	0	3	0	0	5	12	1
	MMSE	28																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
25	0	0	0	4	1	0	0	5	3	0	0	1	4	0	0	4	2	0	10	8	0
	1	0	0	4	3	0	0	1	1	0	0	4	4	0	0	3	4	0	7	11	0
	4	0	0	3	5	0	0	0	5	0	0	1	5	0	0	2	3	0	9	9	0
	9	0	0	3	4	0	0	4	1	0	0	2	5	0	0	3	2	0	9	9	0
	MMSE	24																			

		4AFC				3AFC				2AFC				Incorrect				Foils			
S		Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	N	N	Y	Y
		hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	hi	lo	lo	hi	lo	lo	hi
26	0	0	0	11	6	0	0	1	5	0	0	0	0	0	0	0	1	0	16	2	0
	1	0	0	5	10	0	0	0	6	0	0	0	1	0	0	0	2	0	13	5	0
	4	0	0	5	8	0	0	0	4	0	0	1	1	0	0	1	4	0	15	3	0
	9	0	0	6	5	0	0	2	1	0	0	1	5	0	0	1	3	0	13	5	0
	MMSE	30																			

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
27	0	18	0	1	1	0	0	2	2	0	0	0	0	0	0	0	0	1	6	11	0
	1	8	0	14	0	0	0	1	0	0	0	0	1	0	0	0	0	0	3	14	1
	4	6	0	11	2	0	0	2	2	0	0	1	0	0	0	0	0	0	6	12	0
	9	3	0	13	0	0	0	3	1	0	0	1	0	0	0	3	0	0	8	10	0
	MMSE	30																			

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
28	0	0	0	12	4	0	0	1	3	0	0	1	2	0	0	0	1	0	10	8	0
	1	0	0	3	6	0	0	3	4	0	0	1	2	0	0	2	3	0	8	10	0
	4	0	0	6	6	0	0	1	1	0	0	3	3	0	0	2	2	0	9	9	0
	9	0	0	4	5	0	0	2	4	0	0	2	4	0	0	1	2	0	13	5	0
	MMSE	30																			

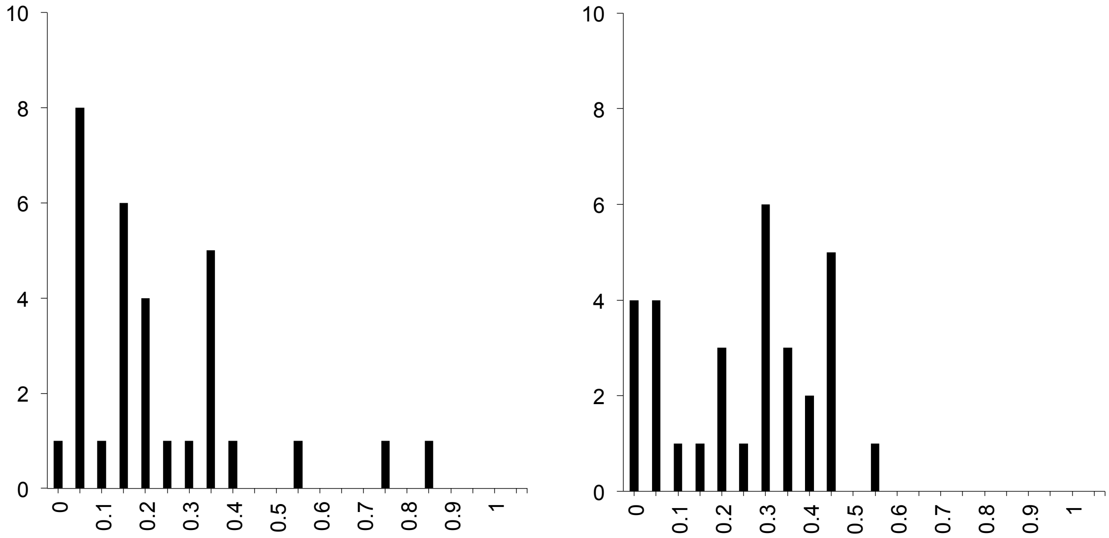
S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
29	0	2	0	5	3	0	0	5	2	0	0	2	3	0	0	0	2	0	13	5	0
	1	1	0	4	4	0	0	1	3	0	0	1	0	0	0	7	3	1	6	9	2
	4	3	0	1	1	2	0	5	4	0	0	3	2	0	0	1	2	0	10	8	0
	9	2	0	4	2	1	0	1	1	1	0	3	2	1	0	5	1	0	8	10	0
	MMSE	29																			

S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
30	0	4	1	2	3	1	0	4	3	0	0	3	2	0	0	0	1	1	10	7	0
	1	5	0	2	1	0	1	1	0	0	0	5	1	0	0	2	6	0	10	7	1
	4	4	0	2	3	0	0	2	0	0	0	3	5	1	1	2	1	0	9	8	1
	9	2	0	6	4	0	0	3	3	0	0	0	1	0	0	3	2	0	10	7	1
	MMSE	30																			

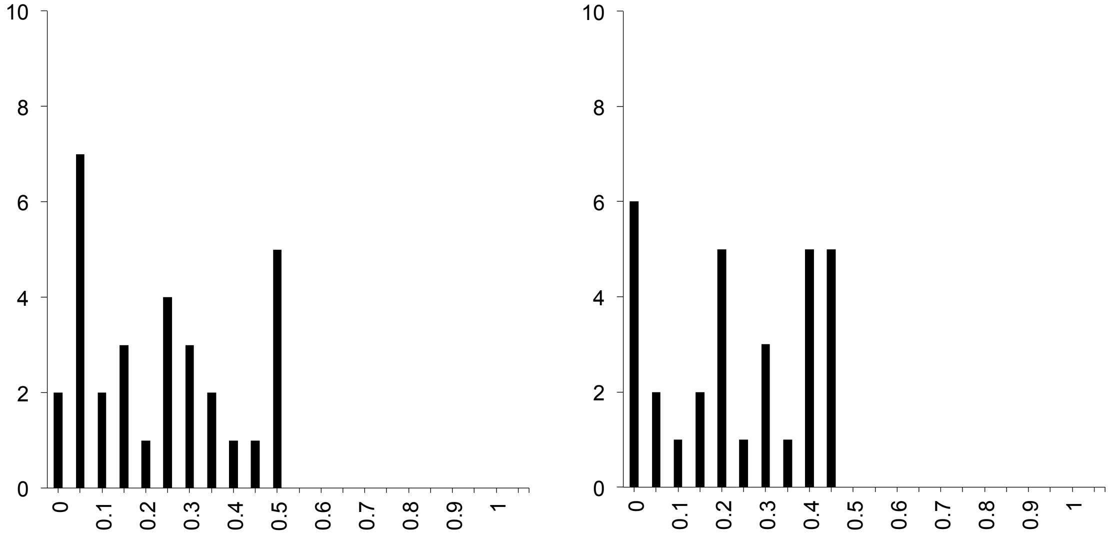
S		4AFC				3AFC				2AFC				Incorrect				Foils			
		Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	Y hi	N hi	Y lo	N lo	N hi	N lo	Y lo	Y hi
31	0	3	0	9	2	0	0	3	3	0	0	1	2	0	0	1	0	0	10	8	0
	1	0	0	8	0	0	0	5	2	0	0	5	0	0	0	3	1	0	4	14	0
	4	0	0	10	0	0	0	9	0	0	0	3	1	0	0	0	1	0	0	18	0
	9	0	0	10	0	0	0	5	1	0	0	3	0	0	0	5	1	0	1	17	0
	MMSE	27																			

Appendix D

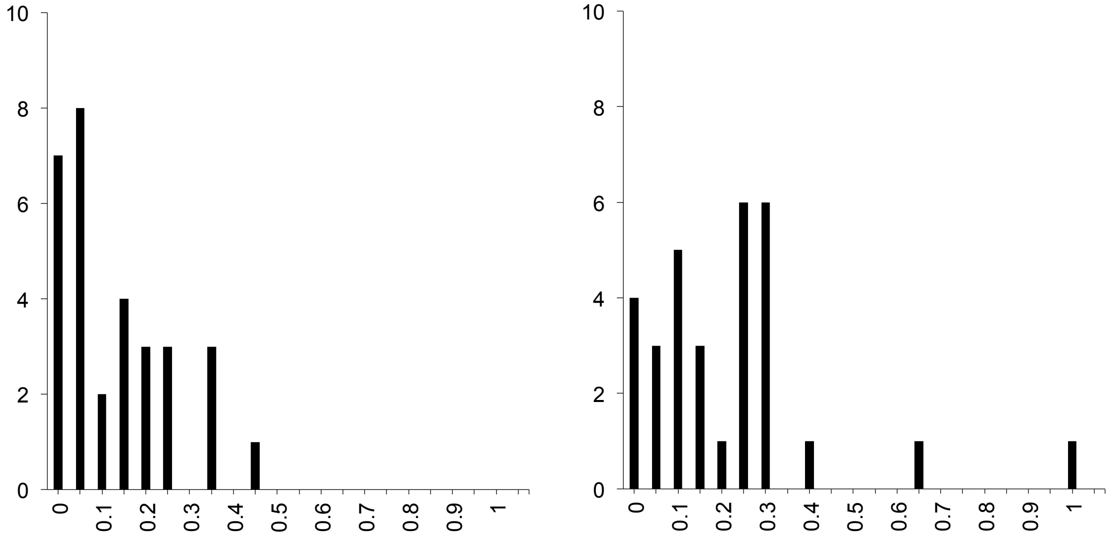
The following figures depict the Frequency distributions for the constructed from the jackknife procedure. There is a frequency distribution for each of the four fundamental memory states, as well as the θ_k parameter, at each of the four retention intervals from Experiment 5. The PPM values for the 0, 1, 4, and 9 conditions are on the left. The distributions for the MLE values for the 0, 1, 4, and 9 conditions are on the right. Viewing the frequency distributions can provide information about skewness, bimodality, and spread among the variables.



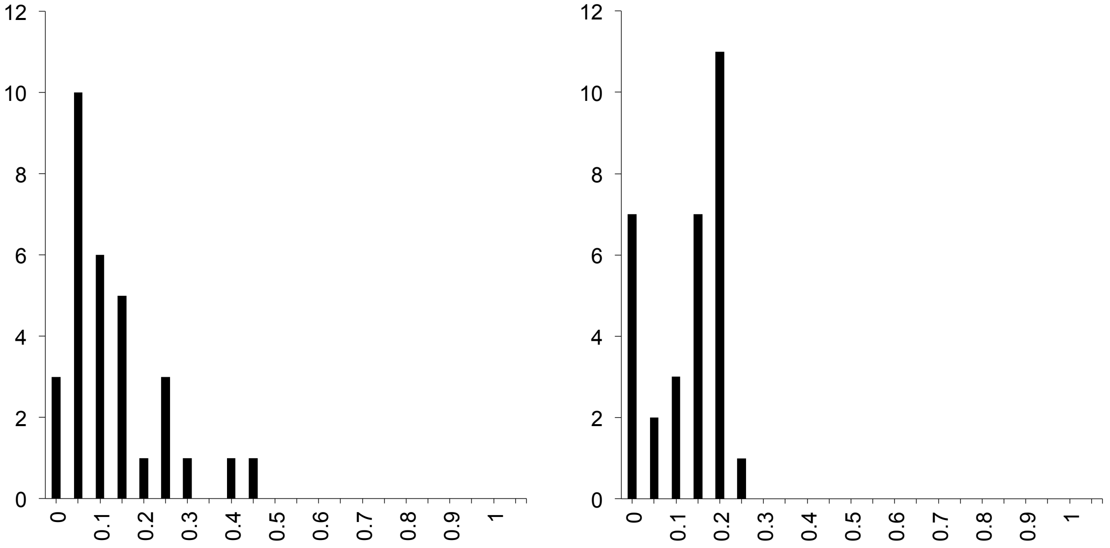
PPM and MLE frequencies for θ_{se} at the 0 retention interval



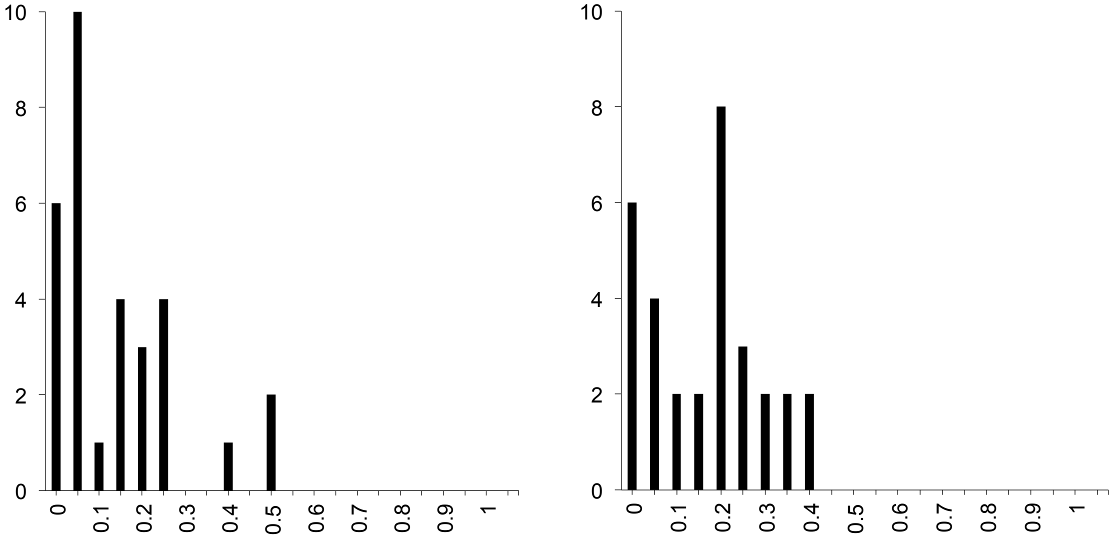
PPM and MLE frequencies for θ_{se} at the 1 retention interval



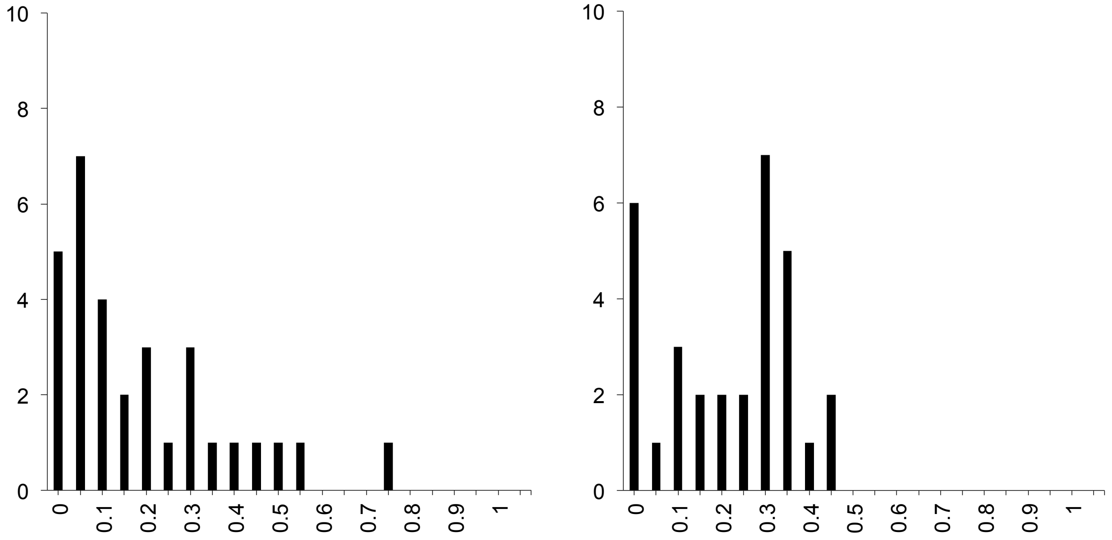
PPM and MLE frequencies for θ_{se} at the 4 retention interval



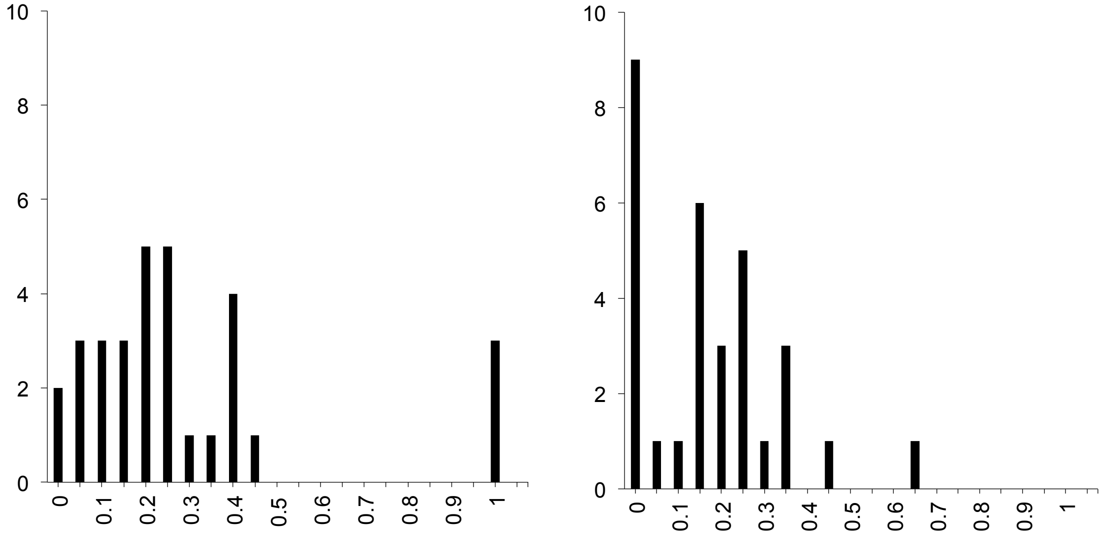
PPM and MLE frequencies for θ_{se} at the 9 retention interval



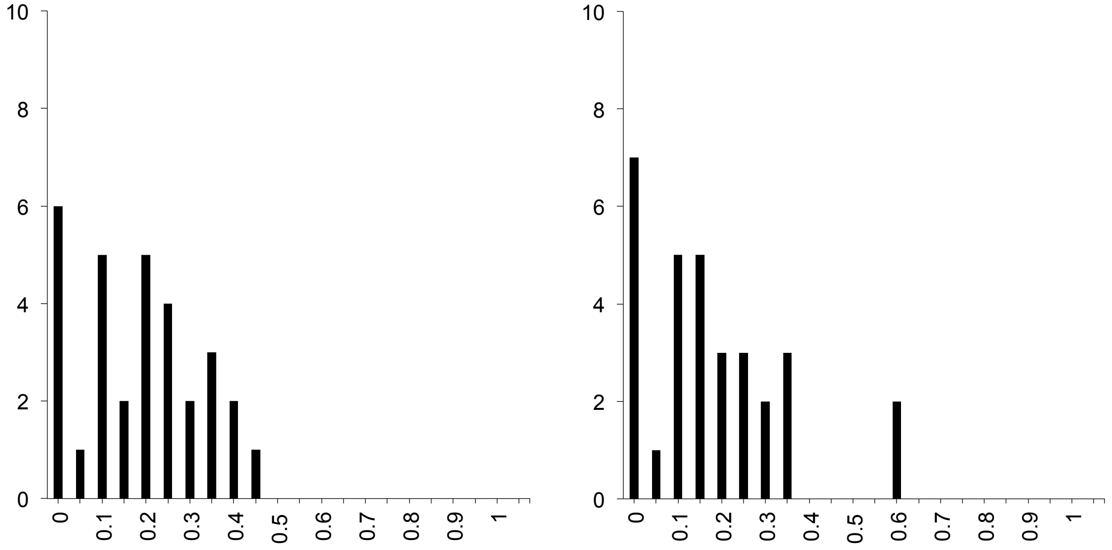
PPM and MLE frequencies for θ_{si} at the 0 retention interval



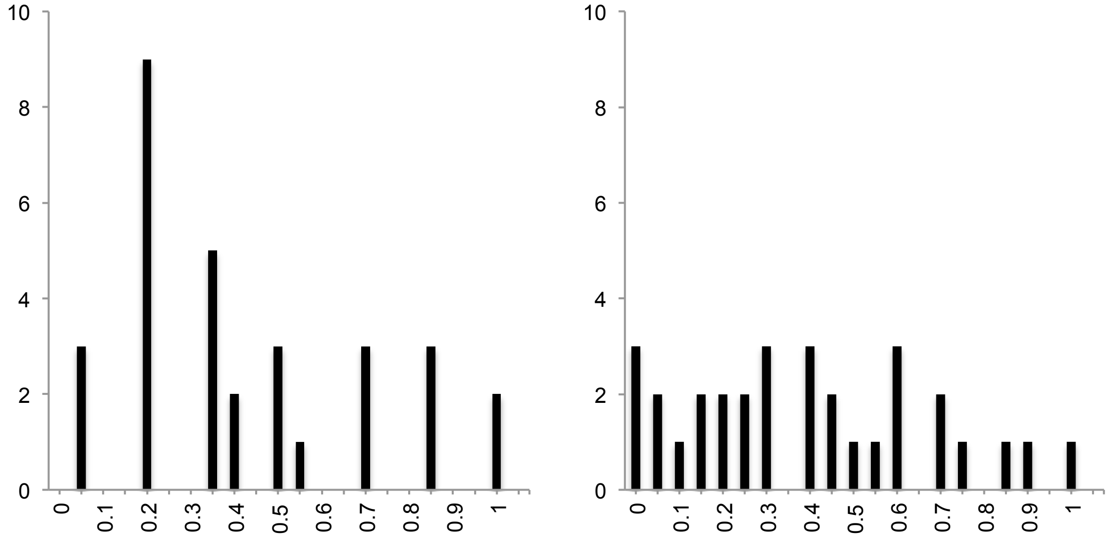
PPM and MLE frequencies for θ_{si} at the1 retention interval



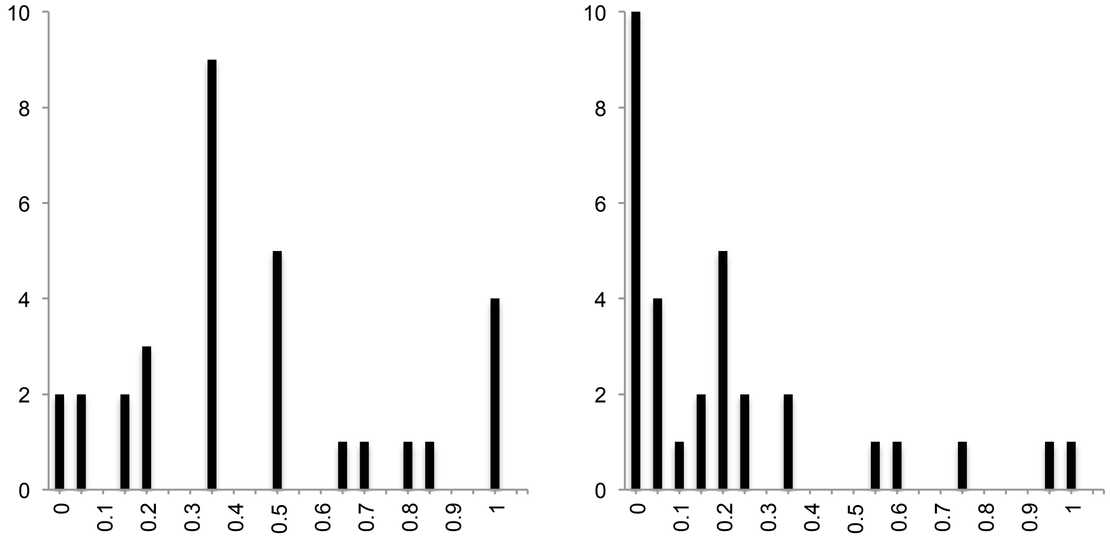
PPM and MLE frequencies for θ_{si} at the 4 retention interval



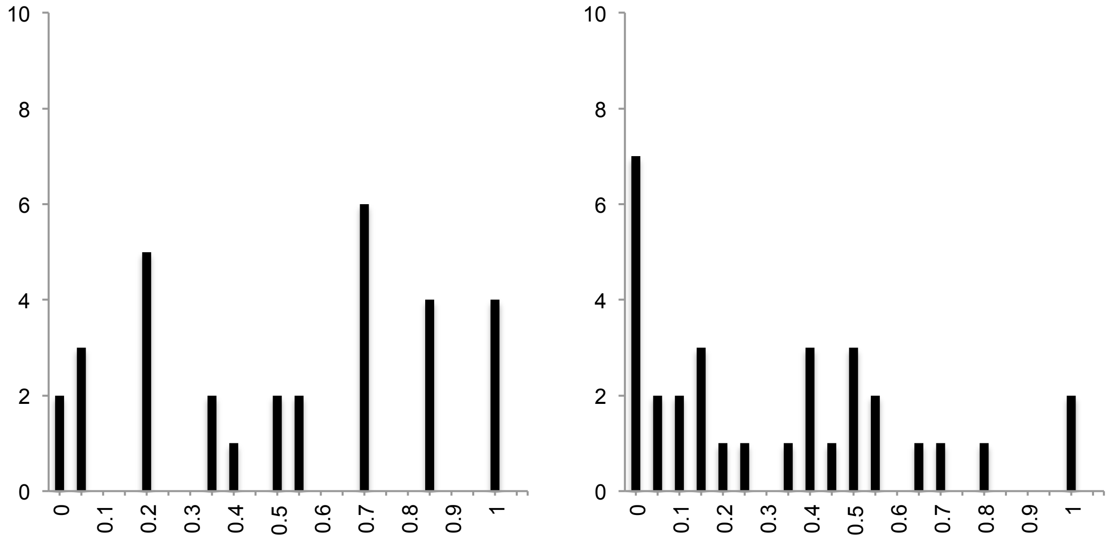
PPM and MLE frequencies for θ_{si} at the 9 retention interval



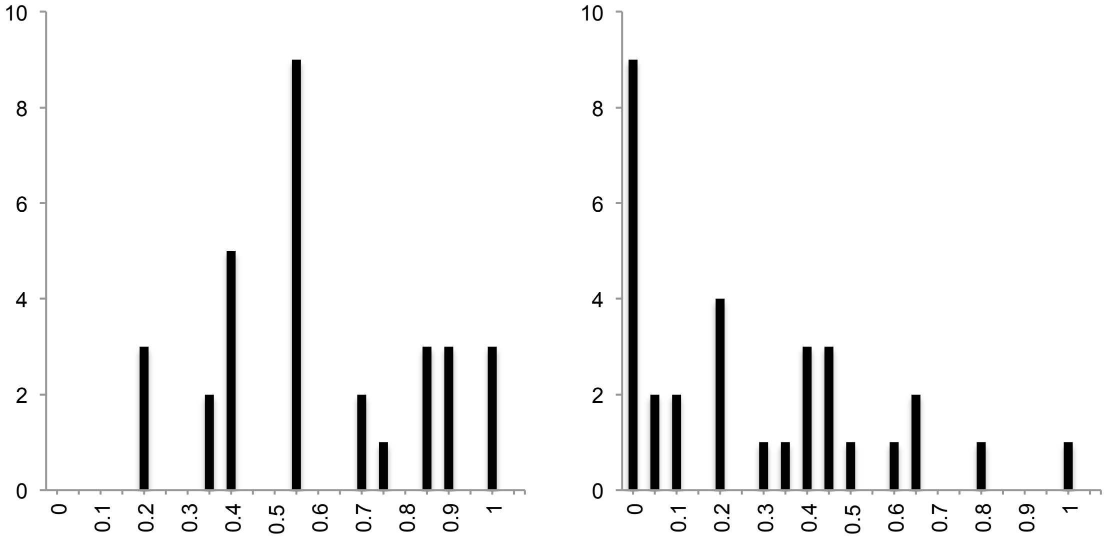
PPM and MLE frequencies for θ_N at the 0 retention interval



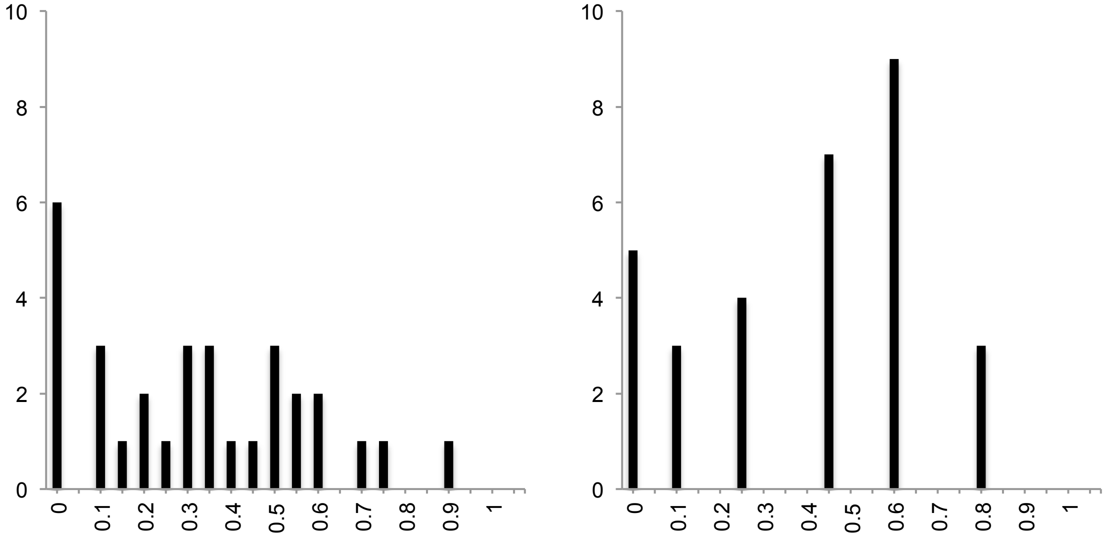
PPM and MLE frequencies for θ_N at the 1 retention interval



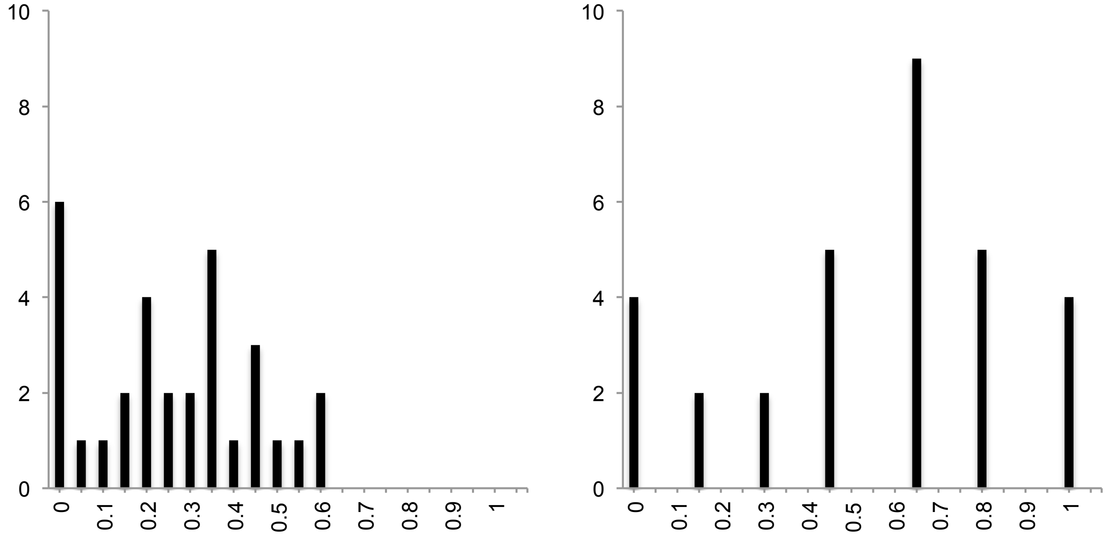
PPM and MLE frequencies for θ_N at the 4 retention interval



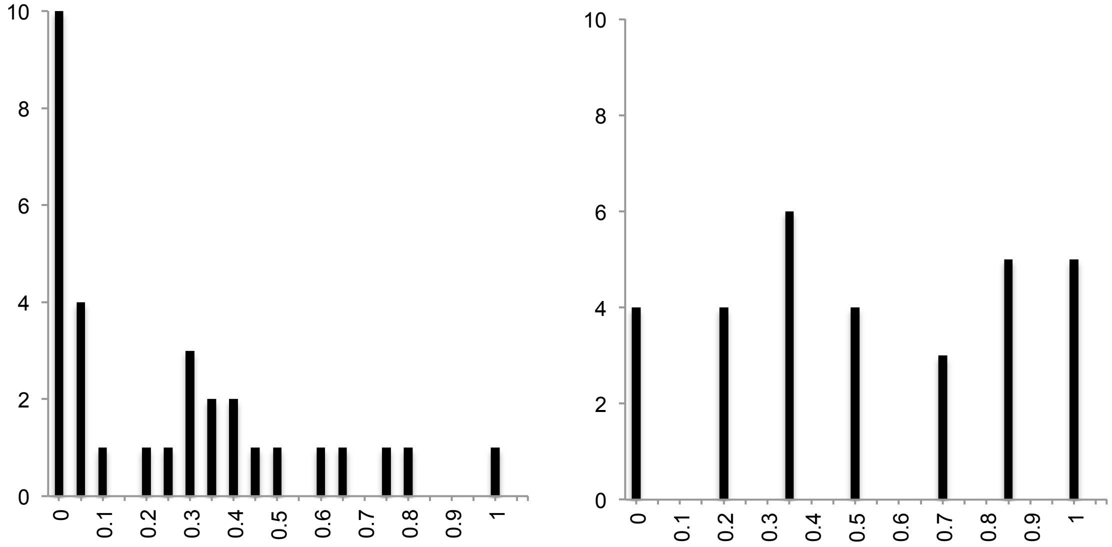
PPM and MLE frequencies for θ_N at the 9 retention interval



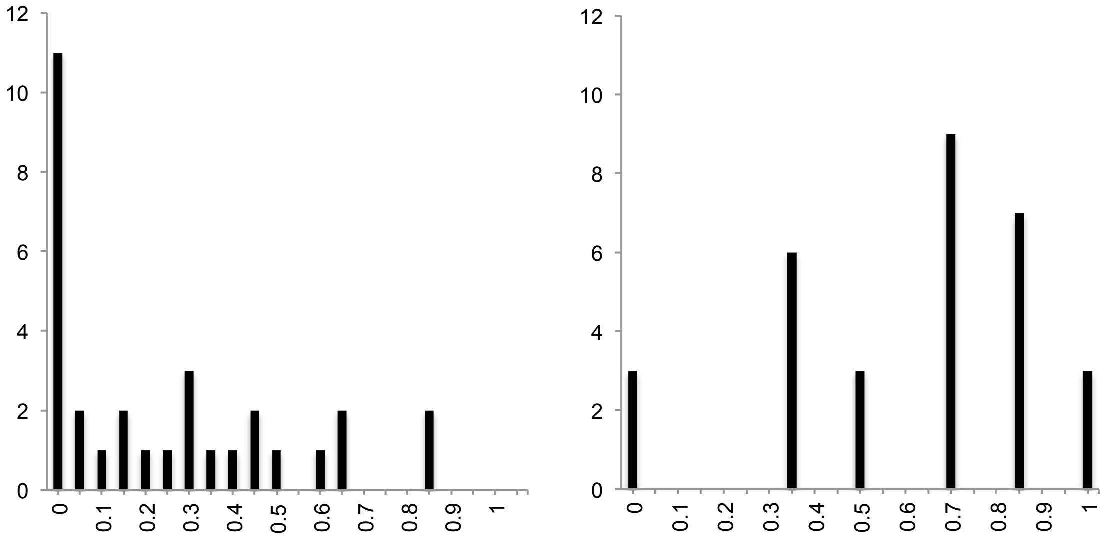
PPM and MLE frequencies for θ_f at the 0 retention interval



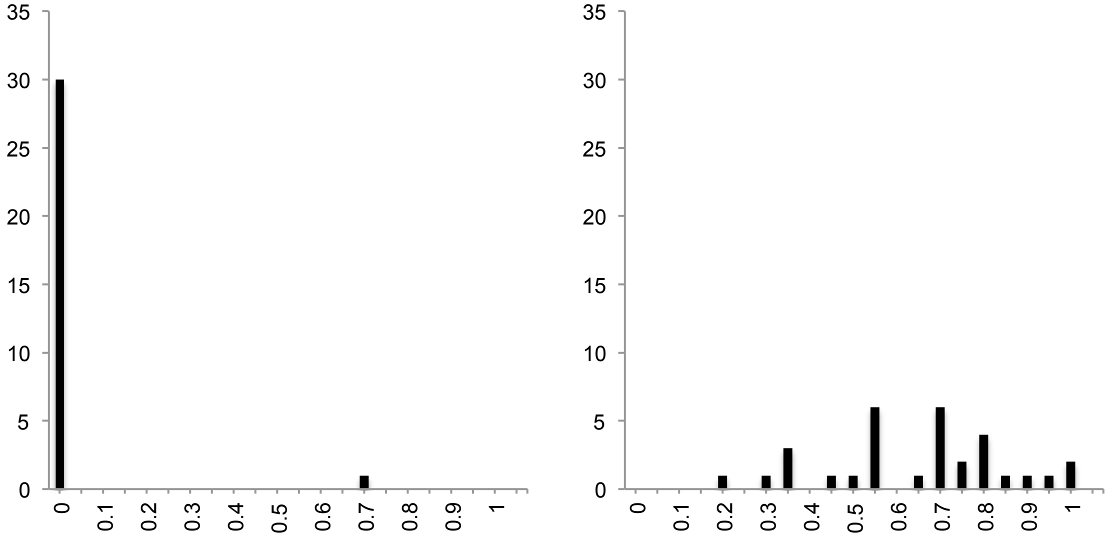
PPM and MLE frequencies for θ_f at the 1 retention interval



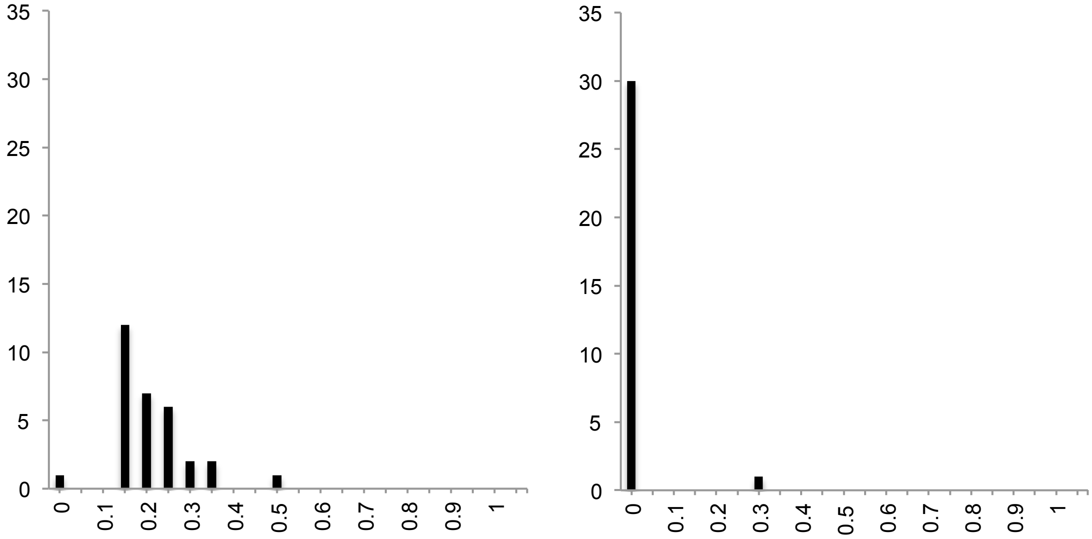
PPM and MLE frequencies for θ_f at the 4 retention interval



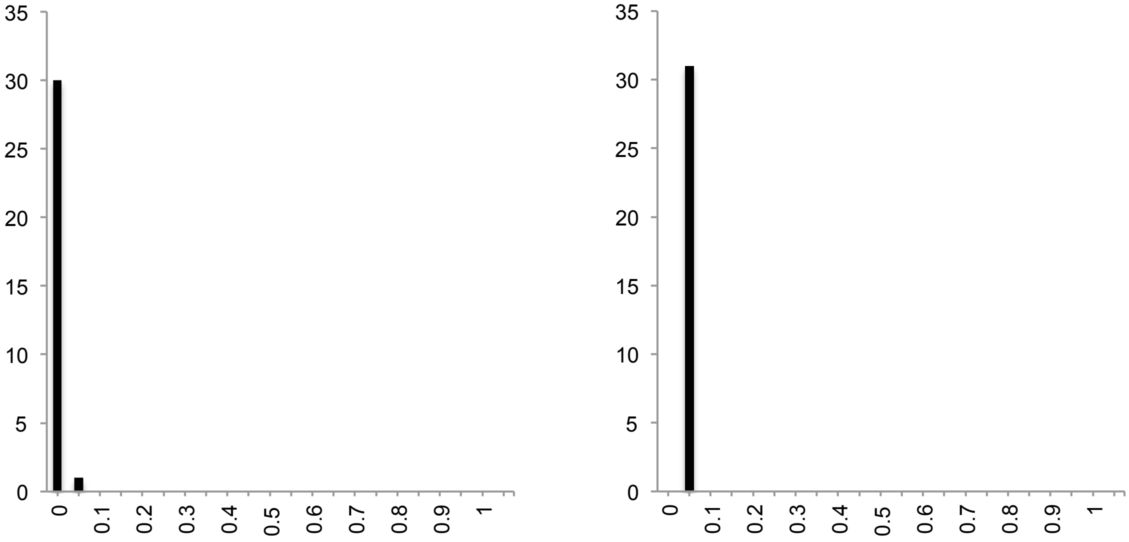
PPM and MLE frequencies for θ_f at the 9 retention interval



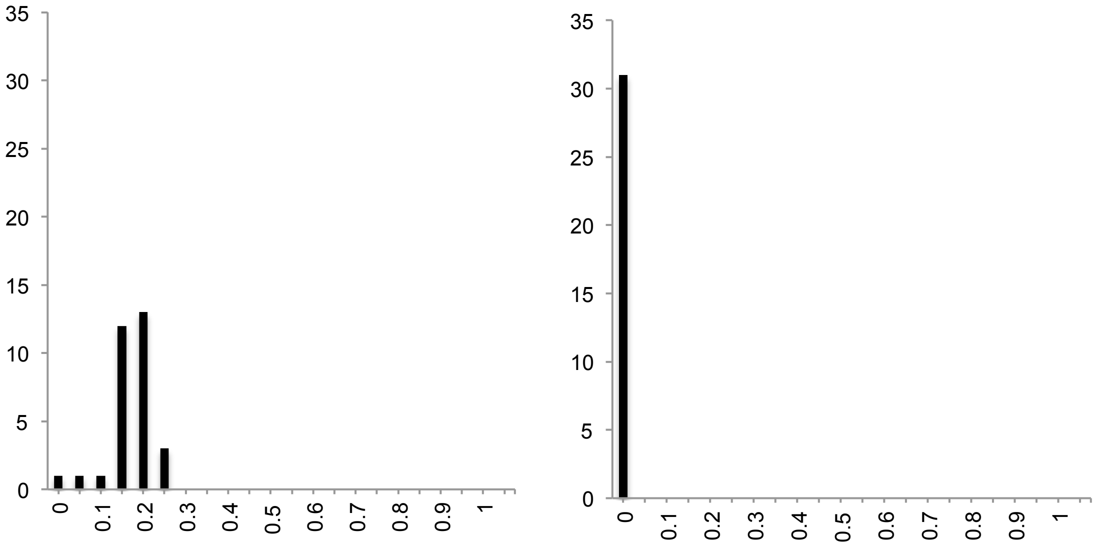
PPM and MLE frequencies for θ_k at the 0 retention interval



PPM and MLE frequencies for θ_k at the 1 retention interval



PPM and MLE frequencies for θ_k at the 4 retention interval



PPM and MLE frequencies for θ_k at the 9 retention interval

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