Age Differences In Transitive Inference: Exploring The Mechanisms Of Problem Solving

Vivian Akerib

A Thesis

in

The Department

of

Psychology

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Arts at
Concordia University
Montreal, Quebec, Canada

September, 2004

Library and
Archives Canada

Published Heritage
Branch

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque et
Archives Canada

Direction du
Patrimoine de l'édition

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 0-494-04320-2
Our file Notre référence
ISBN: 0-494-04320-2

NOTICE:
The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

AVIS:
L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

Canada

Abstract

Age Differences in Transitive Inference: Exploring the Mechanisms of Problem Solving

Vivian Akerib

Transitive inference (TI) is a form of deductive reasoning requiring the ability to infer a serial relationship between two items never explicitly compared. Two studies were conducted to examine age differences in TI reasoning in healthy younger (aged 18-35 years) and older (aged 60 + years) individuals. TI task complexity was manipulated using positive and negative phrasing (e.g., "taller" vs. "not taller"), by increasing the memory load (removing premise sentences while the inference is generated relative to having them remain in view), and by increasing number of premise terms (three, four, and five terms). In both studies, younger adults had higher accuracy than older adults, and the use of five-term premises reduced all participants' accuracy relative to three- and four-terms. Performance for both age groups was better with premises present compared to premises absent or negative phrasing. Reaction time data revealed similar patterns for both age groups, and although premises absent yielded faster responding compared to premises present or negative phrasing, the accuracy data suggested that the TI task was particularly difficult if premises did not remain in view. The relationship between TI performance and neuropsychological measures of executive function, reasoning, and working memory was examined in the second study. In older adults, performance was correlated with verbal reasoning, executive function, and linguistic skill, whereas in younger adults, performance was correlated with working memory and processing speed. Thus, to solve TI tasks, older individuals may rely more on stable resources like verbal reasoning and linguistic skill than on working memory.

Acknowledgements

I would like to thank Dr. Natalie Phillips, Department of Psychology, Concordia University and Lady Davis Institute for Medical Research, The Sir Mortimer B. Davis-Jewish General Hospital, for her supervision and guidance throughout my studies. I would also like to thank her for patience and support while allowing me to venture into this area of cognitive psychology.

I would like to thank Drs. Virginia Penhune and Karen Li, Department of Psychology, Concordia University, for agreeing to be on my committee, and for their resources and consultations, which helped focus the design of these studies and contributed to the final form of this thesis.

Special thanks to Danny Liberman for assisting me in aspects of stimuli production and especially with regard to recruitment and testing of participants. And thanks to Sharon Gagnon and Maria Cristina Vassilli from Concordia University for their help and consideration.

I would like to thank my Dad, Rémi Akerib for his consistent encouragement and badgering. And Margret Akerib for her unconditional support and, as always, helping to keep the peace.

Finally, I would also like to thank my husband, Dr. Jim Pfaus, for his unwavering encouragement and support, for his being a wonderful husband and dedicated father to our son, Joshua, and most of all for his undying faith in me, and my success.

Table of Contents

Age Differences In Transitive Inference: Exploring The Mechanisms Of Problem Solving

What makes some individuals better than others at getting themselves out of predicaments? What are the cognitive processes involved that allow some individuals to solve new problems quickly and efficiently? Reasoning requires the ability to form and manipulate mental representations between objects and events, and is traditionally used as one of several measures of intelligence and higher cognitive function by cognitive and psychometric researchers and clinicians alike using such tests as the Wechsler Adult Intelligence Scale-III (1997) or the Ravens Progressive Matrices (1976). Some problems may be solved by the direct application of previous experience, learned information, and/or procedural knowledge, while novel problems require the ability to integrate new information. The first of these skills based on accumulated knowledge is believed to draw upon what is considered crystallized intelligence, while the later based on novel stimuli draw upon what is termed analytic reasoning or fluid intelligence (Catell, 1963). This thesis is concerned with the investigation of adult age differences in the ability to solve problems in the form of transitive inference. Furthermore, this study examined correlates of reasoning, working memory, and processing speed with transitive inference performance as a way of exploring the underlying cognitive processes involved.

Studies of cognitive ageing have generally found that reasoning declines with age, with sharp declines starting at approximately age 50 years in both longitudinal and cross-sectional data (Salthouse, 1991a; Salthouse, 1992; Baltes & Lindenberger, 1997). Substantial negative correlations have been found between ageing and reasoning, using non-verbal tasks that typically involve geometric stimuli, such as Raven's Progressive Matrices (Babcock 1994; Salthouse, 1991b), Matrix Reasoning, (Salthouse, 2001; Salthouse, 1993a), and Primary Mental Abilities (PMA) Reasoning subtests (for a review see Salthouse, 1992); and non-verbal tasks that typically involve series completion, such as Letter Series Completion, Integrative Reasoning, (for a review see Salthouse, 1992), Analytical Reasoning adapted from typical graduate record exams (Salthouse, 2001) and Syllogistic Reasoning (Fisk & Sharp, 2002). Inferential reasoning seems more ecologically valid than the abstract tests listed above, since drawing inferences is required for adequate comprehension of typical oral and written discourse, including such simple yet important things as getting directions or instructions for medication or sharing an anecdote/recounting an incident. It has even been proposed that the cognitive processes underlying inferential reasoning forms the basis for all significant forms of adult reasoning (Inhelder & Piaget, 1958).

The test of transitive inference (TI) was developed by Piaget to assess capacities for systematic organization of knowledge and logical inference (Piaget, 1928). Since it is a form of deductive reasoning and fluid intelligence, transitive inference can be used as a measure of problem solving ability. TI indicates the ability to infer a relationship between items that have not been explicitly presented together, based on previous learning of overlapping premises (Dusek & Eichenbaum, 1997). For instance, given the two premises *the blue rod is longer than the red rod* and *the red rod is longer than green rod*, one can infer that *the blue rod is longer than green rod.* The ability to make this inference provides evidence of an acquired representation of orderly stimulus relations (Halford, 1984). In order to solve this task one must encode relations amongst paired items and express memories flexibly using inferences about items that are only indirectly related (Sternberg, 1980). Similarly, given *Bill is taller than Charles* (one relation) and *Abe is taller than Bill* (a second relation), to answer the question *Who is taller, Charles or Abe?* one must infer from knowledge of the other two relations. On the other hand, in learning about the stimulus pairs: A>B, B>C, C>D, D>E, if asked to infer the relation between A and E, because these items are at the extremes, one can apply a general rule that A is the bigger than all others and E is the smallest and reach the conclusion that A>E without actually having integrated information about all items. Thus, according to proponents of TI studies in animals, such as Eichenbaum, a true test of transitivity is to inquire about the relation between B and D because both are preceded by bigger items and followed by smaller ones (Dusek & Eichenbaum, 1997). One must primarily attend to and learn about the pairing of the items. What is ultimately required in this task is the integration of multiple relations, which is also necessary for problem solving and planning.

TI is obviously a complex task, which requires encoding relationships between stimuli, making pair-wise comparisons, transforming items, re-ordering items, storing the hierarchical relationships and then remembering them. As such, the demands of this task fulfill Carpenter, Just, and Shell's stipulation that tests of analytic intelligence or reasoning commonly require the decomposition, segmentation, incremental, and reiterative processing of stimuli (1990). TI tests have been used to determine whether animals are capable of relational representation and inferential judgment (McGonigle & Chalmers, 1977). In studies of cognitive aging in non-human primates there are findings of learning and memory deficits related to the integrity of either the prefrontal cortex or medial temporal lobes (Bachevalier et al., 1991; Rapp & Amaral, 1989). However, in humans, while the temporal lobes are implicated in learning and memory, the frontal lobes have been shown to be involved in planning a sequence of processes to complete a goal, inhibition of distracting events, management of multiple tasks, and working memory functions such as organizing and monitoring information retrieved from memory (for reviews, see Dunbar & Sussman, 1995; Shimamura, 1995). Working memory is a limited capacity system that temporarily stores, organizes, and monitors information during processing (Baddeley, 1981). The frontal lobes contain many subdivisions, which are responsible for different abilities. Among these are three main regions consisting of the motor and premotor cortices, which largely contribute to control of movement (Stuss, Eskes & Foster, 1994), and the prefrontal cortex which controls the cognitive processes that guide these movements and translate them into appropriate, goal-directed behavior. The prefrontal cortex itself can be divided into three main regions, the dorsolateral prefrontal cortex, the inferior prefrontal cortex, (which includes the orbital frontal cortex), and the medial frontal cortex (Kolb & Whishaw, 1996). All premotor areas receive projections from the dorsolateral pre-frontal cortex. Among other reciprocal connections, the dorsolateral pre-frontal cortex has a strong relationship with the posterior parietal cortex and the superior temporal sulcus. Areas within the lateral frontal cortex are responsive to auditory, visual, and somatic stimuli. Individuals with orbital frontal cortex deficits may experience difficulties in perseveration and distractibility, while deficits in dorsolateral prefrontal cortex may lead to difficulties in problem solving or attention, (e.g., management of dual tasks), memory, (e.g., working memory, declarative memory and meta-memory), planning, organization, frequency judgments, categorization, hypothesis testing, rule application, fragmentation of sequences, as well as controlling and monitoring information processing (Delis, Squire, Bihrle & Massman, 1992; Milner & Petrides, 1984; Owens, Downes, Sahakian, Polkey & Robbins, 1990; Shallice & Evans, 1978; for reviews, see Shimamura, 1995, and Stuss, Eskes, & Foster, 1994). Among the cognitive processes potentially required for problem solving and reasoning are working memory, processing speed, attention, aspects of executive-control, planning, decision making, and hypothesis testing (Della Sala & Logie, 1993; Lindenberger, Mayr, & Kleigl, 1993; Salthouse, Mitchell, Skovroneck, & Babcock, 1989; Shallice & Burgess, 1991). In some populations, individuals' loss of the ability to problem solve can limit aspects of their everyday functioning for even simple tasks like grocery shopping (Shallice & Burgess, 1991). Some of these types of deficits are not just related to aspects of neurological damage but, to some extent, to aging as well, as evidenced in tasks of working memory and executive function (for reviews see West, 1996 discussed below or Moscovitch & Winocur, 1995).

One role of the frontal lobes is to provide descending inhibitory control over the rest of the brain (Kolb & Whishaw, 1996). Earlier applications of the frontal lobe hypothesis in cognitive aging involved interpretations of reduced efficiency of inhibitory processes that are supported by the prefrontal cortex (Dempster, 1991). Findings from various experimental paradigms, including negative priming (Kane, Hasher, Stoltzfus, Zacks & Connelly, 1994), text processing (Hamm & Hasher, 1992), and speech production (Arbuckle & Gold, 1993) provide support for Hasher & Zacks's inhibition deficit hypothesis (1988), suggesting that age-related impairments observed in a variety of cognitive tasks were products of reduced inhibitory processes in working memory with old age. In a review paper, West (1996) extended the role of the frontal cortex in aging beyond the overall loss of inhibitory control. He suggested that selective frontal lobe pathology underlies the neurobiology of aging and that cognitive functions that rely upon the frontal areas show earlier declines with aging than those sustained by other brain areas. Experiments involving Self-Ordered Pointing Task and source memory, which consistently demonstrate age related declines, provided evidence for this theory. The frontal lobes seem to be further implicated in memory processes, including source and episodic memory, as well as the integration and maintenance of information on-line during task performance. Indeed, D'Esposito, Detre, Alsop, Shin, Atlas & Grossman, (1995) cite working memory, reasoning, and executive function, among the cognitive abilities that are associated with prefrontal cortical function. Therefore, West attempts to incorporate processes of memory, as well as inhibition, into his account of the relationship between aging, cognition, and the prefrontal cortex. Additional support for the frontal lobe theory emerges from presented findings of observed neurobiological changes associated with aging, such as reduction in brain volume, reduced synaptic density, and reduced neurotransmitter levels, as well as reduced regional cerebral blood flow (indicative of localized brain activation typically during a cognitive task). All of these changes in frontal cortex function are more pronounced in older adults and occur earlier in the frontal lobes compared to other cortical regions.

A recent study by Waltz, Knowlton, Holyoak, Boone, Mishkin, de Menezes Santos, et al., (1999) has implicated the frontal lobes in TI task performance as well as other measures of relational reasoning. These authors set out to determine if the prefrontal cortex was critical for relational integration by examining performance TI tasks as a measure of deductive reasoning in 6 patients with prefrontal dementia, 5 with temporal lobe dementia, and 7 age matched controls. The TI problems each involved between two and four propositions, using statements such as *Sam is taller than Nate; Nate is taller than Roy.* Waltz et al. had two levels of complexity where in Level one, the premise pairs were introduced in order of height, allowing for the correct order to be achieved using a simple chaining strategy. In level two complexity, the premise pairs were introduced in scrambled order. At each Level, these authors used three, four and five terms problems, with three problems in each set. All propositions remained in view throughout the trials, diminishing the need to maintain premises in short-term memory. This test was followed by an immediate incidental recognition memory test of the TI premise pairs. Subjects were matched for age and education level, and for severity of dementia in the case of the patient groups. The results demonstrated that the patients with frontal lobe dementia were impaired on the relational reasoning task performance when the premise pairs were presented in scrambled rather than linear order. At the same time Waltz et al. were able to rule out the notion that these deficits could have been caused by a general cognitive impairment since this patient group's performance on episodic and semantic memory tasks was unimpaired. In contrast with the frontal lobe dementia group, the temporal lobe dementia patients' performance on the episodic and semantic memory tasks was impaired while their performance on relational reasoning tasks were comparable to controls. Since the prefrontal patients did well on simpler relation tasks (where premises were presented in serial order) versus the more complex (where premises presented in jumbled order), this rules out explanations of impaired performance due to problems of motivation, inability to follow instructions, or tendency to perseverate. Thus, Waltz et al. demonstrated a double dissociation where the frontal patients' performance were impaired on relational reasoning tasks while their episodic memory remained intact versus the temporal patients whose performance was impaired on episodic memory tasks while performing as normal controls on the relational reasoning tasks. The authors concluded that the prefrontal cortex plays a critical role in relational reasoning-integration of multiple relations. Such relational reasoning might be supported by the executive component of working memory, suggesting that relational integration is the work carried out by working memory. Previous imaging studies have found that both reasoning tasks and working memory tasks involve activation of the prefrontal cortex (for a review, see Moscovitch & Winocur, 1995; Prabhakaran, Smith, Desmond, Glover, & Gabrieli, 1997). However, different regions in the prefrontal cortex are postulated to subserve different functions. For example, the ventromedial region is implicated in emotion and decision-making (Bechara, Damasio, Tranel & Damasio, 1997), whereas the dorsolateral prefrontal cortex is implicated in working memory and executive functions (Braddley, 1992; Cohen et al., 1997; and Smith & Jonides, 1998).

A developmental study by Bryant and Trabasso (1971) confirms involvement of working memory during transitive inference tasks in young children. It had previously been held that transivity only emerges at the age of 7 (Inhelder & Piaget, 1964; Piaget, & Inhelder, 1956; 1969; Smedslund, 1969). However, it had also been postulated that working memory capacity is limited and develops gradually through childhood (Pascual-Leone, 1970). In their study, Bryant and Trabasso familiarized children aged four-6 years with adjacent coloured rods of graduated length on a pair-wise basis (A>B, B>C, C>D, D>E.). Children as young as four years were capable of solving transitive inference problems if their working memory limitations were compensated for by training subjects to criterion, and ensuring memory of initially paired items during the testing phase. These results suggest that earlier failures with preschool children (Piaget & Inhelder, 1960) may have reflected deficits of memory rather than logic, thus implicating working memory processes in transitive inference tasks.

Another source of evidence for memory involvement in TI comes from a study conducted by Smith (1980) in 6 patients with aphasia and four controls following reports that aphasic patients could not solve transitive inference problems (Luria, 1966). In order to discern the potential implication of reduced short-term memory capacities in aphasia, Smith examined whether the aphasic patients' difficulties resulted from failure to grasp the logico-grammatical relations in the premises or from the memory demands of the task using a task that did not draw on linguistic loading or language. In a paradigm adapted from Bryant and Trabasso (1971), Smith used solely non-verbal stimuli like coloured rods of differing length (Experiment 1), objects of differing weight (Experiment 2), objects with the inference elements being arbitrarily related shapes or a variant using meaningless visual symbols (Experiment 3). The results demonstrated that most aphasic patients were capable of solving inference problems if the paradigm compensated for memory limitations by training to criterion, and compensated for language deficits by providing nonverbal stimuli.

It seems that in young children, aphasics, and potentially even in patients with frontal lobe damage, working memory capacity affects performance on transitive inference task. However, it is not clear how working memory capacity would affect healthy older adults' performance on TI. It is recognized that older adults have some diminished capacity in working memory, as it pertains to active mental processing and manipulation of information (Belmore, 1981; Dobbs & Rule, 1989; Foos, 1989; Salthouse, 1990; Wingfield, Stine, Lahar & Aberdeen, 1988). For instance, Dobbs and Rule (1989), using an n-back task, presented ten digits auditorially which subjects had to remember and repeat, according to various time lags, including the digit they just heard (Lag 0), the digit previous to the digit just heard (Lag 1), and the digit two before the one just heard (Lag 2). These investigators found that the Lag 2 condition required the highest degree of mental manipulations or working memory, and that there was an inverse relationship between age and task performance from Lag 1 to Lag 2 conditions.

According to Baddeley's working memory model, it is the central executive that regulates attention and governs two subsystems which process, temporarily store and manipulate either visual or auditory information through the visual sketchpad or the phonological loop, respectively. Baddeley (1995; Baddeley & Hitch, 1974; Baddeley & Logie, 1999) has attributed the active manipulation aspects of working memory to the central executive, and Salthouse (1996) posited that age differences in working memory may be caused by a decline in overall processing speed. Furthermore, imaging studies have implicated the frontal lobes in executive control functions, and it is also acknowledged that frontal lobes show behavioral and neuroanatomical signs of deterioration in aging (for reviews, see Moscovitch & Winocur, 1995; West, 1996). For instance, Daigneault & Braun (1993) and West, Ergis, Winocur, & Saint-Cyr (1998) found that older adults demonstrated a decrement in tasks requiring self-monitoring, a function subserved by the frontal lobes, as revealed by the self-ordered serial pointing task. Still other abilities such as management of dual-tasks and divided attention decline with age (Crossley & Hiscock , 1992; Ponds, Brouwer, and Van Wolffelaar, 1988). Age decrements are also seen in the Wisconsin Card Sorting Task (WCST) and Stroop test, where the inability to suppress preponent responses (Hartman, Bolton & Fehnel 2001), and a lack of inhibition (West & Alain, 2000), respectively, are considered the primary factors. Given what is known about frontal lobe function in aging, older adults may be expected to show a decline in executive and frontal lobe functioning. Thus, one aim of this study is to examine age differences related to working memory, executive control and frontal lobe capacity and attempt to determine if performance on the transitive inference task is affected as a function of these processes.

Additionally, most cognitive aging researchers agree that older adults experience a general slowing in processing speed. For example, performance on cognitive tasks that require both perceptual and information processing declines with age (Salthouse, 1997; 1996; 1993; Lindenberger, Mayr, & Kliegl, 1993). Salthouse (1993b) found that measures of perceptual speed were associated with 74% of the age-related variance in different aspects of fluid cognition. A processing speed theory has been proposed to account for some of the age-related differences in cognitive performance (Salthouse, 1996). The central notion of this theory is that negative trends in speed of processing operations may be responsible for negative age trends in other intellectual abilities. Whether a decrease in processing speed results in impaired cognitive function or whether processing speed itself is just one of several abilities affected by another underlying phenomenon that declines with age, such as reduced sensory abilities (Lindenberger & Baltes, 1997; Li & Lindenberger, 2002) and/or cortical restructuring and compensation (Cabeza, McIntosh, Tulving, Nyberg, & Grady,1997b; Levine, Cabeza, McIntosh, Black, Grady, Stuss, 2002; for a review see Grady, 1998) is still debated.

The findings on reasoning abilities in older aged individuals are mixed and depend largely on the way that reasoning is defined and tested. Furthermore, the reduction in reasoning observed in older adults could be attributed to 1) a general inability to reason, 2) a failure to understand the task demands, 3) inadequate semantic processing, or 4) a general decline in working memory that is amplified when the task is complex, requires imagery or other mental representation for completion (Arenberg & Robertson-Tchabo, 1985; Gick, Craik & Morris, 1988; Light et al., 1982; Salthouse & Prill, 1987). Light et al. (1982) tested these four possibilities in a series of three related experiments on drawing inferences from novel information. These authors used audiotaped sequences of sentence sets that contained minimal or "standard" instructions, stories in which facts had to be recalled and inferences made, and a four-term linear ordering task in which premises were presented in ways that taxed working memory capacity. In the first experiment, young and older participants were presented with sets of three related sentences, such as, 1. *The ants ate the jelly. The jelly was on the table. The table was under the tree;* and 2. *The kitten sat in the box. The box was in the car. The car was in the park.* Then participants were given a two-alternative forced-choice task wherein they had to choose among true and false inferences, such as, 1. *a) The kitten was in the park or b) The kitten was under the tree;* and true and false facts, such as, *2. a) The ants ate the jelly or b) The kitten ate the jelly.* In order to rule out task failure due to an inability to understand the task, there was also a manipulation of the nature of the instructions the participants received. Participants in the standard instructions condition were forewarned that they would be tested, with no mention about the need to make inferences. In the inference-after condition, participants were given the standard instructions and, prior to the test, given examples of strategies for answering both factual and inference type of questions. Those in the inference-during condition received the standard instructions and were told they would be required to answer questions involving inferences on half of the sentence sets as they were being presented. It was thought that this manipulation would induce participants to semantically process and integrate information presented within a set during presentation, and thus improve performance in making inferences immediately following the presentation of sentence sets. Thus, those in the inference-during condition received a test immediately following presentation of each individual sentence set, as well as the final test received by all participants after all sentence sets had been presented. The memory load was kept low during this initial testing phase by keeping the related sentence sets in full view. This memory load manipulation allowed the authors to examine differences in participants' ability to make inferences, when facts had been just processed and still available versus when they had to be retrieved from memory. No evidence was found to support the first three hypotheses. The inference-after instructions failed to improve older adults performance on the final test, allowing the authors to rule out participant confusion about the nature of the task. In the inference-during condition, with relevant stimuli in view, all participants were able to perform well, ruling out lack of semantic processing and inability to reason. However, for the final testing phase, older subjects had an overall reduced capacity to make correct inferences from the stories, and were less likely to recall the relational premises accurately relative to younger subjects. Light et al. concluded that older adults have a reduced ability to reason from new information. Similar findings emerged from their second experiment, whereby older adults continued to do poorly relative to younger adults despite the experimenters' attempts to embed factual stimuli in story contexts. In their third experiment, Light et al. hypothesized that older adults' difficulty in reasoning from novel stimuli was largely caused by limitations of working memory capacity. Participants were presented with short paragraphs such as, *The boys measured their heights. David was taller than Bob. Bob was taller than James. James was taller than Ron.* Participants were then required to answer true-false questions, which either repeated a sentence presented in the paragraph (i.e. fact) or presented an inference based on information from the paragraph. The order of stimulus pair presentation was manipulated to include six problems of each of three combinations: a) AB, BC, CD; b) CD, AB, BC; c) CD, BC, AB. The first of which was thought to be the easiest because it was presented in linear order and required only simple integration. The third order was thought to be more difficult because the premises required re-arrangement. The second order was thought to be most difficult in terms of integration, storage and retrieval demands. Thus, the order manipulation was intended to tap into gradations of working memory load. Participants were tested via two true-false questions, (inferential and factual) after each paragraph. For the six problems of each type, two inferences (one being true, and one false) were represented by two of each, AC, two BD, and two AD. Participants were given examples of each type of answer, and informed of the type of questions, both factual and inferential. The paragraphs did not remain visually present during consideration of the question in this experiment. Participants did not have a time limit to answer questions. While the order of difficulty was found to be the same for both age groups, the older adults performed less well on problems that had higher working memory demands. Across all three experiments, older adults did display some factual memory loss relative to younger adults but this effect did not sufficiently account for their impairments in delayed reasoning tests. Light et al. concluded that although some factual memory loss contributes to impairments in delayed reasoning tests, it is not likely to be the primary source. Similarly, these authors concluded that older adults did not experience a general impairment in reasoning when the working memory capacity was not taxed, but that older adults did demonstrate an impairment in reasoning from new stimuli in instances when working memory capacity was taxed.

Likewise, Cohen (1979) found that older individuals had difficulty making inferences based on short descriptive paragraphs, especially those containing negative premises and exclusion clauses (e.g., not, when, only if, unless). Relative to younger adults these older participants also had difficulty identifying anomalous information in reference to pre-existing everyday knowledge. For example, the statement that *the Jones family was very close to an airport,* was followed later by the statement that *it was very quiet and peaceful*. Upon hearing these auditory messages, participants had to judge whether these statements contained a mistake or could not be true. This required them to access everyday factual knowledge (that airports are noisy) and pick up on the discrepancy in presented stimuli. Older individuals were also less able to extract and retain the gist of information from a story compared to younger individuals. Similarly, Cohen (1981) found older adults had greater difficulty solving logical problems requiring inferential reasoning relative to younger adults. Furthermore, unlike the younger adults, older adults did less poorly when the task was available in written rather than spoken form, (likely due to a reduction in working memory load or need for rehearsal). Based on these data, Cohen argued that older individuals have a limitation in processing capacity that renders them unable to register surface meaning at the same time as performing integrative or constructive processes. Thus, relative to younger individuals, older individuals were less able to multitask. Any procedure that requires more than a single task at a time would therefore be predicted to compromise the ability of older individuals to respond correctly. And in fact, this is what is typically found in working memory (Dobbs & Rule, 1989) and divided attention paradigms (for a review see Hartley 1992).

Gick, Craik, and Morris (1988) manipulated task complexity in a working memory paradigm whereby participants were presented with between one to five sentences in which the accuracy of the sentences had to be verified and the final words had to be remembered. One task complexity manipulation was to include either positive (e.g. Cats usually like to hunt mice) and negatively phrased sentences (e.g. Bookcases are not usually found by the sea). Older individuals performed consistently worse than the younger group in recalling words in up to five positively-phrased sentences, but showed a similar pattern of relative deficits as the younger group when the sentence set sizes increased, (both in terms of increased errors and latencies). However, older individuals made more errors and recalled fewer words in negatively-phrased sentences relative to younger individuals, an effect that was further exacerbated under paced timing conditions. In a similar study, Morris, Gick, and Craik (1988) found that older adults' reaction time performance was penalized when presented with negatively phrased sentences. Thus, according to these authors, it seems that the capacity of working memory is reduced in older individuals in terms of processing incoming information, especially when that information is complex (Morris, et al., 1988).

Salthouse, Mitchell, Skovronek, and Babcock, (1989) examined the effects of age and working memory on inferential reasoning, by presenting between one to four premises, each describing the relation between two variables. These premises were followed by a question requiring the individual to infer what will happen to one variable if a specified change is introduced to the other variable (e.g. For 2 Premises or three terms: *M and N do the opposite. L and M do the same. If L INCREASES, what will happen to N?*). Results of this verbal integrative reasoning task showed decreased decision accuracy as the number of premises presented increased, and these effects were more pronounced with increasing age. Use of a working memory capacity index (Computation Span) for statistical control resulted in the attenuation approximately half of the age effects in reasoning. Further analyses of these data by Salthouse, Legg, Palmon, and Mitchell, (1990) found that decision time increased with a greater number of premises presented, again a result that was more pronounced in older adults. Therefore, to the extent that "reasoning" is limited by working memory capacity, as suggested by Salthouse et al., (1989), then older individuals will be compromised relative to younger individuals.

At least three distinct theoretical approaches have been taken to understanding the decline in working memory that occurs during aging (reviewed in Craik, Anderson, Kerr, & Li, 1995). These involve a consideration of processing resources and lack of inhibition across different age groups. Salthouse (1993b) used indices of cognitive slowing (e.g., WAIS-R digit-symbol substitution task) and correlated them with indices of working memory capacity in individuals from different age groups sorted by decade. The age-related variance in working memory was reduced substantially when the variance attributed to cognitive slowing was removed by hierarchical regression analysis, suggesting that cognitive slowing accounts for most of the age-related changes in working memory. This account lends support to a separate but overlapping theory, namely the processing resources hypothesis in which diminished processing resources in aging reduces the ability to respond to increases in working memory load (Salthouse, & Babcock, 1991; Salthouse et al., 1989). The resource argument postulates that these unspecified resources are required for some but not all cognitive processes, that these processes have a limited capacity, which happen to decline with age, and that this age-related reduction in the quantity of processing resources results in poorer performance in tasks involving resource-demanding processes (Salthouse et al., 1989). Thus, older individuals are more affected by increases in sentence complexity, such as negative phrasing, (Craik, Morris, & Gick, 1990) and by required simultaneous storage and processing operations (Babcock & Salthouse, 1990; Salthouse, et al., 1989; Salthouse, Babcock, & Shaw, 1991). These data suggest that the extent of age-related declines in cognitive tasks depends on the working memory load imposed by the task. Finally, the mechanism for lack of inhibition has been proposed to account for age-related declines in working memory (e.g., Hasher & Zacks, 1988; Stolzfus & Hasher, 1993). It was hypothesized that aging brings about a reduced capacity to inhibit task-irrelevant information. Thus, failures to filter or selectively update information in working memory can reduce its effective operations, in terms of functional processing and storage capacity overall. According to this view, an increase in working memory load is compromised not by a decreased storage capacity of working memory in general, but by the amount of extraneous information held in the working memory buffer during the task. The exact nature of the deficit in processing speed and/or working memory that affects successful task completion in older individuals remains to be specified.

Data reviewed so far indicate that aphasics, older adults with frontal lobe deficits, and healthy young children all have decreased performance on the TI task relative to young adults. Further, imaging studies seem to implicate involvement of frontal lobes in a sample of reasoning tasks. The TI task requires the ability to encode relations amongst paired items and integrate the multiple relations. These abilities likely draw upon executive processes, working memory and processing speed to some extent. Given that executive frontal lobe function, working memory and processing speed are known to decline in aging, it is important to examine problem solving ability in healthy aged adults. However, previous studies of reasoning in healthy aged adults have yielded conflicting results regarding whether aged adults have shown a decline in performance. In cases where they have (e.g., Light et al., 1982; Cohen, 1979;1981), it has been difficult to divorce the decline in performance from working memory or divided attention deficits. Thus, one aim of this study is to examine age differences related to working memory, executive control and frontal lobe capacity and attempt to determine if performance on the transitive inference task is affected as a function of these processes. Unlike many studies in the cognitive aging and working memory literature, this study will include multiple measures of working memory, executive function and/ or frontal lobe function, processing speed, as well as problem solving. It is thought that having multiple measures of each index will facilitate establishing the extent of the relationships between these cognitive constructs and TI. This will then lead to the ability to evaluate whether these cognitive abilities show similar patterns of disruption in aging. If so, they may potentially be part of a working memory construct or some other underlying construct that is affected in aging. The possibility remains however that the multiple cognitive abilities (mentioned above) may be differentially affected by aging and therefore represent separate entities, which rely on diverse resources.

As an example of the TI task used in this study, individuals were presented with the following premise phrases sequentially: Abe *(C)* is taller than Jack *(D)*. Bill *(A)* is taller than Charles *(B)*. Charles is taller than Abe *(C)*. Jack is taller than Tom *(E)*. Individuals were then asked the inference question: Who is taller Charles *(B)* or Tom *(D)*? To answer correctly individuals have to infer a relationship between *B* and *D,* two items never explicitly compared by processing the hierarchical relationships between the other items and perform mental linear reordering. The present study assessed the relative contribution of working memory and processing speed to transitive inference (TI) task performance, and compared this task to others used to assess reasoning ability. It was hypothesized that performance on the TI task, as measured in both reaction time and accuracy, would be reduced in the older adults relative to the younger adults. Because there is evidence that older adults show declines in working memory (Belmore, 1981; Dobes & Rule, 1989; Foos, 1989; Salthouse, 1990) and processing speed (Salthouse, 1996; Lindenberger, Mayr, & Kliegl, 1993), as well as frontal lobe executive function (which subserves working memory; Moscovitch & Winocur, 1995), this study investigated the extent to which measures of those abilities predict individual performance on TI and reasoning tasks. Matrix Reasoning and Similarities subtests of the Wechsler Adult Intelligence Scale, 3rd Edition (WAIS-III, Wechsler, 1997) are established measures of non-verbal and verbal reasoning. It was also hypothesized that subjects' TI performance would predict performance on two other measures of reasoning, Matrix Reasoning and Similarities. If a relationship were found between performances on these three measures, it would also validate the use of the TI task as a measure of reasoning ability. If so, then TI might provide a more efficient way to measure the same underlying structures and processes but provide more flexibility to vary task complexity. As such, TI could be a sensitive tool to examine working memory capacity, frontal lobe functioning, processing speed and attention. In order to examine these cognitive abilities directly, the present study used three manipulations; two manipulations of working memory load, and one of task complexity. First, working memory load was increased by removing premise phrases from view during the presentation of the inference question. Second, negative phrasing was used in certain conditions to require an increase in processing steps, and thus represent a qualitative working memory load manipulation or an increase in task complexity (Sternberg, 1980; Gick, Craik, and Morris, 1988). Use of negative sentence structure has been shown to require additional processing time while not necessarily affecting accuracy of performance (Gick et al., 1988). For example, using grammatical structure such as 'not taller than' instead of 'taller than' should require more processing time. It was therefore expected that the negation condition would slow reaction time in the older group of participants while not affecting their accuracy. Younger adults were also expected to experience a slow in reaction time but to a lesser extent than the older group. Older adult's accuracy in performance was expected to show the greatest decrement in the condition with premise elements absent, and this decrement was predicted to be greater than that shown in the younger group. Finally, working memory load was increased by varying the number of premise terms from between three, four and five, and was predicted to decrease all participants' performance in a linear fashion, with older adults showing slightly greater decrements. A final purpose of this study was to consider individual differences in transitive inference task performance and examine possible correlations with performance on other neuropsychological tasks. As such, a neuropsychological battery including eight tests was selected to tap into processes that should also be required for solving TI problems. Performance on these eight tests was then compared to each subjects' TI performance in correlational analyses. It was expected that amongst older adults working memory and processing speed performance would predict TI performance.

This study was conducted in two parts. In Study 1, there were 15 older adults and 16 younger adults who participated, receiving three conditions of the transitive inference paradigm. In Study 2, 24 subjects in both age groups participated, receiving the complete design that of four conditions of the TI paradigm.

Method

Study 1

Participants

Young Adults. Sixteen young adults between the ages of 18-35 years were recruited through posted advertisements at Concordia University, from the undergraduate Psychology classes, and by circulating sign-up sheets during undergraduate Psychology courses. Young adults who expressed an interest in participating were contacted and a brief screening interview was conducted to determine health status and eligibility for the study. Young participants were compensated ten dollars each for their participation.

Older Adults. Fifteen older adults aged 59 years and older were recruited from a previously established subject pool at the Jewish General Hospital, from notices posted at the Jewish General Hospital, from the "Fifty-Plus Conference for Seniors" held in Montreal, and from advertisements in newspapers aimed at Seniors. Older adult participants were compensated fifteen dollars each for their participation.

Participants were generally matched for sex, general intellectual function and years of education. To meet inclusion criteria, all participants had to be proficient in English, and had to have normal or corrected-to-normal vision. Exclusionary criteria included the presence of any significant chronic medical condition which might interfere with cognitive function (e.g., renal disease, etc.), peripheral vascular, cardiovascular, or cerebrovascular disease, medications known to have central nervous system effects (e.g., beta blockers), neurological disorder, substance abuse, or psychiatric disorder, as assessed by our laboratory's self-report health questionnaire (See Appendix A).

For both subject groups, aside from the remuneration mentioned, participation was on a volunteer basis; no additional methods of persuasion or incentive were employed.

Stimuli

Transitive Inference task. The Transitive Inference Task (adapted from Piaget, 1928) is a measure of inferential reasoning requiring the mental reordering of paired items not explicitly compared. Each transitive inference (TI) problem was comprised of two to four premise phrases that each described the relation between two items or elements in the form of proper names. For instance, a premise phrase could be *Mary is taller than Stan,* wherein *Mary* and *Stan* are the two elements or items to be learned as well as their relative rank order. All premise sentences took the form, "A is X-er than B", where A and B were adjacent terms and X was one of 16 adjectives (taller, smarter, neater, happier, greater, wiser, faster, stronger, funnier, closer, older, younger, richer, nicer, better, quieter.) Additional adjectives were also used for practice trials (namely, tougher, prettier, warmer, bolder and bigger). Each adjective appeared once per condition and each proper name appeared only once in the entire paradigm to limit confusion between problems. Furthermore, within one trial, no two names shared the same first letter to minimize confusion and avoid an unintended task complexity manipulation. All premises were presented in a non-serial order (i.e., a jumbled order) to limit the use of order of presentation in facilitating the forming of associations between items.[1] Stimuli were presented on one of two computers, a Compaq computer and an IBM, using

---

[1] Smith and Foos (1975) found that order of presentation can influence task complexity. For example, they found that participants made more errors and required more time to respond to C>D, A>B, B>C, jumbled input than participants who received A>B, B>C, C>D, serial ordered input.

experimental software, Inquisit 131 (Millisecond Software 2000), to control stimulus presentation. Each premise sentence appeared in orange lettering, 36 point font on a black background on a 13" x 12" inch SVGN computer monitor. The premise sentences appeared one at a time with 5-second intervals between sentences. Each sentence accumulated on the screen until the TI question appeared.

Number of Terms and Conditions. Working memory load for a set of 45 transitive inference problems was manipulated using three task conditions: premise number, premise presence, and premise phrasing. In reference to premise number, the number of terms in the premises was varied between three, four, and five terms in each transitive problem. The premise presence condition refers to whether premises were present or absent on the computer screen while the participants solved the TI problems. That is, premises absent involved removing the premise phrases from view while the inference question was being considered, forcing participants to remember the terms and their relative rank orders. The phrasing condition represents a third variation of the working memory manipulation, using positive or negative sentence structure in the premise phrases before the adjectives, as in 'not taller than'. The phrasing, presence and premise number conditions were blocked and partially crossed with each other yielding three TI task condition blocks (premises present, absent, and premises present with negation), combined with number of terms (either three, four, or five items), were presented in three pseudo-randomized Latin square blocked design of 15 problems each, with 5 trials per number of premises. The Latin square was constrained so that no participant received the condition with premises absent first. For each condition, there were 2 practice trials per block. Deductive reasoning was measured by examining the performance of subjects on a set of 45 transitive inference problems. Both accuracy (defined as % correct) and reaction time (in seconds) were measured automatically by the Inquisit computer program.

Neuropsychological battery. In addition, nine cognitive measures were administered during the testing session. Of these measures, the Mini-Mental Status Exam (MMSE; Folstein, Folstein & McHugh, 1975) a test of cognitive status, examination of orientation, attention, and short-term memory was used to insure healthy cognitive functioning and to screen for dementia. The remaining eight tests are described below. Although all raw scores obtained from subtests of the WAIS-III and WMS-III were compared to normative data categorized by age groups ranging from 16 to 89 years to provide a scaled score in addition to the raw score, only the raw scores were used in analyzing the results presented, given this study's purpose of assessing individual differences.

The Vocabulary subtest of the Wechsler Adult Intelligence Scale, 3rd Edition (WAIS-III, Wechsler, 1997) is a measure of general verbal ability in which subjects must provide oral definitions for words (e.g. *repair*, *fortitude*). This subtest yields a raw value score from 0-66, wherein a high score indicates better performance. The Vocabulary subtest of the WAIS-III was used as a control variable to ensure that subjects from both groups were generally matched for intellectual level, in addition to being used as a measure of general intelligence, which should also relate to the TI task performance.

The WAIS-III Matrix Reasoning subtest is a measure of general non-verbal abstract reasoning, involving non-timed visual perceptual encoding, matching, and identification of logico-mathematical patterns. This subtest yields a dependent variable consisting of a raw value from 0-26, wherein a high score indicates better performance.

The WAIS-III Letter-Number Sequencing subtest is a measure of working memory processing and short-term storage capacity requiring auditory visual perceptual encoding, and mental reordering of intermingled letters and numbers according to defined criteria. The resulting dependent variable was a calculated span, ranging from 0-21 for each subject representative of that subject's working memory processing capacity. The Letter-Number Sequencing subtest assesses working memory capacity, and was used to evaluate the extent to which working memory predicts transitive inference performance for each participant.

The WAIS-III Digit Symbol Coding subtest is a measure of mental processing speed and sustained attention requiring timed visual perceptual encoding, and the transcription of written symbols. This subtest yields a raw score from 0-123, wherein a high score indicates faster performance. This subtest is a measure of processing speed and was used to assess the extent to which processing speed predicts transitive inference performance for each participant.

The WAIS-III Similarities subtest is a measure of verbal abstract reasoning in which subjects must explain the higher-order relation between two items (e.g. being able to say that *orange and banana are fruit*). This subtest yields a raw score from 0-33, wherein a high score indicates better performance. The Similarities and the Matrix reasoning subtests assess abstract and relational reasoning and were included to assess the extent to which a participants' performance on transitive inference is correlated with these two measures of reasoning.

The Wisconsin Card Sorting Task (WCST; Heaton, 1993) is a measure of abstract reasoning, concept formation, rule application, and planning, thought to tap frontal lobe executive functions. Milner (1963, 1964) found that patients with frontal lobe damage had deficient performance relative to healthy controls, thereby establishing the WCST as a test sensitive to frontal dysfunction. The task requires individuals to classify cards according to one of three criteria, (colour, shape, or number of items on the card,) using only the feedback of 'right' or 'wrong' from the administrator. Based on the pattern of examiner's responses, the individual must deduce the criterion on which to categorize the cards. After a sequence of ten consecutive correct categorizations, the examiner shifts the criterion without warning, and the individual must deduce the new sorting rule. The test continues until the participant has completed 6 categories correctly or until 128 cards are all used. The task yields a number of measures. In the current study, the two performance measures used were the average number of errors and the average number of perseverative errors per sorting category. Perseveration errors occur when the individual continues to sort according to the old criterion when this is no longer valid. Each card so placed counts as an error. The number or trials per category is equal to the number or cards placed before that category is successfully completed. The WCST scores were compared to each individuals' transitive inference performance in order to evaluate if differences in transitive inference performance can be explained by degree of executive functioning.

The Logical Memory I and II subtests of the Wechsler Memory Scale, 3rd Edition (WMS-III, Wechler, 1997), are measures of immediate and delayed recall of a short story respectively, which tap into both short- and long-term verbal episodic memory. The subject is read a short story and asked to repeat it as accurately as possible immediately and then again after a 35 minute delay. These subtests yield raw scores from 0-25, wherein a high score indicates a greater number of facts related to the story remembered. There is also a recognition task, which involves asking the participant predetermined probing questions requiring true or false answers, yielding a raw score from 0-15, wherein a high score indicates better memory for the story.

Verbal Fluency using tests of phonological and semantic fluency (Controlled Oral Word Association-FAS) is another task which taps into frontal lobe executive functions (Miceli, Caltagirone, Gainotti, Masullo & Silveri, 1981; Pachana et al., 1996, Both in Spreen & Strauss, 1998). For phonological fluency, the participant is asked to verbally produce as many words as possible beginning with a given letter (F, A, and S) in a 1minute time interval. For the semantic fluency, the participant is asked to produce as many animal names as possible within a 1minute interval. Each of these tests yield a raw score based on total frequency, wherein a high score indicates greater fluency. Duplicate words and plural words formed by adding the letter "s" were excluded.

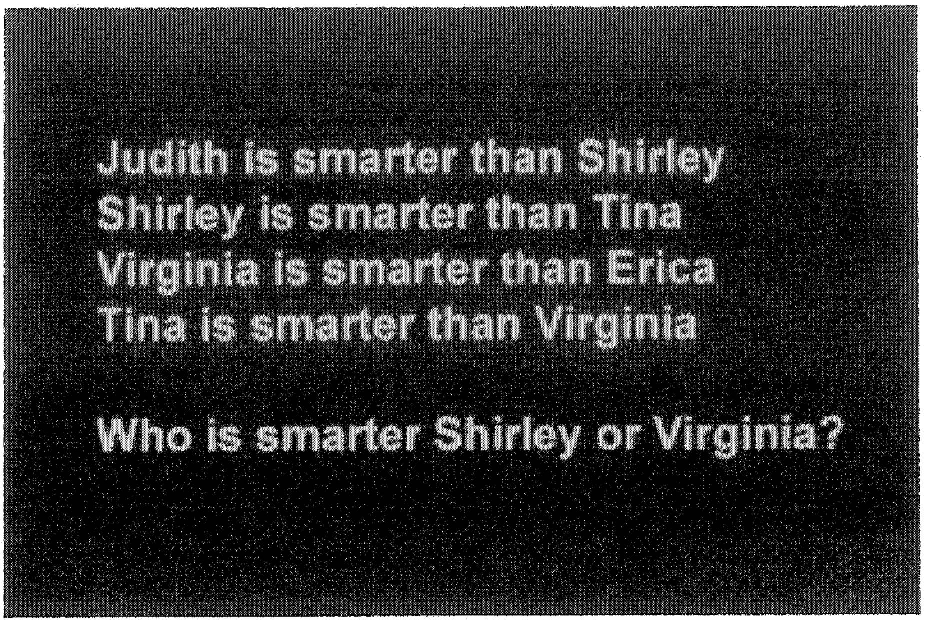
The Cognitive Estimation Test (Levinoff et al., 2004) is a task which requires subjects to estimate answers to questions for which there is no one correct answer, (e.g. *How many miles an hour does an average race horse run?*). This test is thought to tap into abstract reasoning and executive functioning and would yield a dependent variable consisting of a raw value from 0-21, wherein a high score indicates poorer performance as the score is calculated based on number of standard deviations from the normative answer.

Procedure

All participants were tested individually in a laboratory in the Department of Neurology, Jewish General Hospital, or at the Department of Psychology at the Loyola campus of Concordia University. The paradigm was administered by one of two examiners, the author or a paid summer research assistant, both trained by a neuropsychologist to administer the tests in a non-biased, standardized manner. All participants received identical treatment throughout the experiment, including the order of administration of the neuropsychological test battery. The entire cognitive testing session including transitive inference and neuropsychological battery last between 1½ to 2 hours. Participants were allowed short breaks (approximately 2-4 minutes) during the task to relieve fatigue when necessary.

Upon arrival, participants were instructed that they would be asked to answer questions, and complete tasks, such as defining words, copying symbols, and solving problems. They were told that some questions would be easy, whereas others would be more difficult, and they were encouraged to try their best. Prior to the neuropsychological evaluation, subjects completed the TI task. It was assured that all participants were comfortable operating the relevant keys on the number pad of the computer keyboard by requiring them to complete a brief fingering exercise using the relevant keys on the number pad of the keyboard. Participants were then presented with the TI stimuli on the screen. All visual stimuli were presented in an easily legible font size, orange on a black background (see Figure 1). Premise sentences were presented one at a time for a 5-second duration, after which the next sentence appeared underneath it. Previous research and pilot testing for this study has shown that this is a comfortable and adequate reading rate for both young and older age groups. Sentences accumulated on the screen until the presentation of the transitive inference question (e.g. *Who is taller Sally or June?*) with the appropriate key label situated under each name. In the "premises present" condition, the TI question appeared as the last stimulus frame on the screen. In the "premises absent" condition, the premise sentences were removed and the TI question appeared immediately. Participants read the premise sentences silently and responded by pressing one of two buttons in response to a forced choice question with two alternatives. The participants' key press response cued the immediate presentation of the next problem. Participants were allotted a maximum response time of 50 seconds, after which the next problem was automatically cued. Participants were given a 1-minute rest between conditions. For each of the four conditions, the participants received 2 practice problems of three premise terms each. Participants were encouraged to be as accurate as possible on all transitive inference tasks, were instructed that accuracy was more important than speed, and were asked not to guess.

Since it has been found (Light, Zelinski & Moore, 1982) that complete instructions about inference requirement do not influence performance on the transitive inference task, participants were instructed that the inference tasks would require them to make inferences about items not explicitly presented together. Participants were always informed of the type of trials to follow prior to each new condition block.



Judith is smarter than Shirley
Shirley is smarter than Tina
Virginia is smarter than Erica
Tina is smarter than Virginia

Who is smarter Shirley or Virginia?

Figure 1. Stimuli Sample for premises present five terms.

The order of test administration was the TI paradigm, followed by the cognitive tests: the MMSE, Vocabulary, Logical Memory I, Matrix Reasoning, Digit Symbol Coding, Letter Number Sequencing, Logical Memory II, Similarities, CET, WCST, and Verbal Fluency. The tests were not counterbalanced in order to control for interference between tests, as well as to help establish rapport.

Results

Study 1 A total of 15 older and 16 younger adults participated in this study. Data were excluded for one younger and four of the older adults because they did not meet the TI performance criterion (described below). The remaining participants included 11 older adults (2 males, 9 females) and 15 younger adults (4 males, 11 females).

Chi-square analyses were conducted using Statistica Statistical Software Package version 6.0 (Stats Soft Inc.). T-tests, repeated measures analyses of variance (ANOVA), for TI data were conducted using SPSS (Statistical Package for the Social Sciences, version 11.0). Corrections for any violations of assumptions of equal variance or independence, caused by the use of repeated measures design, and homogeneity of variance were made using Greehouse-Geisser when appropriate. In the case of significant interactions, Tukey a post-hoc tests were conducted where appropriate. The alpha to determine statistical significance for all chi-squares, t-tests, ANOVAs, and MANOVAs was set at the 0.05 level.

For TI data, both accuracy and reaction time analyses were conducted separately. As a preliminary check to determine that the older adults and the young adults group did not differ on several potentially confounding variables, two sample t-tests, were conducted comparing these two groups on Mini-Mental Status, education, and the Vocabulary subtest of the WAIS-III as a representative measure associated with intelligence and educational attainment (see Table 1).

As expected, the groups differed in age, t (24) = 17.6, $p < .001$. The two age groups did not differ on MMSE scores t (24) = -1.9, *ns*. All subjects had a MMSE score of at least 26, which was in normal limits on this test. Similarly, the groups did not differ

Table 1

Demographic Information For Younger and Older Groups for Study 1 & 2.

Group	Sex	Age		Education		Vocabulary		MMSE	
Study 1		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Younger (*n* =15)	4 Males 11 Females	26	5.0	17.2	2.9	52.8	6.8	29.4	0.7
Older (*n* = 11)	2 Males 9 Females	73	7.4	13.9	3.3	54.1	7.6	28	1.3
Study 2									
Younger (*n* =23)	7 Males 16 Females	24	4.5	16.1	12.3	53.1	6.6	29.4	0.7
Older (*n* = 21)	8 Males 13 Females	73	7.4	13.9	3.3	54.1	7.6	28	1.3

Note. MMSE is Mini-Mental Score.

in educational attainment, *t* (24) = -2.0, *ns*, or in mean Vocabulary scores, *t* (24) = .06, *ns*. Although there were more female than male participants in both phases of this study, the relative proportion of men and women in each age group did not differ, χ^2 (1, *N* = 26) = .26, *ns*.

TI The research design employed for the transitive inference test of Study 1 was a mixed 2 x 3 x 3 (subject group x number of premise terms x condition) factorial design, wherein the condition blocks were premise elements present, absent, and negation with premises present. The independent variables were age group, number of premise terms and condition and the dependent variables were accuracy (% correct) and reaction time (in seconds). Inclusion criterion for data analysis was based on a minimum performance level on the relatively easiest TI condition, (positively phrased, premises present) of at least 60% accuracy. Four older adults and one young adult failed to meet TI performance criterion, and for this reason their data were excluded from TI analyses. Summary results were tabulated using averages of group means for older adults versus young adults on SPSS software. A summary of mean overall accuracy (% correct) and reaction time (in seconds) for each condition are shown in Tables 2 and 3, and illustrated in Figures 2 and 3, respectively. The data are clearly exemplified in the figures but Tables are presented as well because the standard deviations for these data were too large to include in the figures.

TI accuracy. Averaged TI accuracy (% correct) for old and young as a function of condition block and number of premises are presented in Figure 2. Overall, there was a significant group difference in TI accuracy, whereby the percent correct across all levels of condition for young adults was higher than for older adults, *F* (1,24) = 62.3, *MSE* =

Table 2

Study 1. Summary of Means and Standard Deviations of TI Accuracy (in % correct) for Older and Younger Groups Across Block and Premise Number Conditions.

Group Premise Number	TI Accuracy 3-terms		4-terms		5-terms	
	M	*SD*	*M*	*SD*	*M*	*SD*
Younger						
Premises present	94.7	11.8	96.0	8.3	84.0	20.3
Premises absent	76.0	8.3	72.0	10.1	64.0	20.3
Negatively phrased	86.7	18.0	69.3	24.9	81.3	15.8
Older						
Premises present	85.5	12.9	76.4	21.6	65.5	15.7
Premises absent	47.3	13.5	65.5	15.7	52.7	13.5
Negatively phrased	54.6	23.8	54.6	23.8	45.5	20.2

Table 3

Study 1. Summary of Means and Standard Deviations of TI Reaction Time (in seconds) for Older and Younger Groups Across Block and Premise Number Conditions.

Group	TI Reaction Time					
Premise Number	3-terms		4-terms		5-terms	
	M	*SD*	*M*	*SD*	*M*	*SD*
Younger						
Premises present	10.5	4.7	15.6	9.1	19.0	8.8
Premises absent	3.7	1.2	4.5	3.7	4.4	1.9
Negatively phrased	10.1	5.0	16.8	8.5	19.0	9.8
Older						
Premises present	11.1	7.8	13.7	11.0	16.1	7.3
Premises absent	3.8	1.3	3.4	0.7	3.6	1.1
Negatively phrased	15.2	8.7	18.0	13.8	17.5	11.8

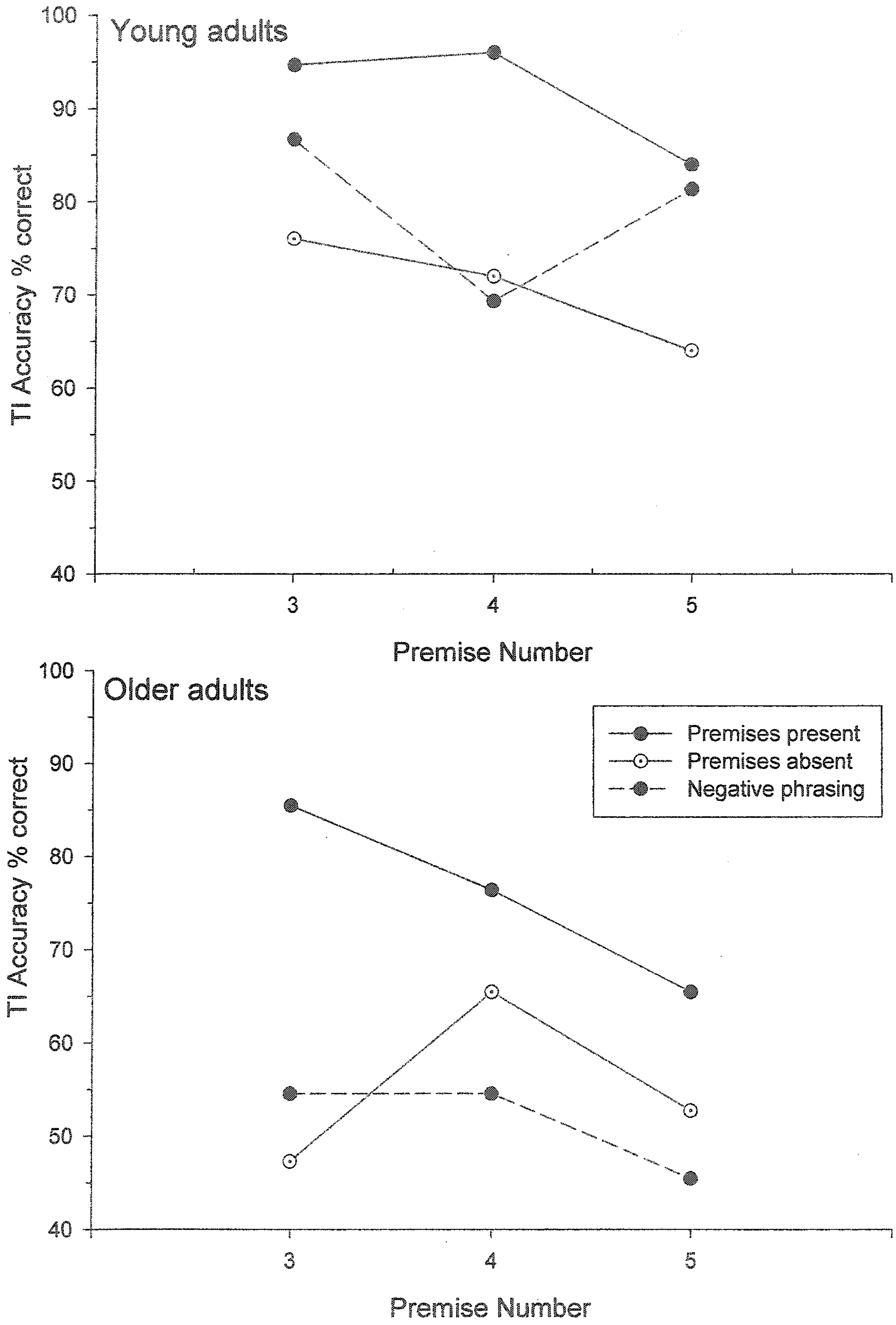


Figure 2. Study 1 Transitive Inference accuracy across condition manipulations in the young and older adults.

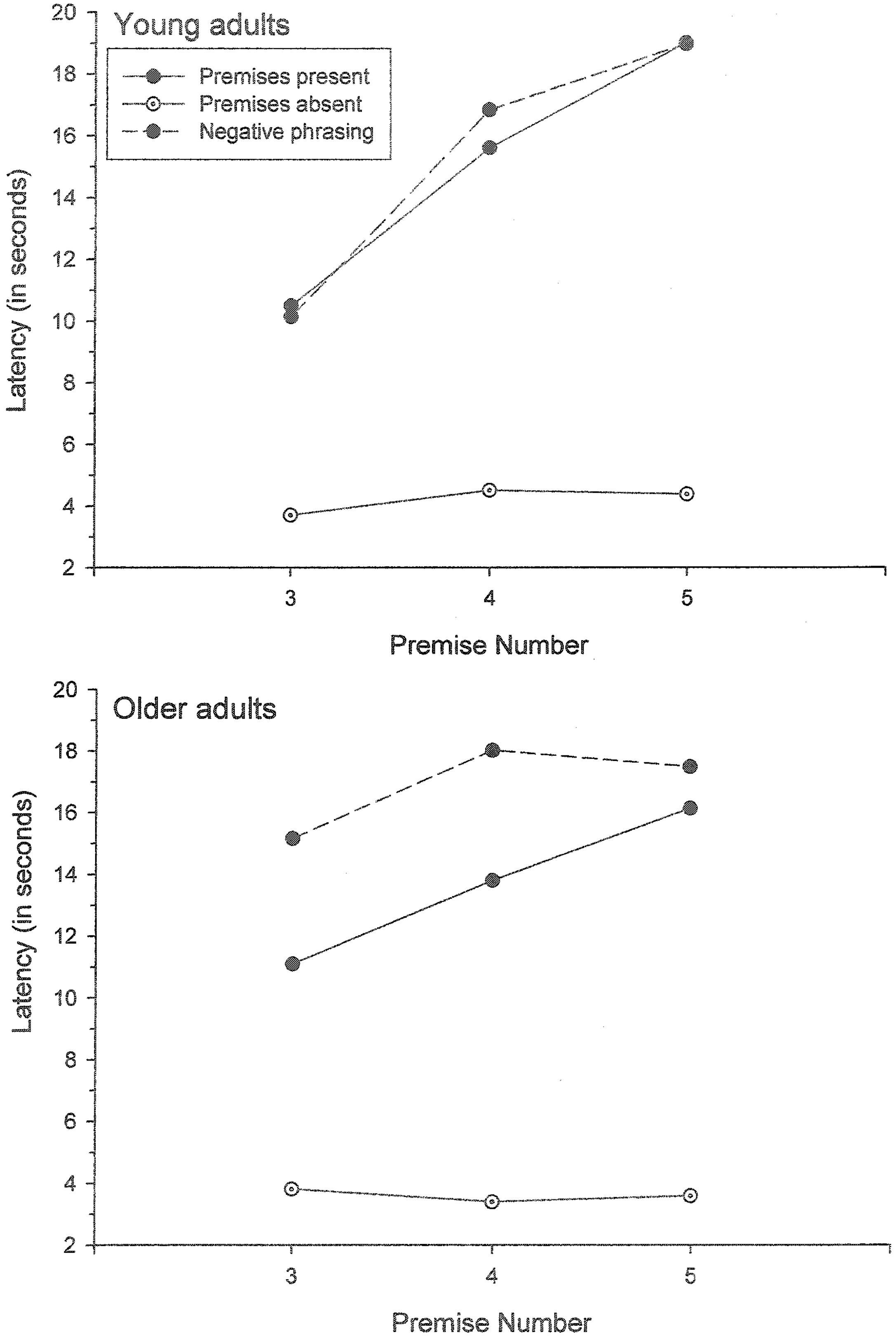


Figure 3. Study 1 Transitive Inference reaction time across condition manipulations in the young and older adults.

353.6, $p < .001$). A significant main effect of condition block was observed, $F\ (2,48) = 39.4$, $MSE = 295.2$, $p < .001$) in which both age groups performed better when the premises remained present relative to the other two conditions, as confirmed by Tukey a post-hoc tests. There was also a significant effect of premise number, $F\ (2,48) = 6.9$, $MSE = 240.0$, $p < .01$. Tukey a post-hoc tests revealed that the performance of both groups declined with the use of five-term problems as compared to three-term problems, $p <.05$, whereas overall performance for three-term versus four-term problems did not differ significantly.

Significant interactions were also observed. Although analysis of group x premise number on TI accuracy yielded no significant interaction, $F\ (2,48) = 2.3$, *ns*, there was a significant interaction of condition x age group, $F\ (2,48) = 3.6$, $MSE = 295.2$, $p < .05$. Tukey a post-hoc comparisons confirmed the main effects, namely that young adults scored significantly higher than older adults in all three conditions, and for both groups, higher scores were observed in the condition with premises present compared to the other two conditions, $p < .05$. Older adults' performance during the premises present condition was significantly better than their performance during the other two conditions but lower than younger adults' performance during premises present. For both age groups, performance dropped in the conditions with premises absent and negative phrasing, and these manipulations did not yield accuracy scores that differed significantly from one another. However, post-hoc tests revealed that performance during the premises absent and negative phrasing conditions between the two age groups were not only significantly different but had the opposite pattern: younger adults performed better in the negative phrasing condition relative to the premises absent condition, whereas older adults did better with the premises absent condition relative to the negative phrasing condition. Although there was a trend towards poorer performance with negative phrasing in the younger group, relative to their performance with premises present, it did not reach significance. The three way analysis of group x condition x premise number on TI accuracy did not yield a significant interaction, *F* (4,96) = 2.0, *MSE* = 401.3, *ns*. The three way analysis of group x condition x premise number on TI accuracy did not yield a significant interaction, *F* (4,96) = 2.0, *MSE* = 401.3, *ns*. (See Appendix B for source tables of these analyses).

TI reaction time. Figure 3 shows average reaction time for young and older participants as a function of condition block and number of premises. Due to the nature of the repeated measures analysis, data missing in certain cells caused the elimination of 2 participants' data from the reaction time analyses. Thus, reaction time analyses included 10 older adults and 14 young adults. Because reaction time data were recorded only if participants made accurate TI responses, some data were based on only 1-2 trials, thereby limiting the reliability of the results. Nevertheless the results are presented because they show a potential pattern or trend which may help explain which cognitive processes participants might be engaging in during TI.

Although there was no significant main effect of age, *F* (1,22) = .003, *MSE* = 239.6, *ns*, there was a significant main effect of premise number, *F* (2,44) = 21.1, *MSE* = 15.7, $p < .001$. Post-hoc tests revealed that reaction times were faster overall with three-terms compared to four or five-terms, while four- and five-term responding did not differ. There was also a significant main effect of condition block, *F* (2,44) = 35.8, *MSE* = 94.2, $p < .001$. Post hoc tests revealed that reaction times were faster during the condition with premises absent compared to the other two conditions, while responding during premises present and negative phrasing did not differ.

Significant interactions were observed. A significant interaction was found between age and premise number, F (2,44) = 3.9, MSE = 15.7, $p < .05$ (see Figure 4). Tukey a post-hoc tests indicated that within each level of premise number, the young and older adults' performance was not significantly different. Among the varying numbers of premises, older adults were faster at solving three-term problems than younger adults solving five-term problems and vice versa; an effect which explains the interaction but is not meaningful. Additionally, among the young adults, reaction times with three-term TI problems were faster than their own reaction times with four and five-terms. A significant interaction was also found between condition and premise number, F (4,88) = 5.7, MSE = 1209.0, $p \leq .001$, (see Figure 5). Post hoc tests revealed that within the conditions with premises present and negatively phrased premises, reaction times with three-terms were faster than with four or five-terms. Within the condition with premises absent there were no differences in reaction times among the number of premises; these reaction times were all extremely fast and at floor levels. No significant interactions were found for age and condition block, F (2,44) = 0.5, MSE = 94.2, *ns*, nor for the three-way interaction of age, condition block, and premise number, F (4,88) = 0.8, MSE = 1209.0, *ns*. (See Appendix B for source tables of these analyses).

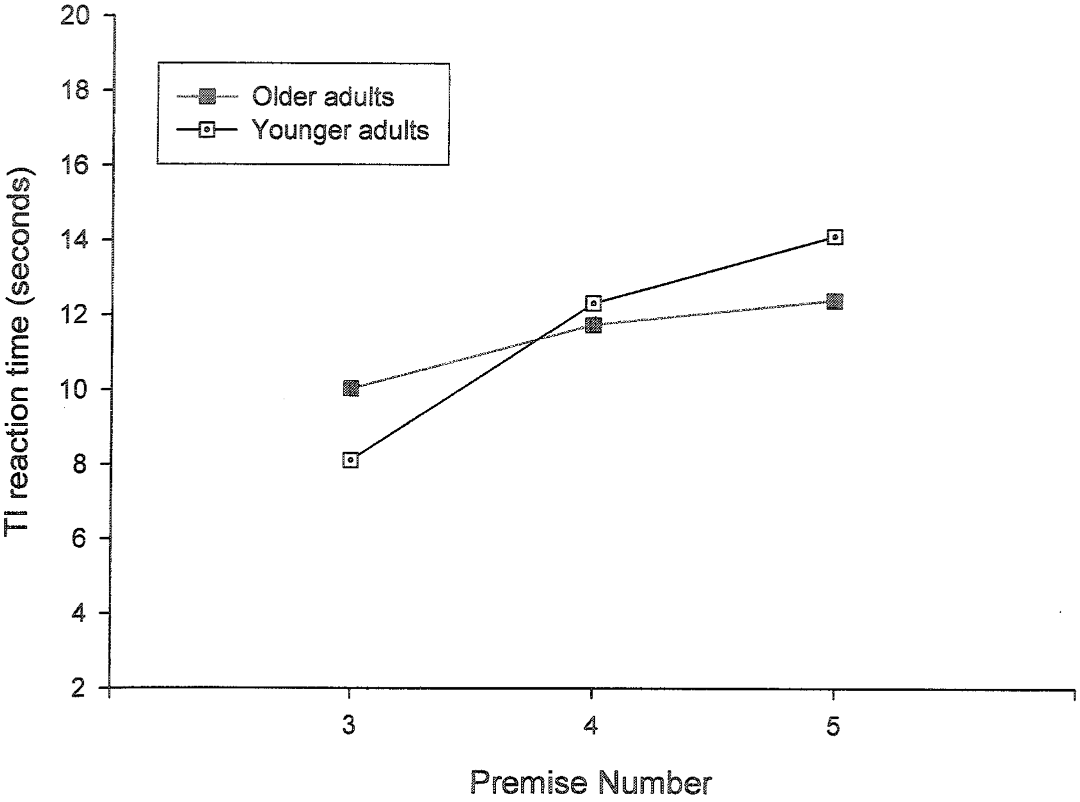


Figure 4. Study 1. Transitive Inference reaction time across premise size in the young and older adults.

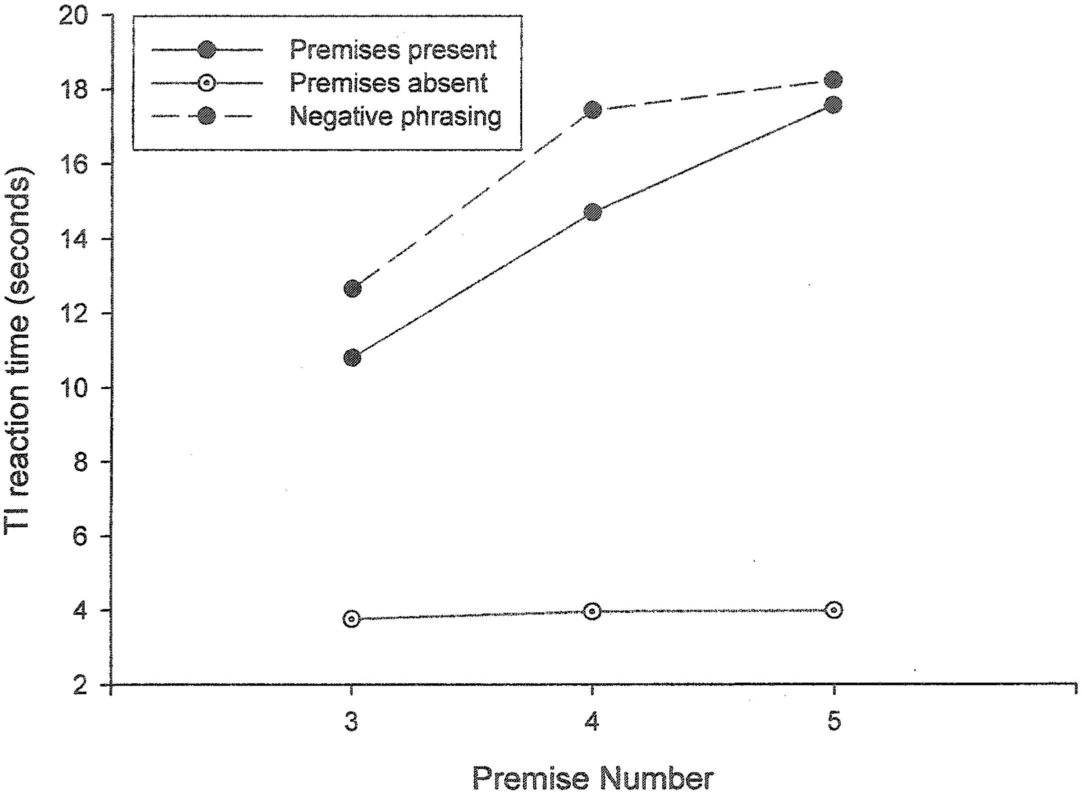


Figure 5. Study 1 Transitive Inference reaction time for condition manipulations across premise size.

Discussion

This first study demonstrated a number of findings consistent with several of the predictions. First, younger adults had greater accuracy overall compared to older adults. Additionally, in general, the condition with the premises present was easiest for both young and older adults, and performance decreased in both groups as the number of premises increased. Certainly the premises being absent, relative to present, hampered both groups' performance. Moreover, the older adults' performance at every single level of condition manipulation, when the premises were present, absent, or when they were negatively phrased was reduced relative to the young adults' performance in the same conditions. Also as expected, it appeared that generally the most challenging manipulations were premises absent and negative phrasing. However, these two manipulations were not consistently or substantially different from one another across the various levels of premise number. This suggests that premise number may be acting as an independent working memory manipulation from presence or phrasing. Furthermore, an apparent age difference existed in the presence and phrasing conditions such that the premises absent and negative phrasing were harder for the older participants to process, whereas in the younger group the negative phrasing condition was only somewhat more difficult than premises present and therefore, the premises absent alone posed the greatest challenge.

As expected, the premise number manipulation yielded a downward linear trend in accuracy performance for both young and older participants but surprisingly only in the condition with premises present. In premises absent, older individuals showed an inverse curvilinear relationship, whereas younger individuals showed a more predictable linear decline. Conversely, in the condition with premises negatively phrased, younger adults showed a curvilinear relationship whereas older adults showed a linear decline. The accuracy results suggest that the condition manipulations may be qualitatively different in that participants may be engaging in unknown different strategies across the various tasks.

Some of the reaction time data were consistent with the literature. For example, processing times for fewer number of premises was found to be faster (Waltz et al., 1999), as well as in the present study, where responding with three terms was generally faster than with four or five terms. As predicted, the manipulation of premise number did lead to a general linear slowing of reaction time; a pattern demonstrated in both age groups but more so in the younger group. More specifically, the younger participants responded more quickly with the fewest number of premises than with greater number of premises, in every single condition. For each level of premise number, older adults generally processed premises only slightly more slowly than younger adults and therefore, the differences were too small to reach significance. Also as predicted, negative phrasing did slow processing time somewhat relative to premises absent relative to premises present but this result failed to reach significance. One unexpected and interesting finding was that having premises absent from the screen seemed to force participants among both age groups to process the premises faster than the other two conditions for which premises were present. This faster responding during premises absent taken in the context of lower accuracy, demonstrates that both age groups necessarily did worse under this circumstance of having to process premises more quickly. Based on information collected during debriefing of participants, this may be due to stress, anxiety, or insufficient time to study and encode the premises before they disappeared. Both age groups demonstrated a slowing of correct responding with increasing premise number in the conditions with premises present and negative phrasing. As mentioned, the condition with premises absent resulted in a floor effect in both age groups (See Figure 3).

Some results were difficult to interpret. For example, in contrast to the reaction time data, it is not clear why a consistent downward effect on accuracy with the manipulation of premise number was not observed. And due to the low number of participants in each group in Study 1, the variance for different measures was high. It was therefore not advisable to apply the neuropsychological data to any correlational analyses, as those results would not likely be reliable or informative. Study 1 also did not employ a fully-balanced design. Study 2 was undertaken to address this concern. A fully-balanced design was used with younger and older participants in which they were exposed to the same numbers of premises (three, four, or five), phrased either positively or negatively, and in which the premises either remained on the screen or were absent. This resulted in a balanced 2 (age) x 3 (premise number) x 2 (phrasing) x 2 (presence) between-within design.

Method

Study 2

Participants

Young Adults. Twenty-four participants between the ages of 18 to 35 years were recruited using the same strategies and inclusion criteria as in Study 1.

Older Adults. Twenty-four older adults (60+ years) were recruited using the same strategies and inclusion criteria as in Study 1.

Stimuli

TI task. The TI task was devised in the same way as in Study 1.

Number of Terms and Conditions. Working memory load for a set of 60 transitive inference problems was manipulated using three task conditions: three, four, and five premises, positive or negative premise phrasing, and premise presence (present or absent) during the TI question. The presence and premise phrasing conditions were blocked and fully crossed with each other yielding four TI task condition blocks (positively phrased terms elements present, positively phrased terms elements absent, and negatively phrased elements present, and negatively phrased elements absent), with premise number nested within each block (either three, four, or five items). These blocks were presented in four pseudo-randomized Latin square blocked design of 15 problems each, with 5 trials per number of premises. The Latin square was modified such that no participant received either premises absent positively phrased or premises absent negatively phrased first, as these were hypothesized to be the most difficult conditions. For each condition, there were 2 practice trials per block. Deductive reasoning was measured by examining the performance of subjects on a set of 60 transitive inference problems. Both accuracy (defined as % correct) and reaction time (in seconds) were measured automatically by the Inquisit computer program.

Neuropsychological battery. The same neuropsychological battery was used as in Study 1.

Procedure

This study was conducted in the same manner as Study 1.

Results

Study 2 A total of 24 older adults and 24 young adults participated in this study. Three older adults did not meet the TI performance criterion and their data were excluded. One additional young adult's data were excluded on the basis of having averaged reaction times greater than three standard deviations above the mean for their age group. These four participants' data were excluded from both the TI analyses and subsequent correlational analyses with neuropsychological data. The remaining participants included 21 older adults (13 females, 8 males) and 23 young adults (16 females, 7 males).

Aside from modifications in design to a 2 x 3 x 2 x 2, identical methods of analyses, statistical programs, corrections for any violations of assumptions, Tukey a post-hoc tests were applied were appropriate as in Study 1. Additionally, post-hoc tests using simple effects ANOVAs, with Bonferroni adjustments for multiple comparisons, multivariate analyses of variance (MANOVA) and multiple regressions were conducted using SPSS (version 11.0). The alpha to determine statistical significance for the all analyses was set at the 0.05 level. Because the directions of the relationships between overall TI performance and neuropsychological measures were predicted, one-tailed correlations were used with alpha to determine significance set at the 0.05 level. However, in all subsequent and secondary analyses, two-tailed tests were conducted, with alpha also set at 0.05, as some of the directions for correlations between various conditions and neuropsychological measures were uncertain, and as a more conservative approach to help control for experiment wise Type I error.

For TI data, both accuracy and reaction time analyses were conducted separately. Correlational analyses were conducted between TI accuracy and neuropsychological data, which were then followed up by a multiple regression for the significantly correlated neuropsychological measures and the TI performance. Reaction time measures were not subjected to correlational analyses because data were in some cases obtained from 1-2 accurate trials (as in Study 1).

As a preliminary check to determine that the older and younger participants did not differ on several potentially confounding variables, two sample t-tests, were conducted comparing these two groups on Mini-Mental Status, age, education, and the Vocabulary subtest of the WAIS-III as a representative measure associated with intelligence and educational attainment (see Table 1). As expected, the groups differed in age t (42) = 27.1, $p < .001$. All subjects had a MMSE score of at least 26, with the exception of one older adult who had a MMSE score of 25 with otherwise acceptable neuropsychology performance being well within normal limits. The MMSE scores for the older adults was significantly lower than the mean MMSE scores of the younger adults, t (42) = -4.0, $p < .001$, but this difference of 1.4 points is considered small and not likely meaningful. The mean number of years education for the older adults was significantly lower than the younger adults, t (42) = -2.6, $p < .05$, but this difference of 2 years is relatively small. However it is noteworthy that the older adults were very well educated for their age cohort. The two age groups did not differ in terms of vocabulary scores, t (42) = .41, *ns*. Although there were more female than male participants in both phases of this study, chi-squares were conducted for sex representation yielding no significant differences, χ^2 (1, N = 44) .29, *ns*, revealing that the proportion of sex representation within each age group was not significantly different. MANOVAs on relevant neuropsychological measures were conducted to evaluate whether older and younger adults differed on many of these measures (see Table 4). In order to verify that participants in Study 1 were not significantly different in terms of their cognitive abilities, a MANOVA was also conducted on neuropsychological measures of older adults versus younger adults (see Table 5). An additional MANOVA was conducted between the younger participant sample of Study 1 and 2, and in the older participant sample of Study 1 and 2, in order to verify that they had comparable neuropsychological data (see Appendix C). The results confirm that the older adults and younger adults differed on many neuropsychological measures in both studies in the following way; as expected differences were observed in Matrix Reasoning, Letter Number Sequencing, Incidental Learning, Digit Symbol Coding, Logical Memory-II, Logical Memory Retention, Semantic Fluency and WCST percent perseverative errors. Differences among the age groups were not found in Similarities, and CET or Phonological Fluency. Furthermore both participant pools in Study 1 and Study 2 are comparable in this regard as well.

TI As in Study 1, the dependant variables were accuracy (% correct) and reaction time for correct answers only (in seconds). As in Study 1, the inclusion criterion for data analysis was based on a minimum performance level on the relatively easiest TI condition, (positively phrased premises remaining present) of equal to or greater than 60% accuracy. Summary results were tabulated using averages of group means for older adults versus young adults on SPSS software. A summary of mean overall accuracy (% correct) and reaction time (in seconds) for each condition are shown in Tables 6 and 7, and illustrated in Figures 6 and 7, respectively.

Table 4

Study 2. Mean and (SD) of Neuropsychological Measures in the Older and Younger Groups.

	Younger	Older	*F*	Eta squared
Matrix Reasoning	20.09	14.14	21.20*	.335
	(3.94)	(4.62)		
Similarities	26.39	24.14	2.72	.061
	(3.12)	(5.68)		
Letter Number	15.17	10.24	20.61*	.329
	(3.68)	(3.52)		
Incidental Learning	23.91	14.05	45.20*	.518
	(4.22)	(5.48)		
Digit Symbol	85.57	56.57	51.15*	.549
	(13.71)	(13.12)		
Logical Memory-II	16.70	12.57	14.42*	.256
	(3.91)	(3.22)		
LM Retention	97.41	88.24	4.46*	.096
	(11.49)	(17.01)		
CET	7.04	6.62	0.17	.004
	(3.57)	(3.28)		
Phonological Fluency	45.52	44.81	.044	.001
	(10.75)	(11.68)		
Semantic Fluency	22.48	18.00	13.25*	.240
	(3.99)	(4.17)		
WCST categories	5.91	5.76	1.09	.025
	(.417)	(.539)		
WCST percent perseverative errors	7.70	10.95	6.35*	.131
	(2.57)	(5.59)		

LM Retention- Logical Memory percent retention; CET- Cognitive Estimation Test; WCST- Wisconsin Card Sorting Test.
$* p < .05$.

Table 5

Study 1. Means and (SD) of Neuropsychological Measures in Older and Younger Groups.

	Younger	Older	*F*	Eta Squared
Matrix Reasoning	21.53	14.09	25.83*	.518
	(1.69)	(5.36)		
Similarities	27.20	24.18	2.85	.106
	(4.13)	(4.98)		
Letter Number	13.27	10.27	9.16*	.276
	(2.96)	(1.62)		
Incidental Learning	23.07	15.09	15.84*	.398
	(4.68)	(5.52)		
Digit Symbol	80.20	55.36	12.37*	.340
	(17.05)	(18.77)		
Logical Memory-II	15.13	13.36	1.01	.041
	(5.11)	(3.23)		
LM Retention	90.30	75.43	3.24	.119
	(17.15)	(25.07)		
CET	8.53	8.36	0.01	.000
	(3.68)	(5.45)		
Phonological Fluency	45.40	47.82	0.49	.020
	(8.95)	(8.37)		
Semantic Fluency	22.47	20.73	0.79	.032
	(5.84)	(3.26)		
WCST categories	6.00	5.36	1.90	.073
	(.000)	(1.80)		
WCST percent perseverative errors	7.20	16.18	3.77	.136
	(2.11)	(17.88)		

LM Retention- Logical Memory percent retention; CET- Cognitive Estimation Test; WCST- Wisconsin Card Sorting Test.
* $p < .05$.

Table 6

Study 2. Summary of Means and Standard Deviations of TI Accuracy (in % correct) for Older and Younger Groups Across Phrasing, Presence, and Premise Number Conditions.

Group Premise Number	TI Accuracy 3-terms *M*	 3-terms *SD*	 4-terms *M*	 4-terms *SD*	 5-terms *M*	 5-terms *SD*
Younger						
Premises present +	89.6	11.8	93.0	13.0	84.3	26.3
Premises present -	58.3	11.9	78.3	15.9	57.4	27.2
Premises absent +	86.7	23.8	66.1	22.9	77.4	20.3
Premises absent -	57.4	20.3	71.3	21.6	53.9	22.9
Older						
Premises present +	76.2	13.6	75.3	23.6	52.4	26.4
Premises present -	56.2	13.6	69.5	23.3	48.6	20.6
Premises absent +	68.6	19.6	62.9	23.1	50.5	20.6
Premises absent -	63.8	22.5	70.5	26.6	57.1	26.3

Note + is positive phrasing; - is negative phrasing.

Table 7

Study 2. Summary of Means and Standard Deviations of TI Reaction Time (in seconds) for Older and Younger Groups Across Phrasing, Presence, and Premise Number Conditions.

Group	TI Reaction Time					
Premise Number	3-terms		4-terms		5-terms	
	M	*SD*	*M*	*SD*	*M*	*SD*
Younger						
Premises present +	7.8	3.8	11.5	5.9	14.2	7.8
Premises present -	3.4	2.5	4.0	3.2	4.1	2.3
Premises absent +	9.8	8.4	12.5	7.1	16.2	8.8
Premises absent -	4.6	3.7	5.2	5.7	4.8	2.0
Older						
Premises present +	11.9	6.7	76.1	8.3	15.5	8.0
Premises present -	4.2	1.8	4.3	2.2	4.7	2.7
Premises absent +	14.8	6.9	17.8	9.4	16.2	8.0
Premises absent -	4.8	1.7	5.0	3.4	5.1	2.4

Note + is positive phrasing; - is negative phrasing.

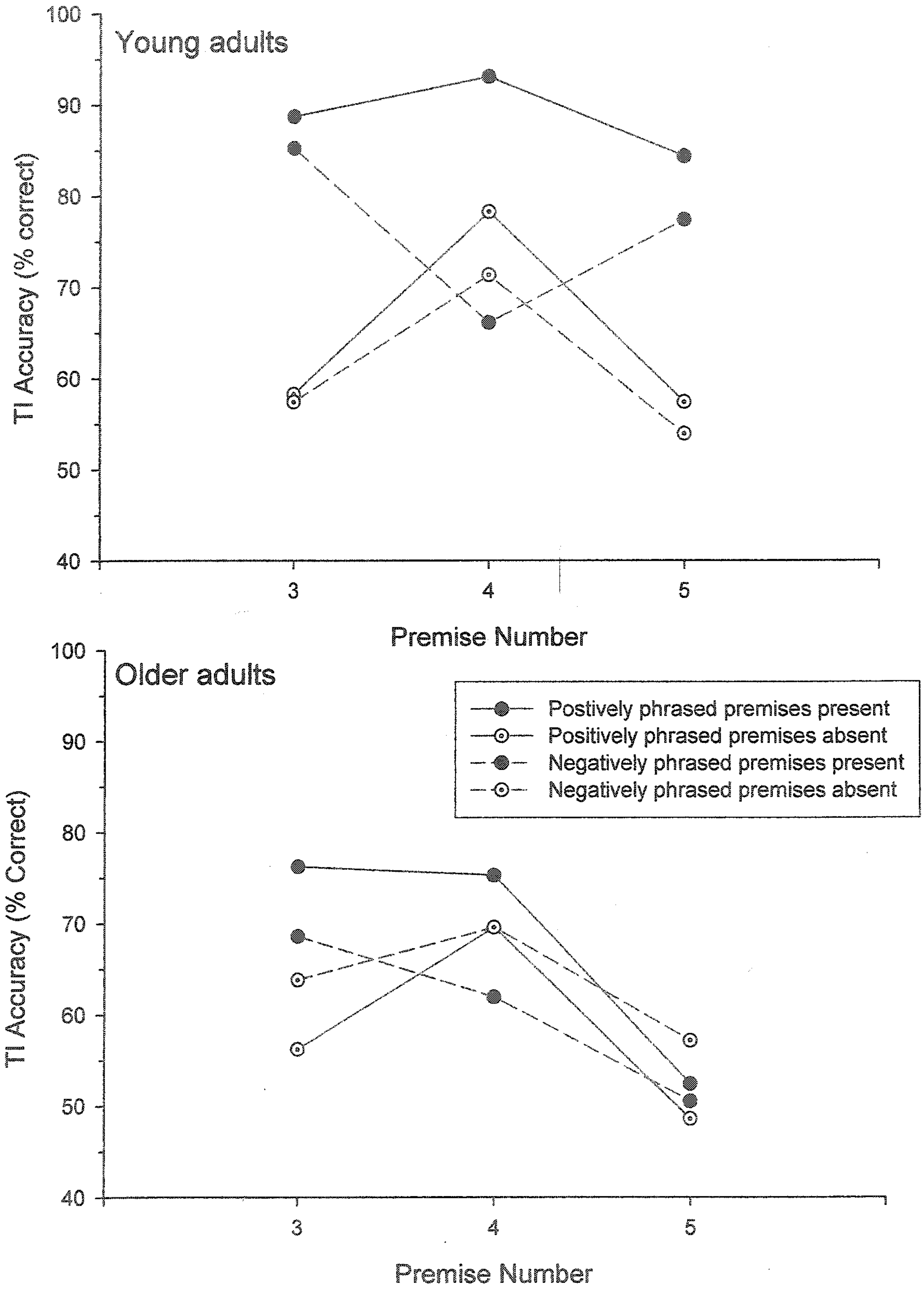


Figure 6. Overall Transitive Inference accuracy across condition manipulations in the young and older adults.

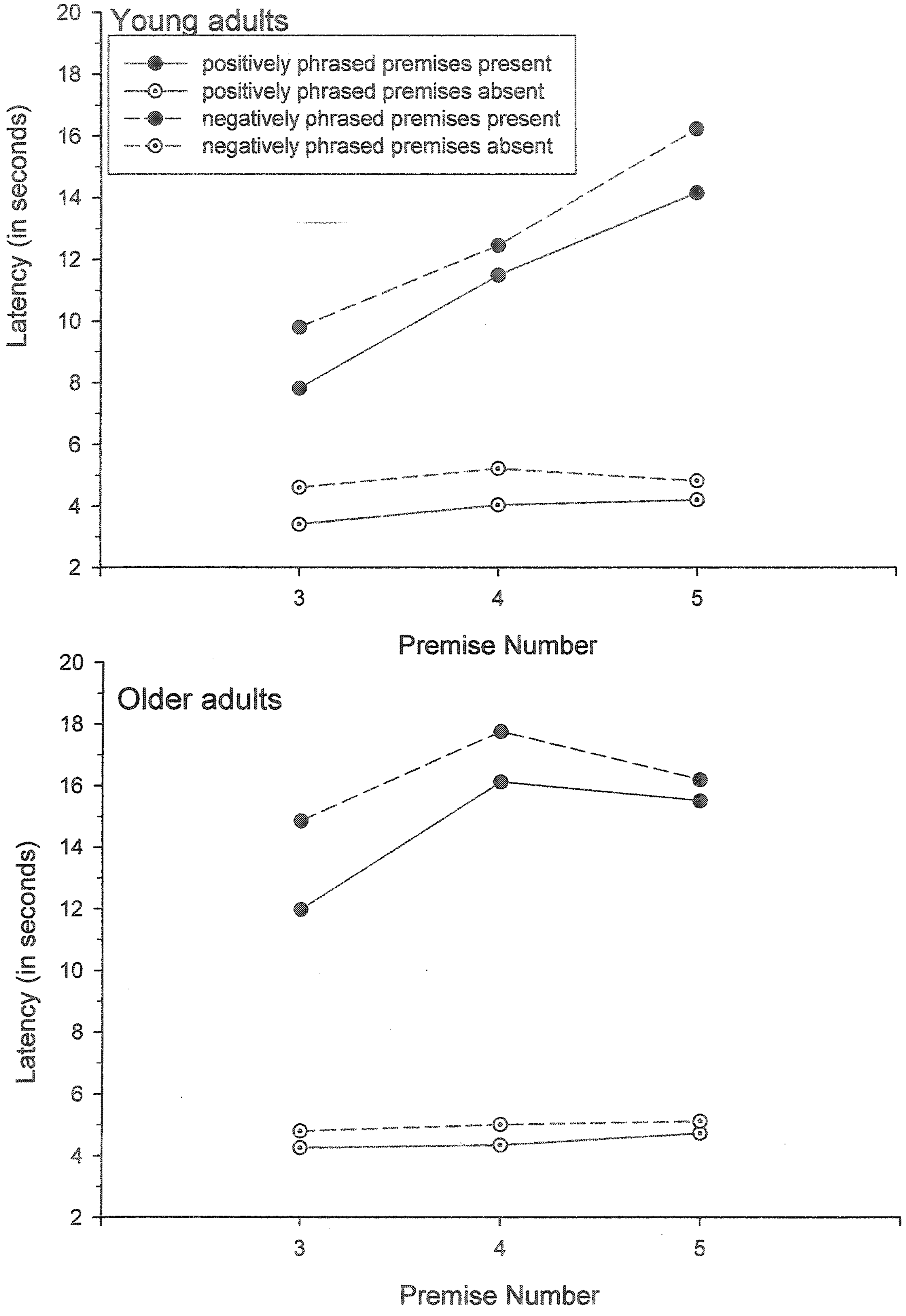


Figure 7. Study 2 Transitive Inference reaction time during condition manipulations in young and older adults.

TI Accuracy. Averaged TI accuracy (% correct) by age is presented in Figure 6 and Table 6. As in Study 1, a significant main effect was found for age, *F* (1,42) = 9.92, *MSE* = 1384.1, $p < .01$, in which young adults were significantly more accurate overall than the older adults. There was also a main effect of phrasing, *F* (1,42) = 4.6, *MSE* = 550.2, $p < .05$, in which performance was greater for positively-phrased compared to negatively-phrased premises. There was also a main effect of presence, *F* (1,42) = 29.1, *MSE* = 623.0, $p < .001$, indicating that both young and older adults were more accurate when premises were present compared to absent. Finally, the ANOVA detected a significant main effect of premise number, *F* (2,84) = 22.2, *MSE* = 389.8, $p < .001$. Post-hoc tests revealed that both groups' performance dropped when confronted with the greatest number of premise terms, as was observed in Study 1.

Significant interactions were observed for the age groups. There was a significant interaction of age and presence, *F* (1,42) = 14.9, *MSE* = 623.0, $p < .001$. Post-hoc tests revealed that young adults performed more accurately than older adults when premises were present, but were not significantly different when premises were absent. The older adults performed poorly across both manipulations of presence. There was also an interaction of age and premise number, *F* (2,84) = 3.2, *MSE* = 389.8, $p < .05$. Tukey a post-hoc tests indicated that the older adults performance with five premise terms was significantly lower than their performance with three or four terms, all of which were significantly lower than the younger groups' performance at every level of premise number. The interaction of age and phrasing was not significant *F* (1,42) = 3.1, *ns*.

Significant interactions were observed for phrasing, presence, and premise number. There was a significant interaction of phrasing and presence, *F* (1,42) = 11.1,

$MSE = 340.8, p < .01$. Post-hoc tests using simple effects in the older group revealed that the manipulation of presence versus absence collapsed across premise size yielded a difference in performance only within positive phrasing. The other manipulations of phrasing by presence did not differ significantly among the older group, suggesting that when premise size is not considered, older adults' performance was most affected by premises absent (positively phrased) compared to premises present (positively phrased). In contrast, the young adults showed poorer performance with premises present which were negatively phrased relative to positively phrased, and poorer performance with premises absent relative to present, regardless of phrasing. This confirms that premises absent positively phrased reduced all participants' accuracy scores. All manipulations of presence versus absence regardless of phrasing affected performance in the young adults. Negatively phrased sentence structure did affect younger adults but only reached significance during premises present; inspection of the means reveals that during premises absent, younger adult's performance was almost at floor and this may explain why negative phrasing did not further affect performance. There was also an interaction of phrasing and premise number, $F\ (2,84) = 4.8, MSE = 397.0, p < .05$, (see Figure 8). Post-hoc tests revealed that performance during positively phrased sentences declined with the use of five terms relative to three and four terms. With the use of four terms, performance was also somewhat better when phrasing was positive than negative, although this effect did not reach significance. Finally, there was a significant interaction of presence and premise number, $F\ (2,84) = 14.0, MSE = 311.0, p < .001$. Post-hoc tests revealed that performance declined in the premise present condition with the presentation

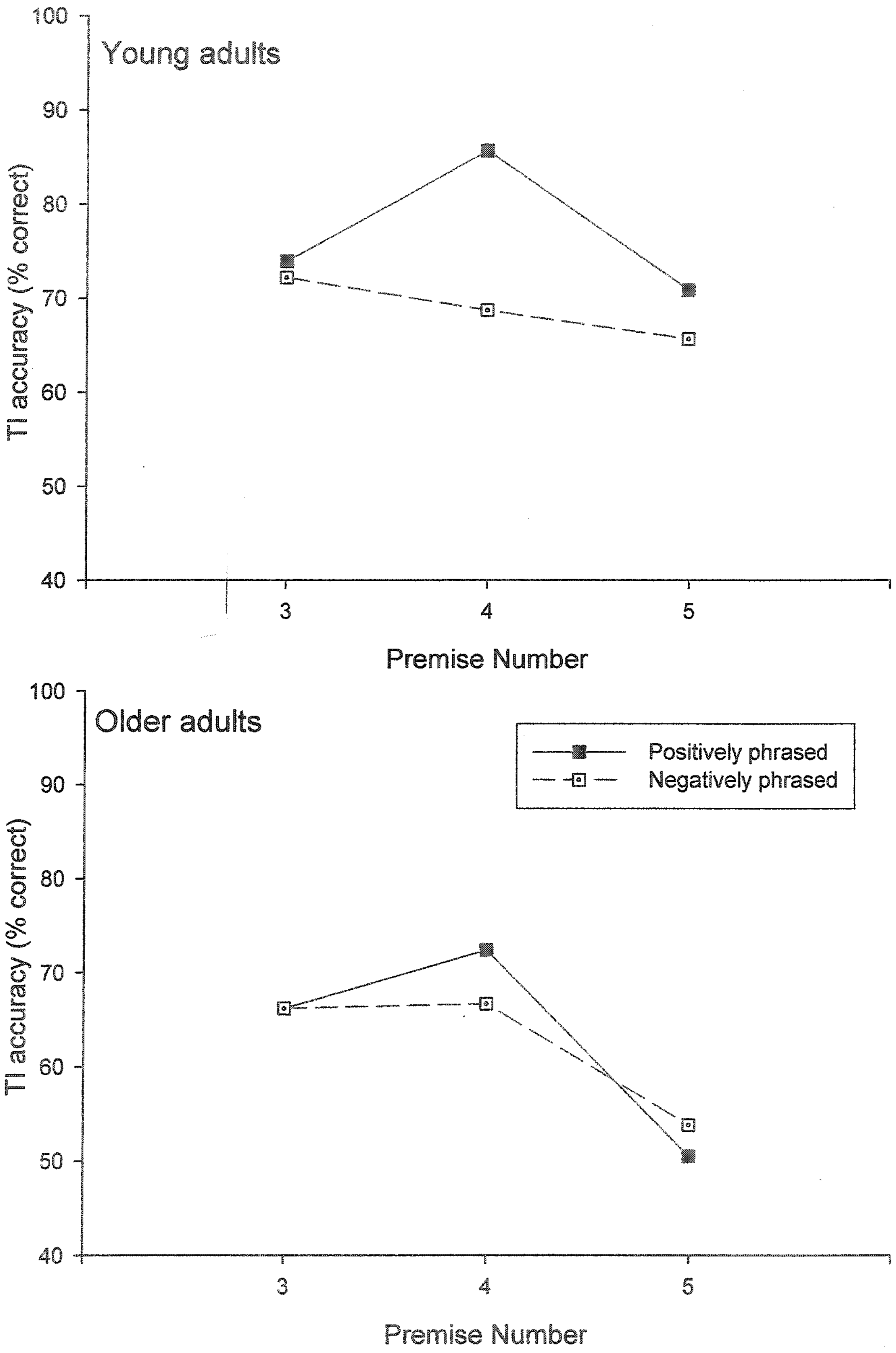


Figure 8. Study 2 Transitive Inference accuracy for premise phrasing across premise size in young and older adults

of five premise terms relative to three or four terms. With three terms, all participants had greater accuracy with premises present relative to absent. Curiously, with premises absent, participants' accuracy was better with four terms versus three or five. Relative to premises present, performance was lower with premises absent during the presentation of three and five terms.

Several three-way interactions were found. There was a significant interaction of age x presence x premise number, *F* (2,84) = 4.1, *MSE* = 279.2, *p* < .05, (see Figure 9). Post-hoc tests using simple effects revealed that within the older group, there was no difference in accuracy performance within presence or absence of premises. Older adults didn't differ in performance with premise number with the exception of premise size three, which during premises absent was unexpectedly low. Further, while the effect for premises present showed incremental decreases, during premises absent, the unusually poor performance at premise size three was unexpected. In contrast, the younger group's accuracy dropped with premises absent relative to present at premise sizes three and five but not for premise size four. Between the two groups, the younger groups' performance was better than the older group's in conditions with premises present, but the younger group dropped to a similar performance level in conditions with premises absent. During premises present, the older participants were less accurate than the younger adults at each respective level of premise size. Visual inspection of Figure 6, with respect to negative phrasing with premises present, suggests an opposite effect in the two age groups: the older adults' performance followed a downward linear trend across the increasing premise size, whereas the younger group's performance declined only when given four terms. The ANOVA did not detect a significant age x phrasing x presence interaction, *F*

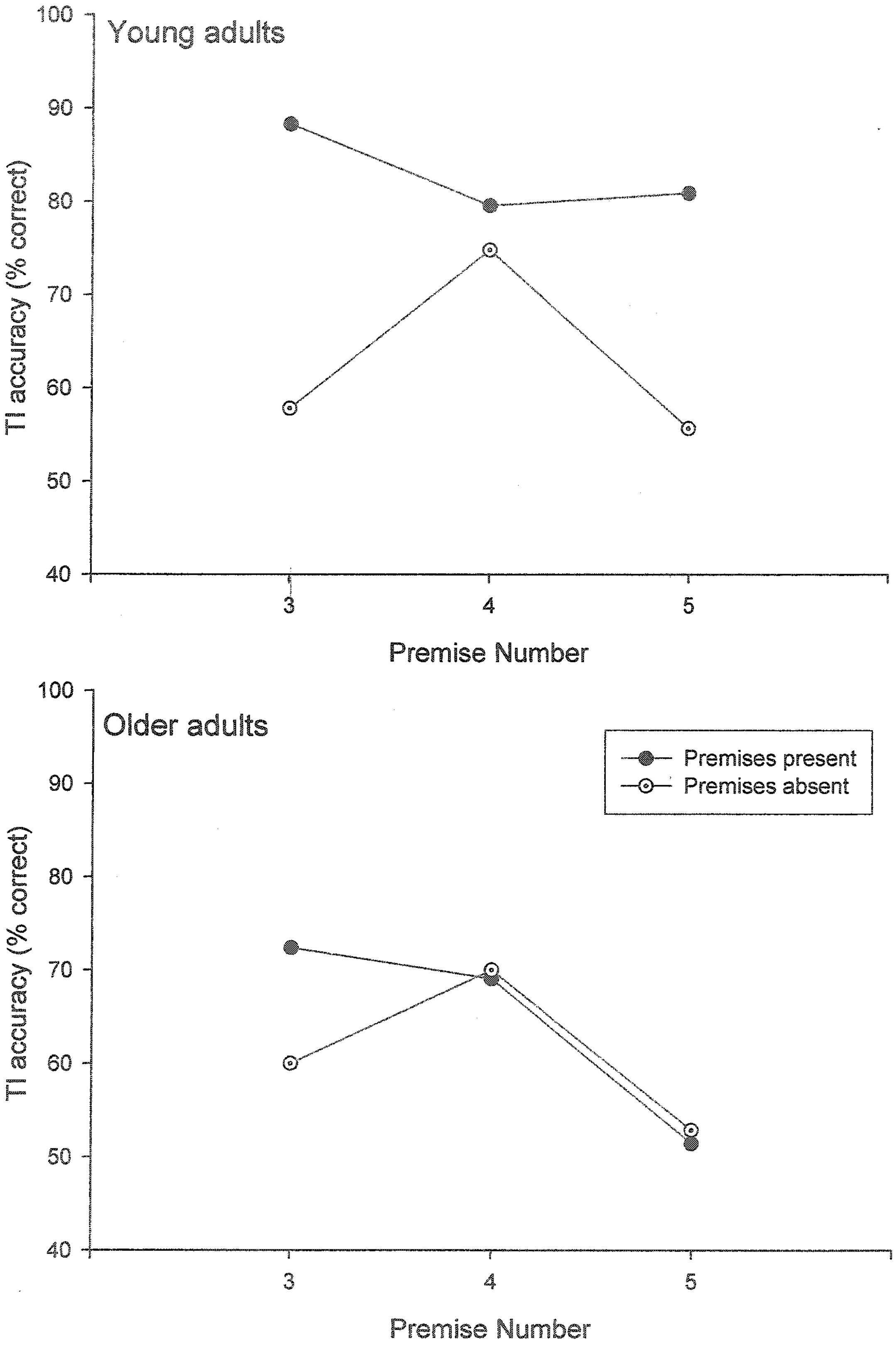


Figure 9. Study 2 Transitive Inference accuracy presence of premises across premise size in young and older adults.

(2,84) = 0.5, *MSE* = 340.8, *ns*, nor did it detect a significant four-way interaction of age x phrasing x presence x premise number, *F* (2,84) = 1.1, *MSE* = 279.2, *ns*. A separate ANOVA was conducted to rule out an effect of order of presentation of conditions with variations on presence and phrasing. Order of presentation was included as a between-subjects variable and did not seem to play a role in the accuracy data as a main effect, *F* (10,28) = 0.9, *MSE* = 15878.6, *ns*, or as an interaction with age *F* (7,28) = 1.1, *MSE* = 15878.6, *ns*. (See Appendix D for source tables of these analyses).

TI reaction time. Because reaction time was tabulated for those problems to which participants responded correctly, there were cases where individuals did not respond to any of the five problems correctly, for that level of manipulation, leading to a small number of cells without latency data. Due to the nature of the within-subjects analysis, the number of participants for reaction time results includes 18 older adults and 22 younger adults. These remaining participants had a minimum of one accurate trial in each cell and the results are described with caution. Results of the four-way ANOVA are presented in Table 7 and illustrated in Figure 7.

As in Study 1, there was no main effect of age, *F* (1,38) = 2.8, *MSE* = 149.2, *ns*. There was a significant main effect of phrasing, *F* (1,38) = 6.0, *MSE* = 30.3, $p < .05$, indicating that participants were faster when judging positively-phrased premises as compared to negatively phrased ones. There was also a main effect of presence, *F* (1, 38) = 111.4, *MSE* = 89.3, $p < .001$, in which all participants responded more quickly with premises absent compared to premises present. Finally, there was a main effect of premise number, *F* (2, 76) = 17.8, *MSE* = 14.5, $p < .001$. Post-hoc tests indicated that reaction times were higher overall with five terms relative to three or four terms, which were not significantly different from one another.

A significant interaction was found between age and premise number, *F* (2, 76) = 3.7, *MSE* = 14.5, $p < .05$. Post-hoc tests revealed that older adults had slower reaction times with each level of premise number relative to younger adults with three terms. Older adults were also slower with four terms than younger adults with four terms. However, with five terms, the groups did not differ, suggesting that this number of premises taxes processing time equally in the two age groups. Within the younger group, reaction times were slower with five terms relative to three terms. No other significant interactions were found between age and the within-subjects' variables.

A significant interaction was observed between presence and premise number, *F* (1, 38) = 37, *MSE* = 14.7, $p < .001$. Post-hoc tests revealed that with premises present, accurate responding slowed during the presentation of four and five terms, relative to three terms. In contrast, with premises absent, every level of premise number yielded faster reaction times relative to premises present. No other two-way interactions were found for the within-subjects variables.

A significant three-way interaction was found for age x presence x premise number, *F* (2,76) = 4.2, *MSE* 14.7, = $p < .05$, and is illustrated in Figure 10. Post-hoc tests using simple effects revealed that, within the older group, responding to three terms premises (which were present) was faster than four terms, but not faster than five. In contrast, within the younger group, responding during premises present yielded a linear pattern of slowing with increasing premise size. In the premises absent condition, latencies were fast for both younger and older adults across all three premise sizes.

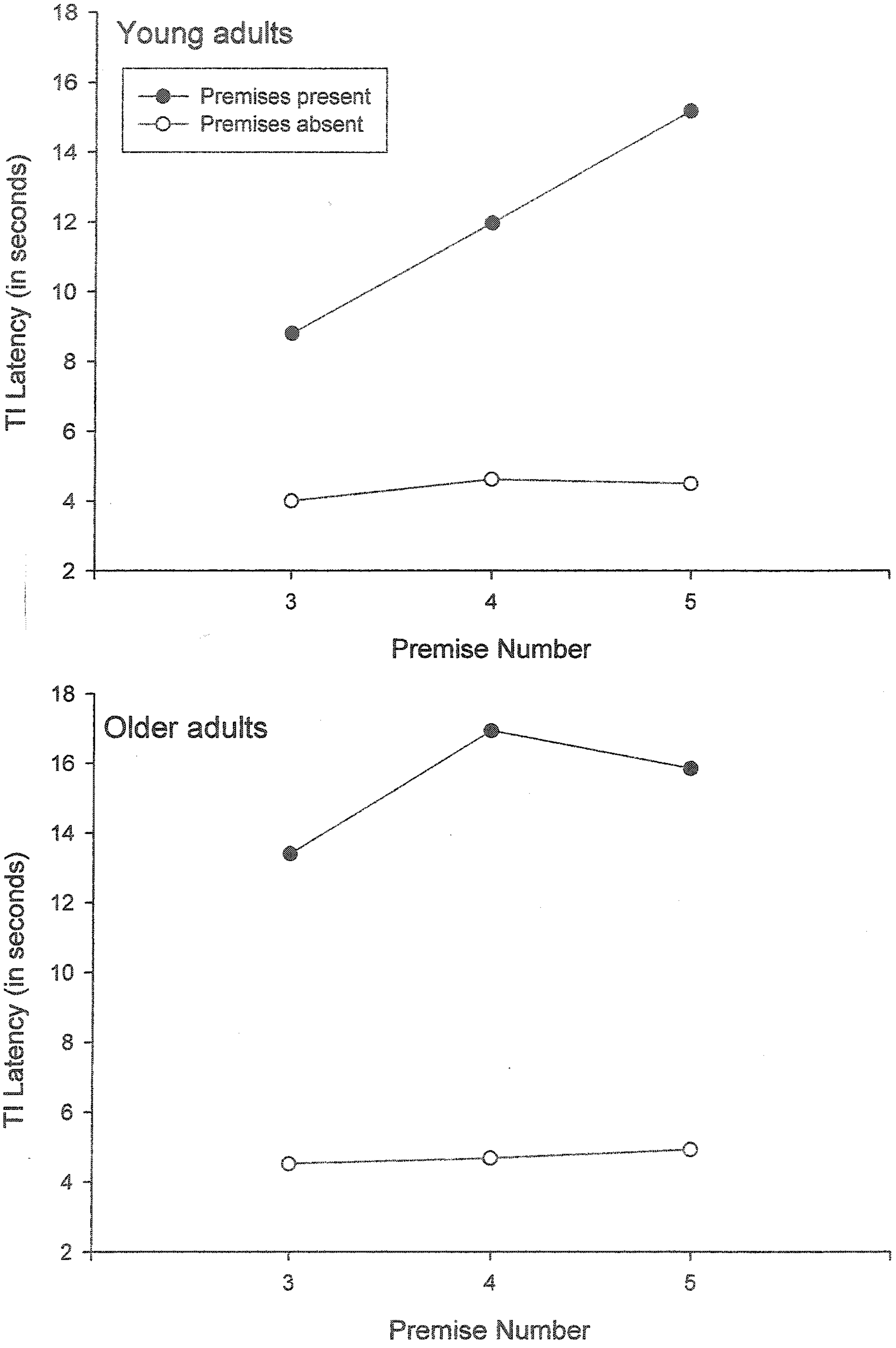


Figure 10. Study 2 Transitive Inference reaction time presence of premises across premise size in young and older adults.

Between the age groups, in conditions with premises present, older adults were slower with both three and four terms compared to the younger group with the same number of terms, while with five terms, both groups' responded within similar latencies. Neither the group x phrasing x premise number interaction, F (2,76) = 0.3, MSE = 9.8, *ns*, nor the four-way group x phrasing x presence x premise number interactions were significant, F (2,76) = 0.6, MSE = 9.1, *ns*. (See Appendix D for source tables of these analyses).

Neuropsychological measures. A series of Pearson product moment correlations were used to analyze the relationship between the measures of reasoning, working memory, processing speed with total transitive inference accuracy performance (% correct) for each individual. Accuracy collapsed over all conditions was used as the single best measure due to the inconsistent patterns of the data. This was followed up by a hierarchical regression technique to examine the relative contributions of various behavioral measures to the transitive inference task for those correlations which were found to be significant.

The resulting correlations for young and older adults are presented in Tables 8 and 9, respectively. The TI performance of younger adults correlated significantly with measures of working memory, namely Letter Number Sequencing, $r = .40$, $p < .05$, (see Figure 11) and psychomotor performance, namely Digit Symbol Coding, $r = .46$, $p < .05$, (see Figure 12). There was also a significant correlation between the ability to solve TI problems and Matrix Reasoning, which is a measure of non-verbal reasoning, $r = .48$, $p < .05$ (see Figure 13). However, visual inspection of the data revealed that this correlation seemed influenced by one participant's extremely low Matrix Reasoning data, which fell more than three standard deviations below the mean for their age group. A subsequent

Table 8

Correlations Between TI Accuracy (% correct) and Neuropsychological Measures For Younger Group for Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Young ($n = 23$)							
1. Age	-	.22	.21	.06	-.28	-.00	.02	-.40*	-.21	.13	-.11	-.45*	-.22	.19	-.25
2. Educ.		--	.32	.24	.08	.15	.03	.13	-.47*	-.07	-.20	.04	.03	.10	-.31
3. TI Cor			--	-.06	.48**	.05	.40*	.46*	.17	-.11	-.27	-.02	-.18	.00	-.08
4. Voc.				--	.08	.45*	.21	-.26	-.09	.19	-.29	.31	.36*	.44*	-.54**
5. Matrix					--	.36*	.20	.35	.31	-.44*	-.57**	.15	.18	.01	.01
6. Sim.						--	-.13	.05	-.34	-.44*	-.34	-.01	.02	.10	-.18
7. LN							--	.36*	.28	.10	-.18	.40*	.31	.25	-.24
8. DS								--	.18	-.29	-.04	.33	.26	-.29	.32
9. LM2									--	.13	-.24	.11	.06	.21	-.11
10. LM R										--	.36*	.09	.09	.09	-.14
11. CET											--	.25	.05	-.49**	.54**
12. P Flu.												--	.53**	-.21	.20
13. S Flu.													--	-.19	.18
14. WCST Cat														--	-.88**
15. WCST PPER															--

$p < .05$, $**p < .01$. Note. TI Cor. is TI Accuracy in (% correct); Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table 9

Correlations Between TI Accuracy (% correct) and Neuropsychological Measures For Older Group Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Old (n= 21)							
1. Age	-	.12	−.12	−.04	−.05	.02	−.33	−.70**	−.43*	−.22	.13	.22	.07	−.15	−.07
2. Educ.		--	.32	.57**	.36	.66**	.24	.06	-.07	−.25	−.29	.22	.29	−.07	-.33
3. TI Cor			--	.38*	.29	.47*	.27	.24	.30	.00	.12	.34	.10	.20	.06
4. Voc.				--	.41*	.82**	.49*	.28	.09	.27	−.56**	.51**	.60	.04	-.45
5. Matrix					--	.54**	.49*	.16	.42*	.48*	−.51**	.01	.26	.30	−.45*
6. Sim.						--	.51**	.16	.05	.09	−.45*	.40*	.47*	.03	-.36
7. LN							--	.37*	.43*	.30	−.40*	.29	.38*	.24	−.51**
8. DS								--	.36	.32	−.19	.27	.18	.25	−.17
9. LM2									--	.68**	−.15	-.06	.06	.43*	−.06
10. LM R										--	-.41*	.11	.08	.15	−.12
11. CET											--	02	−.46*	.12	.44*
12. P Flu.												--	.38*	-.19	−.18
13. S Flu.													--	−.07	-.56**
14. WCST Cat														--	−.24
15. WCST PPER															--

$p < .05$, $**p < .01$.

Note. TI Cor. is TI Accuracy in (% correct); Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

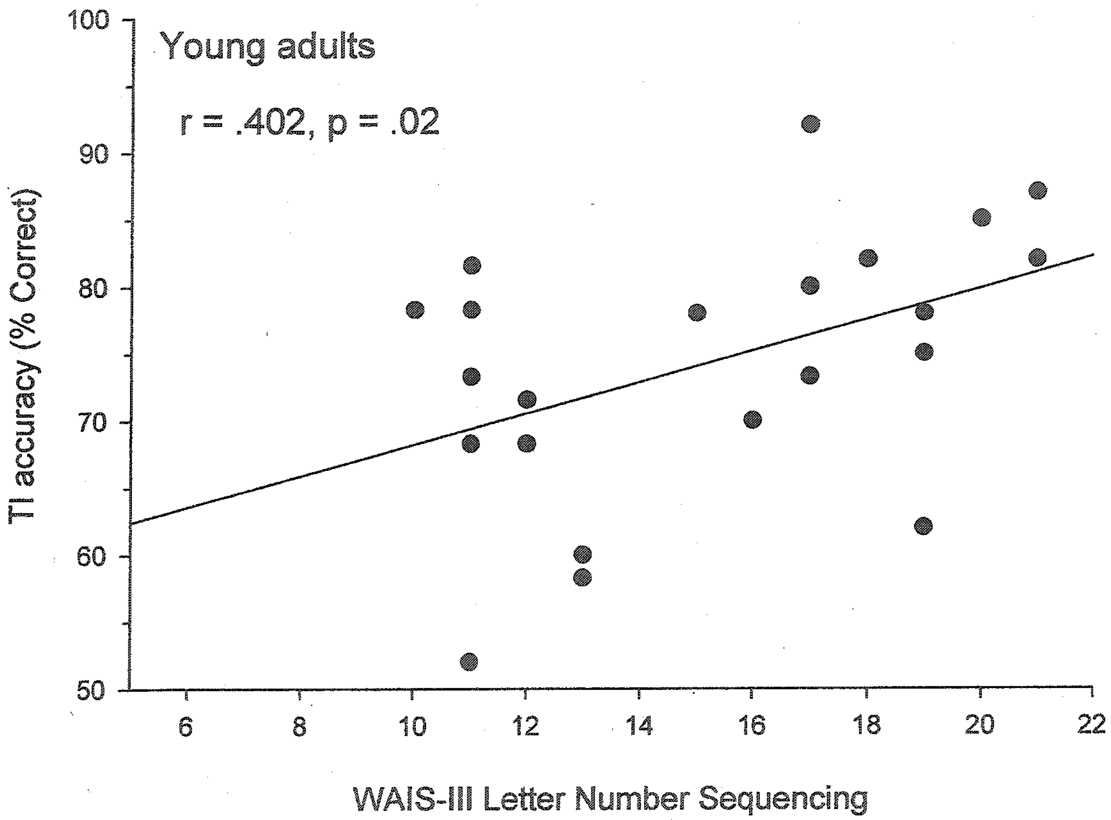


Figure 11. Study 2 correlation between TI accuracy and WAIS-III Letter Number Sequencing in the young adults.

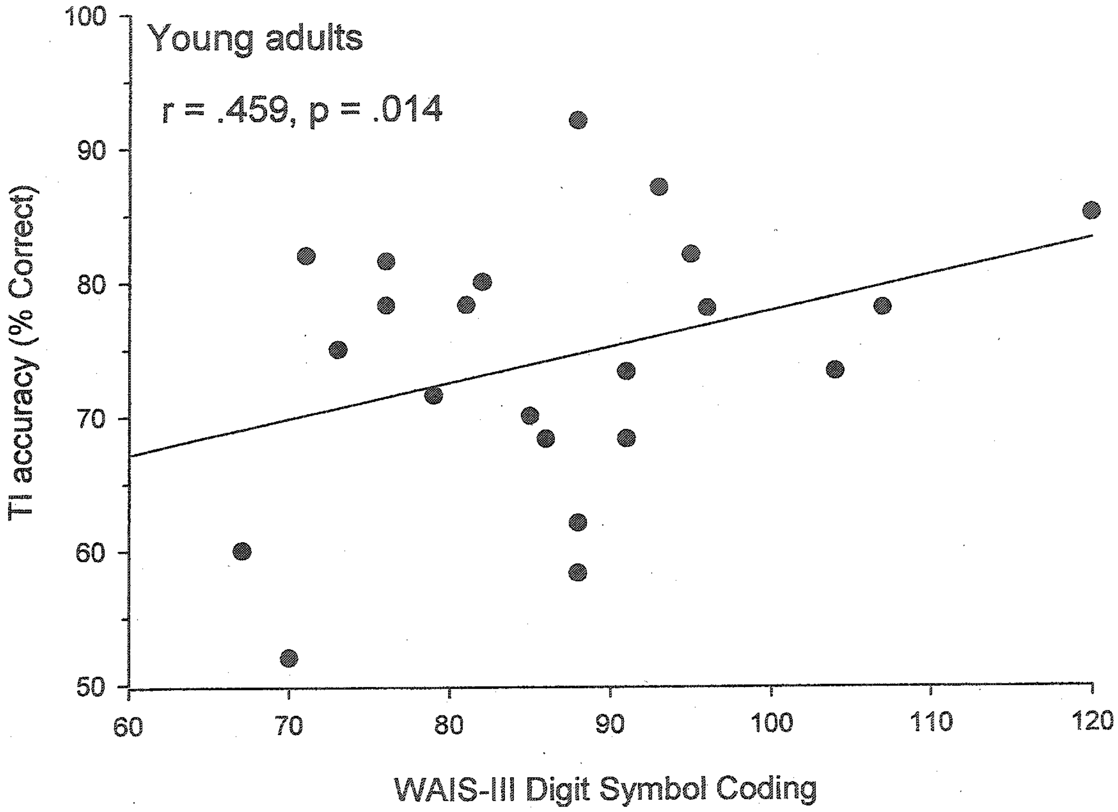


Figure 12. Study 2 correlation between TI accuracy and WAIS-III Digit Symbol Coding in the young adults.

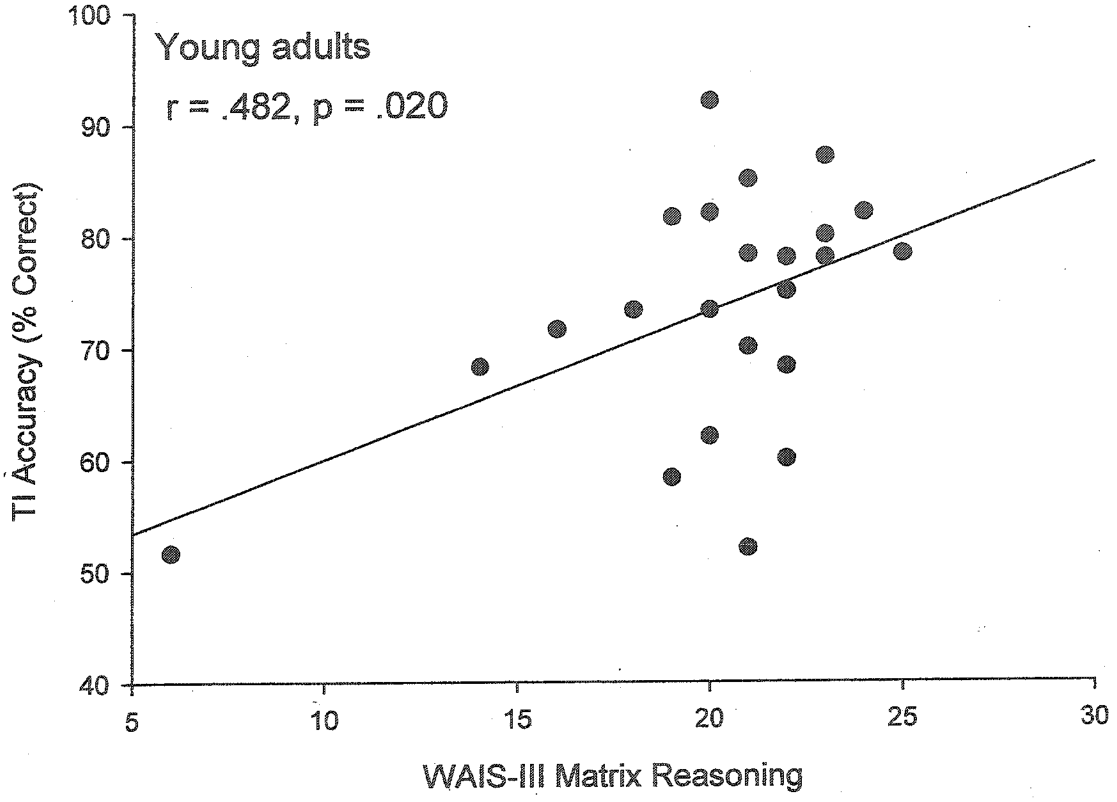


Figure 13. Study 2 correlation between TI Accuracy and WAIS-III Matrix Reasoning in the young adults

correlational analysis between TI and Matrix Reasoning in the younger adults, having excluded this additional individual was not significant. In contrast, TI performance of the older adults correlated significantly with Vocabulary, $r = .38, p < .05$, (see Figure 14), indicating a relationship between solving these verbal problems and one's general knowledge, and with Similarities, $r = .47, p < .05$, (see Figure 15), indicating a relationship with solving TI problems and abstract reasoning ability. There was also a trend towards a correlation with TI and Phonological Fluency, $r = .34$, *ns*, (see Figure 16).

Given that the varying pattern of results across condition manipulations may have reflected different cognitive strategies or processes, it seemed prudent to utilize each accuracy condition block separately when running additional correlational analyses with neuropsychological measures, rather than the overall TI accuracy measure. Frequency distributions were examined to verify that TI accuracy performance for each condition block differed from chance levels and confirmed the value of considering each condition block on its own. The results demonstrated that participants were generally performing above chance levels within each condition block. The results of the correlation analyses for the individual TI blocks with neuropsychological data yielded 96 correlations, of which nine were significant, (see Appendix E). It is not clear whether some of these correlations might have been spurious and due to chance; resolution of this question would require future replication. In the case of premises present (positively phrased) the younger adults TI accuracy was found to correlate with Matrix Reasoning ($r = .68, p < .05$), Incidental Learning ($r = .47, p < .05$), Digit Symbol Coding ($r = .45, p < .05$), and percent retention of the Logical Memory 2 ($r = -55, p < .01$), whereas in the older group

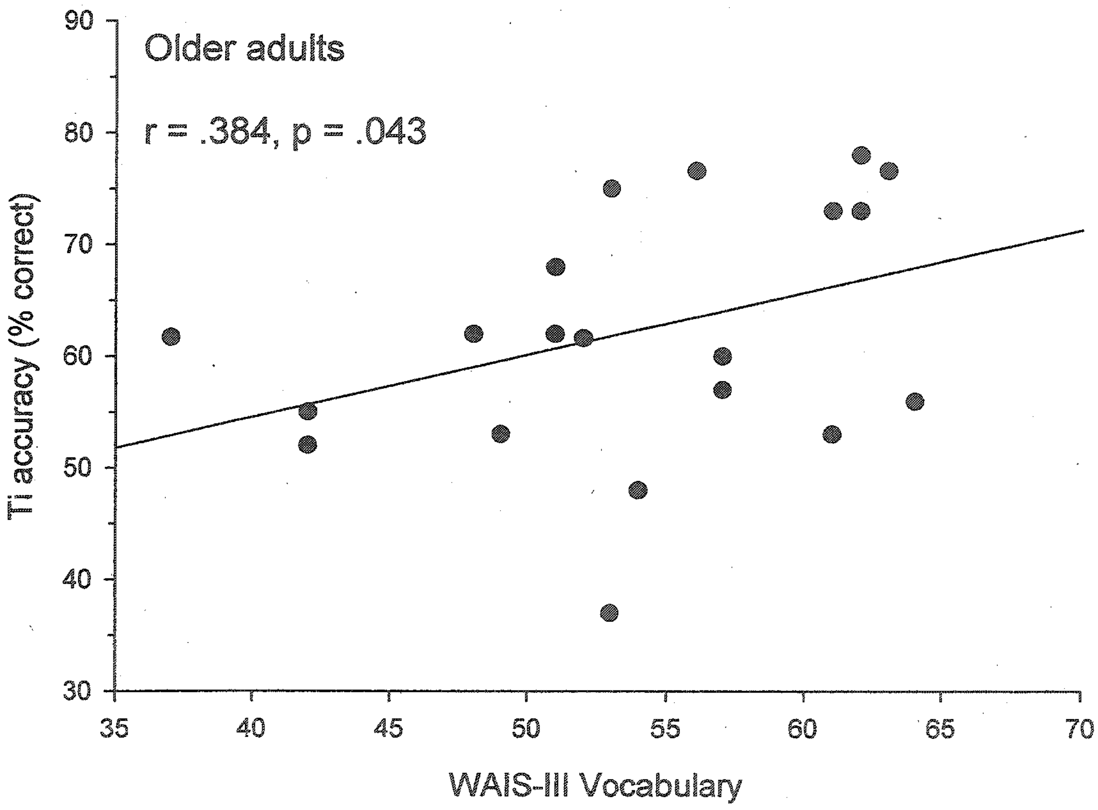


Figure 14. Study 2 Correlation between TI accuracy and WAIS-III Vocabulary in the older adults.

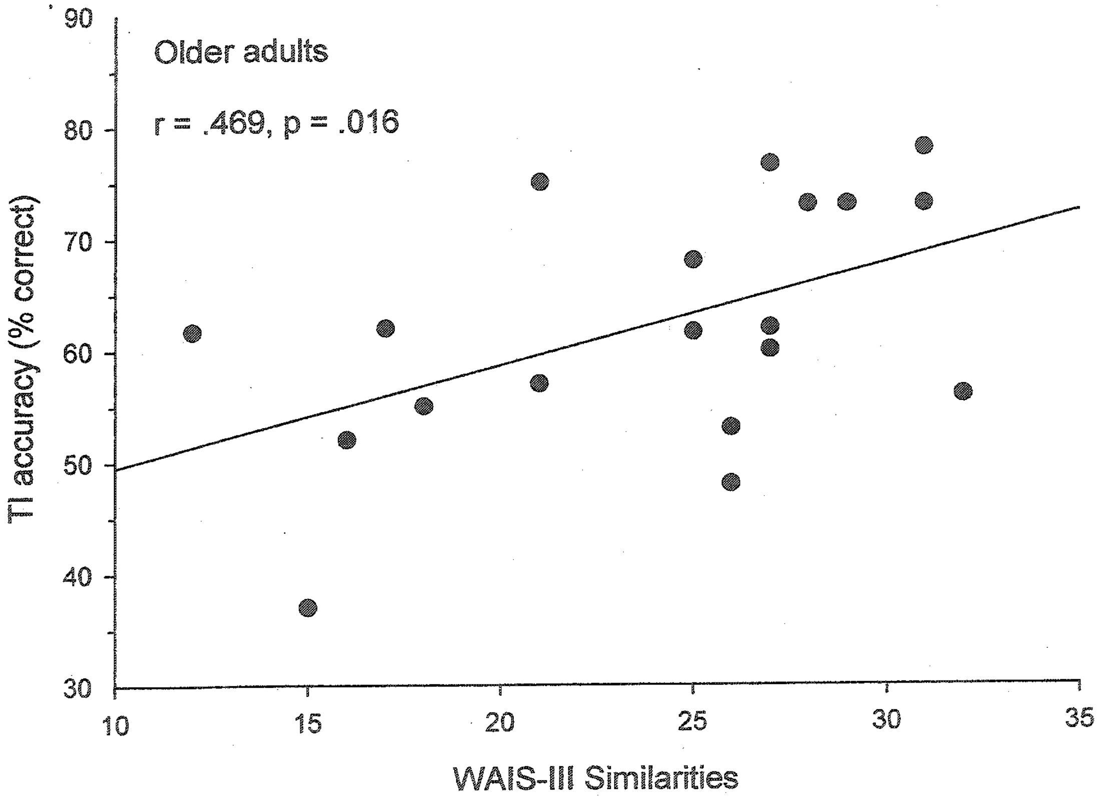


Figure 15. Study 2 Correlation between TI accuracy and WAIS-III Similiarities in the older adults.

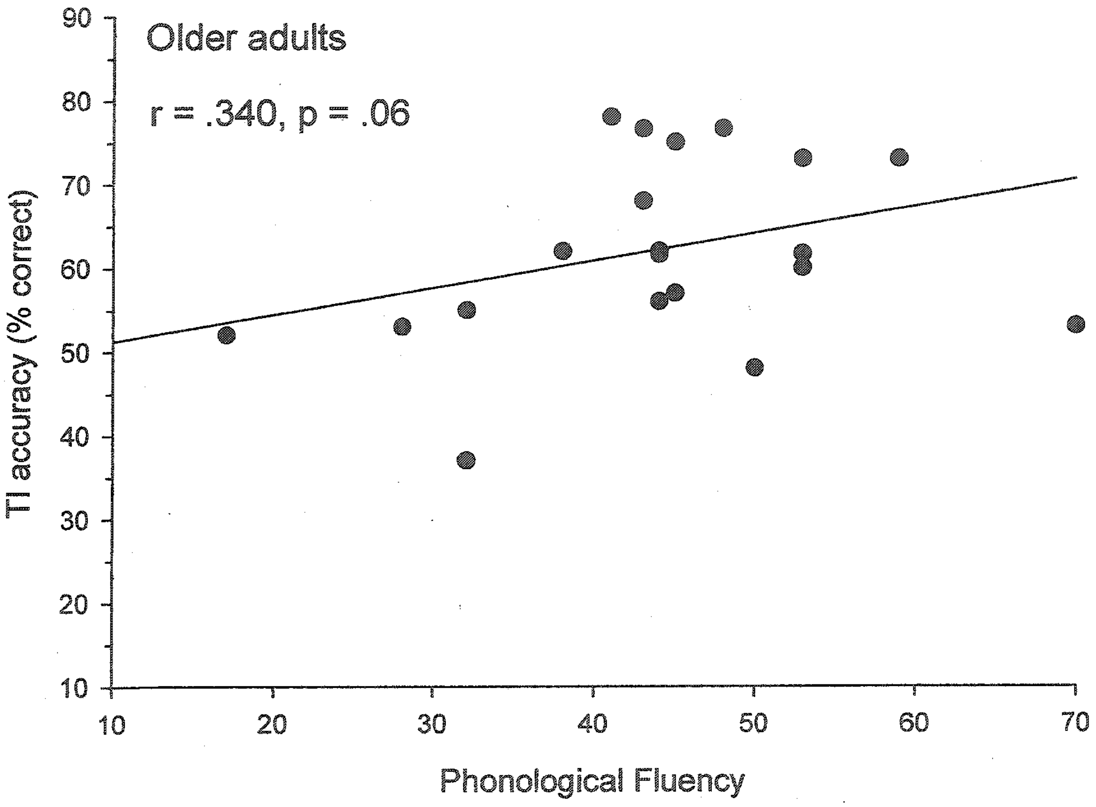


Figure 16. Study 2 Correlation between TI Accuracy and Phonological Fluency in the older adults.

TI accuracy correlated with Matrix Reasoning ($r = .52, p < .05$) and Similarities ($r = .46, p < .05$). In the case of premises absent positively phrased, a correlation between TI accuracy and Matrix reasoning was found only in the younger group ($r = .46, p < .05$).

The remainder of the significant correlations between TI accuracy and neuropsychological measures were both inconsistent and difficult to interpret. For example, level of education was found to correlate with TI accuracy of the condition with negatively phrased premises present in the younger group ($r = .43, p < .05$), but was not correlated with any other blocks for either age group. Similarly, the Wisconsin Card Sorting Task percent perseverative errors measure was found to correlate with premises present negatively phrased in the older group ($r = .41, p < .05$) but not with the younger group or with other conditions.

Further exploratory analyses were conducted examining the first three condition manipulations common to Study 1 and Study 2 collapsed across the two studies (i.e. premises present, premises absent, and negative phrasing) to examine whether similar patterns of correlations with the neuropsychological data emerged in the younger versus older group. The only consistent, reliable pattern that emerged were correlations in the young during premises present between TI accuracy and Matrix Reasoning ($r = .55, p < .001$), Incidental Learning ($r = .37, p <.05$), Digit Symbol Coding ($r = .37, p < .05$) and percent retention of the Logical Memory 2 ($r = -.39, p < .05$). In the case of premises absent, a correlation between TI accuracy and Matrix reasoning was found only in the younger group ($r = .54, p < .001$). These findings are similar to those found in Study 2 alone. In the older group, during the same TI condition, only a correlation with Semantic Fluency emerged ($r = .42, p < .05$). The correlations found in the older group in Study 2 alone with Matrix Reasoning only emerged when tests of significance were reduced to the one-tailed level ($r = .31, p < .05$), and the correlation with Similarities was reduced to a trend ($r = .29, p = .052$). Other analyses involving the other two conditions did not yield results that were either easily interpretable or stable (See Appendix F).

A number of additional secondary analyses were conducted that were collapsed over some conditions to isolate the potential effects of premises present, negation, and compare premises present positively phrased to premises absent positively phrased. Because accuracy for all participants was so low in conditions with premises absent, it seemed more logical to pursue an analysis of condition manipulations with premises present positively phrased. The analyses reported above with premises present yielded results that were straightforward and easily interpretable, leading to the logical use of this condition as the standard to compare other conditions of interest to. Thus, to analyze the predicted effect of negative phrasing on participants' working memory capacities, a new variable was calculated and subsequent correlations of TI scores representing Block 1 premises present positively phrased (collapsed over number of premises) minus Block 3 premises present negatively phrased (collapsed over number of premises) divided by Block 3, yielding a B1-B3/B3 proportional difference score. This score isolates the effects of negation on TI performance. In the younger group this Block1-Block3/Block 3 proportional difference score correlated negatively with age ($r = -.59, p < .01$) (see Figure 17). In the older group this Block1-Block 3/Block 3 difference score correlated significantly with Semantic Fluency ($r = 49, p < .05$) (see Figure 18), and WCST percent perseverative errors ($r = -.44, p < .05$) (see Figure 19). This pattern of results confirms the notion that use of negative phrasing is qualitatively different from positive phrasing

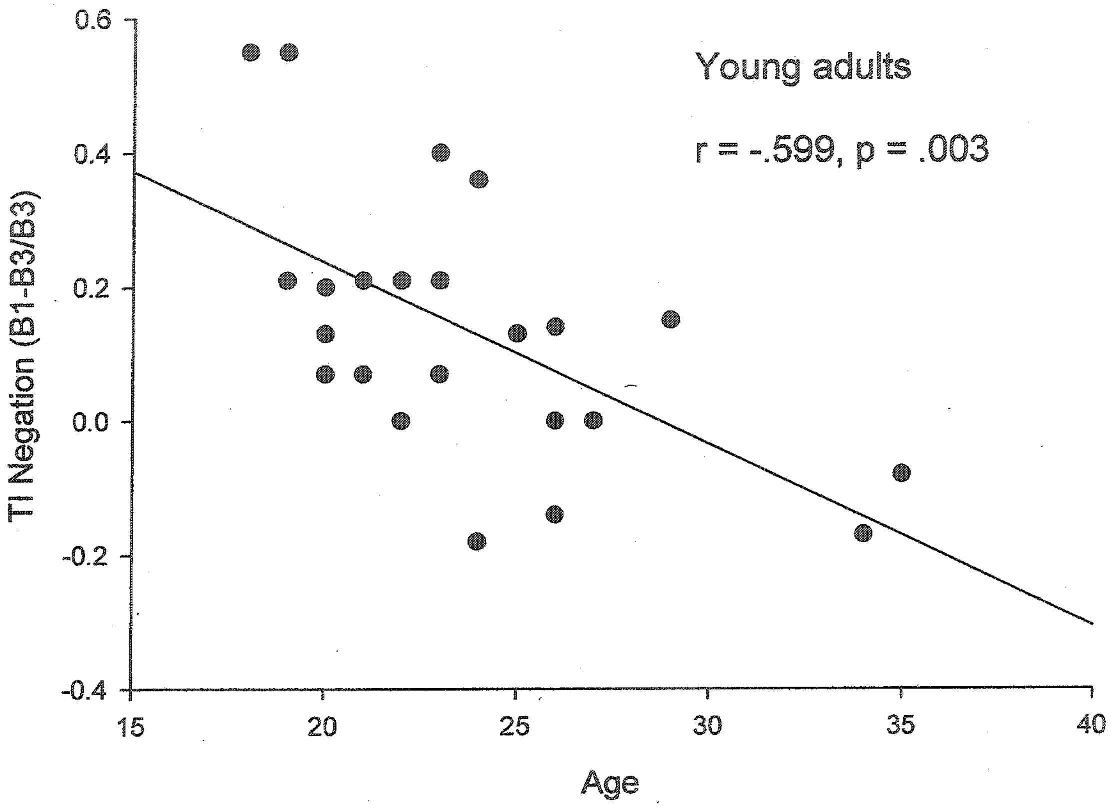


Figure 17. Correlation between TI having isolated the effect of negation and age in the young adults.

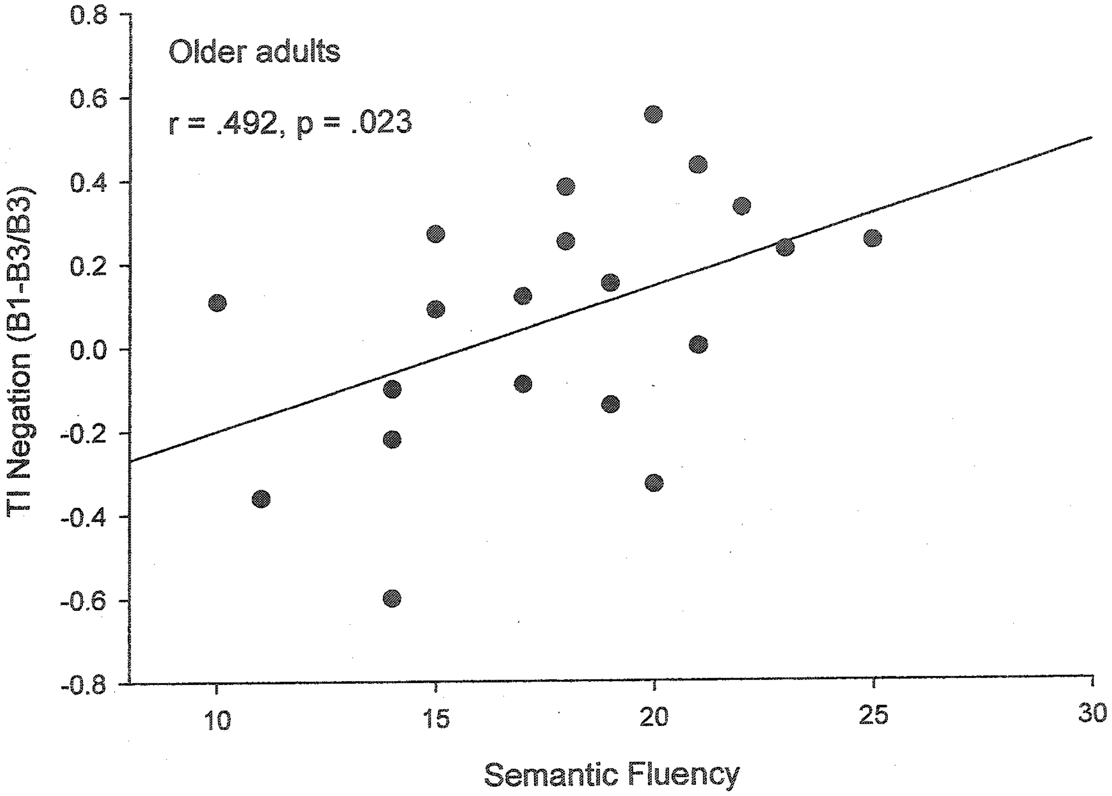


Figure 18. Correlation between TI having isolated the effect of Negation and Semantic Fluency in the older adults.

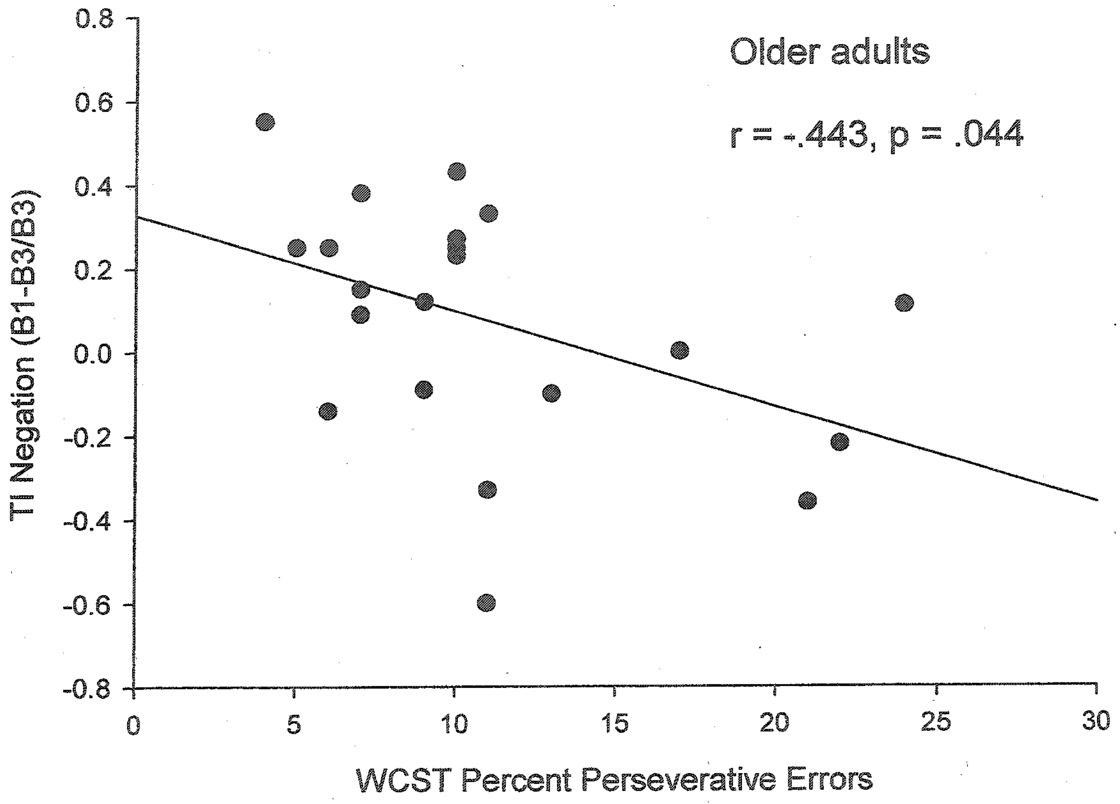


Figure 19. Correlation between TI having isolated the effect of Negation and WCST Percent Perseverative Errors in the older adults.

and is correlated with different neuropsychological measures in the older adults versus the young.

The measure of overall TI accuracy, (based on the total of the four conditions) was the only measure judged to be stable enough to pursue further analyses. Thus, the significant correlations of overall TI percent correct were followed up by a hierarchical multiple regression in order to examine the relative contributions of various behavioral measures to the transitive inference task. For the younger group, the two significant correlations included Digit Symbol Coding and Letter Number Sequencing. Digit Symbol Coding largely reflects processing speed, and psychomotor performance, and as such was considered to be a speed variable that is correlated with Letter Number Sequencing, with the latter expected to involve mental processes (i.e. mental re-ordering and working memory) that were in higher demand during the TI task. Given that mental processing speed may be a more general factor common to both measures, whereas only Letter Number Sequencing involves working memory and re-ordering, it was thought prudent to enter Digit Symbol Coding into the equation first and see what portion of the overall transitive inference performance variance would remain.

For the younger group, the hierarchical multiple regression was conducted between overall TI accuracy performance as the dependant variable and Digit Symbol Coding and Letter Number Sequencing scores as the independent variables, Digit Symbol Coding was forced into the equation first, followed by Letter Number Sequencing. The regression analysis revealed that Digit Symbol Coding was the most significant predictor of TI performance. Table 10 displays the results of the analyses, including the bivariate correlations between the independent variables (IVs) and the dependant variable (DV),

Table 10

Hierarchical Multiple Regression of TI Accuracy and WAIS-III Digit Symbol Coding and Letter Number Sequencing Scores in the Young.

Variables	TI	DigitSym	LetterNumb	B	β	sr^2
	(DV)				(incremental)	
DigitSym	.46			.28	.36	.37
LetterNumb	.40	.36	.29	.80	.27	.029
Means	73.30	85.57	15.17			
SD	10.78	13.71	3.77			$R^2 = .28$
						Adjusted $R^2 = .20$
						$R = .52$

*$p < .05$

[a] Unique variability = 14%.

the unstandardized regression coefficients (*B*) and intercept, the standardized regression coefficients (β), the semipartial correlations (sr^2), and *R*, R^2, and adjusted R^2 after entry of both IVs to the equation. For testing each IV the significance of the regression components, F_i for each IV was based on the change in R^2 after both IVs had entered, and the residual degrees of freedom from the ANOVA table for the final step ($df = 20$; see Tabachnick & Fidell, 2001, pp.144). Digit Symbol Coding accounted for 14% of the variance in TI. Adding Letter Number Sequencing to the equation did not add to the prediction of Digit Symbol Coding.

For the older group, the hierarchical multiple regression was conducted on overall TI accuracy performance as the dependant variable and Vocabulary and Similarities scores as the independent variables. The same method was applied, whereby Vocabulary was entered into the regression equation first because it was expected to be a nuisance variable representing the larger underlying general intelligence factor common to both measures. This model was not significant but a model with Similarities entered into the equation first did reach significance, revealing Similarities as the most significant predictor of TI performance. Table 11 displays the correlations between the variables, the unstandardized regression coefficients (*B*) and intercept, the standardized regression coefficients (β), the semipartial correlations (sr^2), and *R*, R^2, and adjusted R^2 after entry of both IVs to the equation. For testing each IV the significance of the regression components, F_i for each IV was based on the change in R^2 after both IVs had entered, and the residual degrees of freedom from the ANOVA table for the final step ($df = 20$; see Tabachnick & Fidell, 2001, pp.144). Similarities alone accounted for 8.4% of the

Table 11

Hierarchical Multiple Regression of TI Accuracy and WAIS-III Vocabulary and Similarities Scores in the Older adults.

Variables	TI (DV)	Vocabulary	Similarities	B	β (incremental)	sr^2 (incremental)
Similarities	.47	.29	-.001	-.002	.47	.22*
Vocabulary	.38			.91	.00	.22
Means	62.45	54.14	24.14			
SD	11.05	7.6	5.7			$R^2 = .22^a$
						Adjusted $R^2 = .18$
						$R = .47*$

*$p < .05$
[a]Unique variability = 8.4%.

variance in TI. Adding Vocabulary to the equation did not add to the prediction of Similarities.

General Discussion

The two studies described herein were largely exploratory in nature, yielding some results consistent with some of the predictions made, and still others that were largely unexpected. Most of the results of Study 2 were consistent with those observed in Study 1. In terms of the hypotheses, both reduced TI accuracy and increased reaction time were predicted for the older adults relative to the young, but this was only the case for accuracy. TI reaction times were remarkably similar among the two age groups. The hypothesis that negative phrasing would increase TI reaction times in the older adults and to a lesser extent the young, while not affecting either group's accuracy, was not supported. The reaction times of both age groups increased with negative phrasing. The prediction that the use of premises absent was expected to reduce performance in both age groups was confirmed. Given that the younger adults' accuracy dropped down to the level of the older adults' during premises absent, the prediction that this decrement would be greater in the older adults relative to the young was not confirmed. Varying the number of premises between three, four, and five was predicted to decrease performance in all participants in a linear fashion, with older adults showing greater decrements, but this was also disconfirmed in all but two instances in the older adults with premises present and negative phrasing. The hypothesis whereby TI performance was expected to correlate with measures of working memory and processing speed in the older adults was also disconfirmed. TI performance, however, was correlated with those measures in the young. The expected correlation between TI and Matrix Reasoning was not observed, whereas a correlation between TI and Similarities was found, but only in the older adults.

To summarize the accuracy results for Study 2, most importantly the young adults outperformed the older adults, as predicted (see Figure 6). Beyond this overall age difference, both groups generally yielded the same pattern of results when confronted with the various task manipulations in this study. For instance, both groups demonstrated reduced accuracy performance with five terms across most of the various task manipulations. Both groups' performance dropped in conditions with negative phrasing, suggesting that negatively structured TI problems were more difficult to process relative to regular positive sentence structure. Similarly, both groups' performance dropped in most instances of conditions with premises absent relative to premises present, indicating that not having premises available for study while solving the task posed a greater performance challenge. Overall, the accuracy performance suggests that the TI task was particularly difficult for subjects if premises did not remain available for review. Furthermore, both groups demonstrated an inverted U-shaped curve across premise size in conditions with premises absent, a pattern that was more pronounced in the young.

Despite these global similarities, some notable exceptions to the parallel patterns between the two age groups were observed. Across all condition manipulations, older adults performance generally dropped with the use of five terms, whereas the same only held true for younger adults in the two conditions with premises absent. In conditions where premises were present, younger adults were able to maintain a high level of performance over the three premise sizes. Finally, in the condition with negatively phrased premises remaining present, it would appear that the two age groups have an opposite pattern of accuracy performance across premise size. The younger group demonstrated a U-shaped curve across the three levels of premise number, while the older participants demonstrate somewhat of a downward linear trend. The reason for the drop in younger groups' performance with four terms relative to five, which was also seen in Study 1, remains unknown. If this effect holds in future research, especially with inclusion of a greater variety in premise number, it would demonstrate whether it is reliable. In conditions where premises were absent, the older adults' performance declined with the use of five term problems, whereas the younger adults' performance declined with three and five terms relative to four. Younger adults' performance dropped to the level of the older adults when premises were gone, suggesting that the younger group likely enabled a qualitatively different strategy than the older adults while premises remained available for study in premises present; a notion that found support in the findings of reaction time (see below).

During conditions with premises absent, in both Study 1 and Study 2, a higher performance in accuracy was observed in both groups with four terms relative to three or five, indicating an inverted U-shaped function peaking with four terms relative to three or five. This effect, which can be observed in most participants, requires further study and readily leads to the following two verifiable hypotheses. Firstly, this potential effect may reflect a relationship between level of difficulty and optimal level of challenge, triggering a rallying of attention and motivation. Three terms may have been perceived as too easy, and perhaps younger adults underestimated the level of difficulty with this number of premise terms. Alternatively, the inverted U-shaped function may indicate that encoding and chunking an even number of premise terms was easier to track in terms of paired relations than an odd number of premise terms, which can be examined by including six terms in additional experiments. As previously mentioned, an ANOVA ruled out an order of presentation effect. Despite this, there remains a possibility of a confound in this regard, which may have led to better performance with four premise terms because the two age groups were not yoked or assigned to separate Latin squares for order of presentation. However, analyses conducted on frequency distributions, examining the particular TI problems having yielded higher accuracy scores, did not reveal a consistent pattern.

With regard to reaction time in Study 2, once again, the results are interpreted with caution due to the small number of observations. Overall the reaction time differences between the groups were not large enough to be significant (see Figure 7). The results were otherwise predicted in that negative phrasing had the greatest effect in slowing reaction times for solving TI problems for all participants. This slowing is thought to reflect the additional time required to process negative sentence structure (Sternberg, 1980; Gick, Craik, and Morris, 1988). However, in conditions where premises were absent, participants' responding quickened. Because this type of manipulation has not been reported previously in the literature, while the reason for this effect is unknown, in retrospect, it is not surprising and several possible factors are discussed below. In terms of premise number, in conditions with premises remaining present, the fewest number of premises resulted in relatively faster reaction times. During conditions where the premises remained present, the young adults' responding slowed in a linear fashion as the number of premises increased, while the older adults' responding slowed significantly upon the introduction of four term problems and then maintained similar response latencies with five term problems. However, when premises were present, older adults responded more slowly than the younger adults for three and four term premises but group reaction times were equivalent for the highest memory load (five terms), indicating that all participants are having difficulty at that point. In conditions where the premises were absent, none of the premise size manipulations resulted in a significant reaction time change in either age group. In fact, there seems to be a floor effect for all participants where some phenomenon incurred very fast reaction times.

It can be speculated that premises absent incurred faster reaction times because the premises were no longer on screen and thus, unavailable for review, leading individuals to choose among the two response options faster, perhaps even guess more often. Despite the fact that participants were asked not to guess, perhaps facing a TI problem with premises absent forced some individuals to either offer the answer they had already surmised or else guess. Based on participants' reports during debriefing, stress may also have been a factor in no longer having the premises in view may have forced participants to process the premise relations faster and led to more inaccurate responding relative to premises present.

On the contrary, with premises present, reaction times were longer perhaps because individuals were trying to make use of the available stimuli to review and gather more information to solve the TI problem. With premises present, older adults were slower and performed worse than younger adults. Despite that, like the young, older adults performed better with premises present than absent. This important finding suggests that older adults do not benefit from extra cues even when they are made available. Several possible reasons for this include a limited resource capacity issue (for a review see Salthouse 1988) or inability to inhibit irrelevant premise information (Hasher & Zacks, 1988). If the problem were of a limited cognitive capacity issue, older adults might be unable to simultaneously integrate the multiple premises, infer the implicit relation and re-order the premises to sufficiently solve the TI question. If the problem were of an inhibitory deficit older adults may either be unable to ignore the premises and relational information that is not required to solve for the TI premise pair inquired about or they may be allowing other thoughts to interfere with the TI task. This finding also raises the possibility that the older and younger adults utilize different cognitive abilities to accomplish this TI task, a notion supported by the divergent patterns of correlations observed.

In order to understand the cognitive processes underlying this TI task, correlation analyses were conducted between the overall TI accuracy with several neuropsychological tests. However, prior to running the correlation analyses, MANOVAs were conducted to determine whether the pattern of responses between the two age groups on the neuropsychological tests was different. As expected, differences emerged for the majority of measures, including Matrix Reasoning, Letter Number Sequencing, Incidental Learning, Digit Symbol Coding, Logical Memory-II, Logical Memory Retention, Semantic Fluency, and WCST percent perseverative errors. However, differences were not found on CET, phonological fluency, similarities, and WCST categories. Both groups performed in ways that were expected. For example, younger adults showed stronger performances on working memory and processing speed measures. It is also not surprising that the two groups did not differ on Similarities, a measure of verbal crystallized knowledge, based on known concepts, drawing comparisons between concepts not usually compared draws on both crystallized and fluid abilities. Although Matrix Reasoning is a more fluid ability than Similarities, drawing upon more abstract non-verbal, it is known to decline with age (Kaufman & Lichtenberger, 1999). The finding that the two age groups do not differ on CET or phonological fluency while they differ on semantic fluency or structure based on animal categories, coincides with more recent research in which age differences are found to be more common for animal categories versus letter fluency. The lack of differences in CET and WCST categories suggests that the two age groups do not differ on these aspects of executive function.

Accordingly, different pattern of correlations emerged between the two age groups. The older adults' TI performance was correlated with Vocabulary (accumulated semantic knowledge) and Similarities (verbal reasoning) subtests of the WAIS-III, both measures of crystallized verbal intelligence, and more globally measures of general intelligence or g factor. The younger adults' TI performance was correlated with Letter Number Sequencing (working memory) and Digit Symbol Coding (processing speed and psychomotor performance) subtests of the WAIS-III, which ironically was predicted to be correlated in the older adults. The correlation observed between TI performance and Similarities subtest of the WAIS-III in the older group speaks to older adults treating the TI task as a verbal reasoning task, which is understandable given the verbal nature of the stimuli. Since fluid abilities are known to show decrements with aging, while crystallized abilities seem to be largely spared (Kaufman & Nadeen, 1999; Catell, 1963; Horn & Cattell, 1967; and Salthouse 1991), it is conceivable that cognitive compensation may be at play during the TI task. Given that a correlation between TI and education was not found, this dissuades attributions of general, global intelligence or g factor involvement in TI. More specifically, older adults may be relying on their spared cognitive abilities, involving verbal mediation and stored verbal knowledge to solve the TI problems presented in these studies, rather than relying on the more fluid abilities, which tend to be sensitive to the effects aging (Salthouse 1995; Baltes, 1987). This notion is supported by the different pattern of correlations between TI task performance and neuropsychological measures in the two age groups. Based on the correlations obtained with measures of working memory, processing speed, and attention in the younger group, it seems that they needed these abilities to carry out the TI task. With regard to the lack of correlations in older adults between performance on TI and other cognitive tasks which tap into skills thought to be required for reasoning, such as working memory, processing speed and frontal lobe function, this may refute the notion that a common processing resource is deficient in older adults, (Salthouse, Mitchell, Skovroneck, & Babcock, 1989). As mentioned, the alternative interpretation, is that older individuals who managed to do well on the TI task, did so by employing other intact resources and skills, that are not affected by ageing.

To isolate potential effects of the various manipulations (i.e. premises present, premises absent, and negation) on TI accuracy, and examine resources and processes utilized, correlations were run on individual Block manipulations and the neuropsychological measures. The same analyses were conducted having collapsed Study 1 and Study 2 with respect to the first three common conditions (i.e. premises present, negative phrasing, and premises absent). For younger participants, the pattern that emerged from this series of secondary analyses consisted of significant positive correlations between TI accuracy during premises present with Matrix Reasoning, Incidental Learning, Digit Symbol Copy and percent retention of the Logical Memory II, and a significant positive correlation of TI accuracy during premises absent with Matrix Reasoning. These findings suggest that TI with premises present is a task that more closely approximates a fluid reasoning task, which relies on learning, memory and processing speed abilities. In contrast, the findings were less reliable in the older participants. Although significant positive correlations were found between TI accuracy during premises present and Matrix Reasoning and Similarities in Study 2, these correlations were significant only at the one-tailed level with the studies combined. Moreover, a new positive correlation with Semantic Fluency emerged. One possible explanation for these discrepant findings is that the collapsed groups examined here included a greater number of participants but no decrease in variance. This may have strengthened some correlations and weakened others. Caution must be taken when considering these results, as the collapsing of participants' data from Studies 1 and 2 essentially mixed two groups of subjects that experienced different conditions. Notably, Study 2 added a condition of premises absent negatively phrased, representing a total of two conditions with premises absent. Older participants may have found conditions with premises absent more cognitively taxing and stressful than the younger participants, a notion supported by the reduced accuracy performance during conditions with premises absent relative to present and also by participant reports during post-testing debriefing interviews.

To further isolate the effects of negative phrasing of premise phrases on TI performance, a Block 1 minus Block 3 divided by Block 3 percent difference score was calculated. This measure yielded negative correlations with age in the young, suggesting that within the range of 18 to 35 years, as one gets older, one's ability to deal efficiently with negation declines. In the older group, this measure yielded a correlation with Semantic Fluency, signifying accessing of category knowledge and may be related to retrieval, and a negative correlation with WCST percent perseverative errors, related to the ability to inhibit perseverative responses and in both cases, suggestive of executive function, on-line assessment, judgement. Therefore, TI or at least this condition, may require some inhibition. That is, in order to solve the TI task efficiently, one must inhibit the irrelevant relationships and focus on the relevant ones to make deductions. Therefore the effect of negative phrasing above and beyond premises present, does not seem to be related to working memory measures (i.e. Letter Number Sequencing) or processing speed (i.e. Digit Symbol Coding), while it did seem to tap into frontal lobe and executive/ frontal cognitive function in the older group. Again, this different pattern of correlations between the age groups supports the notion that the Older are obliged to call upon additional resources to cope with the task. In the case of negative phrasing, it may be that older adults who perform well call upon the executive abilities mentioned to assist them.

With regard to the hierarchical multiple regressions, the results demonstrated a different pattern in the respective age groups. In the young Digit Symbol Coding accounts for 14% of the variance, relative to Letter Number Sequencing, which does not accounts for any variance of TI accuracy. In the older adults it seems that the verbal reasoning accounts for 22% of the variance of TI accuracy relative to Vocabulary serving as a global intelligence measure accounting for none of the variance associated with TI performance. Thus, the relatively important contribution of processing speed, working memory in TI in the young, and verbal reasoning in TI in the older group was confirmed.

How do the current results fit into existing cognitive aging literature, and the TI literature, both human and animal? Some of the results in the present study are similar to those found previously by other researchers. For example, despite differences in methodology, Morris, Craik and Gick, (1990) found that negative phrasing slowed responding and processing times, whereby all participants took longer to process sentences. These authors also found an age by negation interaction, whereby older adults' accuracy dropped relative to younger adults when the sentences were negatively phrased. The current study yielded a main effect of phrasing, while only a trend of an age by phrasing difference was observed, likely due to differences in methodology and a reduced number of participants in the current study. Morris et al., also observed a slight increase in recall performance with a quantitative increase in working memory load (longer word lists from two to five) in older participants, and in consequence proposed that younger subjects profit from additional processes, such as encoding retrieval from working memory (i.e. memory for rehearsed items or active memory) to improve their performance on longer lists. In a second experiment, Morris et al. observed an increase in performance only in the young as the word list length increased, and reduced performance in both groups with negative phrasing. Furthermore, while the older adults were slower than the younger group, the latencies for both age groups increased during negative phrasing. The authors concluded that the finding in which younger adult's performance increases as word list length increases reflects this age group's higher working memory capacity.

Similarly, Salthouse, Legg et al., (1990), used a relational reasoning task in young and older adults designed to allow examination of the relative contributions of memory and reasoning to decision accuracy and decision time by varying the number of presented premises and number of premises relevant to the decision. For example, participants were presented with premise pairs: *G and H do the OPPOSITE, E and F do the SAME, F and G do the OPPOSITE.* The questions required either one relevant premise pair, two relevant pairs or three, such as, One relevant, *If G DECREASES, what will happen to H?;* Two relevant, *if F INCREASES, what will happen to H?;* Three relevant, *If E DECREASES, what will happen to H?*. This reasoning task was designed so that on some trials, (i.e. one relevant premise) both of the variables asked about were mentioned in the same phrase, and consequently did not require integration. Therefore, trials with one relevant premise were thought to require simple storage and retrieval, while trials with two or more premises were believed to additionally require integrative reasoning; this provided a qualitative difference. Importantly, these authors found a decrease in accuracy and increase in decision time with one-relevant premise when additional non-relevant premises were presented, an effect that increased with age. This demonstrated the cost of having to process irrelevant information and then inhibit it, in order to effectively find a solution. That is, accuracy on the relational reasoning task decreased as the number of premises presented increased, with older adults showing greater declines than younger adults. While Salthouse et al. (1990) did not find age differences in the amount of time allocated to the inspection of each premise, they did find that decision times increased with greater number of premises presented in both age groups, with older adults showing greater slowing. In contrast, these authors also found that increases in the number of relevant premises had no effect on decision accuracy in either age group. The authors concluded that difficulties in encoding and maintaining information on-line, that is working memory factors, are largely responsible for age differences observed in reasoning tasks, whereas simple reasoning per se, when information remains available is not affected by aging. Conversely, Gilinsky and Judd (1994) did find age-related differences in a syllogistic reasoning task, which were only partially mediated by working memory factors based on three separate measures of working memory. Differences in methodology (e.g. different tasks, number of participants, as well as their age spans) may account for the discrepant results among these two studies.

Fisk and Sharp (2002) examined the extent to which processing speed and the central executive component of working memory might mediate age-related deficits in syllogistic reasoning. Their results showed a decline in syllogistic reasoning performance with age. They also found reasoning to correlate with the Chicago Word Fluency, word span, processing speed and psychomotor performance based a composite measure of letter comparison and pattern comparison, (similar to Symbol Search of the WAIS-III and Digit Symbol Coding tasks), education, and negatively with age. These authors present the possibility that cognitive resources in addition to working memory may subserve part of the age deficit in syllogistic reasoning. The results of the current study with respect to reduced accuracy in older adults relative to young, and in particular the correlations between the tasks and processing speed as well as psychomotor performance are similar to those found by Fisk and Sharp.

A proposed model of the cognitive processes involved during TI in the present study with premises present or absent is shown in Figure 20. For premises present, participants needed only to examine the premises, wait until the TI question was

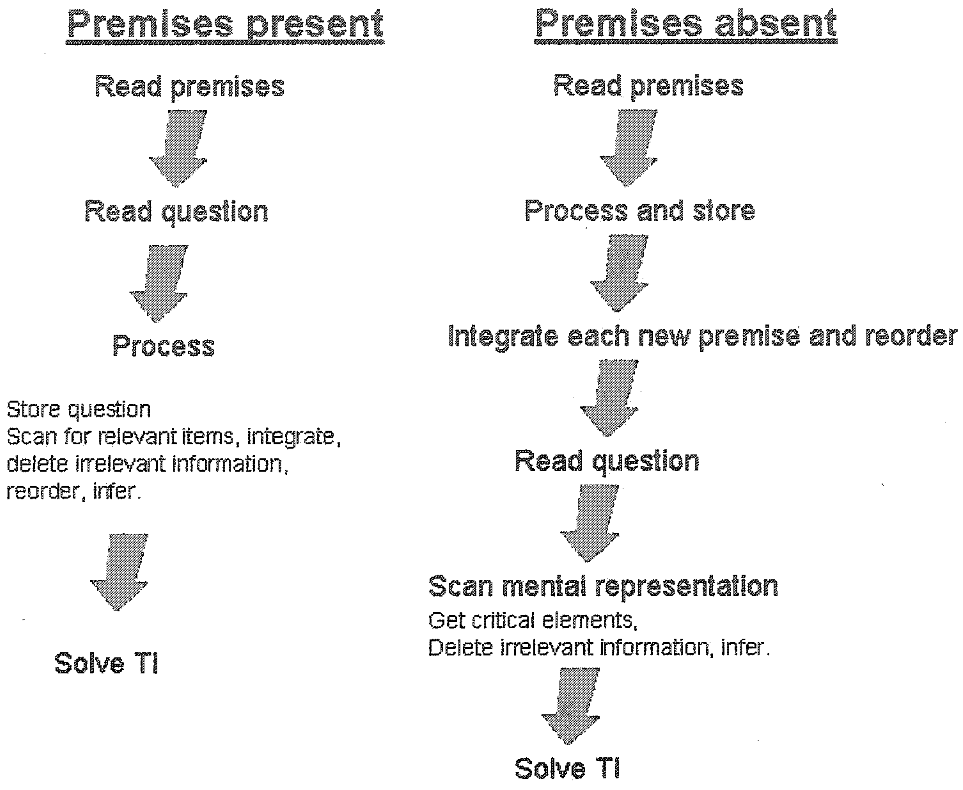


Figure 20. Model of sequential cognitive processes which occur during Transitive Inference Task.

presented, and then, knowing which elements to compare, review, integrate, infer and re-order the premise elements to arrive at a logical solution. Although cognitive processing had to occur to order the elements logically, working memory load was presumed to be minimal, for example, consisting of the relative hierarchy in which particular elements were located depending on different premises relations. In contrast, premises absent represented a larger working memory load. Participants had to remember the relationship of elements in each premise, integrate, infer and re-order them logically as each new premise appeared. This had to be held in working memory until the TI question was presented, after which participants had to scan the hierarchy of elements in working memory to arrive at the logical solution. Premises that were negatively phrased induced more of a cognitive load compared to premises that were positively phrased because one more processing step had to be made to reverse and then deduce the relation between elements in each premise. If the relationship between accuracy or reaction time and processing speed or working memory load was completely linear, the participants' performance and speed should have declined and increased respectively, with an increase in either load. However, the data in both Studies 1 and 2 reveal a curvilinear distribution of responses, in which the task with the highest cognitive and working memory load (premises absent, negatively phrased) induced the lowest accuracy, but also the shortest response latency, in both age groups. It is presumed that both age groups could not overcome the working memory load imposed by having to remember all the premise elements and their relations to one another, and likely made their best guess in the shortest amount of time after the question was posed. It may be the case that reducing the number of premises in this condition or increasing inspection time would be less taxing on working memory, and reveal a corresponding increase in accuracy and response latency, but this would have to be examined empirically. In the premise present condition, the cognitive load imposed by negative phrasing decreased accuracy and increased latencies in a relatively linear fashion. It remains to be determined whether the drop in accuracy among the young participants given four premises would hold in a study that utilized a larger sample size and tested them only using premises present.

The animal TI literature has been very stringent and methodical in applications of varied manipulations, whereas in the human TI literature this is not the case. Part of the rationale of the present studies was an attempt to bridge the gap, in the level of complexity of TI manipulations, between human TI research and that found in the animal literature. This was carried out specifically by increasing the number of premises in a linear fashion, and extending the premise size to at least five, as typically carried out in TI experiments with animals. The human TI studies typically use three-term problems, whereas the present studies varied the presentation between three, four, and five-term problems. Additionally, the level of task complexity was varied by using negative phrasing and having premises absent during TI problem solving. These manipulations were meant to tap working memory, which had not been previously attempted. Within the human literature there was also a lack of TI research in both healthy young adults, as well as healthy ageing adults, and so these populations were the focus of the two studies undertaken in this thesis. Visual inspection of older adults' performance, at three terms in Figure 6 reveals evidence of having created the desired step-wise downward effect in accuracy performance, delineated by the various condition manipulations.

The overall conclusions that can be derived from this study are that younger adults have greater accuracy in this TI task than older adults, although differences in reaction time between the two age groups were not found in any condition. For both age groups, conditions with premises present were easier to solve than premises absent. And for both age groups, positively-phrased premises were easier to solve than negatively-phrased premises. In the premises present conditions, a linear increase in reaction time was observed with increasing numbers of premises for both age groups. In this same condition, a decrease in accuracy was also found in older adults when confronted with an increased number of premises. However, a linear decrease in accuracy was not observed in this condition when either age group was confronted with an increased number of premises. In contrast, the premises absent condition resulted in a floor effect for reaction time in both age groups. These data suggest that, in general, as the task complexity and/or working memory load increased, performance decreased. This was reflected more in accuracy than reaction time; however, reaction time was slowed somewhat by negative phrasing in the premises present condition. Most of these results were consistent across both studies. Therefore, despite the different designs in each study, the overall similarities indicate that the age differences observed in TI performance in both studies are reliable. Furthermore, overall TI performance seemed to rely on different processes in the young and the older adults; in the young processing speed and working memory are contributing factors, while in the older adults, verbal reasoning, linguistic skill and general intelligence seemed to contribute, and potentially aspects of executive/frontal abilities.

Direction for future research/limitations.

Certain limitations are apparent in the current studies and merit consideration. The TI task with all the manipulations applied in this study was quite complex and would require modification to reduce some of the variables. It might have been more straightforward to analyze the effects of premises present versus absent independently from conditions in which positively-phrased versus negatively-phrased stimuli were presented. However, the findings in this study demonstrate that the use of premises absent was quite difficult for all participants, and although it would not be useful to study age differences, it might be useful in parametric studies of the processes involved in the TI task. While the use of negative phrasing was useful to reveal age differences in TI accuracy, the processes supporting this aspect of the task may be qualitatively different and therefore its usefulness may be limited to examinations of reaction time either in general among healthy young adults or among different age groups. The use of premises present yielded the most reliable and interpretable results in terms of accuracy and reaction time. The manipulation of premise number only led to linear effects in reaction time. In the case of the young it may be that in conditions with premises present five premises were not difficult enough to reveal a reduction in accuracy. Including a wider range of premise number (i.e. two to six or seven) may reveal more pronounced within effects and lend further support to the age differences observed. Both the reaction time and accuracy measures were valuable in trying to elucidate potential cognitive processes involved during TI and in revealing potential age differences and similarities during the various manipulations of this task. For example, the finding that older adults took longer to respond during the TI task while their accuracy dropped relative to their performance during other conditions, suggests that they are not benefiting from the available information or employing the same strategies as the younger group. Similarly, the finding that both groups' TI responding quickened while performance decreased in premises absent, demonstrates that improved accuracy does not necessarily follow faster responding. Therefore, future related studies should be mostly limited to premises present with a wider range of premise number examining both accuracy and reaction time measures.

The relatively low number of participants limited the statistical power of the analyses, especially with regard to correlations and multiple regressions. Including a larger sample in related future studies would remedy this problem, and further lead to more reliable TI effects. Similarly, increasing the number of trials in the TI task would lead to more stable and reliable measures, which would be of particular value with regard to reaction time given the visually apparent linear effects in both studies (see Figure 7 and Figure 10). The average level of education for all participants attains university level. Based on comments by Fisk and Sharp (2002), the participants' level of education in these two studies were not variable enough, likely too high, and therefore has potentially limited generalizability with regard to the general population. Creating groups with varying levels of education, with large sample sizes in each group, would allow examination of whether TI performance varies with levels of education. Increasing sample size and increasing spread of TI performers (i.e. finding individuals who have differing levels of ability on TI) to examine correlations with various neuropsychological measures, would be another way to further tease apart cognitive processes involved in TI. Studying good TI performers relative to a range of TI performers may be helpful in deciphering what strategies good performers apply differently than individuals who perform less well. Despite the fact that an order of presentation effect was ruled out in this study, it would be prudent to yoke the two age groups rather than using one Latin square for all participants, to ensure equal distribution of presentation order across both groups. In addition to suggesting a larger sample size, and a more educationally representative sample, the inclusion of very older adults, (i.e. older than 80 years) might add specificity to the age related decrements, and further allow division of older individuals into sub-groups (e.g. 60-70 and 71++, or by decade).

In the current studies, only 2 practice trials using three-term premises were offered prior to each TI condition. This may not have been sufficient to prepare participants and improve their chances of performing well. Adding a greater number of practice trials with the full range of premise manipulations would be advisable in future studies. As one alternative, adding an initial learning phase to 80% criterion level is recommended to help increase participants' performance scores and reduce error variance in future studies. This would lead to more stable and reliable results (for both ANOVAs and correlations), and if the same divergent pattern of correlations between the young and older group still emerged then it can be deemed a real difference, pointing to the exploitation of unique resources. It would be interesting to see if older adults were indeed able reach this level of performance training. If training were indeed successful in improving performance, this would, and therefore have positive implications for cognitive rehabilitation. If the training was only successful in young and not older adults or indeed only a portion of them, this information would also help to reveal aspects of age sensitive abilities in either general aging or a subgroup of aging adults. In the same vein, including very older adults, as mentioned, and then sorting participants by decade could elucidate subgroups based on age or functional deficits (i.e. individual patterns of reduced performance on certain neuropsycholgical tests). However, it may not be practical to spend unlimited time training all participants to this high criterion and further, it may not be possible for older adults to reach this level of ability. Thus another way to carry this out would be using an ascending series of task complexity (i.e. number of premises: 2, 3, 4, 5, 6, 7) and study the "breaking point" (i.e. the task difficulty level at which the individual drops to chance levels or below). Participants could be equated whether young, older, or patient populations based on their performance.

Another way to remove confounds and improve performance might be to create a delay between TI trials, and use auditory and visual cue READY frame before onset of each trial. This might give participants a quick break between trials and ensure attention. Amending the format of the TI question from forced choice to a recognition (True/False) test may also simplify the task and elicite more automatic responses by tapping into implicit knowledge. The addition of motor speed measures, (e.g. key reach and press subtract) and WAIS-III Digit Copy may also help to statistically eliminate some of the variance involved in TI task responding. Given that reliable correlations were not found with Matrix Reasoning, assuming a larger sample size, including additional measures of non-verbal and verbal, as well as spatial reasoning such as, the Block Design of the WAIS-III, which is a visuo-spatial problem solving task, the Spatial Location of the WMS-III, the Ravens Progressive Matrices, the Tower of London, tests of discourse comprehension, syllogistic reasoning might help to examine overlapping abilities using Cluster or Factor Analyses. Furthermore, adding a non-verbal TI task, as well as the use of symbols may help to determine if TI, through different modalities, would be subserved by similar cognitive processes and brain areas. It would be interesting to compare accuracy results and neuropsychological data between a TI task that is visual-spatial in nature and TI premises present at various premise sizes. Previous human studies suggest that verbal TI may call upon frontal areas whereas nonverbal TI may call upon temporal areas. Similarly, use of non-linguistic, abstract, novel symbols may produce different results and be shown to rely on different or alternatively similar processes as TI with premises present.

Further examination of the inverted-U effect with premises absent would be required to see if it turns out to be reliable. It would then be logical to test the hypotheses of heightened arousal or even numbered chunking. Based on participants' reports during post-TI testing about their strategies and impressions of the task, premises absent seemed to be more stressful, anxiety provoking and more difficult. In the same vein, participants could be questioned afterwards with regard their impression of the task when presented with four premises. Although participants were debriefed regarding TI, examiners did not yet have preconception about reduced performance with four terms to specifically inquire about it. Furthermore, measures of arousal (ex: self-report or EMG and EEG techniques) could be used to test the hypothesis predicting higher levels of arousal during task manipulations and increasing premise size. Additionally, including six terms in the premise number manipulation could also help elucidate what might be occurring to yield inverted U shaped curve with use of four premises. If it is the case that even numbered premises are easier to chunk, encode and remember than odd numbers of premises then TI accuracy should increase relative to odd numbered premise sizes.

In the animal literature, the TI tasks are typically used in the context of odour cues paired with spatial locations for reward, which thus far seem to primarily call upon medial temporal regions (hippocampal and parahippocampal areas) of the brain (Dusek & Eichenbaum, 1997). Some researchers consider deductive reasoning and TI in humans (whether verbal or non-verbal, abstract or concrete), to require spatial manipulation, and therefore necessitate visuo-spatial processing (Johnson-Laird, 1994; Goel & Dolan, 2001) or linear gradient spatial navigation (Adams & Jacobs, 2001). This view predicts occipital-parietal-frontal network activation, and medial temporal lobe (hippocampal) activation in TI, for which data has been found (Goel & Dolan) and (Adams & Jacobs) respectively. Perhaps the younger adults are applying an imagery or linear spatial mapping technique to establish a mental hierarchy among premise terms. Furthermore, some young participants reported only reading the first letter of the premise names; effectively changing the concrete nature of the task to abstract. These issues can be partially addressed by including the some of the visuo-spatial and spatial memory neuropsychological measures suggested.

There seems to be two further bifurcations in the application of TI in humans: non-verbal TI tasks are thought to be mediated by the temporal lobes based on studies using fMRI brain imaging (Heckers, Zalesak, Weiss, Ditman & Titone, 2004), while verbal TI tasks are thought to be mediated by the Frontal lobes, based on studies using patient populations with known brain damage or deficits (Waltz et al., 1999; Fales, Knowlton, Holyoak, Geschwind, Swerdloff & Gonzalo, 2003). Waltz et al. found patients with known prefrontal damage (Frontal variant of Fronto-temporal dementia) have impaired ability in performing a verbal TI task, which was very similar to the one utilized in the current study. Similarly, Fales et al. examined TI using the same task as Waltz et al., in patients with Klinefelter's syndrome. Klinefelter's syndrome is genetic disorder characterized by the presence of a YXX chromosome structure, typically resulting in a variety of physical abnormalities and mild cognitive deficits including, attention deficit disorder, sensory integration problems, language based delays, and an overall IQ of approximately 20 points lower than average. Fales et al. found that patients with Klinefelter's syndrome, to have difficulty with both TI and a working memory task (n-back), while these patients performed normally on non-verbal reasoning measures. It would therefore be logical that the TI task used in this study would also be considered a frontal task. However, during three verbal reasoning tasks (syllogistic, spatial, relational) Goel, Gold, Kapur, and Houle (1998) found left hemisphere activation in both frontal and temporal brain areas. Additionally, Acuna, Eliassen, Donoghue & Sanes, (2002) used Functional MRI to examine cortical areas engaged while young adults solved non-verbal (visually presented shapes) TI problems. These authors found participants' reaction times slowed as the number of intervening items increased, and percent correct was inversely correlated with reaction time. The corresponding neuroimaging data revealed that different cortical networks were activated during TI versus 'support processes' including: rule application, decision processes, perception, and movement. The TI reasoning network included bilateral prefrontal cortex (PFC), pre-supplementary motor area (preSMA), Brodmann area 8, premotor area (PMA), insula, precuneus, and lateral posterior parietal cortex. In contrast, cortical regions activated by support processes included the bilateral supplementary motor area (SMA), primary motor cortex (M1), somatic sensory cortices, and right PMA. Acuna et al. considered these results to emphasize the role of a prefrontal-parietal network in manipulating information to form new knowledge based on familiar facts. Their findings also demonstrated PFC activation beyond short-term memory to include mental operations associated with reasoning. Unfortunately, these authors did not include scans of the medial temporal lobes. The particular brain areas elicited by the TI task used in the current study has yet to be examined directly using any imaging or neurophysiological technique. In addition, the present study failed to find a reliable relationship between neuropsychological measures of frontal – executive function and TI. Thus, the nature of the task, and the brain regions that support it, remain to be identified, and the brain activation studies outlined above only serve to suggest involvement of multiple brain areas. The use of different methodologies along with different reasoning and TI tasks appear to activate different regions of the brain, (e.g. syllogistic, spatial, relational; verbal versus non-verbal; concrete versus abstract; varied stimuli, method of presentations and method of responding; variations of load and different types of complexity; inclusion of invalid problems; inclusion of irrelevant stimuli), demonstrating a lack in standardized tests, so it cannot yet be stated unequivocally which regions of the brain are important for this TI task.

De Toledo-Morrel, Morrell, Wilson, Bennett and Spencer (1997), demonstrated that the medial temporal lobe structures were the earliest areas to be affected by Alzheimer's disease. Schnirman (2002) used a TI task in a sample of non-demented older adults with hippocampal atrophy and found females' performance on the transitive inference tests revealed a significant effect of hippocampal atrophy on transitive probe errors. According to findings by Waltz et al. (1999), patients would be expected to perform as well as healthy controls. However, D. Titone (personal communication, April, 19, 2004) reported that the even mildly impaired Alzheimer patients studied had a lot of difficulty learning the premise pairs in the non-verbal TI task; the same task which Heckers, Zalesak, Weiss, Ditman and Titone (2004) had previously demonstrated hippocampal and parahippocampal involvement in healthy young adults. How Alzheimer's patients might be expected to do largely depends on which processes one believes to underwrite TI. It may be worthwhile to examine the TI task, with premises present and a greater range of premise numbers, in patients with Alzheimer's disease compared to both age matched controls and young adults, to evaluate their ability to perform the task; if deficits were found it could become a valuable albeit global diagnostic tool. Although TI seems thus far to depend on several cognitive processes, if the task proves to be sensitive it may be useful as a first level, screening test to evaluate the presence of cognitive difficulties. With accompanying structural or functional MRI scans, use of TI in patient populations may additionally help to identify processes and brain areas involved in the task. Further, such data could help to determine whether brain activation is different or dysfunctional in individuals with memory or cognitive impairments. Similarly, it could be of benefit to examine older individuals with mild cognitive impairments. Fales et al. (2003) conducted a study in men with Kleinfelter's Syndrome. Their patients exhibited deficits on both a TI task, in which participants ordered a set of names based on a list of propositions about the relative heights of the people named and a working memory task (N-back, which uses letters as stimuli), while their non-verbal problem solving on (Raven's Progressive Matrices). This deficit in TI was present even for items in which the propositions were given in order, where a chaining strategy could be applied. The authors proposed that men with KS have intact nonverbal reasoning abilities, but that a difficulty in encoding verbal information into working memory may underlie their executive and linguistic impairments.

In the present studies, TI was shown to be sensitive to the effects of aging in healthy adults. The collection of correlational analyses conducted in Study 2 all reveal a different pattern between the older and younger group with measures of TI performance and neuropsychology. These findings support the idea that the TI task may be tapping into different cognitive resources in the older participants than in the young. The exact nature of these differing resources, and its corresponding neurobiology remains for future research to elucidate. However, the preliminary findings in this study suggest investigations should include measures of verbal reasoning in the older individuals, and areas which subserve some aspects of executive function and linguistic skill, while in the young, measures related to working memory and processing speed, and brain regions which subserve them.

In summary these studies contribute to the existing literature by including more manipulations of memory load (i.e. greater number of premises), more manipulations of task complexity (i.e. premises absent and negative phrasing) and correlational data, which provide more ammunition to suggest that older individuals use different strategies than young individuals. The manipulation of TI with premises absent was too difficult for both age groups. The manipulation with negative phrasing was more difficult for the older group relative to the young, and may be useful in instances where it is desirable to tax older adults' executive functioning.

References

Adams, M. M., & Jacobs, L. F. (2001). Sex differences in logical inference predicted by the dual map model of spatial navigation. Abstract, *29th Annual Meeting for Society for Neuroscience,* San Diego, CA.

Babcock, R. L. (1994). Analysis of adult age differences on the Raven's Advanced Progressive Matrices Test. *Psychology and Aging, 9,* (2), 303-314.

Babcock, R. L., & Salthouse, T. A. (1990). Effects of increased processing demands on age differences in working memory. *Psychology and Aging, 5,* 421-428.

Bachevalier, J., Landis, L.S., Walker, L.C., Brickson, M. Mishkin, M., Price, D. L., & Cork, L. C. (1991). Aged monkeys exhibit deficits indicative of widespread cerebral dysfunction. *Neurobiology of Aging, 12,* 99-111.

Baddeley, A. D. (1981). The concept of working memory: A view of its current state and probable future development. *Cognition, 10,* 17-23.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 8, pp.47-89). New York: Academic Press.

Baddeley, A. D., & R. H. Logie (1999). Working memory: The multiple –component model. In Miyake, A. & Shah, P. (Eds.), *Models of Working Memory: Mechanisms of active maintenance and executive control,* (Chapter 2, pp 29-61), Cambridge, Cambridge University Press.

Baddeley, A. D (1995). Working memory. In Gazzaniga, M, S. (Ed.), *The Cognitive Neurosciences*, (Chapter 47, pp. 755-766), Cambridge, MA.: Bradford Books, MIT Press.

Baddeley, A. D. (1992). Working memory. *Science, 225,* 556-559.

Baltes, P.B. (1987). Theoretical propositions of life-span developmental psychology: On the dynamics between growth and decline. Developmental Psychology, 23, (5), 611-626.

Baltes, P. B., & Lindenberger, U. (1997). Emergence of a powerful connection between sensory and cognitive functions across the life span: A new window to the study of cognitive ageing? *Psychology and Aging, 12,* (1), 12-21.

Bechera, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science, 275,* 1293-1295.

Belmore, S. M. (1981). Age-related changes in processing explicit and implicit language. *Journal of Gerontology, 36,* (3), 316-322.

Bryant, P. E., & Trabasso, T. (1971). Transitive inferences and memory in young children. *Nature, 232,* 456-458.

Cabeza, R., McIntosh, A.R., Tulving, E., Nyberg, L., & Grady, C.L. (1997b). Age-related differences in effective neural connectivity during encoding and recall. *Neuroreport, 8,* 3479-3483.

Carpenter, P. A., Just, M. A., & Shell, P. (1990). What one intelligence test measures: A theoretical account of the processing in the Raven Progressive Matrices Test. *Psychological Review, 97,*(3), 404-431.

Catell, R. B. (1963). Theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology, 54,* 1-22.

Crossley, M., & Hiscock, M. (1992). Age-related differences in concurrent-task performance of normal adults: Evidence for a decline in processing resources. *Psychology and Aging, 7,* 499-506.

Cohen, G. (1981). Inferential reasoning in old age. *Cognition, 9,* 59-72.

Cohen, G. (1979). Language comprehension in old age. *Cognitive Psychology, 11,* 412-429.

Cohen, J.D., Perlstein,W.M., Braver, T.S., Nystrom, L.E., Noll, D.C., Jonides, J., & Smith, E.E. (1997). Temporal dynamics of brain activation during a working memory task. *Nature, 386,* 604-608.

Daigneault, S., & Braun, C. M. J. (1993). Working memory and the self-ordered pointing tassk: Further evidence of early prefrontal decline in normal aging. *Journal of Clinical and Experimental Neuropsychology, 15,* (6), 881-895.

Delis, D. C., Squire, L. R., Bihrle, A., & Massman, P. J. (1992). Componential analysis of problem-solving ability: Performance of patients with frontal lobe damage and amnesic patients on a new sorting test. *Neuropsychologica, 30,* 683-697.

Della Sala, S., & Logie, R. H. (1993). When working memory does not work: The role of working memory in neuropsychology. In F. Boller and J. Grafman (Eds.), *Handbook of Neuropsychology* (Vol. 8, pp. 1-62). Amsterdam: Elsevier Science.

D'Esposito, M., Detre, J.A., Alsop, D.C., Shin, R.K., Atlas, S., & Grossman, M. (1996). The neural basis of the central executive system of working memory. *Nature, 378,* 279-281.

De Toledo-Morrel, L., Morrell, M. P., Wilson, R. S., Bennett, D. A., & Spencer, S. (1997). Alzheimer's disease: In vivo detection of differential vulnerability of brain regions. *Neurobiology of Aging, 18,* (5), 463-468.

Dobbs, A. R., & Rule, B. G. (1989). Adult age differences in working memory. *Psychology and Aging, 4,* (4), 500-503.

Dunbar, K., & Sussman, D. (1995). Toward a cognitive account of frontal lobe function: Simulating frontal lobe deficits in normal subjects. *Annals New York Academy of Sciences, 769*, 289-304.

Dusek, J. A., & Eichenbaum, H. (1997). The hippocampus and memory for orderly stimulus relations. *Proceeding of the National Academy of Science, 94,* 7109-7114.

Fales, C. L., Knowlton, B. I., Holyoak, K. J., Geschwind, D. H. Swerdloff, R. S., & Gonzalo, I. G. (2003). Working memory and relational reasoning in Klinefelter syndrome. *Journal of the International Neuropsychology Society, 9* (6), 839-846.

Fisk, J. E., & Sharp, C. (2002). Syllogistic reasoning and cognitive ageing. *The Quarterly Journal of Experimental Psychology, 55A,* (4), 1273-1293.

Folstein, M., Folstein, S., & McHugh, P. (1975). Mini-mental state: A practical method for grading the mental state for the clinician. *Journal of Psychiatric Research 12,* 189-198.

Foos, P. W. (1989). Adult age differences in working memory. *Psychology and Aging, 4,* (3), 269-275.

Gick, M. L., Craik, F. I. M., & Morris, R. G. (1988). Task complexity and age differences in working memory. *Memory & Cognition, 16*, (4), 353-361.

Gilinsky, A. S., & Judd, B. B. (1994). Working memory and bias in reasoning across the life span. *Psychology and Aging, 9,* (3), 356-371.

Grady, C. L. (1998). Brain Imaging and age-related changes in cognition. *Experimental Gerontology, 33,* (7/8), 661-673.

Goel, V., & Dolan, R. J. (2001). Functional neuroanatomy of three-term relational reasoning. *Neuropsychologia, 39,* 901-909.

Goel, V., Gold, B., Kapur, S., & Houle, S. (1998). Neuroanatomical correlates of human reasoning. *Journal of Cognitive Neuroscience, 10,* (3), 292-302.

Halford, G. S. (1984). Can young children integrate premises in transitivity and serial order tasks? *Cognitive Psychology, 16*, 65-93.

Halford, G.S., Wilson, W.H., & Phillips, S. (1998). Processing capacity defined by relational complexity: Implications for comparative, developmental, and cognitive psychology. *Behavioral and Brain Sciences, 21,* 803-864.

Hartman, M. Bolton, E., & Fehnel, S. E. (2001). Accounting for age differences on the Wisconsin Card Sorting Test: Decreased working memory, not inflexibility. *Psychology and Aging, 16,* (3), 385-399.

Hartley, A. A. (1992). Attention. In Craik, F. I. M. and Salthouse, T. A.. (Eds.), *The handbook of cognitive aging and cognition.* Chapter 1. New Jersey: Lawrence Erlbaum Associates.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In Bower, G. H. (Ed.), *The psychology of learning and motivation: Advances in research and theory,* Vol. 22, pp.193-225. San Diego: Academic Press.

Heaton, R. K., Chelune, G. J., Talley, J. L., et al. (1993). *Wisconsin Card Sorting Test. Manual: Revised.* Odessa, FL: Psychological Assessment Resources.

Heckers, S., Zalesak, M., Weiss, A. P., Ditman, T., & Titone, D. (2004). Hippocampal activation during transitive inference in humans. *Hippocampus, 14,* (2), 153-162.

Horn, J. L., & Cattell, R. B. (1967). Age differences in fluid and crystallized intelligence. *Acta Psychologica, 26*, 107-129.

Inhelder, B. & Piaget, J. (1958). The growth of logical thinking from childhood to adolescence: An essay on the construction of formal operations. London: *Routledge & Kegan, Paul.*

Inhelder, B., & Piaget, J. (1964). The early growth of logic in the child. London: *Routledge & Kegan, Paul.*

Just, M., & Carpenter, P. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99*, 122-149.

Kaufman A. S., & Lichtenberger, E. O. (1999). *Essentials of WAIS-III Assessment,* (pp 187-200). New York: John Wiley & Son, Inc.

Kolb, B., & Whishaw, I. Q., (1996). *Fundamentals of human neuropsychology (*4th ed.), University of Lethbridge, New York: W.H. Freeman and Company.

Levine, B., Cabeza, R., McIntosh, A. R., Black, S. E. , Grady, C. L., & Stuss, D. T. (2002). Journal of Neurology, Neurosurgery and Psychiatry, 73, 2, 173-181.

Levinoff, E.J., Phillips, N.A., Verret, L., Babins, L., Kelner, N., Akerib, V., & Chertkow, H. Cognitive estimation impairment in Alzheimer disease and mild cognitive impairment. Submitted to *Neuropsychology.*

Lezack, M.D. (1995). *Neuropsychological Assessment* (3rd ed.). New York: Oxford University Press.

Li, K. Z., & Lindenberger,U. (2002). Relations between aging sensory/sensorimotor and cognitive functions. *Neuroscience Biobehavioral Reviews, 26,* (7), 777-783.

Light, L.L., Zelinski, E. M., & Moore, E. M. (1982). Adult age differences in reasoning from new information. Journal of Experimental Psychology: *Learning, Memory, and Cognition, 8,* (5), 435-447.

Lindenberger, U., Mayr, U., & Kliegl, R. K. (1993). Speed and intelligence in old age. *Psychology and Aging, 8,* (2), 207-220.

Lindenberger, U., & Baltes, P. B. (1997). Intellectual functioning in old and very old age: Cross-sectional results from the Berlin Aging Study. Psychology and Aging, 12, (3), 410-432.

Luira, A. R. (1966). Higher cortical functions in man, *Basic Books*, New York.

Moscovitch, M., & Winocur, G. (1995). Frontal lobes, memory and aging. Annals of the New York Academy of Sciences, 769, 119-150.

Miceli, Caltagirone, Gainotti, Masullo, & Silveri. (1981). Neuropsychological correlates of localized cerebral lesions in non-aphasic brain-damaged patients. *Journal of Clinical Neuropsychology, 3,* 53-63. In O. Spreen & E. Strauss, (Eds.), A compendium of neuropsychological tests: Administration, norms, and commentary (p. 450). New York: Oxford University Press.

McGonigle, B.O., & Chalmers, M. (1977). Are monkeys logical? *Nature, 267,* 694-696.

Milner, B., & Petrides, M. (1984). Behavioral effects of frontal-lobe lesions in man. *Trends in Neuroscience, 7,* 403-407.

Moscovitch, M., & G. Winocur, G. (1995). Frontal lobes, memory, and aging. *Annals New York Academy of Sciences, 769,* 119-151.

Owens, A. M., Downes, J. J., Sahakian, B. J., Polkey, C. E., & Robbins, T. W. (1990). Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia, 28,* 1021-1034.

Pachana, N. A., Boone, K. B., Miller, B. L., et al., (1996). Comparison of neuropsychological functioning in Alzheimer's disease and frontotemporal dementia. *Journal of the International Neuropsychological Society, 2,* 505-510. In O. Spreen & E. Strauss, (Eds.), A Compendium of Neuropsychological Tests: Administration, norms, and commentary (pp. 450-451). New York: Oxford University Press.

Piaget, J. (1928). Judgment and reasoning in the child. London: *Routledge & Kegan, Paul.*

Piaget, J., & Inhelder, B. (1959). The child's conception of space. London: *Routledge & Kegan, Paul.*

Piaget, J., & Inhelder, B. (1960). The child's conception of geometry. London: *Routledge & Kegan, Paul.*

Ponds, R. W., Brouwer, W. H., & Van Wolffelaar, P. C. (1988). Age differences in divided attention in a simulated driving task. *Journals of Gerontology, 43*, (6), 151-156.

Prabhakran, V., Smith, J. A. L., Desmond, J. E. Glover, G. H., & Gabrieli, J. D. E. (1997). Neural substrates of fluid reasoning: An fMRI study of neocortical activation during performance of the Raven's Progressive Matrices Test. *Cognitive Psychology, 33,* 43-63.

Rapp, P. R., & Amaral, D. G. (1989). Evidence for task-dependent memory dysfunction in the aged monkey. *Journal of Neuroscience, 9,* 3568-3576.

Raven, J. C. (1976). Standard progressive matrices: Sets A, B, C, D, & E. Oxford: *Oxford Psychological Press.*

Salthouse, T. A. (2001). Attempted decompostion of age-related influences on two tests of reasoning. *Psychology and Aging, 16,* (2), 251-263.

Salthouse, T. A. (1988). Resource-reduction interpretations of cognitive aging. *Developmental Review, 8,* 238-272.

Salthouse, T. A. (1990). Working memory as a processing resource in cognitive aging. *Developemental Review, 10,* 101-124.

Salthouse, T. A. (1991a). *Theoretical perspectives on cognitive aging.* Hillsdale, N.J.: Lawrence Erlbaum Associates.

Salthouse, T. A. (1991b). Mediation of adult age differences in cognition b reduction in working memory and speed of processing. *Psychological Science, 2,* 179-183.

Salthouse, T. A. (1995). Redefining the concept of psychological compensation. In R. A. Dixon & L. Bäckman (Eds.), *Compensating for psychological deficits and declines: Managing losses and promoting gains* (pp. 21-34). Mahwah, NJ: Lawrence Erlbaum Associates.

Salthouse, T. A. (1992). Reasoning and spatial abilities. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 167-211). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Salthouse, T. A. (1993a). Influence of working memory on adults age differences in matrix reasoning. *British Journal of Psychology, 84,* 171-199.

Salthouse, T. A. (1993b). Speed mediation of adult age differences in cognition. *Developmental Psychology, 29,* 722-738.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103,* 403-428.

Salthouse, T. A., & Babcock, R. L. (1991). Decomposing adult age differences in working memory, *Developmental Psychology, 27,* (5), 763-776.

Salthouse, T., Babcock, R. L., & Shaw, R. J. (1991). Effects of adult age on structural and operational capacities in working memory. *Psychology and Aging, 6,* 118-127.

Salthouse, T. A., Legg, S., Palmon, R., & Mitchell, D. (1990). Memory Factors in Age-Related Differences in Simple Reasoning. *Psychology and Aging, 5,* (1), 9-15.

Salthouse, T.A., Mitchell, D. R. D., Skovroneck, E., & Babcock, R. L., (1989). Effects of adult age and working memory on reasoning and spatial abilities. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* (3), 507-516.

Schnirman, G. M. (2002). Predicting hippocampal atrophy in a sample of non-demented older adults at increased risk for Alzheimer's disease with two novel memory transfer tests. *Dissertation Abstracts International: Sectoin B: The Sciences and Engineering, 62,* (12-B): 5567.

Shallice, T., & Evans, M. E. (1978). The involvement of the frontal lobes in cognitive estimation. *Cortex, 14,* 294-303.

Shallice, T., & Burgess, P. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain 114,* 727-741.

Shimamura, A. P. (1995). Memory and the prefrontal cortex. *Annals New York Academy of Sciences, 769,* 151-159.

Shimamura, A. P. (1995). Memory and frontal lobe function. In Gazzaniga, M. S. (Ed.), *The Cognitive Neurosciences*, (Chapter 51, pp. 803-813). Cambridge, MA: Bradford Books, MIT Press.

Smedslund, J., (1969). Psychological diagnostics. *Psychological Bulletin,71*, (3) 237-248.

Smith, M. D. (1980). Memory and problem-solving in aphasia. *Cortex, 16,* 51-66.

Smith, E. E., & Jonides, J. (1998). Neuroimaging analyses of human working memory. *Proceedings of the National Academy of Science USA, 95,* 12061-12068.

Spreen, O., & Strauss, E. (1998). A compendium of neuropsychological tests (2nd ed.). New York: Oxford University Press.

Sternberg, R. J. (1980). The development of linear syllogistic reasoning. *Journal of Experimental Child Psychology, 29,* 357-370.

Sternberg, R. J. (1980). Representation and process in linear syllogistic reasoning. *Journal of Experimental Psychology: General, 109,* (2), 119-159.

Stolzfus, E. R., Hasher, L., Ulivi, M. S., et al. (1993). Investigations of inhibition and interference in younger and older adults. *Journals of Gerontology, 48*, (4), 179-188

Stuss, D. T., Eskes, G. A., & Foster, J. K. (1994). Experimental neuropsychological studies of frontal lobe functions. In Boller, F. & Grafman J. (Eds.), *Handbook of Neuropsychology,* (Chapter 6, Vol. 9, pp. 149-185). Amsterdam: Elsevier Science.

Waltz, J. A., Knowlton, B. J., Holyoak, K. J., Boone, K. B., Mishkin, F. S., de Menezes Santos, M., Thomas, C. R., & Miller, B. L. (1999). A system for relational reasoning in human prefrontal cortex. *Psychological Science, 10,* (2), 119-125.

Wechsler, D. (1997). Wechsler Adult Intelligence Scale-III. New York: Psychological Corporation.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120,* (2), 272-292.

West, R., & Alain, C. (2000). Age-related decline in inhibitory control contributes to the increased Stroop effect observed in older adults. Psychophysiology, 37, (2),179-89.

Wingfield, A., Stine, E. A. L., Lahar, C. J., & Aberdeen, J. S. (1988). Does the capacity of working memory change with age? *Experimental Aging Research, 14,* (2), 103-107.

Appendix A

Health Questionnaire

Health Questionnaire

Interviewer: ____________________ Date: ________________

Vacation Plans: ________

In this research, we need to know whether there are factors, in addition to the ones we are studying, that may be affecting the results. Your answers to a few short questions will aid us in this effort. All answers will be kept strictly confidential. Thank you for your help.

Demographics

- Name:
- Phone Number: Source:
- Date of Birth: Age:
- Gender:
- Handedness:

Language

- Place of Birth:
- Languages Spoken:
- Primary Language/Language of Choice:
- Language at home: At Work:
- Language of Education:
- When did you first learn English?
- When did you become fluent in it?
- *Interviewer's subjective rating of subject's fluency (1-5, where one is least fluent) and comments:*

- Education - how many years including kindergarten? (finished -- primary school, highschool, college, university?)

1 2 3 4 5 6	7 8 9 10	12 13	14 15 16	17 18 19 20 21 22 23 24 25
Elementary	Secondary	Cegep	Undergrad	Graduate Professional

- Have you ever skipped or repeated a grade? Why?

- Occupation - Present:
  - Past:

  What would you consider to be/to have been your primary/main occupation?

Medical History

- Do you have now, or have you had in the past -
  - Visual problems: Nearsighted / Farsighted
    Glasses / Contact lenses
    Cataract: Left / Right
    Color blind: NO / YES

- Trouble hearing: NO / YES
Hearing Aid: Left / Right

- Have you ever been unconscious, had a head injury or had blackouts? NO / YES
  Cause:
  Duration:
  Treatment:
  Outcome:

- Have you been seriously ill or hospitalized in the past 6 months? NO / YES
  Duration:
  Cause:

If Yes - <u>Treatment</u>: With what? Since when? Current status?

Do you have now, or have you had in the past :

• Stroke	NO / YES	When?	Transient ischemic attack?
• Heart disease	NO / YES	Nature (MI, angina, narrowing of arteries):	
• High blood pressure	NO / YES	Controlled?	
• High Cholesterol	NO / YES		
• Bypass surgery	NO / YES		
• Surgery	NO / YES	Nature:	
• Seizures	NO / YES	Age Onset: Cause:	Freq: Treatment:
• Epilepsy	NO / YES		
• Diabetes	NO / YES	Type I / Type II	Age Onset:
Insulin dependent?	NO / YES	Treatment:	
• Thyroid disease	NO / YES		
• Frequent headaches	NO / YES	Tension / migraine	

• Dizziness	NO / YES
• Trouble walking/unsteadiness	NO / YES
• Arthritis?	NO / YES
• Any injuries to the lower limbs? (e.g. hip, knee, ankle)	NO / YES
• Serious illness (e.g. liver disease)	NO / YES
• Neurological disorders	NO / YES
• Exposure to toxic chemicals (that you know of)?	NO / YES
• Depression	NO / YES
• Anxiety	NO / YES
• (Other) psychological difficulties?	NO / YES

Medication

Type	Reason for consumption	Age/Duration of consumption/Dose

Hormone replacement? / Steroids?

Alcohol, Tobacco, Drug Consumption (1 drink = 1 beer, 1 glass of wine, 1 oz of liquor) - **Current/Past**

	Amount (per day/week/month/year)		
	Present	Past	Age of Consumption

Alcohol:

Approximately how many drinks of alcohol do you have per week?
(1 drink = 1 beer, 1 glass of wine, 1 oz of liquor) ______________________________

Tobacco (exclude if 20 pack-years)

Do you smoke? NO / YES If YES, How many packs a day? ____________________

Drug use:

Do you use non-prescription drugs for recreational purposes? NO / YES
If YES, How many times per week: (A) 1 - 3 (B) 4 - 6 (C) more than 6

Present Problems - Are you currently troubled by any of the following?

- Concentration / Attention problems NO / YES Nature:
- Memory problems NO / YES Nature:
- Difficulties finding words NO / YES Nature:

What is your **general state of health** (1-5, 1 is poor and 5 is excellent)?
How would you rate your health? *(circle response)*

1) poor 2) fair 3) good 4) very good 5) excellent

Participant contact information:

Name: ____

Address: ____

____

____

____

Phone Number: ______________________________

Are you willing to be contacted for future research? NO / YES

What year will you graduate?

Can we give your information to other Concordia researchers? NO / YES

Source: ____

Appendix B

Study 1 Source Tables for TI Analyses of Variance

Table B2

Source Table for Analysis of Variance of TI Accuracy for Study 1.

Source	*SS*	*df*	*MS*	*F*
Between Subjects				
Group (G)	22022.94	1	22022.91	62.28***
Error	8486.47	24	353.60	
Within Subjects Blocks (B)				
B	19615.17	2	11642.16	39.44***
B x G	1810.04	2	1074.31	3.64*
Premise number (P)	3133.61	2	1663.37	6.93**
P x G	1041.31	2	552.74	2.30
B x P	2611.78	4	769.10	1.92
B x P x G	2714.34	4	799.30	2.00
Error	32707.88	48	401.32	

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table B2

Source Table for Analysis of Variance of TI reaction time for Study 1.

Source	*SS*	*df*	*MS*	*F*
Between Subjects				
Group (G)	.830	1	.830	.003
Error	5271.43	22	239.61	
Within Subjects				
Blocks (B)				
B	6100.54	2	3367.44	35.77***
B x G	80.75	2	44.58	.47
Premise number (P)	649.26	2	331.37	21.12***
P x G	120.70	2	61.60	3.93*
B x P	314.66	4	102.00	5.73***
B x P x G	45.91	4	14.88	.084
Error	1208.96	88	17.81	

* $p < .05$, ** $p < .01$, *** $p < .001$.

Appendix C

MANOVAs for each age group comparing Study 1 and 2

Table C1

Studies 1 and 2 Mean and (SD) of Neuropsychological Measures in the Younger Groups.

	Study 1	Study 2	*F*	Eta squared
Matrix Reasoning	21.53	20.09	1.79	.05
	(1.69)	(3.94)		
Similarities	27.20	26.39	.47	.01
	(4.13)	(3.12)		
Letter Number	13.27	15.17	2.83	.07
	(2.96)	(3.68)		
Incidental Learning	23.07	23.91	.34	.01
	(4.69)	(4.22)		
Digit Symbol	80.2	85.60	1.15	.03
	(17.05)	(13.71)		
Logical Memory-II	15.13	16.70	1.14	.03
	(5.11)	(3.91)		
LM Retention	90.30	97.41	2.35	.06
	(17.15)	(11.49)		
CET	8.53	7.04	1.54	.04
	(3.68)	(3.57)		
Phonological Fluency	45.40	45.52	.00	.00
	(8.37)	(10.75)		
Semantic Fluency	22.47	22.48	.00	.00
	(5.84)	(3.99)		
WCST categories	6.00	5.91	.65	.02
	(.00)	(.42)		
WCST percent perseverative errors	7.20	7.70	.39	.01
	(2.11)	(2.57)		

LM Retention- Logical Memory percent retention; CET- Cognitive Estimation Test; WCST- Wisconsin Card Sorting Test.

Table C2

Studies 1 and 2 Mean and (SD) of Neuropsychological Measures in the Older Groups.

	Study 1	Study 2	*F*	Eta squared
Matrix Reasoning	14.09	14.14	.00	.00
	(5.36)	(4.62)		
Similarities	24.18	24.14	.00	.00
	(4.98)	(5.68)		
Letter Number	10.27	10.24	.00	.00
	(1.62)	(3.52)		
Incidental Learning	15.09	14.05	.26	.01
	(5.52)	(5.48)		
Digit Symbol	55.36	56.57	.05	.00
	(18.77)	(13.11)		
Logical Memory-II	13.36	12.57	.44	.01
	(3.23)	(3.22)		
LM Retention	75.43	88.24	2.94	.09
	(25.07)	(17.01)		
CET	8.36	6.62	1.29	.04
	(5.45)	(3.28)		
Phonological Fluency	47.82	44.81	.55	.02
	(9.09)	(11.68)		
Semantic Fluency	20.73	18.00	3.55	.11
	(3.26)	(4.17)		
WCST categories	5.36	5.76	.90	.03
	(1.80)	(.54)		
WCST percent perseverative errors	16.18	10.95	1.55	.05
	(17.88)	(5.59)		

LM Retention- Logical Memory percent retention; CET- Cognitive Estimation Test; WCST- Wisconsin Card Sorting Test.

Appendix D

Study 2 Source Tables for TI Analyses of Variance

Table D1

Source Table for Analysis of Variance of TI accuracy for Study 2.

Source	*SS*	*df*	*MS*	*F*
Between Subjects				
Group (G)	13723.83	1	13723.83	9.92**
Error	58133.75	42	1384.14	
Within Subjects				
Phrasing (Phrase)	2529.80	1	2529.80	4.60*
Phrase x G	1696.47	1	1696.47	3.08
Presence (Pres)	18152.96	1	18152.96	29.14***
Pres x G	9307.51	1	9307.51	14.94***
Premise number (P)	16124.29	2	8634.16	22.15***
P x G	2315.20	2	1239.73	3.18*
Phrase x Pres	3778.00	1	3778.00	11.09**
Phrase x P	3184.31	2	1919.14	4.84*
Pres x P	8343.60	2	4341.97	13.96***
Phrase x Pres x G	174.97	1	174.97	.51
Phrase x P x G	526.73	2	317.45	.80
Pres x P x G	2425.42	2	1262.18	4.06*
Phrase x Pres x P	596.62	2	312.78	1.12
Phrase x Pres x P x G	581.46	2	304.83	1.09
Error	22371.57	84	279.24	

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table D2

Source Table for Analysis of Variance of TI reaction time for Study 2.

Source	*SS*	*df*	*MS*	*F*
Between Subjects				
Group (G)	413.80	1	413.80	2,77
Error	5668.74	38	149.18	
Within Subjects				
Phrasing (Phrase)	182.17	1	182.17	6.01*
Phrase x G	1.27	1	1.27	.04
Presence (Pres)	9944.99	1	9944.99	111.39***
Pres x G	282.09	1	282.09	3.16
Premise number (P)	512.85	2	512.85	17.83***
P x G	105.12	2	53.07	3.67*
Phrase x Pres	26.22	1	26.22	.083
Phrase x P	10.94	2	5.4	.56*
Pres x P	336.02	2	169.20	11.48***
Phrase x Pres x G	2.09	1	2.09	.07
Phrase x P x G	5.42	2	2.71	.28
Pres x P x G	122.51	2	61.69	4.19*
Phrase x Pres x P	7.00	2	3.68	.41
Phrase x Pres x P x G	10.80	2	5.68	.63
Error	654.17	76	8.61	

* $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix E

Correlational analyses between TI accuracy and neuropsychological measures Study 2

Table E1

Correlations Between TI Accuracy (% correct) Block 1 and Neuropsychological Measures For Younger Group In Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Young ($n = 23$)							
1. Age	-	.22	-.19	.06	-.28	-.00	.02	-.40**	-.21	.13	-.11	-45.	-.22	.19	-.25
2. Ed.		--	.10	.24	.08	.15	.03	.13	-.46*	-.07	-.20	.04	.03	.10	-.31
3. TI B1			--	-.09	.68**	.23	.14	.45*	.06	-.55**	-.31	.12	.11	-.20	.19
4. Voc.				--	.08	.45*	.21	-.26	-.09	.19	-.29	.31	.36*	.44*	-.54**
5. Matrix					--	.36*	.20	.35	.31	-.44*	-.57**	.15	.18	.01	.01
6. Sim.						--	-.13	.05	-.34	-.44*	-.34	-.01	.02	.10	-.18
7. LN							--	.36*	.28	.10	-.18	.40*	.31	.25	-.24
8. DS								--	.18	-.29	-.04	.33	.26	-.29	.32
9. LM2									--	.13	-.24	.11	.06	.21	-.11
10. LMR										--	.36*	.09	.09	.09	-.14
11. CET											--	.25	.05	-.49**	.54**
12. P Flu.												--	.53**	-.21	.20
13. S Flu.													--	-.19	.18
14. WCST Cat														--	-.88***
15. WCST PPER															--

*$p < .05$, **$p < .01$, ***$p < .001$.

Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table E2

Correlations Between TI Accuracy (% correct) Block 2 and Neuropsychological Measures For Younger Group In Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Young (*n* = 23)							
1. Age	-	.22	-.07	.06	-.28	-.00	-.02	-.40*	-.21	.13	-.11	-.45*	-.22	.19	-.25
2. Ed.		--	-.04	.24	.08	.15	.03	.13	-.47*	-.07	-.20	.04	.03	.10	-.31
3. TI B2			--	-.34	.46*	-.02	.34	.43*	.29	-.01	-.13	-.07	-.33	.04	.07
4. Voc.				--	.08	.45*	.21	-.26	-.09	.19	-.29	.31	.36*	.44*	-.54**
5. Matrix					--	.36*	.20	.35	.31	-.44*	-.57**	.15	.18	.00	.01
6. Sim.						--	-.13	.05	-.34	-.44*	-.34	-.01	.17	.01	-.18
7. LN							--	.36*	.28	.10	-.18	.40*	.31	.25	-.24
8. DS								--	.18	-.29	-.04	.33	.26	-.29	.32
9. LM2									--	.13	-.24	.11	.06	.21	-.11
10. LMR										--	.36*	.09	.09	.09	-.14
11. CET											--	.25	.05	-.49**	.54**
12. P lu.												--	.53**	-.21	.20
13. S Flu.													--	-.19	.18
14. WCST Cat														--	-.88***
15. WCST PPER															--

**p* < .05, ***p* < .01, ****p* < .001.

Note. Ed. is Education. TI B2 is TI Accuracy in (% correct) for Block 2; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table E3

Correlations Between TI Accuracy (% correct) Block 3 and Neuropsychological Measures For Younger Group In Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Young ($n = 23$)							
1. Age	-	.22	.41*	.06	-.28	-.00	.02	-.40*	-.21	.13	-.11	-45*	-.22	.19	-.25
2. Ed.		--	.43*	.24	.08	.15	.03	.13	-.46*	-.07	-.20	.04	.03	.10	-.31
3. TI B3			--	.04	.33	.15	.34	.33	-.06	-.03	-.25	-.15	.06	-.05	-.08
4. Voc.				--	.08	.45*	.21	-.26	-.09	.19	-.29	.31	.36*	.44*	-.54**
5. Matrix					--	.36*	.20	.35	.31	-.44*	-.57**	.15	.18	.01	.01
6. Sim.						--	-.13	.05	-.34	-.44*	-.34	-.01	.02	.10	-.18
7. LN							--	.36*	.28	.10	-.18	.40*	.31	.25	-.24
8. DS								--	.18	-.29	-.04	.33	.26	-.29	.32
9. LM2									--	.13	-.24	.11	.06	.21	-.11
10. LMR										--	.36*	.09	.09	.09	-.14
11. CET											--	.25	.05	-.49**	.54**
12. P Flu.												--	.53**	-.21	.20
13. S Flu.													--	-.19	.18
14. WCST Cat														--	-.88***
15. WCST PPER															--

*$p < .05$, **$p < .01$, ***$p < .001$.

Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table E4

Correlations Between TI Accuracy (% correct) Block 4 and Neuropsychological Measures For Younger Group In Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Young ($n = 23$)							
1. Age	-	.22	.30	.06	-.28	-.00	.02	-.40*	-.21	.13	-.11	-45*	-.22	.19	-.25
2. Ed.		--	.23	.24	.08	.15	.03	.13	-.46*	-.07	-.20	.04	.03	.10	-.31
3. TI B4			--	.18	.06	-.05	.28	.17	.13	.19	-.06	.05	-.32	.18	-.23
4. Voc.				--	.08	.45*	.21	-.26	-.09	.19	-.29	.31	.36*	.44*	-.54**
5. Matrix					--	.36*	.20	.35	.31	-.44*	-.57**	.15	.18	.01	.01
6. Sim.						--	-.13	.05	-.34	-.44*	-.34	-.01	.02	.10	-.18
7. LN							--	.36*	.28	.10	-.18	.40*	.31	.25	-.24
8. DS								--	.18	-.29	-.04	.33	.26	-.29	.32
9. LM2									--	.13	-.24	.11	.06	.21	-.11
10. LMR										--	.36*	.09	.09	.09	-.14
11. CET											--	.25	.05	-.49**	.54**
12. P Flu.												--	.53**	-.21	.20
13. S Flu.													--	-.19	.18
14. WCST Cat														--	-.88***
15. WCST PPER															--

*$p < .05$, **$p < .01$, ***$p < .001$.

Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table E5

Correlations Between TI Accuracy (% correct) Block 1 and Neuropsychological Measures For Older Group In Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Older ($n = 21$)															
1. Age	-	.12	-.07	-.04	-.05	.02	-.33	-.70**	-.43*	-.22	-.13	.22	.07	-.15	-.07
2. Ed.		--	.34	.57**	.36	.66**	.24	.06	-.07	-.25	-.29	.22	.29	-.07	-.33
3. TI B1			--	.42*	.52**	.46*	.29	.07	.36	.21	-.08	.27	.34	.24	-.20
4. Voc.				--	.41*	.82**	.49*	.28	.09	.27	-.55**	.51**	.60**	.04	-.45*
5. Matrix					--	.54**	.49	.16	.42*	.47*	-.51**	.01	.26	.30	-.45*
6. Sim.						--	.51**	.16	.05	.09	-.45*	.40*	.47*	.03	-.36
7. LN							--	.37*	.43*	.30	-.40*	.29	.38*	.24	-.51**
8. DS								--	.36	.32	-.19	.27	.18	.25	-.17
9. LM2									--	.68**	-.15	-.06	.06	.43*	-.06
10. LMR										--	-.41*	.11	.08	.15	-.12
11. CET											--	-.02	-.46*	.12	.44*
12. P lu.												--	.38*	-.19	-.18
13. S Flu.													--	-.07	-.56**
14. WCST Cat														--	-.24
15. WCST PPER															--

*$p < .05$, **$p < .01$, ***$p < .001$.

Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table E6

Correlations Between TI Accuracy (% correct) Block 2 and Neuropsychological Measures For Older Group In Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Older ($n = 21$)							
1. Age	-	.12	-.05	-.04	-.05	02	-.33	-.70**	-.43*	-.22	-.13	.22	.07	-.15	-.07
2. Ed.		--	.11	.57**	.36	.66**	.24	.06	-.07	-.25	-.29	.22	.29	-.07	-.33
3. TI B2			--	.15	-.06	.26	.17	.18	.05	-.27	-.18	.23	.42*	.08	-.12
4. Voc.				--	.41*	.82**	.49*	.28	.09	.27	-.55**	.51**	.60**	.04	-.45*
5. Matrix					--	.54**	.49	.16	.42*	.47*	-.51**	.01	.26	.30	-.45*
6. Sim.						--	.51**	.16	.05	.09	-.45*	.40*	.47*	.03	-.36
7. LN							--	.37*	.43*	.30	-.40*	.29	.38*	.24	-.51**
8. DS								--	.36	.32	-.19	.27	.18	.25	-.17
9. LM2									--	.68**	-.15	-.06	.06	.43*	-.06
10. LMR										--	-.41*	.11	.08	.15	-.12
11. CET											--	-.02	-.46*	.12	.44*
12. P lu.												--	.38*	-.19	-.18
13. S Flu.													--	-.07	-.56**
14. WCST Cat														--	-.24
15. WCST PPER															--

*$p < .05$, **$p < .01$, ***$p < .001$.Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories;WCST PPER is WCST percent perseverative errors.

Table E7

Correlations Between TI Accuracy (% correct) Block 3 and Neuropsychological Measures For Older Group In Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Older ($n = 21$)							
1. Age	-	.12	.14	-.04	-.05	02	-.33	-.70**	-.43*	-.22	.13	.22	.07	-.15	-.07
2. Ed.		--	.12	.57**	.36	.66**	.24	.06	-.07	-.25	-.29	.22	.29	-.07	-.33
3. TI B3			--	.11	-.26	.16	-.25	.04	.15	.17	.26	.12	-.31	.13	.41*
4. Voc.				--	.41*	.82**	.49*	.28	.09	.27	-.55**	.51**	.60**	-.04	-.45*
5. Matrix					--	.54**	.49*	.16	.42*	.47*	-.51**	.01	.26	.30	-.45*
6. Sim.						--	.51**	.16	.05	.09	-.45*	.40*	.47*	.03	-.36
7. LN							--	.37*	.43*	.30	-.40*	.29	.38*	.24	-.51**
8. DS								--	.36	.32	-.19	.27	.18	.25	-.17
9. LM2									--	.68**	-.15	-.06	.06	.43*	-.06
10. LMR										--	-.41*	.11	.08	.15	-.12
11. CET											--	-.02	-.46*	.12	.44*
12. P lu.												--	.38*	-.19	-.18
13. S Flu.													--	-.07	-.56**
14. WCST Cat														--	-.24
15. WCST PPER															--

*$p < .05$, **$p < .01$, ***$p < .001$.Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1;
Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II;
LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency;
WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table E8

Correlations Between TI Accuracy (% correct) Block 4 and Neuropsychological Measures For Older Group In Study 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Older ($n = 21$)							
1. Age	--	.12	-.25	-.04	-.05	02	-.33	-.70**	-.43*	-.22	.13	.22	.07	-.15	-.07
2. Ed.		--	.34	.57**	.36	.66**	.24	.06	-.07	-.25	-.29	.22	.29	-.07	-.33
3. TI B4			--	.41*	.09	.46*	.42*	.31	.26	-.05	-.06	.32	-.01	.11	.01
4. Voc.				--	.41*	.82**	.49*	.28	.09	.27	-.55**	.51**	.60**	-.04	-.45*
5. Matrix					--	.54**	.49*	.16	.42*	.47*	-.51**	.01	.26	.30	-.45*
6. Sim.						--	.51**	.16	.05	.09	-.45*	.40*	.47*	.03	-.36
7. LN							--	.37*	.43*	.30	-.40*	.29	.38*	.24	-.51**
8. DS								--	.36	.32	-.19	.27	.18	.25	-.17
9. LM2									--	.68**	-.15	-.06	.06	.43*	-.06
10. LMR										--	-.41*	.11	.08	.15	-.12
11. CET											--	-.02	-.46*	.12	.44*
12. P lu.												--	.38*	-.19	-.18
13. S Flu.													--	-.07	-.56**
14. WCST Cat														--	-.24
15. WCST PPER															--

**p* < .05, ***p* < .01, ****p* < .001.Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Appendix E

Correlations between TI Blocks 1, 2 and 3 and neuropsychological measures across both Study 1 and 2

Table F1

Correlations Between TI Accuracy (% correct) Block 1 and Neuropsychological Measures For Younger Group In Study1 and 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Young (*n* = 38)							
1. Age	-	.29	-.14	.15	-.03	.32~	-.11	-.47**	-.15	.01	-.0.3	-.21	.04	.17	-.24
2. Ed.		--	-.08	.35*	.18	.26	.08	-.13	-.05	.07	-.23	.08	.19	.10	-.20
3. TI B1			--	-.08	.55**	.04	.21	.36*	.07	-.40*	-.18	.12	.10	-.15	.14
4. Voc.				--	.09	.47**	.15	-.27	.18	.30	-.40*	.34*	.45**	.33*	-.38*
5. Matrix					--	.33*	.07	.11	.20	-.27	-.34*	.15	.16	.03	-.06
6. Sim.						--	-.18	-.21	-.12	-.09	-.29	-.06	.19	.08	-.29
7. LN							--	.25	.38*	.20	-.29	.37*	.25	.16	-.05
8. DS								--	.10	-.19	-00	.23	.13	-23	.27
9. LM2									--	.50**	-.47**	.26	.17	.12	-.13
10. LMR										--	-17	.24	.26	.02	-.20
11. CET											--	-.07	-.17	-.34*	.27
12. P Flu.												--	.48**	-.18	.19
13. S Flu.													--	-.12	.10
14. WCST Cat														--	-.74**
15. WCST PPER															--

**p* < .05, ***p* < .01, ****p* < .001, ~ indicates a strong trend p = .053.
Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table F2

Correlations Between TI Accuracy (% correct) Block 2 and Neuropsychological Measures For Younger Group In Study1 and 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Young ($n = 38$)							
1. Age	-	.29	.00	.15	-.03	.32~	-.11	-.47**	-.15	.01	-.0.3	-.21	.04	.17	-.24
2. Ed.		--	.02	.35*	.18	.26	.08	-.13	-.05	.07	-.23	.08	.19	.10	-.20
3. TI B2			--	-.32~	.46**	-.04	.20	.26	.15	-.11	-.06	.04	-.30	.01	.12
4. Voc.				--	.09	.47**	.15	-.27	.18	.30	-.40*	.34*	.45**	.33*	-.38*
5. Matrix					--	.33*	.07	.11	.20	-.27	-.34*	.15	.16	.03	-.06
6. Sim.						--	-.18	-.21	-.12	-.09	-.29	-.06	.19	.08	-.29
7. LN							--	.25	.38*	.20	-.29	.37*	.25	.16	-.05
8. DS								--	.10	-.19	-00	.23	.13	-23	.27
9. LM2									--	.50**	-.47**	.26	.17	.12	-.13
10. LMR										--	-17	.24	.26	.02	-.20
11. CET											--	-.07	-.17	-.34*	.27
12. P Flu.												--	.48**	-.18	.19
13. S Flu.													--	-.12	.10
14. WCST Cat														--	-.74**
15. WCST PPER															--

*p < .05, **p < .01, ***p < .001, ~ indicates a strong trend p = .054.
Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table F3

Correlations Between TI Accuracy (% correct) Block 3 and Neuropsychological Measures For Younger Group In Study1 and 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Young (*n* = 38)							
1. Age	-	.29	.29	.15	-.03	.32~	-.11	-.47**	-.15	.01	-.0.3	-.21	.04	.17	-.24
2. Ed.		--	.23	.35*	.18	.26	.08	-.13	-.05	.07	-.23	.08	.19	.10	-.20
3. TI B3			--	-.13	.32~	.01	.24	.24	-.08	-.14	-.00	-.15	-.03	-.03	-.16
4. Voc.				--	.09	.47**	.15	-.27	.18	.30	-.40*	.34*	.45**	.33*	-.38*
5. Matrix					--	.33*	.07	.11	.20	-.27	-.34*	.15	.16	.03	-.06
6. Sim.						--	-.18	-.21	-.12	-.09	-.29	-.06	.19	.08	-.29
7. LN							--	.25	.38*	.20	-.29	.37*	.25	.16	-.05
8. DS								--	.10	-.19	-00	.23	.13	-23	.27
9. LM2									--	.50**	-.47**	.26	.17	.12	-.13
10. LMR										--	-17	.24	.26	.02	-.20
11. CET											--	-.07	-.17	-.34*	.27
12. P Flu.												--	.48**	-.18	.19
13. S Flu.													--	-.12	.10
14. WCST Cat														--	-.74**
15. WCST PPER															--

**p* < .05, ***p* < .01, ****p* < .001, ~ indicates a strong trend p = .053.
Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table F4

Correlations Between TI Accuracy (% correct) Block 1 and Neuropsychological Measures For Older Group collapsed across Study1 & 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Older ($n = 32$)							
1. Age	-	.17	-.00	.21	-.03	.20	-.32	-.60**	-.30	-.15	-.06	.26	.20	-.14	.01
2. Ed.		--	.25	.58**	.18	.60**	.06	-.17	.05	-.23	-.27	.00	.36*	-.36*	.25
3. TI B1			--	.13	.31	.29	.21	-.17	.24	-.02	-.02	.28	.42*	.08	-.03
4. Voc.				--	.35	.83**	.26	.17	.01	.05	-.52**	.23	.48**	-.25	-.00
5. Matrix					--	.52**	.39*	.28	.14	.36*	-.35*	.09	.19	.33	-.42*
6. Sim.						--	.37*	.14	-.03	.01	-.47**	.27	.49**	-.10	-.90
7. LN							--	.34~	.34~	.29	-.29	.27	.26	.22	-.32
8. DS								--	.16	.20	-.18	.12	-.03	.19	-.18
9. LM2									--	.58**	-.06	.03	.02	.25	-.11
10. LMR										--	-.19	.21	-.16	.57**	-.58**
11. CET											--	.07	-.39*	.01	.20
12. P lu.												--	.29	.23	-.33
13. S Flu.													--	-.23	.02
14. WCST Cat														--	-.87**
15. WCST PPER															--

$*p < .05$, $**p < .01$, $***p < .001$, ~ indicates a strong trend (p = .056).

Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table F5

Correlations Between TI Accuracy (% correct) Block 2 and Neuropsychological Measures For Older Group collapsed across Study1 & 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Older ($n = 32$)							
1. Age	-	.17	-.18	.21	-.03	.20	-.32	-.60**	-.30	-.15	-.06	.26	.20	-.14	.01
2. Ed.		--	.05	.58**	.18	.60**	.06	-.17	.05	-.23	-.27	.00	.36*	-.36*	.25
3. TI B2			--	.02	-.04	.15	.16	.18	.00	-.15	.04	.09	.26	.08	-.09
4. Voc.				--	.35	.83**	.26	.17	.01	.05	-.52**	.23	.48**	-.25	-.00
5. Matrix					--	.52**	.39*	.28	.14	.36*	-.35*	.09	.19	.33	-.42*
6. Sim.						--	.37*	.14	-.03	.01	-.47**	.27	.49**	-.10	-.90
7. LN							--	.34~	.34~	.29	-.29	.27	.26	.22	-.32
8. DS								--	.16	.20	-.18	.12	-.03	.19	-.18
9. LM2									--	.58**	-.06	.03	.02	.25	-.11
10. LMR										--	-.19	.21	-.16	.57**	-.58**
11. CET											--	.07	-.39*	.01	.20
12. P lu.												--	.29	.23	-.33
13. S Flu.													--	-.23	.02
14. WCST Cat														--	-.87**
15. WCST PPER															--

$*p < .05$, $**p < .01$, $***p < .001$, ~ indicates a strong trend (p = .056).

Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding;; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.

Table F6

Correlations Between TI Accuracy (% correct) Block 3 and Neuropsychological Measures For Older Group collapsed across Study1 & 2.

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								Older (n = 32)							
1. Age	-	.17	.22	.21	-.03	.20	-.32	-.60**	-.30	-.15	-.06	.26	.20	-.14	.01
2. Ed.		--	-.03	.58**	.18	.60**	.06	-.17	.05	-.23	-.27	.00	.36*	-.36*	.25
3. TI B3			--	-.05	.11	.04	-.16	-.15	.16	.33	.15	.21	-.28	.24	-.05
4. Voc.				--	.35	.83**	.26	.17	.01	.05	-.52**	.23	.48**	-.25	-.00
5. Matrix					--	.52**	.39*	.28	.14	.36*	-.35*	.09	.19	.33	-.42*
6. Sim.						--	.37*	.14	-.03	.01	-.47**	.27	.49**	-.10	-.90
7. LN							--	.34~	.34~	.29	-.29	.27	.26	.22	-.32
8. DS								--	.16	.20	-.18	.12	-.03	.19	-.18
9. LM2									--	.58**	-.06	.03	.02	.25	-.11
10. LMR										--	-.19	.21	-.16	.57**	-.58**
11. CET											--	.07	-.39*	.01	.20
12. P lu.												--	.29	.23	-.33
13. S Flu.													--	-.23	.02
14. WCST Cat														--	-.87**
15. WCST PPER															--

*$p < .05$, **$p < .01$, ***$p < .001$, ~ indicates a strong trend (p = .056).

Note. Ed. is Education; TI B1 is TI Accuracy in (% correct) for Block 1; Matrix is Matrix Reasoning; LN. is Letter Number Sequencing; DS. Is Digit Symbol Coding;; LM 2 is Logical Memory-II; LM R is Logical Memory Retention; CET is Cognitive Estimation; P Flu. is Phonological Fluency; S Flu. is Semantic Fluency; WCST Cat. is WCST categories; WCST PPER is WCST percent perseverative errors.