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The Standardized Memory Assessment: A Psychometric Evaluation Of A Computerized Cognitive Battery

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THE STANDARDIZED MEMORY ASSESSMENT: A PSYCHOMETRIC EVALUATION OF A COMPUTERIZED COGNITIVE BATTERY

by

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ABSTRACT

The purpose of this study was to begin developing and to examine psychometrically a computerized assessment of memory: the Standardized Memory Assessment (SMA). Computers open the door to great opportunities for the field of psychological testing, offering many advantages for purposes of standardized assessment. Of foremost advantage is that computers allow for testing constructs that were previously difficult or impossible to test, such as comprehensive measure of memory.

The psychometric properties of the SMA were examined by analyzing the data obtained from a sample of 227 undergraduates. It was determined that most subscales and scales of the SMA had moderate reliabilities. The construct validity of the SMA was examined by observing how well the obtained relationship between the subscales was explained by the information processing theory upon which the SMA was based. It was found that the information processing theory, more specifically a hierarchical version of the theory, explained the data very well. The SMA results were compared to those from intelligence test. Results indicated that memory can be viewed as distinct from the construct measured in traditional intelligence tests, although there is a strong relationship between the two psychological constructs. The SMA was also administered to a sample of 80 elderly individuals. Evidence for a general decline in cognitive ability was found, but little evidence that memory deficits associated with aging are localized to one aspect of memory. Overall, the results of the study are encouraging for further research and use of the SMA.

KEYWORDS: test construction, psychometrics, reliability, validity, computer, memory, intelligence, aging

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CHAPTER I

Computerized Assessment and Memory

Psychological assessment is entering a new phase as computers are becoming more commonplace in all settings. Computers are now being used in each step of the test development process, and no longer only for analyzing data. These many purposes of computers now include the task of test administration (Ben-Porath & Butcher, 1986). With the availability of microcomputers increasing at an incredible rate and at decreasing costs, imagining a computer in every psychological setting is not difficult. The administration of psychological tests on computers, rather than verbally or using paper-and-pencil procedures, will become much more commonplace, and may eventually render most existing traditional tests obsolete.

The advantages of computerized assessment are many (Hunt & Pellegrino, 1985; Kratochwill, Doll, & Dickson, 1985; Ben-Porath & Butcher, 1986; Aaronson, 1994). Computerized administrations of tests are likely to become more economical than paper-and-pencil administrations, both in terms of time used to complete and score the examinations and in terms of financial costs. With computerized assessment, the same tool can be used to provide the stimuli, obtain the data, analyze and score the information, and even interpret the results. Computers can store and score data as the participant is responding and, if required, can provide a score and an interpretation of the score immediately after completion of the test, as well as providing immediate feedback to participants while they are completing the test. The computer allows for a more efficient presentation of tests in several ways. For example, there are no test booklets and, therefore, no pages to turn, such that completion of one section and moving on to the next is made easier. Human errors, such as skipping a page in the examination booklet or writing a response in the wrong area of the response-sheet, are virtually removed in computerized administration. The computer generally uses the client's time more efficiently.

Computers likely maximize standardization of test administration. The instructions and presentation of the items in computerized administrations are identical from client to client. Unlike human administrators, the computer does not get bored, have a bad day, forget the exact wording, etc.

Another reason the computer can improve the efficiency of test administration is that it offers the opportunity for tailored testing (Wainer, 1990). Computers can select the next item to present based on a client's pattern of responses on the previously administered items. For example, an individual completing an aptitude test may start with items of middle difficulty. If they perform above a certain level, they move on to more difficult items, bypassing the easier items. If the individuals do poorly, they move on to easier items bypassing the difficult items. This is a very simplified example of computerized adaptive testing. Computerized adaptive testing may drastically decrease the time spent completing a test without decreasing the psychometric properties of the test (Wainer, 1990).

An additional advantage of computers, and the one of most interest in this paper, is that computers are capable of several types of assessments that other forms of test administration could not handle as well. In their article on the development of computerized assessment, Hunt and Pellegrino (1985) criticize the failure to take advantage of the computer's capability to test what has not been tested previously.

Most of the major assessment instruments have been converted into computerized format (Ben-Porath & Butcher, 1986). The focus of research on computerized assessment has been an examination of computerized tests' psychometric equivalency with their paper-and-pencil counterpart. Although translating a pre-existing paper-and-paper test does take advantage of some of the computer's efficiency and economic benefits, it fails in using all the potential the computer offers. Hunt and Pellegrino (1985) state that it is time we stop simply translating paper-and-pencil tests into computerized versions, and start developing tests that use the computer to its fullest. It is time for the validation procedure of computerized assessment to start with the computer version of an assessment technique rather than a pre-existing paper-and-pencil test.

Hunt and Pellegrino (1985) make numerous suggestions about what additional constructs computers could be used to measure. One suggested construct is that of memory. Although noncomputerized assessments of memory are available [e.g., the Wechsler Memory Scale - Revised (Wechsler, 1987); the California Verbal Learning Test (Delis, Freeland, Kramer, & Kaplan, 1988), the Denman Neuropsychology Memory Scale (Denman, 1987); the Guild Memory Test (Gilbert, Levee, & Catalano, 1968); the Randt Memory Test (Randt & Brown, 1986), the Memory Assessment Scales (Williams, 1991); the Rivermead Behavioural Memory Test (Wilson, Cockburn, & Baddeley, 1985), Microcog (Powell, Kaplan, Whitla, Weintraub, Catlin, & Funkenstein, 1993], these are often limited and focus on a very narrow definition of memory. A closer examination of three of these memory scales is completed to demonstrate some of the conceptual difficulties that exist in the currently used cognitive scales.

Wechsler Memory Scale. The best known of these memory assessments is the Wechsler Memory Scale (WMS) (Wechsler,1945). The test has seven scales (Information, Orientation, Mental Control, Logical Memory, Digit Span, Visual Reproduction, and Associative Learning) that measure different aspects of memory. However, theoretical difficulties existed with the WMS from the onset. One of these difficulties is that the WMS limits its investigation to the stores of memory, with no examination of the processes of memory. It failed at providing a comprehensive view of memory (Reeves & Wedding, 1994)

Russell (1975; 1982) provides a revision of the WMS, using only the Logical Memory and Visual Reproduction subtests completed twice with a half-hour period between presentations. With this battery, one can obtain two recall scores for each subtest (immediate recall and delayed recall), and one measure of retention for each subtest. The measures of retention are calculated by counting the number of words recalled both at immediate recall and at delayed recall, and dividing this number by the total number of words recalled during immediate recall. The revision introduced a delayed-recall component to the original WMS, yet still reflected a limited view of memory.

Russell's revisions of the WMS lead to some additional psychometric difficulties. For example, the retention measures have been found to have poor reliability (O'Grady, 1988). The retention measures also are lacking in convergent and discriminant validity;

the two measures correlate more highly with the two recall measures used to calculate the retention score than with each other (O'Grady, 1988; Russell, 1982), even though the retention measures should be measuring the same construct. Interpreting the three types of scores (i.e., immediate recall, delayed recall, and retention) from the Russell-revised WMS as distinct is questionable.

Following Russell's (1982) revision, the Wechsler Memory Scale (WMS-R) was developed (Wechsler, 1987). This revision incorporated all of Russell's revisions, and incorporated measures of memory of verbal and figural stimuli, and memory of meaningful and abstract material. Although becoming more wide-ranging, the WMS-R still presents a limited view of memory. In addition, incorporating Russell's revisions introduces a psychometrically unsound component to the measure: scores computed from two other interpretable scores. Research has suggested that the reliability of the WMS-R may be questionable (Elwood, 1991).

Exploratory factor analyses of the WMS-R have led to varied results (Woodard, 1993; Bornstein & Chelune, 1988). If the delayed variables are removed from the analyses, exploratory analyses typically reveal two memory factors (Wechsler, 1987; Roid, Prifitera, & Ledbetter). If the delayed variables are included in the analyses, three memory factors are extracted from the WMS-R scales (Bornstein & Chelune, 1988).

Woodard (1993) completed a confirmatory factor analytic study comparing various models explaining the data obtained from the WMS-R. Woodard (1993) found that a three-factor solution, defined by what Woodard labels attention/concentration, immediate memory, and delayed recall, best describes the data. Yet, even this three-factor solution only provides a moderate fit of the WMS-R. The normed fit index and the comparative fit index, both provided by the EQS (Bentler, 1989) package that Woodard (1993) used, are `14 and .881 respectively. Woodard (1993) himself states that both these indices should be above .90 before a model is considered to have a good fit. Roth, Conboy, Reeder, and Boll (1990) completed a similar set of analyses to that completed by Woodard (1993) and made a similar conclusion. A three-factor solution (attention/concentration, immediate memory, and delayed recall) best described the WMS-

R data. As before, the adjusted goodness-of-fit obtained by Roth et al. using the LISREL (Joreskog & Sorbom, 1986) program was a very low .83. In addition, the sample of 107 participants used by Roth et al. (1990) is likely too small for purposes of structural equation modelling (Bollen, 1989; Boomsma, 1983). Both Woodard (1993) and Roth et al. (1990) test every possible variation of the variables, making the confirmatory nature of their analyses questionable. Their analyses are still very much exploratory in nature; no clear theory guides the authors in their analyses.

California Verbal Learning Test. A more recent example of an existing memory battery is the California Verbal Learning Test (CVLT; Delis et al., 1988). This battery is perhaps more extensive than the WMS and the Russell revision, yet still has similar conceptual difficulties. The CVLT involves examining memory performances for two lists of words, A and B. Performance on list A is tested over five trials and performance on list B is tested once. The five trials for list A include short and long delay free recall tasks, short and long delay cued recall tasks, and a recognition task. List B is tested using immediate recall, and is presented immediately after the presentation of list A, but prior to any testing of list A. From these six presented tasks, 26 measures of memory are derived (Wiens, Tindall, & Crossen, 1994). Attempts are made to get at the processes of memory by calculating scores for clustering strategy, consistency, and intrusion errors.

Various validity studies have been completed on the CVLT. These studies largely focus on its relationship with the WMS-R (Delis, Cullum, Butters, & Cairns, 1988; Schear & Craft, 1989) and its usefulness in categorizing patients with cognitive difficulties (Delis, Massman, Butters, Salmon, Cermak, & Kramer, 1991). Wiens et al. (1994) completed an exploratory factor analysis on 19 of the CVLT variables and extracted the following seven factors: general verbal learning, response discrimination, learning strategy, proactive effect, acquisition rate factor, serial position effect, and retroactive/short-delay effect. Because of how scores are computed, it is unclear if the resulting factor structure is due to meaningful theoretical constructs, or due to the computations used to calculate each score.

There are many conceptual difficulties with the CVLT. Performance in each trial is used as a distinct score. The remaining scores are computed using various combinations of the performances on the six tasks. As with the Russell-revised WMS retention scores, it is very likely that these scores will correlate highly with the scores used in computing each value. In addition, testing the same list of words five times to obtain five hypothetically distinct performance scores may be questionable. These characteristics of the CVLT may lead to difficulties with the structure of the scales (i.e., a lack of independence between the processes and the structures of memory), and may lead to difficulty in obtaining adequate reliability data. Kramer & Delis (1991) provided construct validity evidence by demonstrating that the CVLT is sensitive to interference when looking at group performances. Unfortunately, the study does not provide any information on how successful the interference measures are at an individual participant level.

One of the major weakness with all of the previously mentioned memory assessments is that their development is not theory driven. The inclusions or exclusions of many of the scales seem arbitrary. Interpretation of the tests seems statistically driven rather than theoretically driven. No explicit framework is set down prior to the development of the scale. This is a key component in constructing a valid assessment tool. How can one measure something without having some knowledge about what one is measuring?

Microcog. Computerized memory assessments are beginning to emerge, with Microcog (Powell et al., 1993) being a recent addition to the memory assessment field. The assessment is much more wide-ranging than the previously mentioned memory tests, with memory performance being but one part of the complete assessment. It includes most of the tasks used in the previously mentioned memory assessments, and tests that mirror subscales from the Wechsler Adult Intelligence Scale - Revised (Wechsler, 1981) and other aptitude/intelligence assessments. In addition, it also includes measures of processing speed.

Microcog was developed with some theoretical framework: A process-oriented neuropsychological approach (Kaplan, 1988). The tasks which were chosen have been shown to be sensitive to various neuropsychological functions in previous research. In addition, tasks were chosen that were sensitive to normal and pathological aging.

Exploratory factor analysis of the Microcog results in a two-factor solution defined by information processing accuracy and information processing speed (Powell et al., 1993). Scales that could produce interdependency problems were removed from these analyses. The Microcog, as with the WMS-R and the CVLT, includes measures of delayed and immediate recall, and retention. As mentioned earlier, interdependent scales such as these will produce many unwanted psychometric properties. The authors must exclude these interdependent scales when examining the construct validity of the Microcog. Treating these scales as independent for the purpose of interpretation remains questionable. In addition, it is unclear if the obtained factor structure confirms the process-oriented theory used to develop the Microcog.

Standardized Memory Assessment. The primary purpose of this study was to begin developing the Standardized Memory Assessment (SMA), a computerized assessment of memory in which most cognitive dimensions are measured. The tool would use many of the benefits that computers provide for purposes of psychological assessment. Of key importance is that, unlike most of the previously mentioned memory assessments, the development of the SMA would be theory driven.

In the area of memory, there have been two major traditions of research: Research completed by cognitive psychologists and research completed by clinical psychologists. Cognitive research focused the theoretical research in the hope of understanding memory more thoroughly. Clinicians on the other hand focused on individual differences of memory, with the hope that it may help in diagnosing psychological abnormalities. Unfortunately, the communication between these two traditions has been minimal.

The SMA attempts to create a bridge between the work completed in cognitive psychology and the needs of the clinical psychologists. The SMA was created using a theory developed by the cognitive psychologists as a framework for the battery, with the purpose of defining individual differences in memory. The SMA began with Rannie (1989). The SMA avoids using scores derived from other interpretable scores and focuses on tasks that could be associated with adequate psychometric properties. Much of the early investigation of the properties of the SMA scales began with Rannie (1989), and the current version of the SMA is derived from many of the psychometrically sound scales obtained in that study. The theoretical framework of the SMA is the information processing theory of memory (Atkinson & Shiffrin, 1968; Cowan, 1988). The theory focuses on a system describing how normal memory works. Whereas Microcog focuses on tasks associated with memory abnormalities, the SMA will focus on tasks associated with the normal workings of memory. Tasks used in the SMA are tasks often used to investigate the normal functioning of memory in many cognitive studies.

The current research on the SMA was completed in three steps. In the first step, the psychometric properties of the SMA were examined. This was completed by examining the battery's test-retest and internal consistency reliabilities, as well as examining evidence of its construct validity. In the second step, the data produced from the SMA was compared to the data from an intelligence battery. The purpose of this study was to examine the relationship between memory, as defined by the SMA, and intelligence, as well as providing some discriminant validity for the SMA. The last step of the current research was to have an older sample of individuals complete the SMA so that they could be compared to a younger sample of individuals. A memory battery is likely to be used with an older population, such that the norms of their performance must be collected. In addition, there is much research in cognitive psychology examining the relationship of aging and memory, such that further validity evidence could be collected by examining how an aged sample performs on the SMA.

CHAPTER II

A Theoretical Framework: The Information Processing Theory

Although the tools used are different, the basic steps of constructing a computerized test should be no different from those of more traditional tests. In recent years, the importance of construct validity has been emphasized (Messick, 1988).

The first step in developing the SMA is to find an appropriate theory of what is to be measured. This theory would then be used to guide the test builder through the construction of the test and the validation processes. One general theory of memory that is prevalent and has been for some time is the information processing theory (Atkinson & Shiffrin, 1968; Kaszniak, Poon, & Riege, 1987; Poon, 1985; Klatzky, 1980; Hartley, Harker, & Walsh, 1980; Cowan, 1988; Rouleau, Labreque, Saint-Hilaire, Cardu, & Ghard, 1989; Light and Lindsay, 1991). Due to its popularity and relative acceptance in the area, it was used as the theoretical framework in the development of the Standardized Memory Assessment.

The Information Processing Theory

Briefly, the information processing theory suggests that memory can be divided into a number of distinct structures and processes. The memory traces hypothetically move from structure to structure by means of the processes. The structures hypothesized to exist include sensory memory, primary memory, and secondary memory. The processes include pattern recognition/attention (moving the information from sensory memory to primary memory), encoding (moving the memory trace from primary memory to secondary memory), and retrieval (returning the information from secondary memory to primary memory). The SMA was developed from four of the six structures and processes within the information processing theory: primary memory, encoding, secondary memory, and retrieval.

Primary memory. To a large extent, the information processing theory dates back to Miller's (1956) classic article describing the limitations humans have in processing information (Shiffrin & Nosofsky, 1994; Baddeley, 1994). In the article, Miller (1956) defines the amount of information that humans can handle at once to be the magical number seven chunks of information (plus or minus two). Modern concepts of Primary memory (short term memory) are derived from this observation. In terms of the information processing theory, primary memory is viewed as one of the early memory stores that information travels through. Information within the primary store decays rapidly, lasting approximately 30 seconds when no attention (rehearsal) is directed toward the memory trace. As mentioned, the capacity of the primary store, typically measured by means of digit span tasks, is small: approximately seven plus or minus two pieces (chunks) of information (Miller, 1956). Information within this store is theoretically coded in an acoustic (phonemic) manner rather than a semantic manner (Conrad, 1964; Conrad and Hull, 1964).

Baddeley's (1992) concept of working memory offers an alternative, yet relatively compatible view of primary memory. In his working memory model, working memory is defined by three distinct components: the phonological loop, the visuo-spatial sketchpad, and the central executive. The phonological loop is similar to the traditional view of primary memory, with verbal information being rehearsed in a subvocal manner. The visuo-spatial sketchpad is similar to the phonological loop, but deals with the visual and spatial component of working memory, a concept lacking in the traditional primary memory concepts. Finally, the central executive is, in Baddeley's (1992) terms, the attentional control system of working memory. In terms of the traditional information processing theory, this concept would be closely tied to the concept of encoding.

Encoding. As with the concept of primary memory, the concept of encoding probably dates back to Miller (1956) (Shiffrin & Nosofsky, 1994; Baddeley, 1994). Miller's concept of chunking implied that some manipulations were being completed on the information within primary store. These manipulations increase the amount of information held in each chunk (i.e., the information in primary memory), as well as help in the transfer of information from primary memory to a more permanent storage system. Encoding within an information processing system is viewed as the transfer of information from the primary store into the secondary store. Encoding can involve such behaviors as organization of the information, elaborating upon the information, forming visual images of the items, etc.

Secondary memory. The next stage in the information processing theory is that of the secondary store, or the actual long-term storage of the information. Theoretically, the store has an unlimited capacity, and information within it has a very long lifespan. The permanence of the memory trace in secondary memory is still a controversy yet to be adequately answered (Loftus & Loftus, 1980; Loftus, 1993; Olio, 1994; Loftus, 1994). This does not mean that information cannot be forgotten once it has entered this store. Forgetting can be considered a failure of retrieval or inappropriate encoding, as well as the information being erased from the storage area.

Retrieval. The final stage in the information processing theory is retrieval. Retrieval is the process of getting the information out of secondary store and returning it to primary memory. It is the process that most individuals typically identify as memory. One point to note is that retrieval may be closely tied to the process of encoding (Jacoby & Craik, 1979). Jacoby and Craik theorize that successful retrieval of an item will occur if the retrieval process successfully "mirrors" the encoding process. Jacoby and Craik (1979) would argue that it may be difficult, if not impossible, to separate these two constructs.

Although much research seems to support the theoretical structures and processes of the information processing theory, this theory is not without its problems. The distinction of the constructs of encoding and retrieval (Jacoby and Craik, 1979) is one such problem. In addition, much of the criticism directed toward the theory can be attributed to the concept of primary memory (Craik & Lockhart, 1972; Crowder, 1982).

Some theoretical issues include the following: 1) the concept of capacity is poorly defined. Measures of primary memory capacity have ranged from two items using recency effect measures (looking at the free recall of the last few items from a list of words), to 20 when the numbers of words that can be recalled from a sentence are measured (Craik & Lockhart, 1972; Zhang & Simon, 1985). Stating that it is the number of chunks in memory that defines the capacity without precisely defining a chunk is not an adequate solution to this problem; 2) the distinction of different types of coding in the two memory stores is not as clear as was originally thought. Primary memory, as defined by the information processing theory, can accept a variety of codes besides acoustic codes. This type of coding may very possibly include semantic coding (Baddeley, 1992; Zhang & Simon, 1985), supposedly only done within the secondary store; 3) retention of material within each hypothetical store should be invariant across all paradigms. This has not been the case. For example, paired associate forgetting in primary memory is much slower than free recall forgetting in the primary store. Similarly, reports of measures of sensory memory forgetting have varied greatly depending on what measure and material were being used (Craik & Lockhart, 1972).

Due to these difficulties, a few revisions to the information processing theory have been suggested. Cowan (1988; 1993) presents a new form . the information processing theory that attempts to take these problems into account. First, Cowan divides the traditional sensory memory store into two parts. One aspect (the early part) of traditional sensory memory is true sensory memory. The second part (the later stages) is in actuality a part of primary memory. Cowan also views primary memory as a subset of secondary memory; i.e., the primary memory storage is within the secondary memory storage. Imagine a desktop with information written all over it. On top of this information is an opaque cover. On the cover is a small clear window, where the information can be seen. This window can be moved all over the desktop, but only the information within the window is available at one time. The information on the desktop is Cowan's view of secondary memory, and the window is primary memory. Retrieval and encoding of information are viewed by Cowan as active processes of a single central processor.

The traditional information processing theory would lead to the prediction that there should be several dimensions of memory that are open to individual differences. Therefore, several distinct factors should exist among the scores of different types of memory tests. Table 1 provides the hypothesized factor structure of memory based on the author's interpretation of the traditional information processing theory and includes the cognitive measures from the SMA used to measure each hypothesized construct.

Cowan's (1988) version of the information processing theory would imply a similar but slightly different factor structure than that predicted by the older version of the theory.

Table 1

Hypothesized factor structure of the Standardized Memory Assessment

Primary Memory	Secondary Memory	Encoding	Retrieval
Primary Memory Capacity I	Free Recall	Primary Memory II Latencies	Single Word Categorization Latencies
Primary Memory Capacity II	Cued Recall	Working Memory Latencies	Secondary Memory Access Rate
Working Memory	Continuous Recognition	Working Memory Study Time	Continuous Recognition Latencies

A factor for both primary memory and secondary memory should still exist and be identical with that hypothesized in the earlier version of the theory. Secondly, there should be a significant correlation between the two structures not hypothesized in the traditional information processing theory. The third factor should be one related to the central processor. It should include the tasks implied to measure encoding and retrieval in the earlier version of the information processing theory.

It must be pointed out that it is not the purpose of this paper to investigate what model of memory is best. It may be plausible that a level of processing framework (Craik & Lockhart, 1972; Lockhart & Craik, 1990), or other theories of memory, may explain the data similarly or better than the information processing theory. It may be possible that some of the memory components of the information processing theory are multidimensional in nature. For example, Baddeley (1986) would view short-term memory as being multidimensional. In addition, numerous theories of long term memory propose that it may also be multidimensional (e.g., dual coding theory (Paivio, 1971;1986), the implicit/explicit learning distinction (Tulving & Schacter, 1990; Baddeley & Hitch, 1993), and the semantic/episodic distinction (Tulving, 1972)). While some of these multidimensionalities may be indirectly examined, the primary purpose of this research is to determine if the information processing theory, as stated, provides a framework from which a psychometrically sound assessment tool can be derived.

CHAPTER III

The Development of the Standardized Memory Assessment

The version of the SMA being examined in this study is derived from an earlier multivariate study of memory (Rannie, 1989). The original memory assessment had 17 tasks yielding 19 memory measures. Exploratory factor analysis of these measures revealed the existence of three stable factors consistent with Cowan's (1988) version of the information processing theory: a primary memory factor, a secondary memory factor, and a central processor factor. There was no conclusive differentiation between the encoding measures and the retrieval measures, such that Cowan's (1988) revised version of the information processing theory more adequately explained the results. This lack of differentiation may have been due to an inaccurate method of measuring the reaction times, and one improvement on this version of the SMA is a more accurate timing routine.

The Tasks of the Standardized Memory Assessment

There are numerous available cognitive tasks that could be translated into computerized format. Most tasks used in this version of the SMA were originally used in the Rannie (1989) study. The tasks used in that study were versions of cognitive tasks that were used in numerous past cognitive studies, and were readily translatable into a computerized format. For purposes of this version of the SMA, three cognitive measures were chosen as measures for each hypothetical factor of memory (see Table 1). In order to obtain these twelve memory scores, ten computerized tasks were used.

All measures of reaction times were obtained using a timing program provided by Buhrer, Sparrer, and Weitkunat (1987). The program is reportedly accurate up to 1 msec. All responses are made via the computer keyboard and all data are stored on the computer's hard-drive immediately after completion of each task.

Primary memory and encoding

The first two constructs based on the information processing theory are those of primary memory and encoding. The measures of primary memory were traditional measures of digit-span as well as a measure of working memory. When attempts were made to measure encoding in older memory batteries, the attempts focused on the qualitative nature of encoding. These measures usually involved some combination of other measures within the assessment to derive a new measure. As mentioned, this technique is guaranteed to introduce numerous psychometric properties to the battery (i.e., unreliable measures and interdependency). If we had the luxury of including additional measures that are strictly used for purposes of encoding (i.e., the measures are not used in computing secondary or primary memory scores), then the problem of interdependency would be removed. But such measures would lead to an extremely lengthy assessment tool.

The encoding measures of the SMA focus on the quantitative nature of the construct. Baddeley (1992) views encoding as the central executive of working memory. To define encoding, the SMA focuses on the efficiency of this central executive. This will be done by examining the speed of information processing in various task of primary memory. The speed of processing measures are restricted to primary memory tasks to limit the retrieval component of the tasks. It is recognized that this is a restricted view of encoding, but such speed of processing measures have been theoretically tied to encoding and can be used as a proxy measure of encoding. For example, Salthouse (1993; 1994a; 1994b) explains the encoding deficits by stating they are largely due to a deficit in the speed of processing.

Primary Memory Capacity I task. This task measures the participant's ability to recall items from primary memory. Participants were required to recall accurately a short string of digits. The first presented string was three digits in length. After every correct recall, the next string was increased in length by one digit. An incorrect recall caused the next string to be shortened by one digit. Each string of digits stayed on the screen for 2 seconds. The short presentation time in this task, and in the other primary memory performance tasks, was used to limit the secondary memory components of the tasks.

After presentation, the screen was cleared for 2 seconds and participants were prompted to recall the string of digits by typing in the response using the computer keyboard. The task ended when the participant fluctuated between two lengths of digits for five consecutive trials. The size of the smaller of these two string lengths was then stored as the participant's primary memory capacity.

Primary Memory Capacity II task. This task measures the participant's ability to recall information from primary memory and the speed of this recall. In this task, participants viewed a series of twelve nine-digit strings (see Appendix I for a list of the strings). Individual digits could reappear several times within a single nine-digit string, up to a maximum of three times. Each individual nine-digit string stayed on the screen for 2 seconds, then was erased from the screen. After approximately 1 second, the string reappeared with one digit replaced by a dash. The participant's task was to recall the missing digit (i.e., the number that had been replaced by the dash). The participants were scored on the accuracy of each response and how fast each response was made. The number of correct responses was used as a measure of primary memory capacity. The reaction time was used as a measure of encoding.

Working Memory task. In this task, the participants performed three mathematical computations, one at a time, while attempting to memorize the solution of each equation. In each trial, the three equations were labelled either X, Y, or Z (in random order), and ranged in difficulty from no manipulations (e.g., X = 1), one manipulation (e.g., X = 1 + 2), to two manipulations (e.g., X = (1 + 3) - 2). All answers were integers from zero to nine. See Appendix I for a list of the values.

Participants viewed each of the three equations indiv . .ly until they felt ready to recall the solution correctly (i.e., participants could study the item for as long as necessary). They showed their readiness by pressing any key on the keyboard, whereby the next equation would appear. After the three labels and their respective equations were presented, the computer prompted the participant to type in the value of a particular label (e.g., "X = "). This continued until all three labels had been responded to, whereby the next trial started. There were fifteen trials in total. The computer recorded the participant's study time, the accuracy of each response, and the reaction time in making each response.

The number of correct trials was used as a measure of primary memory. Both the study time required to memorize the label values and the reaction times required to respond to the prompts were used as measures of encoding.

<u>Secondary memory and retrieval</u>

The next factors are those defining secondary memory and retrieval. Tasks within this factor should include those that traditionally measure secondary memory performance. For the SMA, these include measures of free recall, cued recall, and recognition memory. Although there are some theories of memory that argue that secondary memory is defined strictly from the qualitative nature of encoding and retrieval (Craik and Lockhart, 1972; Jacoby & Craik, 1979), it is not the purpose of this study to test this distinction. Performance on these traditional secondary memory tasks will be labelled secondary memory and will be treated as distinct from the concepts defined as encoding and retrieval, as it is in the traditional information processing theory.

The last construct hypothesized from the information processing theory of memory is one associated with the retrieval process. As with the encoding construct, reaction time measures were used to define this dimension. Several tasks were used that measure how long it takes to retrieve information within the secondary store. The measures within tne SMA that were chosen to define retrieval include a measure of recognition reaction time, a measure of secondary memory access rate, and a measure of single word categorization reaction time. In each of these tasks, the participant is required to 1) read and bring the stimuli into long term memory, 2) search secondary memory, 3) bring the accessed information out of secondary memory into primary memory, and 4) make the decision required of the task. Making the decision is corrected for in the SMA, but all other phases are what will be defined as retrieval. The first phase may arguably be looking at encoding rather than strictly retrieval. As mentioned, it may be impossible to completely separate encoding and retrieval. Jacoby and Craik (1979) would argue that this "encoding phase" is critical to successful retrieval and is part of the retrieval process, in that successful retrieval is dependent on how well the "encoding phase" mirrors the original encoding that originally placed the information into secondary memory. While the retrieval tasks will tap into a process previously measured by the encoding measures, it does examine unique processing properties (searching secondary memory and bringing the information out), such that it is felt that enough information can be obtained to demonstrate its uniqueness from the encoding measures.

Free Recall task. This task is a measure of the participant's secondary memory performance. The words used in this task were defined on two dimensions: frequency and imagery. These dimensions were based on scores reported in Paivio, Yuille, and Madigan (1968). The task included sixteen words distributed as follows: four were high imagery/high frequency, four were high imagery/low frequency, four were low imagery/high frequency, and four were low imagery/low frequency. The purpose of these dimensions is to provide some additional depth to the Free Recall measure. It is still expected that these dimensions of free recall will be highly intercorrelated such that one measure will adequately define this task. Attempts were made to choose words that were easy to spell, simple (less than three syllables) and unambiguous. The different types of words were randomly distributed within the list. See Appendix I for a list of the words.

Immediately after presentation of the list of words, participants were asked to complete several simple additions for 30 seconds. The purpose of this distracter task was to remove the primary memory component in the free recall score. Immediately after this distracter task, participants were asked to recall the list of words in any order. Participants were required to type each word separately. Each word typed was visible at the top of the screen throughout the task, so that participants could refer to the recalled words throughout their performance. Participants were scored in terms of the number of words that were correctly recalled.

Cued Recall task. In this task, participants are required to study sixteen pairs of words. Five of the pairs were defined as high-associates, six were low-associates, and five were non-associates[1]. See Appendix I for a list of the pairs of words. As with the Free Recall task, the use of the dimension of association was to provide some depth to the task. It is expected that one score will define all the association levels adequately.

The types of pairs were randomly distributed within the list. Each pair stayed on

[1] The unequal number of items between the three types of pairs was due to a programming error that was not caught until late in the data collection. Rather than change the program, and lose the data that had been collected, the program was left as it was.

the screen for 4 seconds. Similar to the Free Recall task, a distracter task consisting of performing simple additions for 30 seconds was completed after presentation of all the pairs. After these computations, the left word of each pair was presented one at a time in random order. The participant's task was to recall the corresponding word associated with the stimulus word. The participant's score was the number of correct responses.

Continuous Recognition task. The continuous recognition task involves the presentation of 81 words, one at a time. Participants had to decide whether the word presented on the centre of the screen had been seen previously in the list of words. The 81 words were divided into nine groups of nine words: 1) critical words; 2) duplication of critical words; 3) low associates of the critical words; 4) high associates of the critical words; 5) neutral words; 6) duplication of the neutral words; 7) and 8) pairs of homonyms; and 9) control words. The words were randomly distributed within the list with the following restrictions: words and their appropriate pairs in other categories were separated by at least five words and no more than 20 words. See Appendix I for the words used in this task.

The participants completed the task by pressing a key on the computer keyboard labelled "YES" (located on the "Z" key of the keyboard) if they had seen the word, and pressing a key labelled "NO" (located on the "?" of the keyboard) if they had not. The task continued until responses were determined for all 81 words. The time required to complete each response was recorded along with the accuracy of each response. The number of correct hits (correct responses to the second occurrence of a word) was used as a measure of secondary memory. The reaction time scores from the hit items are used as a measure of retrieval.

Secondary Memory Access Rate tasks. The measure of secondary memory access rate involved two of the eleven tasks used in the study. In the first task, participants were presented with sixteen pairs of words. Half the pairs were identical, the other half were different (see Appendix I for a list of the word pairs). To respond accurately, participants had to press the "YES" key (as described in the Continuous Recognition task) when the words were identical, and the "NO" key when the words were different. Each pair of words remained on the screen until a response was made or five seconds expired. The accuracy and the response time of each response were recorded by the computer.

The second task was identical with the same-different task, except that the sixteen pairs of words were either synonyms or antonyms (eight of each) (see Appendix I for a list of the word pairs). Participants responded by pressing the "YES" key (as described in the Continuous Recognition task) when the words were synonyms, and the "NO" key when they were antonyms. By subtracting the same-different response latencies from the synonym-antonym latencies, a measure of secondary memory access rate is possible (Vernon & Vollick, 1986). This reaction time measure was then used as a measure of retrieval.

Single Word Categorization task. A second measure of secondary memory access rate is possible through this task. In the task, participants view 16 single words, each either having positive connotations (e.g., always) or negative connotations (e.g., never) associated with it. The positive and negative nature of the words were determined in the earlier version of the SMA (Rannie, 1989). Synonyms for the word positive and negative were obtained from Roget's Pocket Thesaurus (1973). Then synonyms and antonyms of these words were subsequently obtained, until a list of approximately fifty words was collected. This list was then presented to a small sample of individuals who were asked to indicate whether the words were positive or negative. Thirty words with 90% or greater agreement with the appropriate dimension were kept in that version of the SMA. This version of the SMA used sixteen of those words. See Appendix I for a list of the words used in this task.

Participants had to decide which connotation, positive or negative, was associated with each word. If the word was positive, they should press the "YES" key (as described in the Continuous Recognition task), and if the word was negative they would press the "NO" key. Each word remained on the screen until a response was made. Participants were scored on the accuracy and speed of each response. The mean of these reaction time measures was used as a measure of the participant's retrieval ability

Correction Tasks

In addition to measures of the four memory constructs described, tasks were included in the SMA not to specifically measure a particular construct of memory, but to correct the measures that are obtained. There were two such correcting measures included in the SMA: movement time and typing speed.

In the previously defined reaction time tasks, the scores contained how long it took the participant to make the decision required in the task, as well as how long it took the participant to press the appropriate key once the decision is made. This latter part of the reaction time score is not of interest in determining the cognitive score and is a source of error. The movement time measure attempts to determine how long it takes for the candidate to press a key with very little cognitive requirements, such that this time can be subtracted from all the cognitive reaction time measures.

In addition, some of the cognitive tasks require some typing in order to complete them. There was some concern that an individual's typing speed may affect performance on these tasks. In order to examine this possibility and make the appropriate corrections if required, a measure examining an individual's typing speed was introduced.

Movement time task. In this task, participants viewed either the word "YES" or the word "NO" at the centre of the screen. All that was needed to respond accurately was to press the appropriate key ("YES" or "NO" as described in the Continuous Recognition task). There were twenty trials in all, ten "YES" and ten "NO". The means of the reaction times were used to define this scale.

Typing Speed task. In this task, participants were presented with sixteen words, one at a time. They were required to type in the word exactly as shown using the computer keyboard. The words were chosen such that each letter of the alphabet was used at least once. The one exception is the letter "Z", which is not used in the SMA tasks as it is labelled "NO". The average typing speed was used to define this scale. The purpose of this scale was to investigate the possibility that typing speed may affect performance on the tasks requiring typing. These tasks include the Free Recall task, the Cued Recall task, and the Primary Memory Capacity I task.

CHAPTER IV

The Performance of the Standardized Memory Assessment

The first step in examining the newly constructed SMA was to determine some of its psychometric properties. This was completed by examining the reliabilities of the individual subscales and the derived scale scores. In addition, the patterns within the subscales were examined to determine if the information processing theory adequately explained them.

The SMA was administered to a sample of undergraduates. The purpose of this administration was to examine the psychometric properties of the SMA. For the SMA to be useful, it must demonstrate adequate reliability and validity. The reliability of the SMA was examined using test-retest statistics as well as internal consistency coefficients. Validity was determined by examining how well the constructs of memory as defined by the information processing theory explains the obtained data.

METHOD

Participants

A total of 228 undergraduates at the University of Western Ontario participated in the experiment. Of these, 107 were male and 121 were female. Ages ranged from 16 to 36 years, with a mean of 19.77 years and a standard deviation of 2.32 years.

Apparatus

The Standardized Memory Assessment (SMA) was completed on an IBM compatible personal computer equipped with a CGA colour monitor. The display area for the screen was 26 cm X 19 cm. The SMA consisted of the previously described tasks of cognitive ability administered in the following order: Movement Time, Free Recall, Primary Memory Capacity II, Single Word Categorization, Continuous Recognition, Primary Memory Capacity I, Synonym-Antonym and Same-Different tasks (Secondary Memory Access Rate), Working Memory, Cued Recall, and Typing Speed.

Procedure

Before starting the Standardized Memory Assessment, participants were instructed on the use of the computer keyboard; the experimenter pointed out the back-arrow key used to correct typing mistakes, and the "enter" key used to inform the computer that one has completed typing. Participants were asked only to use the typing section of the keyboard and to avoid the numerical keypad and the function keys. This was done to keep the requirements of the tasks standardized from computer to computer (i.e., location of the keys to be pressed in the task). Few differences exist with the typing section of the keyboard, but greater differences can exist in the location and arrangements of the other sections of the computer keyboard, such as the numeric keypad. In addition, avoidance of the numeric keypad standardizes the requirements for responses from individual to individual (i.e., when pressing "1", all participants had to reach to the top row, second key from the left of the keyboard).

The SMA began with a set of general instructions presented on the computer screen, read at the participants' pace (See Appendix II). These general instructions informed participants of the responses they would have to make to complete the tasks. Participants were told to familiarize themselves with the location of the keys labelled "YES" and "NO" as these keys would be used often in the completion of the SMA. Participants were told to work as fast as they could, because they would be timed in many tasks.

After reading these general instructions, the instructions for the first task appeared. The task-specific instructions are presented in Appendix II. Instructions for each task were presented in two or three screens just before the administration of the practice trial for the particular SMA task. Usually, the first screen(s) gave full instructions about what the participants would have to do in the upcoming cognitive task. The last screen gave the participants one or two examples of appropriate responses for the task.

After the task-specific instructions, a short practice trial was completed for every task except the Primary Memory Capacity I task. Practice trials were shorter versions (typically 4-6 items in length) of the task at hand. With these practice trials, participants became familiar with the particular keys used in the task, and the procedures required to respond accurately. Practice trials were not given for the Primary Memory Capacity I task due to the adaptive nature of the task (i.e., participants could practice while completing the task). After completion of the practice trials, the particular task started.

The researcher remained with the participants for the first three tasks to explain the procedures verbally to them and/or to correct any difficulties. The participants completed the last eight tasks on their own. Of the 228 students participating in this part of the study, 37 participants (27 females and 10 males ranging from 18 to 28 years) completed the SMA twice, with a 2-week interval between sessions. This was done so that some indication of the temporal stability of the SMA scores could be obtained. On the second occasion, participants worked on their own for all eleven tasks. Completion of the SMA on the first occasion took between 45 and 60 minutes. Completion of the SMA on the second occasion was typically faster (30 - 45 minutes).

Preliminary Transformations

A few adjustments to the latency (reaction time) scores were made. First, only the latencies obtained from correct responses were used to compute the scale's statistics. Latencies from incorrect responses were recoded as missing values.

Second, a minimum number of correct responses had to be achieved before individual latency statistics were calculated. This was done to minimize the possibility that guessing was involved in the latency measures. If the minimum scores were not reached, the individual was given a missing value for the latency measure. The minimum scores were set at the point where less than 10% of the population would obtain that score or better, if they were guessing (see Appendix III for the computations). The following were the minimum scores used in the latency measures: a) Primary Memory Capacity II Latencies- 3 out of 12 answered correctly; b) Single Word Categorization Latencies - 12 out of 16 answered correctly; c) Continuous Recognition Hits Latencies - 13 out of 18 answered correctly; d) Synonym-Antonym and Same-Different latencies - 12 out of 16 answered correctly; and e) Movement Time Latencies - 14 out of 20 answered correctly. One male participant was found to have a suspected guessing score on four of these measures. Due to concerns about the validity of this participant's data, his SMA scores were deleted from all analyses, bringing the sample used to 227 participants. In the rest of the sample, this correction resulted in deleting the Single Word Categorization Latencies data for 1 participant, the continuous Recognition Latencies data for 17 participants, and the synonym-antonym data for 21 participants.

Third, the reaction times for each individual and in each reaction time task were investigated for outliers. If a particular individual's reaction time was more than three standard deviations from that individual's mean reaction time on the specific task, the outlier was recoded as a missing value.

Due to the number of missing latency values that occur for each individual from the adjustments, internal consistency measures were calculated by including all participants, regardless of whether or not there were missing latencies, using the "MISSING=INCLUDE" option in SPSS-X's reliability routine. This routine allowed for the calculation of an internal consistency score even though participants may have missing latencies due to the previously mentioned corrections. It was felt that participants that obtain perfect performance scores on the reaction time measures represent a very limited portion of the population (i.e., those that are extremely careful not to make any errors). They are likely unrepresentative of the population as a whole.

RESULTS

To explore plausible multidimensionality, each subscale, except the Primary Memory Capacity I and the Continuous Recognition False Alarm subscales, underwent factor analysis. No factor analysis was completed on the Primary memory Capacity I scale due to its adaptive nature (i.e., candidates did not receive the same stimulus). The Continuous Recognition False Alarm subscale was not factor analyzed because some of the items have no variability (i.e., everybody gets them correct).

The number of factors extracted for the analyses was determined using the parallel analysis routine (Longman, Cota, Holden, & Fekken, 1988; Zwick & Velicer, 1986). The obtained factor matrix was compared with a factor matrix of random variables that had the same dimensions as the obtained factor matrix (i.e., the number of variables by the number of variables). An obtained factor must be associated with an eigenvalue above that of the equivalent factor from the random matrix before being considered as a true factor. Following the determination of the number of factors, factor loadings of greater than .35

on a factor were interpreted as a variable loading on that particular factor.

Results of these factor analyses are reported in Appendix IV. Except for the Free Recall and the Primary Memory Capacity II subscales, a one factor solution was sufficient to explain the variance in all of the subscales. Analysis of the Free Recall task resulted in a two-factor solution. These two factors seem to reflect a primacy and a nonprimacy effect (i.e., location of items in the list of words), rather than either the visual or frequency dimensions of the stimuli. Individual performances can vary in terms of how an individual performs on the first few items of the list, and how the individual performs on the remaining items. A Primacy Free Recall score was computed using items 1 to 6. A Non-primacy Free Recall score was computed using items 7 to 16. The correlation between the two new scores is .11 (p = ns), providing further evidence of the relative independence of the two scores. Therefore, the Free Recall subscale will be defined by these two scores.

Analysis of the Primary Memory Capacity II subscale also resulted in a two-factor solution. This solution is difficult to interpret, yet it appears that one factor represents performance on items where the missing digit was at the beginning or at the end of the string of digits. The second factor represents performance when the missing digit was in the middle of the string. These factors perhaps reflect Cowan's (1988) view that primary memory measures consist of both a true primary memory component, and a sensory memory component. Yet, the correlation between the two scales is .30 ($p < .05$). This high correlation limits the usefulness of defining the subscale using two distinct scores. Therefore, the Primary Memory Capacity II subscale will continue to be defined by a single total score.

The correlation between the Continuous Recognition Hit and the Continuous Recognition False Alarm subscales is -.003 (p = ns). This low correlation provides evidence for the usefulness of using both scores to define the Continuous Recognition task.

The reliability of the Secondary Memory Access Rate was extremely low when the score is computed using the synonym-antonym and the same-different performances (.21). In addition, the computation led to some negative reaction time values for some

Table 2

Means, standard deviations, and reliability coefficients of the Standardized Memory Assessment subscales

Subscale	Mean	Standard Deviation	Coefficient Alpha	Test Retest
Primary Memory				
Primary Memory Capacity I	7.51	1.18		0.69
Primary Memory Capacity II	8.83	2.20	0.58	0.69
Working Memory	11.06	3.06	0.75	0.40
Secondary Memory				
Primacy Free Recall	3.10	1.41	0.38	0.50
Nonprimacy Free Recall	4.35	1.85	0.36	0.54
Cued Recall	12.32	2.62	0.67	0.71
Continuous Recognition Hits	15.93	3.47	0.90	0.79
Continuous Recognition False Alarms	5.95	4.71	0.80	0.50
Encoding				
Primary Memory II Latencies	1702.1	415.3	0.60	0.73
Working Memory Latencies	3134.6	1075.2	0.77	0.79
Working Memory Study Times	11443.5	4794.6	0.83	0.88
Retrieval				
Single Word Categorization Latencies	820.8	246.0	0.83	0.61
Secondary Memory Access Rate	1381.6	413.3	0.77	0.69
Continuous Recognition Latencies	748.7	161.8	0.82	0.74
Correcting Tasks				
Movement Time	378.2	41.3	0.77	0.56
Typing Speed	3748.7	1312.0	0.94	

Note: All measures of Encoding, Retrieval, and Correcting tasks are reported in milliseconds participants. Due to these results, the Secondary Memory Access Rate subscale will be defined by performance on the synonym-antonym task alone.

The means and standard deviations of the resulting subscales are found in Table 2. Also included in the Table 2 are the test-retest and the internal consistency reliabilities of the resulting subscales. Due to the tailored nature of the task, no internal consistency measure can be computed for the Primary Memory Capacity I task.

The reliabilities of the scales are for the most part in the moderate to moderate-low ranges. Considering the many unknowns that occur with cognitive tasks, these are fairly reasonable and encouraging results and are comparable to reliabilities obtained in other memory scales. One would not expect the reliability of a single item to be exceptional. These subscale scores are in many ways equivalent to the single item. Of importance for the SMA is the combination of the subscales to form scale scores that define memory. It is expected that when scale scores based on groups of these subscales are computed, the psychometric properties of the SMA will improve.

<u>To Correct or Not to Correct?</u>

As mentioned earlier, the relatively low reliabilities of the movement time task were of some concern with regard to its use in correcting the latencies of the SMA. It was originally planned to correct the latencies by simply subtracting the movement time from each latency (subtracted three times from the two working memory latencies, because each is based on three keyboard responses). Table 3 shows the effects on test-retest reliabilities when this correction is used. For the most part, the correction seems to have little effect on the test-retest reliabilities.

Correction for typing speed on the measures involving typing was investigated. The Primacy Free Recall, Nonprimacy Free recall, Cued Recall, and Primary Memory Capacity I measure correlated .02 ($p = ns$), -.06($p = ns$), -.09($p = ns$), and -.34 ($p < .05$) respectively with typing speed. The only measure typing correlated significantly with is the primary memory measure.

These results are not surprising, considering the theoretical construct each measure is supposedly measuring. According to the information processing theory, the information

Table 3

Effect of correcting for Movement Time and Typing Speed on affected Standardized Memory Assessment subscales

Subscale	Test-Retest Before Correction	Test-Retest After Correction
Primary Memory II Latencies	0.73	0.72
Working Memory Latencies	0.79	0.79
Working Memory Study Time	0.88	0.88
Single Word Categorization Latencies	0.61	0.58
Secondary Memory Access Rate	0.69	0.66
Continuous Recognition Latencies	0.62	0.58

in secondary memory is relatively stable; once it is in the storage area, it stays there relatively permanently. No matter how long one spends typing each word, if a trace is in memory it can be theoretically retrieved. In the primary memory task, on the other hand, the memory trace is very easily and detrimentally affected by distractions, and can easily be lost. Distractions are much more likely to occur if the participant's typing speed is slow. Therefore, typing speed should theoretically affect primary memory, but have relatively small effects on secondary memory.

The only way to correct the capacity measure is using a regression method. The unstandardized linear equation between typing and the Primary Memory I Capacity measure was computed. A slope of -.00026 was computed between the Primary Memory Capacity I measure and the Typing Speed measure. Typing speed was then removed from the primary memory measure by this factor. Unfortunately, because there are no retest data available on the typing measure, the effect on reliability caused by this correction is unknown.

Of concern with this correction is that typing speed may reflect manipulations of memory traces within primary memory (i.e., encoding) already measured by some of the other cognitive measures of the SMA. There may be a true correlation between primary memory and encoding, and correcting for typing speed may remove this true correlation, statistically forcing primary memory and encoding to be more independent from each other, when in fact they should not be.

To examine this concern, each of the three encoding variables was entered into a regression routine with the Primary Memory Capacity I measure as the dependent variable, and then typing was entered to see if it added anything to the equation over and above the encoding variables. This was done both with the encoding variables uncorrected and the encoding variables corrected for movement time. In both cases, the contribution of typing speed was not significant. These results cast some doubt on the usefulness of correcting the measure using typing speed, so the correction will not be used.

While these corrections for the most part seem to have little effect on the reliabilities of the scales, it is unknown at this point the effects each may have on the

Table 4

Means and standard deviations of corrected Standardized Memory Assessment subscales

Subscale	Corrected Mean	Corrected Standard Deviation
Primary Memory II Latencies	1,324.3	404.3
Working Memory Latencies	2,002.8	1,037.8
Working Memory Study Time	10,311.3	4,786.5
Single Word Categorization Latencies	445.0	234.2
Secondary Memory Access Rate	992.4	323.4
Continuous Recognition Latencies	359.2	111.5

Note: All latencies are reported in milliseconds validity of the scale. Table 4 provides the new means and standard deviations of the corrected scales.

Confirmatory Analyses of the SMA Data

As mentioned, the SMA was designed using the information processing theory of memory as a guide. An examination of the theory was made to see if it adequately explains the obtained SMA data. The purpose of these analyses is to examine the validity evidence of the SMA and the psychometric properties of any scale scores based on the theoretical constructs within the SMA.

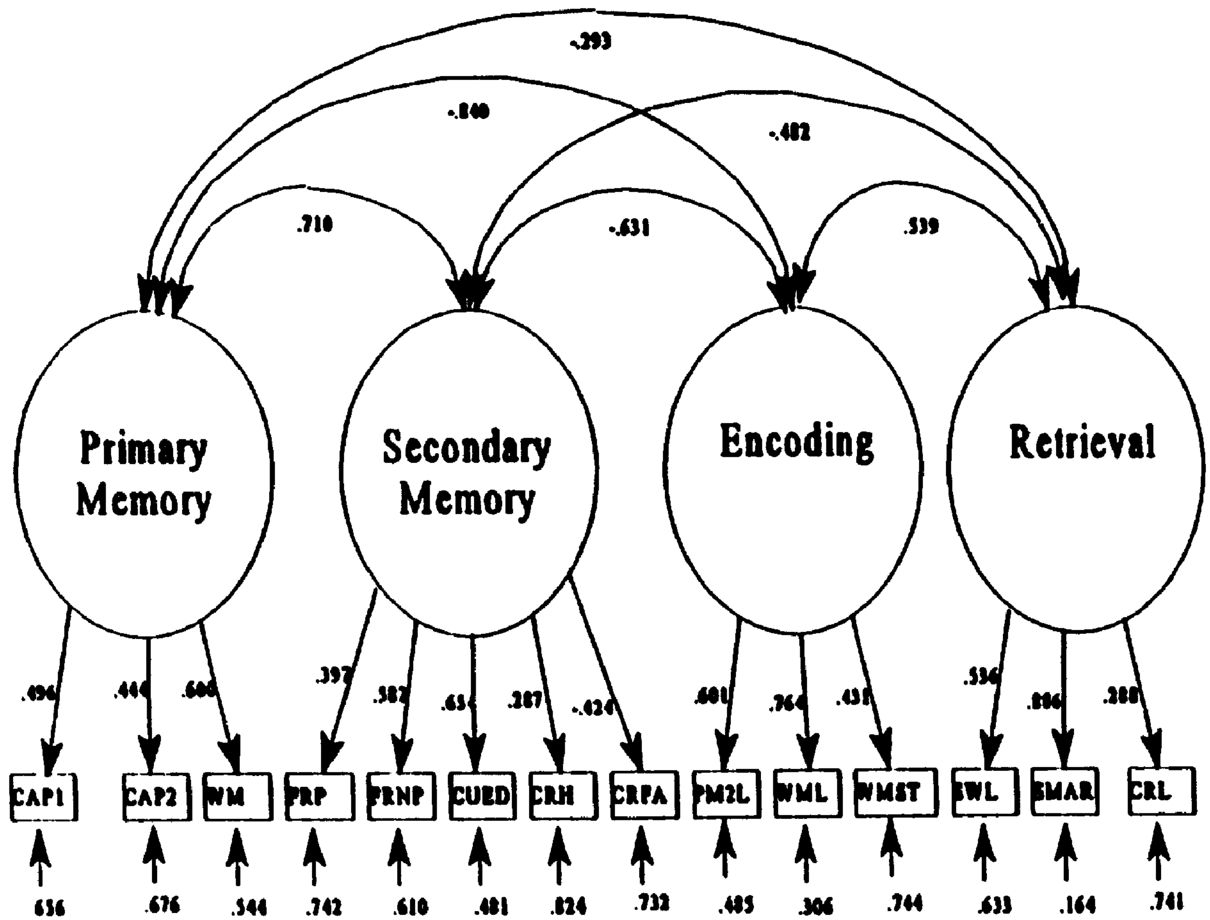
Analyses in this section, unlike the subscale analyses, are confirmatory rather than exploratory. Listwise deletion of missing data was used for these sets of analyses. To examine the effects of correcting the SMA subscales for movement time, two correlation matrices were compared. They include the following: 1) a matrix based on the uncorrected SMA (n = 198); 2) a matrix based on the SMA corrected for movement time (n = 198). Analyses examining the differences in the patterns between these two matrices revealed minimal differences. Because of these limited differences, all further analyses will focus on one correlation matrix: The SMA subscale matrix corrected for movement time. To scale the constructs in a LISREL environment, the variances for each latent construct were fixed to one.

The first set of confirmatory analyses will focus on the four factors of memory as defined by the information processing theory. As mentioned earlier, one would predict the existence of four factors within the SMA using the information processing model as a guide: primary memory, secondary memory, encoding, and retrieval (see Figure 1).

The correlation matrix of the subscales used for purposes of the analysis can be found in Appendix V. The model resulted in a Chi square of 86.76 (df = 71, p = ns), and adjusted goodness-of-fit index of .907, and a root mean square residual of .077. From the goodness-of-fit indices, it would seem that a four-factor model does a satisfactory job of explaining the data in the matrix. Figure 1 provides the resulting best fitting paths for the four factor model. The numbers in the figure represent factor loadings. All loadings are scaled such that the variances of the latent variables (i.e., the memory constructs) are

Figure 1

<u>The four-factor model of memory.</u>



equal to 1. The larger the loadings, the stronger the relationship. The relationships between the constructs, except for the primary memory/retrieval relationship, are all relatively high and significant. These large intercorrelations may imply that some of the latent constructs could be collapsed into a smaller number of constructs.

The four-factor model was compared to various competitive theoretical models of memory including a three-factor model with the encoding and retrieval being defined by one factor (Cowan, 1988), a two-factor model defined by a processing speed factor and a processing accuracy factor (Powell et al., 1993), and a one-factor general memory model (Elwood, 1991). Although all of the models provided adequate fit indices, the four-factor model provided the best fit (the adjusted goodness of fit indices for the three-, two-, and one-factor model of memory are .87, .87, and .85 respectively).

One or Two Secondary Memory Factors?

One of the unexpected results obtained in the analyses of the subscales was the possible existence of two factors within the secondary memory factor, because two of the measures of secondary memory, the Free Recall task and the Continuous Recognition task, are best described by two relatively independent scores. It may be possible that there are two separate aspects to secondary memory. Various investigations have provided evidence showing various dual components of secondary memory. Paivio's (1986) view of memory includes both a visual and a verbal component to memory. Much research is currently being directed towards the concept of implicit (unconscious) and explicit (conscious) memories (Baddeley & Hitch, 1993), and this could be a plausible set of distinctive components of secondary memory. Nyberg (1994) completed a confirmatory analysis to examine the semantic/episodic distinction of memory (Tulving, 1972). Nyberg (1994) did find that the distinction explained the data that he collected.

To examine the usefulness of using two scale scores to define secondary memory, a factor analysis of the five secondary memory subscales was completed. Exploratory analysis is used rather than confirmatory analysis because there is no clear theory to be confirmed within the secondary memory data (i.e., there are no clear groupings among the obtained SMA subscales).

Table 5

Factor analysis of the Standardized Memory Assessment's scale scores

Subscale	Factor I
Cued Recall	0.80794
Non-Primacy Free Recall	0.75034
Primacy Free Recall	0.61901
Continuous Recognition False Alarms	-0.56386
Continuous Recognition Hits	0.42368

A one factor solution accounted for 49% of the total variance (see Table 5 for the obtained factor loadings). All Secondary Memory subscales loaded greater than .35 on this factor, with the Continuous Recognition False Alarm measure loading negatively. The fact that a one factor solution can account for almost half of the total variance limits the usefulness of using two or more scores to define secondary memory. Therefore, the Secondary Memory scale of the SMA will be defined by a single score: the means of the five obtained secondary memory measures.

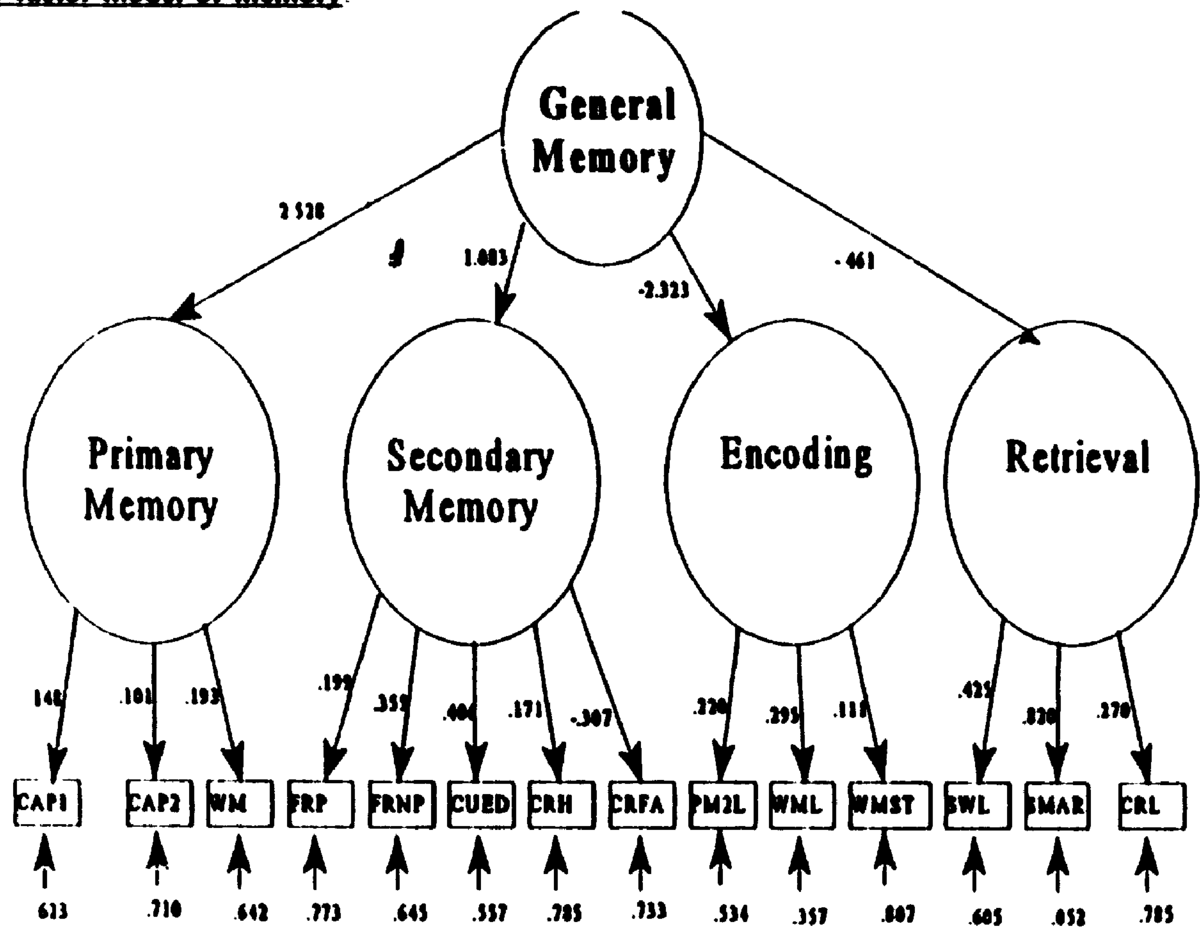
A Hierarchical View of Memory

Although a four-factor solution as defined by the information processing model does adequately explain the data, the high intercorrelations between the memory factors are interesting. The intercorrelations imply the possible existence of a general factor of memory. Memory, as defined by the SMA, may be hierarchical in nature. To examine this possibility, a hierarchical version of the four-factor model, as described in Figure 2, was analyzed using LISREL procedures. As with Figure 1, the numbers in Figure 2 represent factor loadings. All loadings are scaled such that the variances of the latent variables are equal to 1. The larger the loadings, the stronger the relationship. The model resulted in a Chi Square of 87.45 (df = 72, p=ns), an adjusted goodness-of-fit of .900, and a mean square residual of .087. The fit indices are comparable to the non-hierarchical four-factor solution, even though there are more degrees of freedom in the hierarchical model (i.e., it is a more compact model). It would seem a general factor of memory is a plausible explanation of the obtained covariances between the memory factors.

The final scales of the SMA to be calculated from the subscale data will include four scales defining each of the four memory dimensions (Primary Memory, Secondary Memory, Encoding, and Retrieval), and a General Memory scale. Computations of each of the five memory scales were completed by obtaining a mean of the standardized subscale scores that make up that scale. The reason the mean of the subscales was used rather than the sum of the subscales is that the mean value was more capable of handling missing values. Although missing subscale values occur infrequently with the younger population (i.e., the data that were used for these analyses), they are more common, as we will see in

Figure 2

<u>A hierarchical four-factor model of memory</u>



Chapter 6, with special populations such as the elderly, and therefore need to be addressed in the computations of the scale's scores.

The paths obtained from the LISREL equations were not used to weight each subscale. Unit weighting was felt to be more resistant to sample dependent results (Jackson & Chan, 1980). The signs of the standardized scores for the encoding and retrieval subscales (i.e., all of the latencies), and the Continuous False Alarm Rate subscale were reversed, such that a high positive score on all subscales would indicate an efficient system. For ease of interpretation, each scale score was then transformed into a T-score (mean = 50, standard deviation = 10). The General Memory score was calculated by obtaining a mean of the available scale scores, and then transforming this mean into a T-score distribution.

The Reliabilities of the Standardized Memory Assessment Scales

Table 6 presents the internal consistency and test-retest reliabilities of the SMA scales. The uncorrected data were used to compute the internal consistencies of the reaction time scales. Internal consistencies were computed by examining all the items of the subscales that make up the scale in question. These alpha coefficients should be interpreted with some caution because the subscales differ in the number of items within them and so are not weighted equally. The internal consistency values may, to a large extent, only represent the reliability of the subscale that has the majority of the items (e.g., in the case of the Secondary Memory measure, over half the items come from the continuous recognition task's false alarm items). When computing the scale scores, the subscale scores are standardized; thus compensating for the disproportional number of items in the subscales. This is not the case in our calculations of internal consistency.

Internal consistencies range from a low of .72 for the Primary Memory scale to a high of .86 for the Retrieval scale. Each coefficient is moderate to substantial in size, indicating that the scale scores have relatively high internal consistency. Test-retest reliabilities for the scales range from a low of .68 for the Primary Memory scale to a high of .82 for the Encoding scale. Except for the Primary Memory scale, which has a moderately low test-retest reliability, the reliabilities are moderate in size.

Table 6

Internal consistency and test-retest reliabilities of the Standardized Memory Assessment scales

Scale	Alpha Coefficient	Test-Retest
Primary Memory	0.72	0.68
Secondary Memory	0.81	0.79
Encoding	0.82	0.82
Retrieval	0.86	0.73
General	0.80	0.79

An Examination of the Practice Effects

There is a possibility that the test-retest reliabilities obtained in the SMA are affected by the practice effect of completing the same task twice. That is, individuals get better at a particular memory task with repeated administration, and the amount of this improvement differs from individual to individual. A 2-week interval was used in an attempt to limit these effects, but they may still be pervasive in participants' scores.

The practice effects within each of the subscales were first examined. An overall effect due to the practice effect was significant among the differing scales ($F(1,27) = 45.15$, $p < .05$). The univariate tests of significance for each scale were then examined, and significant differences were found (alpha = .05) for eight of the fourteen scales (see Table 7). The subscales with non-significant differences were for the Primary Memory Capacity I measure, the Working Memory measure, the Continuous Recognition Hit Rate measure, the Primary Memory II Latency measure, the Single Word Latency measure, and the Continuous Recognition Hit Latency. Some of the observed differences were quite large. For example, the average improvement between the two administrations for the Working Memory Latency measure was 528.57 ms, a 28% improvement from the first administration.

The practice effects for the specific memory scales were then examined (See Table 7). There was a significant overall effect due to the practice effect ($F(1,27) = 53.07$, $p < .05$). An examination of the individual scales found that all scales except for the primary memory scale had significant differences (alpha < .01) in the scores for the two administrations of the SMA. Once again, some of these improvements were relatively large in size. The measure of general memory also is much affected by practice ($t(df=37) = -7.42$, $p < .01$).

Are There Differences Between the Sexes?

When dealing with any standardized test, one must be concerned if separate norms are required for the two sexes. To examine this concern, an investigation was completed to determine whether there are sex differences in the individual subscales. Table 8 provides the means of the subscales for each sex. A MANOVA analysis of the subscale data led to

Table 7

Effects of repeated presentation on the Standardized Memory Assessment subscales and scales.

Subscales	Mean at First Attempt	Mean at Second Attempt	p *
Primary Memory Capacity I	7.54	7.51	ns
Primary Memory Capacity II	8.65	9.70	< .01
Working Memory	11.31	11.28	ns
Primacy Free Recall	3.16	4.57	< .01
Non-primacy Free Recall	3.92	5.54	< .01
Cued Recall	12.31	13.56	< .01
Continuous Recognition Hits	15.30	15.68	ns
Continuous Recognition False Alarms	5.03	4.62	ns
Primary Memory II Latencies	1177.13	1141.39	ns
Working Memory Latencies	1905.44	1376.87	< .01
Working Memory Study Time	10358.22	7786.53	< .01
Single Word Categorization Latencies	430.32	343.83	< .05
Secondary Memory Access Rate	1004.97	792.28	< .01
Continuous Recognition Latencies	358.65	345.94	ns
Scales			
Primary Memory	49.98	51.93	ns
Secondary Memory	49.35	58.24	< .01
Encoding	52.08	57.13	< .01
Retrieval	49.85	55.16	< .01
General	50.29	59.09	< .01

Note: all latency scores are reported in milliseconds

* ns = not significant

Table 8

Sex differences in the Standardized Memory Assessment subscales and scales

Subscales	Male Means	Female Means	p *
Primary Memory Capacity I	7.61	7.42	ns
Primary Memory Capacity II	8.88	8.79	ns
Working Memory	11.37	10.80	ns
Primacy Free Recall	3.28	2.94	ns
Non-primacy Free Recall	4.21	4.47	ns
Cued Recall	11.67	12.86	< .01
Continuous Recognition Hits	16.27	15.61	ns
Continuous Recognition False Alarms	6.88	5.13	< .01
Primary Memory II Latencies	1364.75	1288.83	ns
Working Memory Latencies	1908.41	2083.68	ns
Working Memory Study Time	9904.89	10662.97	ns
Single Word Categorization Latencies	445.40	444.63	ns
Secondary Memory Access Rate	990.07	987.38	ns
Continuous Recognition Latencies	381.36	339.29	< .01
Scales			
Primary Memory	50.97	49.15	ns
Secondary Memory	49.00	50.87	ns
Encoding	50.14	49.89	ns
Retrieval	49.27	50.65	ns
General	49.55	50.40	ns

Note: all latency scores are reported in milliseconds

* ns = not significant

significant results (F (14, 183) = 4.18, p < .05), indicating it was appropriate to look at the univariate tests of significance. The univariate tests indicated that there were three subscales that resulted in significant sex differences: the Cued Recall score, the Continuous Recognition False Alarm score, and the Continuous Recognition Latency score.

For the Cued Recall score, females perform better than males (t(177.5) = -3.34, p < .01). Males obtain more false alarms on the Continuous Recognition False Alarm subscale (t(225)=2.83, p < .01). In the case of the Continuous Recognition Latencies, males responded slower than females (t(168.3)=2.73.p < .01).

The next step in the analysis was to examine if these sex differences are associated with the memory construct, or are simply an artifact of the particular subtests. To do this, we examined sex differences in the four memory scales. The means for these scores for the different sexes are also found on Table 8. In this case, a multivariate analysis provided no evidence of any sex differences (F(5,196) = 2.22, p = ns), indicating that univariate tests are inappropriate.

The last analysis of sex differences involved the general memory score. The means for the sexes on this measure can also be found on Table 8. Once again, no significant sex differences are found (t(196) = -.61, p = ns). It would seem that the sex differences found in the subscale scores are an artifact of the individual subscales, and not of the memory constructs. In terms of the scale scores, there is no evidence for the requirement of a different set of norms for the two sexes, at least for the age group studied. Although interpretation of the subscales scores was never an intention in the development of the SMA, if such interpretations are made, separate sex norms may be required for some of the subscales.

DISCUSSION

Overall, the SMA seems to demonstrate adequate psychometric properties, especially considering the numerous variables involved in cognitive tasks such as those used in the battery. The subscale reliabilities range from somewhat low to moderate reliability. The best way to view the subscales is as items or components of the scale score. One would not necessarily expect a single item on a test to have high reliability. The scale reliabilities are of moderate size, although there is room for improvement. The values tend to be similar and often superior to those obtained with the subscales of the Microcog (Powell et al., 1993).

The SMA does seem to demonstrate adequate validity. The information processing theory does a relatively good job at explaining the data. Confirmatory analysis can never prove a theory, it can only disprove one. Although the information processing theory does explain the data, it is possible that other theories of memory may equally explain the data. It is not the purpose of this study to determine what theory of memory best explains the obtained data. The purpose for the analyses was to see if the theory that formed the framework for the SMA can successfully explain data collected with the SMA and therefore provide construct validity evidence.

Why are the reliabilities low for some subscales, and not for others? There are numerous explanations that could each lead to different solutions on how to improve the SMA. First, a low reliability may be an indication that there are not enough items within the subscale and/or scale. Table 9 describes how much a subscale or a scale needs to be increased such that it would have a reliability of .80 or .90. These numbers were calculated using the Spearman-Brown prophecy formula and using the internal consistency measures for each subscale, except for the Primary Memory Capacity I subscale where the test-retest measure was used. The test-retest reliabilities of the SMA scales were also used for these computations. Some of these suggested increases are feasible, while others are impractical.

The problem with increasing the length of the test drastically is the fatigue factor. Because the intention is to use the SMA for special populations such as the elderly, the original goal was to construct a test that would take on average 1 to 2 hours to complete. Fatigue can cause relatively serious side-effects for special populations, the foremost being an unwillingness to continue with the test. As mentioned, the young population takes on average 45 minutes to complete the test. An elderly population takes on average 1.5 hours

Table 9

Required increase in the Standardized Memory Assessment subscale and scale lengths to obtain reliabilities of .80 or .90

SMA Subscale	Obtained Reliability	Reliability = .80		Reliability = .90	
		Factor Increase	Required Items/subscales	Factor Increase	Required Items/subscales
Primary Memory Capacity I	0.69	1.8		4.0	
Primary Memory Capacity II	0.58	2.9	35	6.6	78
Working Memory	0.75	1.3	20	3.0	45
Primacy Free Recall	0.38	6.5	39	14.7	88
Non-primacy Free Recall	0.36	7.1	71	16.0	160
Cued Recall	0.67	2.0	32	4.4	71
Continuous Recognition Hits	0.90	1.0	18	1.0	18
Continuous Recognition False Alarms	0.80	1.0	63	2.2	142
Primary Memory II Latencies	0.60	2.7	32	6.0	72
Working Memory Latencies	0.77	1.2	18	2.7	40
Working Memory Study Times	0.83	1.0	15	1.8	28
Single Word Categorization Latencies	0.83	1.0	16	1.8	28
Secondary Memory Access Rate	0.77	1.2	18	2.7	40
Continuous Recognition Latencies	0.82	1.0	18	2.0	36
Movement Time	0.77	1.2	24	2.7	54
Typing Speed	0.94	1.0	16	1.0	16
SMA Scales					
Primary Memory	0.68	1.9	6	4.2	13
Secondary Memory	0.79	1.1	6	2.4	12
Encoding	0.82	1.0	3	2.0	6
Retrieval	0.73	1.3	5	3.4	10
General	0.79	1.1	15	2.39	34

to complete the SMA. This leaves some room for increasing the length of the test, but not much.

One of the results obtained is the limited use of the Typing Speed measure. It may be useful to remove this measure from the SMA, and replace it with either new items or a new subscale. From the statistics found in Table 9, the following suggestions are made as to which subscale would increasing the number of items be a useful solution: 1) because two measures are derived from the Primary Memory II task and because the Primary Memory scale reliability has room for improvement, it may be useful to increase the number of items of the Primary Memory II subscale from 12 to around 30, so that the reliabilities of the capacity and latency measures may approach .80; 2) for similar reasons, it may be useful to increase the Working Memory task from 15 to approximately 20 triads; 3) because the task is quickly and easily completed by the participants and because it is used to compute all of the latency measures, the Movement Time task should be increased from 20 to approximately 50 items. Improving the subscales should in turn improve the psychometric properties of the scales.

The use of accessory equipment may improve the quality of the SMA. The original intention in designing the SMA was to have an easy to understand battery that could be completed by anyone: it was felt that accessory equipment would simply complicate the test. Further investigation on the usefulness of accessory equipment may be required. For example, most computers these days include a mouse. The mouse may prove to be a valuable tool for response purposes, especially for any YES/NO responses (Crosbie, 1990).

As well as technical explanations of the scale reliabilities, there are some theoretical reasons for the differences in the psychometric properties. Attempts were made to limit the influence of nuisance variables in the procedures involved in the subscales (e.g., by limiting the presentation time of primary memory measures). It is possible that these techniques were not completely successful; it is likely there exist other variables that were not controlled.

There are likely a large number of nuisance variables at work in the cognitive tasks such as those measured in the SMA (e.g., the time of day a participant is taking the SMA, the health of the individual at the time of test, the anxiety of the individual, etc.). It may be that the only way to control for these 'nuisance' variables is to measure them; that is, increase the length of the SMA administration to incorporate all measurements of variables that may effect memory. However, it is likely impossible to completely control for or eliminate all of them. As mentioned earlier, it is likely impractical to increase the length of the SMA administration drastically, and is next to impossible to incorporate all the different measurements of memory into one battery.

The validity evidence obtained for the SMA is encouraging. The good fits obtained in the LISREL analyses would seem to imply that the SMA data are explained by the most popular theory of memory: the information processing theory. In other words, we have some evidence that we are measuring memory when using the SMA. Analysis on the individual subscales indicated that each is performing as one would expect it to perform given the information processing theory and previous research on similar measures.

Perhaps the SMA could be used as a general screening device. When one is interested in a particular area of cognitive ability, additional components of the SMA investigating those specific areas could be developed. Although not conclusive, some evidence was found that secondary memory may be multidimensional. A tool could be developed to measure secondary memory more extensively, such that its dimensions may be more adequately measured. The current Secondary Memory subscales load on one factor, but the scale was developed with the assumption that a single factor defined Secondary memory. Perhaps there is a need to develop a separate test of secondary memory that assumes the concept is multidimensional. This secondary memory battery could be developed using the current theories of secondary memory: Dual coding (Paivio, 1986), the episodic/semantic distinction (Tulving, 1972), and the implicit/explicit distinction (Tulving & Schacter, 1990). This add-on battery focusing on the distinctions in secondary memory may be useful at further examining the results obtained from the SMA.

Another improvement may be to have different versions of the general SMA, each perhaps focussing on different methods of measuring memory. The SMA at the moment involves reading words or strings of digits on a computer screen. Perhaps a version can be devised where the words are not presented on the screen, but rather are read by the computer to the participant: the technology for this is available. Similarly, a version of the SMA that involves graphics rather than words may also lead to some interesting findings. It would provide stronger evidence for the validity of the SMA if the information processing theory could adequately explain the memory constructs of these methodologically different versions of the SMA, as well as limit the amount of proactive interference that likely exists in the subscale performances. Alternatively, perhaps the information processing theory is limited in that it adequately explains the constructs of the current version of the SMA, but would fail at explaining different versions of the SMA and any differences between the versions. Further research is required.

CHAPTER V

The Standardized Memory Assessment and Intelligence

It was established in the last chapter that the information processing theory provides a plausible explanation of the data obtained using the SMA. More specifically, a hierarchical model that includes the factors of memory associated with the information processing theory making up one of the levels best explained the data. At the top of this hierarchical model is a general component of memory that seems to adequately explain much of the relationship between the various factors of the information processing theory. Another area of cognitive ability associated with a general component is that of intelligence. It may be possible that the general component of memory obtained with the SMA may be related to that obtained with intelligence tests.

The concepts of memory and intelligence are intuitively closely related. Measures of memory are often incorporated within intelligence scales, or are often used together with intelligence scales. For example, digit span tasks, such as the Primary Memory I task of the SMA, are often incorporated in intelligence tests. Measures of crystallized intelligence have also been used as measures of long term memory in some studies. Although the relationship between memory and intelligence is typically accepted, there has been little investigation examining this relationship. Many questions remain concerning this relationship. Are memory and intelligence distinct psychological processes, or are the two concepts one and the same? Is one construct a component of the other? Could the information processing theory of memory be adapted to incorporate the concept of intelligence?

Scores on both the WMS and the WMS-R are related to intelligence. Higher scores on the WAIS-R are usually associated with higher scores on the WMS and WMS-R (Kear-Colwell, 1973), at least for participants with average or below average intelligence. Participants with higher than average intelligence tend to reach the ceiling on the WMS and WMS-R scales, limiting their relationship with intelligence (Waldmann, Dickson, & Kazelskis, 1991). Yet even with this strong relationship between memory and intelligence, factor analytic studies of the combined data from the WAIS-R and the WMS-

R result in a separate factor that defines memory (Harmon, Clausen, & Scott, 1993).

One common theory of the relationship between intelligence and memory is that intelligence is restricted by the working memory abilities or attentional capacities of individuals. The concept of intelligence may be a component of memory; it may be defined by the information processing model's concept of primary/working memory. Stankov and Myors (1990) examined the relationship between working memory and intelligence, particularly fluid intelligence. They used number and letter series tasks in their investigation, manipulating the working memory components within the tasks. The authors found a significant interaction between intelligence and working memory. The difference in the tasks' scores between low and high intelligence participants increased as the working memory strain increased. In other words, the correlation between intelligence and a task score was higher when the strain on working memory was higher. One problem with the Stankov and Myors (1990) study is the choice of the working memory task (i.e., number-series tasks). There may be a confound in the results considering that number series tasks are often incorporated within most intelligence tasks.

The relationship between intelligence and simple reaction time measures have been investigated in several studies (Vernon, 1983; Jensen, 1987, Barret, Eysenck, & Lucking, 1986; Schweizer, 1993). The general conclusion is that intelligence correlates with even the simplest of cognitive reaction time tasks, including reaction time tasks similar to the SMA's movement time task. Because the SMA's Encoding and Retrieval measures are determined using reaction time tasks, it is expected that the relationship between these concepts and intelligence will be significant.

Miller and Vernon (1992) measured intelligence, reaction times, and primary memory and showed that measures of primary/working memory had strong correlations with intelligence. As a matter of fact, this correlation in large part explained the correlation between reaction time tasks and intelligence. When primary memory was partialled out from the correlation between intelligence and reaction time tasks, the correlation was near zero. Both Stankov and Myors (1990) and Miller and Vernon (1992) would support the existence of a strong relationship between memory and intelligence, perhaps to the point that the two concepts are inseparable.

Several factor analytical studies of intelligence and memory have been completed (Larrabee, Kane, and Schuck, 1983; Harmon, Clausen, & Scott, 1993). Larrabee et al. (1983) completed a factor analysis of the WAIS and the Wechsler Memory Scale together. Their results indicated a number of distinct intelligence and memory factors: verbal and performance factors for intelligence, and attention/concentration (primary memory), verbal learning/recall, and information/orientation (secondary memory) factors for memory. Of interest is that the obtained factors from an oblimin rotation showed a high correlation between the intelligence factors and the memory factors. As a matter of fact, the correlations between the intelligence and the memory factors are higher than that between the two intelligence factors. Although an interesting result, the authors fail to investigate these correlation patterns, and therefore no explanation of the pattern is given.

Harmon et al (1983) factor analyzed the results of impaired individuals' results on the WAIS-R and the Verbal and Visual Memory indices of the WMS-R. The authors use only these two scales of the WMS-R because Harmon et al (1983) judged them to be the only reasonably reliable measures of the WMS-R. The authors extracted three factors: verbal comprehension, perceptual organization (Performance), and freedom from distractibility. The freedom-from-distractibility factor was made up of the two WMS-R measures, as well as the digit span measure of the WAIS-R, a scale that is used in the SMA to define primary memory. Because a sample of impaired individuals was used in the study, it is unclear if the results would generalize to a sample more representative of the general population. Similarly, the sample size used in the study (54 individuals) is likely too small to make any strong conclusions.

The research seems to indicate that, while a strong relationship exists between intelligence and memory, they are distinct. An examination of the relationship between memory and intelligence in the present study was completed. Specifically, an examination of the relationship between memory, as measured by the SMA, and intelligence, as measured by the Multidimensional Aptitude Battery (Jackson, 1984), was completed. It is expected that results obtained from previous research would be largely replicated in the current study. Memory, as measured by the SMA, can be treated separately from intelligence, as measured by the MAB. The SMA can provide information that is distinct from the information provided using the MAB. But as demonstrated in previous research, it was expected that the scores obtained using the SMA and the MAB would be closely related.

METHOD

Participants

A total of 96 undergraduates at the University of Western Ontario participated in this study. Of these, 48 were male and 48 were female. Ages ranged from 16 to 36, with a mean of 19.91 and a standard deviation of 2.59. The SMA data collected from these individuals were also used in the psychometric analyses of the SMA described in Chapter IV.

Apparatus and Procedure

Each participant completed the SMA on an individual basis as described in the method section of Chapter IV. After completing the SMA, the participants were scheduled to complete the Multidimensional Aptitude Battery (MAB) (Jackson, 1984) in a group session. The MAB provides 10 subscale scores, five of which are combined to provide a verbal score and five of which are combined to compute a performance score. All ten MAB subscales are combined to compute a general intelligence score.

So that standardization could be maximized, instructions for the MAB were presented to the participants using a recording of the standardized MAB instructions. Verbal subscales were completed first, followed by the Performance subscales. Completion of the MAB took approximately 1.5 hours.

RESULTS

Table 10 provides the means and standard deviations for each of the subscale and scale scores obtained for both the MAB and the SMA. Subscale scores of the MAB are reported in raw score format. Scale scores for the MAB are reported in IQ format (i.e., they have been transformed and adjusted for age differences). Subscale scores for the SMA are reported in raw score format. Scale scores for the SMA are reported in the

Table 10

Means and standard deviations for the subscales and scales of the Standardized Memory Assessment and the Multidimensional Aptitude Battery

SMA scales	Mean	Standard Deviation
Primary Memory	50.45	9.32
Secondary Memory	50.79	9.55
Encoding	49.90	[illegible].14
Retrieval	50.21	9.33
General	49.74	9.78
MAB subscales		
V1 - Information	53.50	8.21
V2 - Comprehension	54.58	6.12
V3 - Arithmetic	59.16	7.04
V4 - Similarities	57.32	7.08
V5 - Vocabulary	53.45	7.72
P1 - Digit Symbol	61.37	8.39
P2 - Picture Completion	53.15	7.23
P3 - Spatial	58.62	10.93
P4 - Picture Arrangement	59.79	8.60
P5 - Object Assembly	59.10	7.01
MAB scales		
Verbal	108.72	10.72
Performance	117.57	13.33
Total	113.58	12.01

previously described T-score format.

Correlations among the SMA subscales and scale scores with the MAB subscale and scales scores are reported in Table 11. The correlations between the SMA subscales and the MAB subscales vary greatly, ranging from a low of .01 (The SMA's Primary Memory Capacity I subscale with the MAB's Picture Arrangement subscale) to a high of -.53 (the SMA's Primary Memory II Latencies subscale with the MAB's Spatial subscale). The SMA scales tend to correlate significantly with most of the MAB subscales, and the MAB scales tend to correlate significantly with most of the SMA subscales. As for the correlations between the two assessments' scale scores, every correlation is significant. From the correlation matrix, it would seem that there is a moderate relationship between memory and intelligence. The next question to address is whether they are separate constructs. This was examined using numerous techniques.

The data were examined using multiple regression techniques. In this set of analyses, we examined how well we can predict the memory scores obtained from the SMA from knowledge of an individual's intelligence scores obtained from the MAB. If memory is a part of intelligence, one would expect these predictions to be relatively accurate.

In the case of Primary Memory, the MAB subscales account for 37% of the variance (adjusted $R^2 = .29$; $F(10,85) = 4.94$, $p < .05$), with the Arithmetic and the Digit Symbol subscales having the largest contributions. Verbal and Performance IQ account for 12% of the variance (adjusted $R^2 = .10$; $F(2,93) = 6.52$; $p < .05$), with Performance IQ having the only significant contribution. Total IQ accounts for 12% of the variance (adjusted $R^2 = .11$; $F(1,94) = 12.31$; $p < .05$).

For the Secondary Memory measure, the intelligence subscales account for 21% of the variance (adjusted $R^2 = .11$; $F(10,85) = 2.22$; $p < .05$), with no one subscale providing any significant contribution. The Verbal and Performance scores account for 15% of the variance in the Secondary Memory scores (adjusted $R^2 = .13$; $F(2,93) = 8.30$, $p < .05$), with Verbal IQ providing the only significant contribution. Total IQ accounted for 15% of the Secondary Memory measure variance (adjusted $R^2 = .14$; $F(1,94) = 16.03$; $p < .05$).

Table 11

Correlation between the Standardized Memory Assessment and the Multidimensional Aptitude Battery measures

	MAB Subscales										MAB Scales		
SMA Subscales	V1	V2	V3	V4	V5	P1	P2	P3	P4	P5	Verb	Perf	Total
Primary Memory Capacity I	-0.02	0.06	0.37	0.02	0.11	0.28	-0.08	0.09	0.01	0.07	0.13	0.12	0.14
Primary Memory Capacity II	0.03	0.16	0.34	0.07	0.11	0.15	-0.02	0.16	-0.03	0.17	0.17	0.12	0.16
Working Memory	0.20	0.20	0.28	0.40	0.20	0.12	0.25	0.26	0.26	0.30	0.29	0.42	0.38
Primacy Free Recall	0.14	0.10	0.14	0.15	0.10	0.1	-0.03	0.07	-0.09	0.08	0.19	0.05	0.14
Nonprimacy Free Recall	0.06	0.13	0.17	0.13	0.18	0.19	0.06	0.13	0.02	0.18	0.16	0.15	0.16
Cued Recall	0.18	0.26	0.31	0.19	0.25	0.36	0.20	0.14	0.06	0.28	0.30	0.29	0.32
Continuous Recognition Hits	0.17	0.12	-0.02	0.07	0.10	0.01	0.13	0.07	0.10	0.04	0.09	0.09	0.10
Continuous Recognition False Alarms	-0.07	-0.21	-0.25	-0.28	-0.21	-0.17	0.01	-0.27	-0.24	-0.22	-0.25	-0.26	-0.29
Primary Memory II Latencies	-0.25	-0.34	-0.29	-0.26	-0.21	-0.37	-0.21	-0.53	-0.29	-0.32	-0.34	-0.49	-0.46
Working Memory Latencies	-0.30	-0.38	-0.39	-0.25	-0.22	-0.41	-0.44	-0.44	-0.35	-0.51	-0.39	-0.60	-0.54
Working Memory Study Times	-0.10	-0.10	-0.19	-0.05	0.02	-0.23	-0.05	-0.16	-0.10	-0.05	-0.10	-0.16	-0.14
Single Word Categorization Latencies	-0.32	-0.22	-0.12	-0.28	-0.33	-0.10	-0.20	-0.07	-0.10	-0.02	-0.34	-0.13	-0.28
Secondary Memory Access Rate	-0.43	-0.34	-0.21	-0.25	-0.41	-0.26	-0.28	-0.20	-0.22	-0.16	-0.43	-0.31	-0.43
Continuous Recognition Latencies	-0.16	-0.12	-0.12	-0.21	-0.09	-0.19	-0.33	-0.40	-0.20	-0.34	-0.18	-0.42	-0.33
SMA Scales													
Primary Memory	0.11	0.26	0.54	0.15	0.17	0.41	0.07	0.26	0.12	0.27	0.30	0.33	0.34
Secondary Memory	0.24	0.30	0.32	0.32	0.32	0.28	0.14	0.27	0.14	0.30	0.37	0.32	0.38
Encoding	0.28	0.36		0.25	0.18	0.44	0.29	0.48	0.31	0.37	0.36	0.54	0.49
Retrieval	0.39	0.28	[illegible]	0.36	0.35	0.24	0.36	0.30	0.23	0.22	0.41	0.38	0.45
General	0.40	0.47	0.56	0.42	0.39	0.54	0.34	0.52	0.31	0.47	0.56	0.62	0.65

For the Encoding measure, the intelligence subscales accounted for 34% of the variance (adjusted $R^2 = .26$; $F(10,85) = 4.39$; $p < .05$), with the Spatial subscale providing the only significant contribution. The MAB scales account for 29% of the variance in the SMA Encoding measure (adjusted $R^2 = .27$; $F(2,93) = 18.94$; $p < .05$), with Performance IQ providing the only significant contribution. Total IQ accounts for 24% of the variance (adjusted $R^2 = .23$; $F(1,94) = 29.94$; $p < .05$).

The MAB subscales account for 24% of the variance in the Retrieval measure (adjusted $R^2 = .15$; $F(10,85) = 2.63$; $p < .05$), with no one subscale providing a significant contribution. The MAB scales account for 19% of the variance (adjusted $R^2 = .17$; $F(2,93) = 10.66$; $p < .05$), with Verbal IQ providing the only significant contribution. Total IQ accounts for 20% of the variance in the SMA Retrieval scale (adjusted $R^2 = .19$; $F = 23.04$; $p < .05$)

The MAB subscales account for 48% of the variance in the SMA General Memory measure (adjusted $R^2 = .42$; $F(10,85) = 7.78$; $p < .05$), with the arithmetic and digit symbol subscales providing significant contributions. The MAB scales account for 42% of the General Memory variance (adjusted $R^2 = .40$; $F(2,93) = 32.99$; $p <.05$), with both Verbal and Performance IQ providing significant contributions. Total IQ accounts for 41% of the General Memory variance (adjusted $R^2 = .40$; $F(1,94) = 64.62$; $p < .05$).

The next set of analyses involved examining the correlations between the SMA scales and the MAB scales when the effects of one of the SMA scales are partialled out of each correlation. The purpose of these analyses is to determine what specific aspect of memory would best explain the correlations between the cognitive measures and intelligence (i.e., the part of memory that, when removed from correlations between other aspects of memory and intelligence, leads to significantly lowered correlations).

Table 12 describes the results of these analyses. For the most part, removing the effects of one SMA scale from the SMA/MAB correlations has very little effect. The one exception is the SMA General Memory measure. When this measure is removed from the correlations, most SMA/MAB scale correlations become near zero correlations.

Table 12

Effects of partialling out the effects of Standardized Memory Assessment scores from the correlation between the Standardized Memory assessment and Multidimensional Aptitude Battery measures

	No partialling			Primary Memory Partialled out			Secondary Memory Partialled out		
	Verb.	Perf.	Total	Verb.	Perf.	Total	Verb.	Perf.	Total
Primary Memory	0.30	0.33	0.34				0.20	0.25	0.25
Secondary Memory	0 37	0.32	0.38	0.30	0.24	0.30			
Encoding	0.36	0.54	0.49	0.31	0.49	0.44	0.34	0.52	0.48
Retrieval	0.41	0.38	0.45	0.43	0.40	0.48	0.36	0.33	0.41
General	0.56	0.62	0.65	0.50	0.52	0.58	0.46	0.57	0.58

	Encoding Partialled out			Retrieval Partialled out			General Memory Partialled out		
	Verb.	Perf.	Total	Verb.	Perf.	Total	Verb.	Perf.	Total
Primary Memory	0.22	0.23	0.25	0.34	0.36	0.39	-0.05	-0.04	-0.06
Secondary Memory	0.34	0.29	0.36	0.33	0.27	0.34	-0.09	-0.24	-0.19
Encoding				0.28	0.48	0.42	0.01	0.25	0.14
Retrieval	0.33	0.25	0.35				0.15	0.08	0.17
General	0.45	0.38	0.48	0.45	0.51	0.53			

In the next set of analyses, the SMA and MAB subscales correlation matrix was factor analyzed using procrustes techniques. For the hypothesis matrix, only unit weightings were used: 1) all the MAB subscales were hypothesized to measure a g component and no memory subscales loaded on this hypothetical factor; and 2) all the SMA subscales loaded on factors derived from the structure described in Table 1. Again, only unit weightings were used and no MAB subscales loaded on any of the hypothetical memory subscales.

The first unrotated factor, hypothetically measuring intelligence, accounted for 25% of the variance. The four memory factors accounted for 30% of the variance. The factor matrix was rotated to be maximally congruent with the hypothetical factor structure. The obtained factor structure is found in Table 13, along with the obtained coefficients of congruence.

DISCUSSION

The results support that memory and intelligence are moderately related to each other. Moreover, evidence was obtained to support the notion that memory, as measured from the SMA, is a distinct construct from intelligence, as measured by the MAB.

From the multiple regression analysis, it can be seen that intelligence can predict the memory scores to some extent, but there is still much that the intelligence measures cannot explain. The one exception is the SMA's General Memory measure, which is predicted well by the intelligence measures. A second interesting aspect of the multiple regression analyses is that the individual subscales of the MAB do not do as good a job at predicting SMA performance as do the MAB scales. It would seem that the unique components of the MAB have little in common with the SMA scores, but rather it is what the subscales have in common (i.e., the g component) that best predicts the memory scores.

There is an intelligence component to the SMA scores and it would seem that the predictive value of the MAB likely depends on the size of this component. In the MAB, the g component of the test is basically calculated by combining the results of each of the

Table 13

Factor analysis of the Standardized Memory Assessment and the Multidimensional Aptitude Battery subscale scores using procrustes rotation

SMA Subscales	Factor I Intelligence	Factor II Primary Memory	Factor III Secondary Memory	Factor IV Encoding	Factor V Retrieval
Primary Memory Capacity I	-0.16	0.32	0.44	-0.41	0.00
Primary Memory Capacity II	-0.01	0.49	0.50	0.07	0.02
Working Memory	0.39	0.43	-0.03	-0.15	0.36
Primacy Free Recall	0.06	0.11	0.46	0.26	-0.24
Nonprimacy Free Recall	0.03	0.28	0.57	-0.02	-0.25
Cued Recall	0.34	0.31	0.34	0.09	-0.09
Continuous Recognition Hits	0.29	0.10	0.01	0.01	0.60
Continuous Recognition False Alarms	-0.20	-0.10	-0.46	0.09	-0.14
Primary Memory II Latencies	-0.35	-0.21	0.17	0.66	0.28
Working Memory Latencies	-0.66	-0.34	0.00	0.31	0.02
Working Memory Study Times	-0.04	0.05	0.09	0.79	-0.07
Single Word Categorization Latencies	-0.22	0.40	-0.22	0.21	0.54
Secondary Memory Access Rate	-0.45	0.26	0.03	0.13	0.39
Continuous Recognition Latencies	-0.40	-0.27	0.34	-0.11	0.57
MAB Subscales					
V1 - Information	0.74	-0.38	0.18	-0.04	-0.08
V2 - Comprehension	0.76	-0.25	0.35	-0.11	-0.06
V3 - Arithmetic	0.45	0.33	0.36	-0.27	-0.11
V4 - Similarities	0.69	-0.29	0.22	0.07	-0.14
V5 - Vocabulary	0.67	-0.36	0.38	-0.01	-0.14
P1 - Digit Symbol	0.41	0.36	0.13	-0.40	-0.14
P2 - Picture Completion	0.74	0.03	-0.25	0.03	-0.17
P3 - Spatial	0.54	0.38	-0.10	-0.16	-0.35
P4 - Picture Arrangement	0.57	0.02	-0.27	-0.19	0.19
P5 - Object Assembly	0.70	0.37	-0.08	0.05	-0.08
Coefficients of congruence					
Factor I	0.85	0.05	0.18	-0.26	-0.26
Factor II	0.05	0.49	0.28	-0.20	0.15
Factor III	0.20	0.36	0.56	0.10	0.06
Factor IV	-0.25	-0.21	0.09	0.75	0.10
Factor V	-0.26	0.17	0.05	0.10	0.65

subscales. It would seem that if one was interested in the g component of the SMA, a similar procedure would apply. This procedure is exactly how the General Memory measure was calculated, so that the high efficiency of the MAB in predicting the General Memory is not surprising: General memory is strongly related to the concept of g. One possible explanation of the intercorrelations between the SMA scales is that the intercorrelations may be reflecting the g component of the memory scales. The multiple regression results seem to support this explanation.

This explanation is made even more convincing when one looks at the partial correlation results. When one partials out the effects of the General Memory measure from the correlations between the SMA and the MAB scales, all correlations become zero correlations. No one SMA scale has anywhere near the same effect on the correlations. Memory is a distinct construct from intelligence. The two are related due to the fact that the General Memory component seems to be equivalent to the g component of the MAB.

Another explanation of the previous set of analyses is that once the general component is removed from the SMA scores, there is little variance left in the score. In other words, there is no distinct memory variance, such that when the general component is partialled out from the scores, all correlations will become zero. The procrustes analyses were completed to investigate this possibility.

Although the first factor (Intelligence) alone does account for a large part of the variance, the four memory factors do account for a relatively large additional amount of information. This seems to imply the possibility that there is something more than an intelligence component within the SMA scores. In addition, the congruence coefficients for the hypothetical model are relatively good. The four constructs of memory, as defined by the information processing thesis, do an adequate job of explaining the remaining variance.

The analyses do seem to support the hypothesis that memory, as defined by the information processing theory, and intelligence are distinct, but there is a relationship between the two concepts. It is likely impossible to remove all g influence from any cognitive task, and the relationships demonstrated in this study likely reflect this fact.

However, the analyses do demonstrate that the SMA based on the information processing theory (i.e., Primary Memory, Secondary Memory, Encoding, and Retrieval) can give additional information to that provided by traditional intelligence tests.

The results do provide some interesting possibilities on how results obtained from memory scales may need to be reported. The strong relationship between the SMA and the MAB means that intelligence should be taken into account when interpreting the SMA memory scales. There are methods in which this could be completed. First, we could statistically correct the SMA score using some measure of intelligence. This could mean using an external measure of intelligence, such as the MAB, or perhaps the General Memory scale score. While using the General Memory scale to statistically correct the subscales would not require the use of an external test, further research would be needed to determine the equivalence between intelligence and what is measured by the General Memory scale.

Similarly, an alternative method of adjusting the memory score according to intelligence would be to norm the scale score using various ranges of intelligence or ranges in General Memory Performance. Further research is required to determine the feasibility of this process, especially if additional norms and corrections are required due to other variables, such as age.

CHAPTER VI

Developmental changes in Standardized Memory Assessment performance

One plausible purpose for a standardized test of memory such as the SMA is to help in the diagnosis of cognitive disorders such as dementia in the earliest stages. This task has been attempted with cognitive measures in the past with some limited success (Delis, Massman, Butters, Slamon, Cermak, & Kramer, 1991; Nebes & Madden, 1988; Ferris, Crook, Flicker, Reisberg, & Bartus, 1987; Ferris, Crook, Flicker, Reisberg, & Bartus, 1987; Branconnier, 1987). Because dementia typically occurs in an elderly population, it is important to evaluate the SMA on this population. To successfully use the SMA for diagnosing dementias, the cognitive patterns in a normal elderly population must first be understood. The purpose of this study is to examine the performance on the SMA of a normal elderly sample.

Although the different aspects of memory are viewed as relatively distinct constructs in a population where memory works "normally", this may not be the case in a population where memory problems exist. The information processing theory is a fluid model with memory traces moving from construct to construct. If an early part of the memory system is malfunctioning, it may affect the performance in all of the later stages of memory, such that distinctions between constructs may be difficult to identify in a population where memory deficits occur.

Many studies have demonstrated the existence of a memory deficit in normal elderly samples when compared to a normal young sample. Deficits in every aspect of the information processing theory, including the sensory store and attention (Gilmore, Allan, & Royer, 1986; Hoyer & Plude, 1980), have been suspected at one time or another to be the cause of memory deficits found in an elderly population. Many early examinations of the memory deficits assumed the problem was within the primary store (Smith, 1975). This belief was because the elderly seemed capable of remembering very old memories much better than newly acquired ones. As research progressed, this deficit theory was put aside. Primary memory capacity is stable across age groups (Drachman & Leavitt, 1972; Craik, 1977, West & Crook, 1990), showing little evidence that something is wrong with this structure of memory in an elderly population.

It has also been speculated that the memory deficit may be due to problems in storage within the secondary memory. The data again do not seem to support this claim. The theory would lead to predictions that an elderly population should be more prone to the effects of proactive and retroactive interference, yet evidence indicates otherwise (Smith, 1980). The theory also leads to the prediction that elderly people should forget new information at a faster rate than the young, because if the information cannot be adequately stored, it will be forgotten. The forgetting rate is quite stable throughout all age groups (Smith, 1980).

Due to the fact that a memory deficit is found when elderly people complete free recall tasks but not when they perform recognition tasks, it was felt that the memory deficit was perhaps due to a retrieval problem. Recognition tasks are felt not to place as many retrieval demands as free recall tasks (Schonfield & Robertson, 1966). The problem with the retrieval hypothesis is that it fails to adequately explain many of the observed memory phenomena in an elderly population. For example, the retrieval hypothesis would lead to the prediction that providing a cue at retrieval but not at study should reduce the observed memory deficit in that the cue should relieve the retrieval strains of the task. The empirical evidence does not support this prediction. The cue at retrieval paradigm produces the same memory deficits observed in the free recall paradigms (Smith, 1980; Craik, Byrd, & Swanson, 1987). The retrieval hypothesis would also lead to the hypothesis that an interaction should exist between the length of a list of words to be memorized and age, because the longer the list, the more strain on retrieval. Little evidence for this interaction has been observed (Smith, 1980). Vernon & Vollick (1988) found that their measure of secondary memory access rate (i.e., retrieval speed), similar to the one used in the SMA, is unaffected by age. Although all of the results are not conclusive, they do tend to cast some doubt on the retrieval deficit hypothesis.

The aspect of the information processing theory generally accepted to be the cause the memory deficit is that of encoding (Smith 1980; Salthouse, 1994). All aspects of the memory deficits due to age are more thoroughly explained by encoding problems than by any other single explanation (Smith, 1980). For example, the observation that there are few age effects found in recognition performances, previously used as evidence for a retrieval problem, can also be explained using an encoding deficit approach. In recognition, one does not have to fully encode the information in order to perform adequately. Such is not the case with free recall, where the encoding must be thorough to complete the task adequately. Some evidence of the encoding explanation is provided by Vernon and Vollick (1988). While their measure of secondary memory access rate showed only small age effects, their measure of primary memory retrieval (one aspect of encoding) does show a memory deficit associated with age.

Encoding is probably closely tied to retrieval (Jacoby & Craik, 1979; Cowan, 1988). Jacoby and Craik (1979) theorize that successful retrieval of information will occur only if the retrieval process successfully "mirrors" the encoding process. To say that the age deficit is due to problems in encoding does not rule out the possibility that problems also occur within the retrieval process. Although the encoding hypothesis more fully explains the observed memory deficit on its own, it is possible, if not likely, that encoding problems may occur in conjunction with retrieval problems.

Although it is generally accepted that encoding is the source of the aging deficit, there are a number of possible explanations as to what caused the encoding problems in the first place. The theory of general slowing hypothesizes that all (or most) processes are slowed with aging. This slowing leads to the observed deficits in memory because the elderly can no longer encode as efficiently (Hale, Lima, & Myerson, 1991; Hale, Wagstaff, Poon, & Smith, 1990; Biren, Woods, & Williams, 1980; Salthouse, 1993; 1994a; 1994b). Salthouse (1994a) studied the memory deficit using a large sample of elderly participants. He concluded that the deficit is due to less effective encoding in the elderly sample. He found a relationship between the encoding inefficiency and the participants' speed of processing, such that he concludes that the lack of efficiency in the encoding processes is due to limitations in the speed of processing. The general slowing theory has been used to explain severe memory deficits, such as those found in Alzheimer patients. It is hypothesized that these severe memory problems may be caused by a severe slowing of the cognitive processes (Nebes & Brady, 1992).

Another explanation of the encoding deficit is the attentional deficit theory (Craik & Simon, 1978; Craik, 1977; Duchek, 1984). The theory hypothesises that the attentional capacity of the elderly is diminished, such that the encoding process cannot handle as much information as in the past. This lack of attentional capacity limits the amount of information that can enter the working memory, and hence limits memory performance. Other theories exist (Mantyla & Backman, 1990; Gould, Trevithick, & Dixon, 1991), but the general slowing and the attentional deficit theories are the most popular.

Even if we accept that an encoding deficit is the reason for the observed memory deficit and that this deficit is due to general cognitive slowing or a decrease in attentional capacity, there is some controversy as to whether the process of aging is the actual cause of the encoding deficit. The young and old populations differ in numerous ways, and many of these differences have been used to explain the observed memory deficit. Health, lifestyle (Craik et al., 1987), lack of education, intelligence (Hultsch, Hertzog, and Dixon, 1990), and fitness (Clarkson-Smith & Hartley, 1990) have all been investigated as alternative causes to the problems in encoding. For example Craik et al. (1987) showed that a memory deficit is commonly observed in a group of elderly people in normal retirement homes (the population of elderly people most commonly used in memory deficit studies), but if one looks at a group of active elderly individuals living on their own, the memory deficit is small. Perhaps it is not aging that strictly causes the observed memory deficit, but maybe it is another variable often associated with aging, such as a less active lifestyle.

The purpose of this study is to determine the existence of memory deficits in a normal elderly population using the SMA to measure memory. The existence of such memory deficits would indicate the definitive requirement of separate age norms for the SMA, similar to those used in traditional intelligence tests. In addition, if deficits are found in an elderly population, an examination of what memory constructs (i.e., the SMA scales) are affected would be informative. It is expected that such deficits will exist, and that these deficits will be focused on the SMA's measure of Encoding. In addition, there is some interest in finding out whether an elderly population would readily accept the computer as a testing tool.

METHOD

Participants

Eighty elderly persons participated for this study. These were recruited using the following methods: 1) using a control group participating in a local Alzheimer research project; 2) placing an advertisement in a local newspaper; and 3) using a list of retirees obtained from a local insurance company. All participants were healthy and living on their own. Participants included 34 males and 46 females. These participants ranged from age 55 to 90, with a mean age of 73.18 and a standard deviation of 8.38. Scores of these participants will be compared to scores obtained from the 227 undergraduate participants previously described in Chapter IV.

Apparatus and Procedure

Each participant completed the SMA on an individual basis as described in the procedure section of Chapter IV. Participants were given the option to complete the SMA at university laboratories (as was done with the undergraduate samples), or in their homes. The computer used in the home had the same graphic capabilities and screen size as that used at the university. In 76 of the 80 cases, the participants completed the SMA in their homes. Due to the fact that the experiment often occurred in an individuals' home and because elderly individuals tended to be unfamiliar with the computers, the experimenter stayed with the participants during all stages of the SMA. Completion time of the SMA in this sample ranged from approximately 1 to 2 hours, averaging approximately 1.5 hours.

RESULTS

Table 14 provides the means and standard deviations of the SM . subscales and scales for both the young and the old samples. Also included in this table are the internal consistency measures for the individual subscales for both the young and the old samples.

A MANOVA was completed on the subscale data. The analysis examining the effects of age was significant ($F(14,205) = 8.36$, $p < .05$). Due to the large number of missing data in the Working Memory measures within the older sample, the analysis was

Table 14

Means, standard deviations, and reliability coefficients of the Standardized Memory Assessment subscales and scales for the young and older populations

SMA Subscales	Young Population n	Mean	Standard Deviation	Alpha Coefficient	Old Population n	Mean	Standard Deviation	Alpha Coefficient
Primary Memory								
Primary Memory Capacity I	226	7.51	1.18		77	6.03	1.10	
Primary Memory Capacity II	227	8.83	2.20	0.58	76	5.43	2.92	0.72
Working Memory	222	11.06	3.06	0.75	42	4.95	4.31	0.90
Secondary Memory								
Primacy Free Recall	227	3.10	1.41	0.38	77	1.62	1.23	0.39
Non-primacy Free Recall	227	4.35	1.85	0.36	77	2.81	1.70	0.47
Cued Recall	221	12.32	2.62	0.67	78	7.96	2.75	0.70
Continuous Recognition Hits	227	15.93	3.47	0.90	75	13.44	3.91	0.83
Continuous Recognition False Alarms	227	5.95	4.71	0.80	75	7.83	7.13	0.89
Encoding								
Primary Memory II Latencies	227	1,324.28	404.28	0.60	61	2,039.67	701.09	0.48
Working Memory Latencies	221	2,002.79	1,037.83	0.77	32	4,439.12	1,491.78	0.91
Working Memory Study Times	222	10,311.25	4,786.54	0.83	36	15,810.40	6,155.72	0.78
Retrieval								
Single Word Categorization Latencies	226	444.99	234.24	0.83	78	723.08	499.66	0.88
Secondary Memory Access Rate	220	988.63	320.58	0.77	70	1,374.63	490.48	0.71
Continuous Recognition Latencies	213	359.24	111.53	0.82	58	488.31	221.04	0.77
Correcting Tasks								
Movement Time	227	378.15	41.27	0.77	80	597.60	142.23	0.74
Typing Speed	114	3,748.71	1,312.01	0.94	73	11,874.53	9,250.18	0.92
SMA Scales								
Primary Memory	227	50.00	10.00	0.72	79	27.31	14.27	0.88
Secondary Memory	227	50.00	10.00	0.81	80	32.93	12.52	0.88
Encoding	227	50.00	10.00	0.82	63	24.27	20.04	0.85
Retrieval	227	50.00	10.00	0.86	79	33.72	21.31	0.86
General	227	50.00	10.00	0.80	80	19.44	17.80	0.83

repeated without the Working Memory subscales. Again, the results were significant ($F(11,229) = 14.97$, $p < .05$), indicating that it is appropriate to examine the individual subscale comparisons. A similar MANOVA was completed on the scale data and lead to significant results ($F(5,283) = 64.31$, $p < .05$), indicating that interpretations of the individual scale comparisons are appropriate.

Table 15 provides the results of the individual t-tests performed on the SMA subscales and scales in comparing the young sample to the old sample. Every SMA measure indicates that significant differences do exist between the two samples. Also included in the table is the amount of variance accounted for by age for each SMA measure. These statistics vary greatly depending on the subscale or scale in which one is interested.

To further examine the effect of age on the memory scores, the analyses were repeated to determine if age explained any variance in the SMA scale scores over and above the contribution of the general memory score (i.e., does age affect the pure unique memory' component of the SMA scales, or simply the general component). The results of these analyses are reported in Table 16. In all of the scores except for the Secondary Memory measure, age added a significant amount of explanatory information to the differences between the two samples. The amount of additional information provided by age tends to be relatively small, usually at approximately the 1% level. For Retrieval, age seems to be having a positive effect over and above the influence of General Memory (i.e., increase in age is associated with improvement in the unique components of these scales).

Also included in Table 16 are analyses performed to determine the influence of age on a particular SMA scale, when the effect of one of the other scales is removed. Age information seems to account for a significant part of the variance in each of the SMA scales over and above the effects of an individual scale.

The next set of analyses reported in Table 16 is the effect of age on a particular memory construct after the effects of the remaining memory constructs (except for General Memory) are accounted for. Age does add a significant amount of information in every analysis, but note that the amount of variance explained is greatest for encoding.

Table 15

Comparing performance on the Standardized Memory Assessment between the young population and the older population

SMA Subscales	t-value *	df	Variance Accounted for
Primary Memory			
Primary Memory Capacity I	10.02	140.26	0.24
Primary Memory Capacity II	9.28	105.03	0.27
Working Memory	8.78	49.12	0.32
Secondary Memory			
Primacy Free Recall	8.79	149.38	0.18
Non-primacy Free Recall	6.72	141.51	0.12
Cued Recall	12.17	129.52	0.34
Continuous Recognition hits	4.90	114.98	0.08
Continuous Recognition False Alarms	-2.13	96.22	0.02
Encoding			
Primary Memory II Latencies	-7.64	71.05	0.27
Working Memory Latencies	-8.93	35.47	0.35
Working Memory Study Times	-5.12	42.14	0.13
Retrieval			
Single Word Categorization Latencies	-4.74	88.95	0.12
Secondary Memory Access Rate	-6.18	88.52	0.17
Continuous Recognition Latencies	-4.30	65.09	0.12
Correcting Tasks			
Movement Time	-13.62	82.76	0.59
Typing Speed	-7.46	73.86	0.32
SMA Scales			
Primary Memory	13.06	105.90	0.44
Secondary Memory	11.02	116.50	0.35
Encoding	9.86	70.78	0.41
Retrieval	6.55	90.22	0.21
General	14.57	97.14	0.54

* all t-value reported are those calculated for samples with unequal variances

Table 16

Analyses examining the additional contribution of age in explaining the variance in the Standardized Memory Assessment Scales

Variables Partialled out		Primary Memory	Secondary Memory	Encoding	Retrieval
General Memory	t	-2.70	1.82	-3.21	3.02
	Increase in R^2*	0.01	0.00	0.01	0.01
	p	< .05	ns	< .05	< .05
Primary Memory	t		-5.29	-8.63	-3.65
	Increase in R^2*		0.05	0.14	0.03
	p		<.05	< .05	< .05
Secondary Memory	t	-9.79		-10.41	-4.89
	Increase in R^2*	0.16		0.21	0.06
	p	<.05		<.05	<.05
Encoding	t	-6.78	-5.72		-2.96
	Increase in R^2*	0.09	0.08		0.03
	p	< .05	<.05		< .05
Retrieval	t	-11.90	-8.86	-11.73	
	Increase in R^2*	0.25	0.16	0.27	
	p	< .05	<.05	< .05	
All SMA memory factors (Except General Memory)	t	-5.07	-3.29	-7.12	-1.541
	Increase in R^2*	0.05	0.02	0.09	0.01
	p	<.05	<.05	<.05	ns
Movement Time	t	-5.89	-2.91	-5.56	-1.38
	Increase in R^2*	0.06	0.02	0.06	0.00
	p	< .05	<.05	< .05	ns

* Increase in variance accounted for when age is entered into the equation

The analyses were repeated to determine if age added any information over and above the measure of Movement Time (i.e., simple reaction time). These analyses are also reported in Table 16. In these analyses, age added little to explaining the population differences for the Retrieval measure, but did explain a significant amount of the additional variance in the other SMA scales.

One very plausible explanation of the results is that they reflect cohort differences between the two groups. In order to determine if the age effects observed are strictly cohort differences, an examination of the correlation between age and the SMA scores was made for the two populations. These correlations and their significance are reported in Table 17. There is a predominance of significant correlations between age and the SMA scales in both populations.

DISCUSSION

One concern with a computerized battery is that an elderly population would neither want to complete nor be able to complete the tasks required due to their relative unfamiliarity with computers. This was not the case for the SMA. Although very few elderly individuals had any experience with a computer, the vast majority had few problems with the SMA procedures. Most of the participants reported enjoying taking the SMA, and very few expressed fear of the computer after completion of the tasks. Note that the internal consistency measures for the elderly population are very similar to those for the young population. It would seem that at least this psychometric property of the SMA carries over from the young population to the older population.

The results obtained strongly imply the need for separate SMA norms for different age groups. It seems fairly evident that age differences do exist. What perhaps is not so evident is why these age differences exist. Every comparison using SMA measures between the two age groups leads to significant differences. It would be easy simply to claim that age is associated with an overall memory decline, and that the SMA will require separate norms if it is to be used with varying age groups. But why do these differences exist?

Table 17

Correlation between age and the Standardized Memory Assessment scales for the young and the older population

SMA Subscales	Young Population		Old Population	
	r	p	r	p
Primary Memory				
Primary Memory Capacity I	-0.07	ns	-0.13	ns
Primary Memory Capacity II	-0.09	ns	-0.39	< .05
Working Memory	-0.22	<.05	-0.38	< .05
Secondary Memory				
Primacy Free Recall	-0.18	<.05	-0.07	ns
Non-primacy Free Recall	-0.02	ns	-0.22	ns
Cued Recall	-0.08	ns	-0.42	< .05
Continuous Recognition hits	-0.04	ns	-0.14	ns
Continuous Recognition False Alarms	0.02	ns	0.24	< .05
Encoding				
Primary Memory II Latencies	0.06	ns	0.36	< .05
Working Memory Latencies	0.21	<.05	0.22	ns
Working Memory Study Times	0.09	ns	0.43	< .05
Retrieval				
Single Word Categorization Latencies	0.08	ns	0.26	< .05
Secondary Memory Access Rate	0.24	<.05	0.45	< .05
Continuous Recognition Latencies	0.12	ns	0.26	< .05
Correcting Tasks				
Movement Time	0.17	< .05	0.41	< .05
Typing Speed	0.32	< .05	0.42	< .05
SMA Scales				
Primary Memory	-0.18	<.05	-0.35	< .05
Secondary Memory	-0.12	ns	-0.36	< .05
Encoding	-0.19	< .05	-0.34	< .05
Retrieval	-0.18	< .05	-0.39	< .05
General	-0.25	< .05	-0.50	< .05

One method of attempting to answer this question is to examine what area of memory is seemingly most affected by aging. One way this could be done is to simply look at the absolute size of the amount of variance accounted for by age in the various SMA measures. Is there a particular area of memory,as previously hypothesized, that seemingly is more affected by aging? Recent theories focus on the effect of encoding. Do the results bear out this hypothesis?

The information in Table 15 indicates that age explains a large part of the variance in the Primary Memory, Secondary Memory, and the Encoding scales. The amount of variance explained in the Retrieval scale, although significant, is somewhat less. Hence, we do find that age has a large effect on the Encoding measures, but not more so than the effects of age on Secondary Memory and Primary Memory. Also of interest in Table 15 is the large amount of variance accounted for by age in the General Memory measure. This would seem to imply that age may have a general effect on memory performance, rather than a specific effect on any one memory component. Results from Table 16 can be used to examine this hypothesis. If there is a general memory decline, then the amount of variance that age would explain in the individual SMA scales over and above what is explained by the General Memory score should be negligible. The effect of age remains significant for all of the SMA scales, except for the Secondary Memory scale. In other words, aging has a significant effect on the unique memory components over and above a general memory decline, except for the secondary memory component. As has been found in previous research (Smith, 1980), secondary memory is more resistant with respect to the effects of aging and the present results seem to support these findings.

The amount of variance explained by aging over and above changes in General Memory is rather small (on average about 1%) Both Encoding and Primary Memory seem to be equally affected by aging. With this set of analyses, we find little evidence that encoding is the focus of the memory decline. The effects of aging over and above the general memory decline on the Retrieval measures seem to be positive in nature. That is, aging is associated with a significant increase in retrieval skills, but this increase is negated by the general overall decline of memory.

Because encoding is implicated as the root of the age deficits, one would expect that if encoding scores are removed from the analysis of age on any particular SMA score, the age effect would be drastically minimized. If the deficit is focussed in the encoding process, one would expect that the additional information that age would provide in explaining the group differences in the SMA scores would be negligible once the Encoding measure is partialled out. The change in the amount of variance accounted for is somewhat less when encoding is partialled out, but likely not significantly less than when primary memory is partialled out (see Table 16). Some evidence for encoding being more affected by age is found when one looks at the results of the analysis when the effects of all other SMA scales (except for General Memory) are removed. Age accounts for the largest amount of additional variance for the Encoding measure; almost twice as much variance is accounted for as for any of the other SMA scales.

One popular hypothesis of aging and memory is that the memory decline is due to a general slowing of behavior (Hale et al., 1991; Hale et al., 1990; Biren et al., 1980; Salthouse, 1993; 1994a; 1994b). To examine this hypothesis, we can look at the results in Table 16 on the effects of aging over and above the Movement Time measure. The Movement Time measure, a simple reaction time measure, is the most basic measure of speed available in the SMA. The correlation between Movement time and General Memory is rather large (For the young sample, $r = -.38$; for the old sample, $r = -.56$; for the combined sample, $r = -.77$). Perhaps the analysis of the effects of age beyond General Memory could be replicated by using Movement Time rather than General Memory. The results in Table 16 to a large extent confirm this.

Once the effects of general slowing are removed, there seems to be only a minor, although significant, effect of age on the memory variables. The results are similar to those obtained when the effects of General Memory are removed. Although there is some effect on the amount of variance accounted for when the effects of a particular scale are partialled out of the other scales, the effect does not come near to replicating the effects of partialling out general memory or movement time. It is likely that the small effects resulting from partialling out any one scale score, including the Encoding score, on the analyses are to a large extent related to the general memory component of the particular scale rather than its unique component. The study does seem to replicate much of the findings collected in Salthouse's research (1993, 1994a). A general slowing of cognitive processes is observed, and this slowing explains a very large proportion of the observed memory deficit.

As was noted in study 2, the young sample used in this study is probably not representative of the young population. In general, this may lead to an exaggeration of the memory deficit and provide one explanation for seeing significant differences between the young and old population in areas of memory that previous research has demonstrated were stable as to age effects (for example, in Primary Memory). The generalizability of the age differences results should be investigated further by examining the SMA scores of a more representative young population (i.e., non-university students), as well as representative samples of other age groups.

Although it is possible that the age deficit is magnified in the study due to the makeup of the young sample, the results reported in Table 17 seem to indicate that the effects of aging are still very pervasive. Even in the young sample, there are significant correlations between age and the memory scores on the SMA. The only non-significant correlation between age and SMA memory scale scores in the young sample is that with Secondary Memory.

The correlations between age and memory are magnified in the older population. Although the correlations are larger with the older population than the younger group, the patterns within the SMA scale score correlations are very similar to that of the young sample, with General Memory providing the highest correlation.

These significant age correlations lead to another implication in terms of final norms for the SMA. The age group to be used should be more extensive than simply two age groups. Intervals of 2 to 3 years will likely have to be used to group individuals, and perhaps even narrower intervals in the older population. The large intervals that have been used in this study will likely have limited usefulness for purposes of norming the SMA.

The results from this study do suggest that a few additional improvements to the SMA may be necessary. First, note the much smaller sample size obtained for the Working Memory measures when compared to the other SMA measures. The reason for this is that the older participants often refused to complete the measure after becoming very frustrated with the task. The measure was therefore skipped for approximately half of the sample. The main reason is that the elderly population had great difficulty with the working memory tasks in which the load on working memory is greater than 0. This incident is consistent with the attentional deficit theory of memory decline (Craik & Simon, 1978; Craik, 1977; Ducchek, 1984), in that the tasks with high memory load would theoretically fill an older participant's attention, such that additional memory tasks would be impossible for most members of an older population. This likely affected the obtained results. The Working Memory measures are integral in computing the SMA's Primary Memory and Encoding measures. It is likely that had working memory measures been obtained, the observed memory deficits for the SMA's Primary Memory and Encoding would have been even greater.

There are two options available in order to improve the working memory scale. The first is to strongly encourage participants to complete the scale in spite of their great difficulties. This way, attentional deficit information may be able to be calculated from the scores. Although this option is good for theoretical reasons (i.e., it might provide further insight as to the memory decline with age), it is not a good one for practical reasons. It must be kept in mind that it is hoped the SMA will be used to predict disorders associated with memory deficits. That is, it will be used for populations that are more disadvantaged than the older population used here. The Working Memory test provides little information beyond the fact that the elderly have great difficulty completing tasks with memory loads greater than 0. If this healthy population of elderly people cannot complete the task, then the tasks will provide no information in distinguishing healthy individuals from individuals with cognitive deficits, who would be more likely to be incapable of completing the Working Memory task.

The second option is to revise the Working Memory task. Due to the fact that few individual differences are found between the memory loads in a younger population, and that the elderly cannot complete tasks with a memory load greater than 0, one suggested revision is to only use triads with a memory load of 0. The task would no longer be a 'working memory' task, but simply a task examining the participant's ability for cued recall using their primary memory. This type of task may be of more practical use in helping to predict cognitive deficits than the Working Memory task as it now stands, and perhaps could lead to improvements in the psychometric properties of the scale. Another suggestion is to change the working memory task that is used in the SMA. The key is to find one that an elderly sample could complete, that preferably would not have a ceiling effect among the young population, and that is amenable to a computerized format. With the ever increasing technology (e.g., verbal presentation using the computer), the computer places few limits on what tasks can be used.

In returning to the options of lengthening the SMA, the elderly group took approximately 1.5 hours to complete the test. This is already longer than would be desired, so increasing the SMA has only limited practical appeal. One aspect to note is that typing speed is seriously affected in the older population. This could be for various reasons, including a lack of familiarity with the computer keyboard and the general slowing that has already been discussed. The typing task takes the older population on average three times as long to complete as compared to the younger population (see table 14). As has already been discussed, this measure is likely of very limited use (it was not used in any of the analyses on this older population). With the removal of this scale, additional items in other subscales could easily be added, as might an additional subscale.

CONCLUSIONS

Overall, the results are encouraging for the possibility of an extensive, computer-based assessment of memory. This is not to say that there is not any room for improvement in the present version of the SMA. The SMA must be viewed as an assessment tool that will continue to evolve with successive improvements. The main reason for this is the continuous improvements in computer technology. We must be reminded once again of the criticisms made by Hunt and Pellegrino (1985): We must begin designing tests that use the computer to its fullest. This means that any new computer technological advances that are made that could lead to a better and more psychometrically sound SMA should be investigated for their usefulness for test development purposes. For example, current improvements in the area of multimedia technology open up numerous possibilities to improving upon the SMA. The SMA, as it now stands, is a very simple computer program. The psychometric properties obtained considering this fact are relatively impressive. They are certain to improve if various methods of presenting stimuli (e.g., sound, pictorial, video) are incorporated in the SMA, such that a more complete view of memory is presented. This improvement may also limit the proactive interference that likely is occurring within the SMA due to its 100% verbal stimuli.

In addition, improved computer technologies may provide for simple, reliable, and valid indicators of sensory memory and attention, as well as a psychometrically sound qualitative measure of encoding. A test based on the information processing theory would not be complete without some subscales measuring these concepts.

The SMA scales demonstrate moderately high reliabilities. Analysis of the constructs in the SMA does seem to provide evidence of its validity, as do the analyses of various subscales. It was found that the constructs being measured by the SMA are related to the constructs measured in an intelligence test such as the MAB, yet it was also found that there is evidence of independence between the constructs of the two scales. The SMA does seemingly provide additional information to that given by intelligence tests. It was found that an older population has few problems handling the computer presentation format of the SMA, and usually enjoyed the experience. It was found that there is a memory deficit due to age, and it appears to be very pervasive. To a large extent, this memory deficit can be explained by a general slowing of mental processes rather than the effects of aging on one particular area of memory.

No claims are being made that the SMA is ready for use in a clinical setting. The studies completed do point out numerous weaknesses in the SMA that would need to be corrected prior to being used on a clinical sample. The purpose of the studies was not to have a final version of a clinical scale. It was to examine the feasibility of completing a standardized memory scale that would have construct validity; i.e. could a memory scale be designed based on the popular information-processing theory of memory. A computerized presentation offered some unique methods of measuring the concepts, methods that are cumbersome or impossible for traditional methods of testing.

The next step in the SMA development process is to make some of the minor adjustments to the content of the battery in order to improve its psychometric properties. These steps would minimally include: 1) removing the Typing Speed task from the SMA and replacing it with additional items in subscales requiring additional items (e.g., Primary Memory Capacity II task; Working Memory tasks); and 2) revising the Working Memory Scale to a task that a normal elderly sample could complete.

After content changes have been made, the next step is to improve the computer presentation of the SMA. Due to the fact that the SMA is intended to be used with populations with mild cognitive difficulties, the key concept to keep in mind when making any adjustment to the computer presentation is "**user friendliness**". Improvements to the SMA should be limited to items that make the task easier for the participants, so that the variety of individuals that can complete the SMA can be maximized.

Further study could be completed to examine performance of the SMA over time. This may provide an additional method of viewing memory, incorporating a learning component to the measure. Care would have to made about any independent interpretation of both the memory scores and any learning scores. Otherwise, the SMA would incorporate the problem of interdependency much like other existing memory scales.

The final step would be to norm the SMA on a large representative sample of both normal individuals and individuals with mild cognitive disorders. It is hypothesized that the pattern of memory loss may be different in the population with cognitive deficits, such that the SMA scores could be used to predict such cognitive deficits. Although we have used people in the early stages of Alzheimer's disease as an example of a cognitive deficit that the SMA may be used to predict, the SMA is likely not limited to this disorder. There are numerous cognitive disorders that affect every age group. For example, it may be possible to use the SMA to quantitatively diagnose learning disabilities in young adults and perhaps even in young children, although some major changes to the presentation of the SMA would need to be made for very young children.

The possibilities of a battery measuring memory skills are numerous. There has always been a need for an adequate measurement of memory structures and processes, but while computers were not available, many of the cognitive measures were difficult to measure in a standardized and economical manner. Now that the computer technology is here, the need for an adequate measurement tool has not disappeared and cognitive batteries such as the SMA may prove to be very useful.

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APPENDIX I - Stimuli used in the Standardized Memory Assessment

Primary Memory Capacity II

(Number in bold is the number that would be missing in the string's second presentation)

1) 8 7 2 **4** 1 9 8 4 7
2) 4 1 5 3 4 6 9 3 **2**
3) 6 **8** 7 7 0 4 4 1 9
4) 5 9 3 9 5 6 **7** 7 6
5) 3 **1** 7 5 4 0 5 6 2
6) 1 4 0 3 **0** 9 2 6 9
7) 8 7 9 **3** 4 4 7 2 2
8) 6 7 9 2 5 4 **1** 4 6
9) 3 **2** 5 8 1 0 0 1 7
10) 9 6 5 7 4 **1** 3 8 9
11) 3 2 0 3 2 5 1 **1** 5
12) **6** 6 7 7 8 2 8 3 4

Working Memory

Triad 1

Z = (8 - 5) + 6
X = (7 / 1) * 1
Y = (2 * 1) + 0

Triad 2

Y = 0
X = 9
Z = 4

Triad 3

Y = (4 * 2)
Z = (1 + 1)
X = (7 / 7)

Triad 4

y = (8 / 2)
X = (5 * 1)
Z = (7 - 4)

Triad 5

Z = 5
X = 9
Y = 8

Triad 6

Z = 3
X = 7
Y = 2

Triad 7

X = (7 * 0) / 4
Z = (2 + 1) * 3
Y = (5 / 5) * 7

Triad 8

X = (9 / 3) * 1
Y = (6 + 1) / 7
Z = (2 + 3) - 5

Triad 9

X = (8 - 5)
Z = (4 + 3)
Y = (8 / 2)

Triad 10

Z = (2 + 2) / 4
Y = (3 * 2) - 2
X = (9 - 1) / 4

Triad 11

Y = (6 / 3)
Z = (3 * 2)
X = (8 - 1)

Triad 12

Y = (8 - 2) / 2
Z = (8 / 4) - 2
X = (3 * 3) - 7

Triad 13

Z = (7 - 7)
Y = (1 + 4)
X = (9/3)

Triad 14

Y = 3
X = 9
Z = 7

Triad 15

X = 2
Y = 9
Z = 4

Free Recall

1) SLUSH
2) CHANCE
3) INTERIM
4) SOUL
5) FOREST
6) JUGGLER
7) CHAIR
8) GIST
9) BABY
10) STAR
11) ACROBAT
12) CONTEXT
13) IDEA
14) ACCORDION
15) FOIBLE
16) FACT

Cued Recall

1) INSECT - CATERPILLAR
2) SMALL - ANIMAL
3) WANT - CITY
4) AFRAID - SCARED
5) FINGER - PRINT
6) HOT - COLD
7) SOFT - CABBAGE
8) CLEAN - DETERGENT
9) ROUND - SUN
10) BULB - LIGHT
11) SHOULDER - CHEESE
12) THOUGHT - CANDLE
13) BOY - RIVER
14) SLOW - FAST
15) WET - DRY
16) SKY - SEA

Continuous Recognition

1) LABOR
2) PATENT
3) MAKER
4) LAKE
5) REFLECTION
6) COMPETITION
7) WORK
8) GRASS
9) LABOR
10) PATENT
11) PEAR
12) MOUNTAIN
13) MAKER
14) MONEY
15) LAKE
16) PAIR
17) WATER
18) CELL
19) TREE
20) GREEN
21) CUBE
22) AMBASSADOR
23) GRASS
24) COMRADE
25) BRAKE
26) GODDESS
27) SELL
28) ICE
29) COMRADE
30) BACKGROUND
31) BLOCK
32) GODDESS
33) MITE
34) CAPTIVE
35) STEEL
36) EAT
37) HEAL
38) CUBE
39) BACKGROUND
40) BREAK
41) EAT
42) DISASTER
43) HEEL
44) MIGHT
45) SESSION
46) TRIBUTE
47) AIR
48) ODOR
49) LAMB
50) GOOD
51) STEAL
52) PLEDGE
53) FOOD
54) SUBSTITUTE
55) ODOR
56) DISASTER
57) TRIBUTE
58) SOUP
59) HEIR
60) STEM
61) BEAT
62) PRAY
63) LAMB
64) IGNORANCE
65) SHEEP
66) STEM
67) SMOOTH
68) FLOWER
69) LONG
70) BARON
71) IGNORANCE
72) ROUGH
73) COARSE
74) SMOOTH
75) ECONOMY
76) BEET
77) GROW
78) LONG
79) PREY
80) SHORT
81) TIME

Single Word Categorization

1) TRUE
2) FAKE
3) PESSIMISTIC
4) NO
5) ACTUAL
6) DOUBTFUL
7) DUBIOUS
8) YES
9) DEFINITIVE
10) NOTHING
11) CONFIDENT
12) DENY
13) EVERYTHING
14) ACCEPT
15) CLEAR
16) VOID

Secondary Memory Access Rate: Synonym-Antonym

1) LAUGH - CRY
2) EMPTY - FULL
3) ADD - SUM
4) BUSY - ACTIVE
5) SHRINK - CONSTRICT
6) IMPLY - EXPRESS
7) WHOLE - TOTAL
8) POLITE - RUDE
9) HIGH - TALL
10) BLACK - WHITE
11) CLOSE - SHUT
12) STRONG - WEAK
13) BIRTH - DEATH
14) CHOOSE - SELECT
15) NEAR - FAR
16) THICK - WIDE

Secondary Memory Access Rate: Same-Different

1) APATHY - APATHY
2) CIPHER - CIPHER
3) ARRAIGN - ARRAY
4) COUNT - COUNT
5) BRISK - BRING
6) EMBRACE - EMBRACE
7) GREAT - GREAT
8) DECEIVE - DECIDE
9) ENTIRE - ENTITLE
10) INFIDEL - INFIDEL
11) GROAN - GROUP
12) LEAD - LEARN
13) MASK - MASK
14) PALTRY - PALTRY
15) PARTIAL - PARTAKE
16) QUALITY - QUANTITY

APPENDIX II - The Standardized Memory Assessment's instructions

General instructions

THANK YOU FOR PARTICIPATING IN THE EXPERIMENT. THE FOLLOWING TEST IS DESIGNED TO EVALUATE DIFFERENT ASPECTS OF YOUR MEMORY. THERE WILL BE 11 DIFFERENT TASKS. COMPLETION OF THE TASKS SHOULD TAKE APPROXIMATELY 1 HOUR.

EVERY TASK WILL INVOLVE RESPONDING USING THE KEYBOARD IN DIFFERENT WAYS. IN SOME TASKS YOU WILL BE REQUIRED TO PRESS DIGITS. USE ONLY THE DIGIT KEYS ON THE TOP ROW OF THE KEYBOARD TO COMPLETE THESE TASKS. PUSHING ANY OTHER KEY WILL RESULT IN THE ITEM BEING JUDGED WRONG. IN OTHER TASKS YOU MUST PUSH THE KEYS MARKED 'YES' AND 'NO'. FAMILIARIZE YOURSELF TO THE LOCATION OF THESE KEYS SINCE THEY WILL BE USED OFTEN. STILL OTHER TASKS WILL REQUIRE YOU TO TYPE IN WORDS OR STRINGS OF DIGITS. NOTE THAT YOUR SPEED OF RESPONSE WILL OFTEN BE TIMED. FOR THE TASK INVOLVING PRESSING THE 'YES' OR 'NO' KEYS YOU MAY HAVE A FINGER ON TOP OF EACH KEY READY TO PRESS IT AT THE APPROPRIATE MOMENT. THIS TACTIC IS NOT RECOMMENDED FOR THE TASKS IN WHICH DIGITS ARE REQUIRED TO BE PRESSED.

COMPLETE INSTRUCTIONS WILL BE GIVEN BEFORE EVERY TASK. MOST TASKS ALSO WILL HAVE A FEW SHORT PRACTICE TRIALS BEFORE THE ACTUAL TEST. THIS ALLOWS YOU TO BECOME FAMILIAR WITH THE TASK AND THE KEYS USED IN THE TASK. NOTE THAT IF YOU HAVE ANY DOUBTS ABOUT THE INSTRUCTIONS FEEL FREE TO ASK THE EXPERIMENTER.

Primary Memory Capacity I

IN THE FOLLOWING TASK, YOU WILL BE SHOWN A SHORT LIST OF DIGITS FOR TWO SECONDS. THE LENGTH OF THE STRING OF DIGITS WILL DEPEND ON HOW WELL YOU ARE DOING IN THE TASK. YOUR TASK IS TO ATTEMPT TO MEMORIZE THE STRING OF DIGITS. DIRECTLY AFTER PRESENTATION, YOU WILL BE PROMPTED TO RECALL THE STRING. YOU COMPLETE THE TASK BY

TYPING THE APPROPRIATE DIGITS IN THE SAME ORDER AS PRESENTED WHEN THE PROMPT APPEARS. AFTER ALL THE DIGITS HAVE BEEN TYPED IN, PRESS THE <ENTER> KEY. ONCE THE ENTER KEY HAS BEEN PRESSED, YOU CAN NOT CHANGE YOUR ANSWER. BE CAREFUL AS TO THE DIGITS YOU TYPE IN. ANOTHER STRING OF NUMBERS WILL THEN BE PRESENTED AND YOU ARE TO REPEAT THE TASK.

FOR EXAMPLE, LET US SAY THE STRING '3 6 4' IS PRESENTED. THE NUMBERS WILL STAY ON THE SCREEN FOR TWO SECONDS, THEN THE SCREEN WILL GO BLANK FOR A SECOND, AND YOU WILL THEN BE PROMPTED TO REMEMBER THE STRING OF DIGITS. TO RESPOND CORRECTLY FOR OUR EXAMPLE, YOU MUST HAVE TYPED IN '364' WHEN THE PROMPT APPEARED AND THEN HAVE PRESSED THE ENTER KEY. THERE WILL NOT BE ANY PRACTICE TRIALS IN THIS TASK, SO IF YOU HAVE ANY QUESTIONS, IT IS IMPORTANT TO ASK THE EXPERIMENTER NOW.

Primary Memory Capacity II

IN THE NEXT TASK YOU WILL BE SHOWN A STRING OF NINE DIGITS FOR TWO SECONDS. THE SCREEN WILL THEN BE CLEARED FOR A SECOND AND THE STRING WILL REAPPEAR WITH ONE DIGIT REPLACED BY A '_'. YOUR TASK IS TO ATTEMPT TO RECALL THE MISSING DIGIT. YOU CAN DO THIS BY PRESSING THE APPROPRIATE DIGIT ON THE KEYBOARD. THE COMPUTER WILL ACCEPT ONLY ONE PRESS OF A DIGIT. PLEASE BE CAREFUL WHAT DIGIT YOU PRESS. YOU RESPONSES WILL BE TIMED AND WILL BE SCORED AS TO WHETHER YOU WERE CORRECT IN YOUR RESPONSE.

FOR EXAMPLE: LET US SAY THE STRING '1 2 3 4 5 6 7 8 9' IS PRESENTED. THE STRING WILL STAY ON THE SCREEN FOR 2 SECONDS THE SCREEN WILL THEN CLEAR FOR A SECOND AND A STRING SUCH AS '1 2 3 4 _ 6 7 8 9' WILL APPEAR. TO RESPOND CORRECTLY YOU MUST PRESS THE '5' KEY ON THE KEYBOARD AS FAST AS YOU CAN. THERE WILL BE A FEW PRACTICE TRIALS TO GET YOU FAMILIAR WITH THE TASK. ASK THE EXPERIMENTER IF YOU HAVE ANY QUESTIONS.

Working Memory

IN THIS TASK, YOU WILL BE SHOWN A SERIES OF THREE LETTERS (X, Y, AND Z), ONE AT A TIME, AND A VALUE ASSOCIATED WITH EACH. THIS VALUE MAY BE PRESENTED EITHER AS A SIMPLE DIGIT OR AS A SIMPLE COMPUTATION, IN WHICH THE VALUE MUST BE COMPUTED FOR EACH LETTER. THE VALUE OF THE LETTERS WILL BE AN INTEGER FROM 0 TO 9 INCLUSIVE, AND NO TWO LETTERS WILL HAVE THE SAME VALUE. YOUR TASK IS TO MEMORIZE THE VALUE OF EACH LETTER. YOU MAY STUDY THE THREE LETTERS INDIVIDUALLY FOR AS LONG AS YOU LIKE. WHEN YOU ARE READY, PRESS ANY KEY TO STUDY THE NEXT LETTER. AFTER STUDYING THE LETTERS, ONE OF THE LETTERS WILL APPEAR. YOU WILL BE PROMPTED TO TYPE IN THE VALUE ASSOCIATED WITH THE LETTER. SIMPLY PRESS A DIGIT FROM 0 TO 9 ON THE KEYBOARD AS QUICKLY AS YOU CAN. THE COMPUTER WILL ONLY ACCEPT ONE KEY PRESS, SO BE CAREFUL WHAT KEY YOU PRESS. AFTER RESPONDING, A SECOND LETTER WILL APPEAR. AFTER RESPONDING TO THIS LETTER, THE THIRD LETTER WILL APPEAR. RESPONSE TO THIS LETTER WILL CLEAR THE SCREEN AND THE THREE LETTERS WILL REAPPEAR WITH NEW VALUES ASSOCIATED WITH THEM. YOU WILL BE SCORED HOW ACCURATE YOU ARE IN REMEMBERING THE VALUES OF EACH LETTER, AND HOW QUICKLY YOU RESPOND TO EACH LETTER.

FOR EXAMPLE, YOU MAY BE PRESENTED WITH THE FOLLOWING:

Z = (9 - 3) / 2

THEN AFTER YOU PRESS A KEY

X = (4 + 5) - 7

AND AGAIN AFTER YOU PRESS A KEY

Y = (4 X 2) + 1

YOU MAY STUDY EACH LETTER UNTIL YOU FEEL YOURSELF READY TO RECALL ITS VALUES. YOU PRESS ANY KEY, AND THEN AFTER A SECOND, THE COMPUTER MAY DISPLAY 'X = '. YOU MUST THEN RECALL THE VALUE OF X AND PRESS THE '2' KEY ON THE KEYBOARD TO RESPOND CORRECTLY. THE COMPUTER MAY NEXT ASK FOR THE VALUE OF Z. A CORRECT RESPONSE WOULD HAVE BEEN 3, AND FOR Y IT WOULD HAVE BEEN 9. THERE WILL BE A FEW PRACTICE TRIALS TO GET YOU ACQUAINTED WITH THE TASK. IF

THERE ARE ANY QUESTIONS, ASK THE EXPERIMENTER.

Free Recall

IN THE FOLLOWING TASK, YOU WILL BE PRESENTED WITH A SERIES OF 16 WORDS ONE AT A TIME. YOUR TASK IS TO MEMORIZE THE LIST OF WORDS SUCH THAT YOU MAY LATER RECALL THE WORDS. EACH WORD WILL BE PRESENTED FOR APPROXIMATELY FOUR SECONDS. AFTER PRESENTATION OF THE 16 WORDS, YOU WILL BE ASKED TO CALCULATE SOME SIMPLE ADDITIONS. YOU DO THIS BY SIMPLY TYPING IN THE SUM OF THE NUMBERS IN QUESTION. THE COMPUTER WILL TELL YOU WHEN YOU HAVE MISCALCULATED.

AFTER COMPLETION OF SEVERAL OF THESE CALCULATIONS, YOU WILL BE ASKED TO REMEMBER AS MANY WORDS AS YOU CAN. YOU DO THIS BY SIMPLY TYPING EACH WORD, ONE AT A TIME AND IN ANY ORDER, INTO THE COMPUTER AND PRESSING ENTER. AFTER EACH WORD RECALLED, YOU WILL BE GIVEN A CHANCE TO CORRECT ANY SPELLING ERRORS. EVERY WORD RECALLED WILL BE DISPLAYED AT THE TOP OF THE SCREEN AT ALL TIMES. IF YOU CANNOT THINK OF ANY WORDS, TYPE IN THE WORD 'END'. THE COMPUTER WILL THEN ASK YOU IF YOU ARE SURE YOU CANNOT THINK OF ANY MORE WORDS. IF YOU ARE, PRESS THE 'YES' KEY. OTHERWISE, PRESS THE 'NO' KEY. IF 16 WORDS ARE RECALLED, THE TASK WILL AUTOMATICALLY END.

YOU WILL BE GIVEN A SHORT PRACTICE LIST OF WORDS TO GET YOU ACQUAINTED WITH THE TASK. KEEP IN MIND THAT THE PRACTICE LIST OF WORDS IS MUCH SHORTER (6 WORDS) THAN THE TEST LIST (16 WORDS). IF YOU HAVE ANY QUESTIONS, ASK THE EXPERIMENTER.

Cued Recall

IN THE FOLLOWING TASK, YOU WILL BE PRESENTED WITH A SERIES OF 16 PAIRS OF WORDS ONE AT A TIME. YOUR TASK IS TO MEMORIZE THE PAIRS OF WORDS SUCH THAT YOU MAY LATER RECALL THE WORD ON THE RIGHT. EACH WORD WILL BE PRESENTED FOR APPROXIMATELY FOUR SECONDS. AFTER

PRESENTATION OF THE 16 PAIRS. YOU WILL BE ASKED TO CALCULATE SOME SIMPLE ADDITIONS. YOU DO THIS BY SIMPLY TYPING IN THE SUM OF THE NUMBERS IN QUESTION. THE COMPUTER WILL TELL YOU WHEN YOU HAVE MISCALCULATED.

AFTER COMPLETION OF SEVERAL OF THESE CALCULATIONS, THE LEFT WORD OF THE PAIRS OF WORDS WILL BE PRESENTED IN RANDOM ORDER. YOU WILL BE ASKED TO REMEMBER THE WORD ASSOCIATED WITH THE LEFT WORD. IN OTHER WORDS, YOU WILL BE ASKED TO REMEMBER THE WORD THAT WAS ON THE RIGHT SIDE. YOU DO THIS BY SIMPLY TYPING EACH WORD WHEN THE COMPUTER PROMPTS YOU TO, AND PRESSING ENTER. AFTER EACH WORD RECALLED, YOU WILL BE GIVEN A CHANCE TO CORRECT ANY SPELLING ERRORS. IF YOU CANNOT THINK OF THE WORD, JUST PRESS THE ENTER KEY AND THEN THE YES KEY."

YOU WILL BE GIVEN A SHORT PRACTICE LIST OF PAIRS OF WORDS TO GET YOU ACQUAINTED WITH THE TASK. KEEP IN MIND THAT THE PRACTICE LIST OF WORDS IS MUCH SHORTER (6 PAIRS) THAN THE TEST LIST (16 PAIRS).
IF YOU HAVE ANY QUESTIONS, ASK THE EXPERIMENTER.

Continuous Recognition

IN THIS TASK, YOU WILL BE SHOWN A LONG SERIES OF WORDS ONE AT A TIME. YOUR TASK WILL BE TO INDICATE IF YOU HAVE SEEN THE PRESENTED WORD EARLIER IN THE LIST OF WORDS. THE WORDS WOULD HAVE ONLY BEEN PRESENTED WITHIN THIS TASK, AND NOT ANY OF THE PREVIOUS TASKS. IF YOU BELIEVE YOU THAT THE WORD HAS BEEN REPEATED, PRESS THE 'YES' KEY. IF YOU HAVE NOT SEEN THE WORD BEFORE, PRESS THE 'NO' KEY. THE COMPUTER WILL ONLY ACCEPT ONE RESPONSE, SO BE CAREFUL WHAT KEY YOU PRESS. AFTER YOU RESPOND, THE SCREEN WILL CLEAR, AND A NEW WORD WILL APPEAR. YOU WILL BE SCORED AS TO OW ACCURATE YOU ARE AND AS TO HOW FAST YOU RESPOND.

FOR EXAMPLE, LET US SAY THE WORD 'ELBOW' SHOWS UP FOR THE FIRST TIME. BECAUSE YOU HAVE NOT SEEN THE WORD BEFORE, YOU WOULD PRESS

THE 'NO' KEY AS QUICKLY AS POSSIBLE. IF LATER IN THE LIST THE WORD 'ELBOW' REAPPEARS, YOU WOULD PRESS THE 'YES' KEY TO RESPOND CORRECTLY, BECAUSE YOU HAD SEEN THE WORD PREVIOUSLY IN THE LIST. THERE WILL BE A SHORT PRACTICE LIST OF WORDS THAT WILL BE PRESENTED SO THAT YOU MAY GET ACQUAINTED WITH THE TASK. KEEP IN MIND THAT THIS PRACTICE LIST IS MUCH SHORTER THAN THE TEST LIST IF YOU HAVE ANY QUESTIONS, PLEASE ASK THE EXPERIMENTER.

Single Word Categorization

IN THE FOLLOWING TASK, YOU WILL BE SHOWN A SERIES OF SINGLE WORDS AT THE CENTER OF THE SCREEN. YOUR TASK IS TO DECIDE IF YOU FEEL THE WORD IS A POSITIVE WORD OR A NEGATIVE WORD. IF YOU FEEL THE WORD IS POSITIVE IN NATURE, PRESS THE 'YES' KEY. IF IT'S NEGATIVE, PRESS THE 'NO' KEY. YOU ONLY HAVE THESE TWO CHOICES; THERE IS NO NEUTRAL CHOICE. THE COMPUTER WILL ONLY ACCEPT ONE PRESS OF EITHER THE 'YES' OR 'NO' KEY. YOU WILL BE SCORED HOW LONG IT TAKES YOU TO MAKE THE DECISION, AND HOW ACCURATE YOU ARE IN YOUR DECISION.

FOR EXAMPLE, LET US SAY THE WORD PRESENTED IS 'DISSENT'. THE WORD HAS NEGATIVE CONNOTATIONS ASSOCIATED WITH IT, AND SO TO RESPOND CORRECTLY, YOU SHOULD PRESS THE 'NO' KEY AS QUICKLY AS YOU CAN. SIMILARLY, HAD THE WORD BEEN 'CONCORDANT', YOU SHOULD PRESS THE 'YES' KEY TO RESPOND ACCURATELY SINCE THE WORD HAS POSITIVE CONNOTATIONS. THERE WILL BE A FEW PRACTICE TRIALS TO GET YOU ACQUAINTED WITH THE TASK. IF THERE ARE ANY QUESTIONS, ASK THE EXPERIMENTER.

Secondary Memory Access Rate - Synonym-Antonym

IN THE NEXT TASK, A SERIES OF TWO WORDS WILL APPEAR AT THE CENTER OF THE SCREEN. YOUR TASK IS TO DECIDE IF THE WORDS ARE SYNONYMS OR ANTONYMS. IF THE WORDS ARE SYNONYMS (SIMILAR MEANING), PRESS THE 'YES' KEY AS QUICKLY AS POSSIBLE. IF THE WORDS ARE ANTONYMS

(OPPOSITE MEANING). PRESS THE 'NO' KEY. THE COMPUTER WILL ONLY ACCEPT ONE PRESS OF EITHER THE 'YES' OR 'NO' KEY. YOU WILL BE SCORED FOR ACCURACY AND TIMED HOW LONG IT TAKES YOU TO RESPOND.

FOR EXAMPLE, LET US SAY 'PLUMP - LEAN' IS PRESENTED SINCE THE TWO WORDS ARE ANTONYMS. YOU SHOULD PRESS THE 'NO' KEY AS QUICKLY AS POSSIBLE TO RESPOND ACCURATELY. THERE WILL BE A FEW PRACTICE TRIALS TO GET YOU ACQUAINTED WITH THE TASK. IF THERE ARE ANY QUESTIONS, ASK THE EXPERIMENTER.

Secondary Memory Access rate - Same-Different

IN THE NEXT TASK, A SERIES OF TWO WORDS WILL APPEAR AT THE CENTER OF THE SCREEN. YOUR TASK IS TO DECIDE WHETHER THE TWO WORDS ARE IDENTICAL. IF THE TWO WORDS ARE THE SAME, THEN YOU WOULD PRESS THE 'YES' KEY. IF THE TWO WORDS ARE DIFFERENT, THEN YOU WOULD PRESS THE 'NO' KEY. THE COMPUTER WILL ACCEPT ONLY ONE PRESS OF EITHER THE 'YES' OR 'NO' KEYS. YOU WILL BE SCORED ON ACCURACY AND TIMED HOW LONG IT TAKES YOU TO MAKE THE DECISIONS.

FOR EXAMPLE, LET US SAY THE WORDS 'REJOICE - REJOICE' ARE PRESENTED. SINCE THE TWO WORDS ARE IDENTICAL, YOU SHOULD PRESS THE 'YES' KEY AS QUICKLY AS POSSIBLE TO RESPOND ACCURATELY. THERE WILL BE A FEW PRACTICE TRIALS TO GET YOU ACQUAINTED WITH THE TASK. IF YOU HAVE ANY QUESTIONS, ASK THE EXPERIMENTER.

Movement Time

IN THE NEXT TASK THE WORD 'YES' OR 'NO' WILL APPEAR AT THE CENTER OF THE SCREEN. YOUR TASK IS TO PRESS THE KEY ASSOCIATED WITH THE WORD. THE COMPUTER WILL ONLY ACCEPT ONE PRESS OF EITHER THE 'YES' OR 'NO' KEY. YOU WILL BE SCORED AS TO HOW ACCURATE YOU ARE IN PRESSING THE APPROPRIATE KEY AND HOW FAST YOU ARE AT PRESSING THE KEY.

FOR EXAMPLE: LET US SAY THE WORD 'YES' APPEARS AT THE CENTER OF THE SCREEN. TO COMPLETE THE TASK ACCURATELY YOU MUST PRESS THE 'YES' KEY AS QUICKLY AS POSSIBLE. THERE WILL BE A FEW PRACTICE TRIALS. ASK THE EXPERIMENTER IF YOU HAVE ANY QUESTIONS.

Typing Speed

IN THIS FIRST TASK, WE WILL EXAMINE YOUR TYPING SPEED. ALTHOUGH TYPING EXPERIENCE IS NOT REQUIRED TO COMPLETE THIS ASSESSMENT, IT MAY AFFECT THE SCORES IN SOME OF THE TASKS. IN THE TASK, A WORD WILL APPEAR IN THE CENTER OF THE SCREEN. YOUR TASK IS TO TYPE IN THE WORD EXACTLY AS PRESENTED USING THE COMPUTER KEYBOARD. ACCURACY IN THIS TASK IS IMPORTANT. TYPE IN THE WORD USING YOUR NORMAL TYPING SPEED. YOUR ACCURACY AND SPEED WILL BE RECORDED BY THE COMPUTER.

FOR EXAMPLE, IF THE WORD 'HELLO' APPEARS IN THE CENTER OF THE SCREEN, YOU SHOULD TYPE 'HELLO' AND THEN HIT THE 'ENTER' KEY TO COMPLETE THE TRIAL. THERE WILL BE A FEW PRACTICE TRIALS TO GET YOU ACQUAINTED WITH THE TASK.

APPENDIX III - Computing guessing rate for reaction time tasks

Primary Capacity II latencies

Guessing rate = .1

number of responses = 12

p(0 correct|guessing) = ${}_{12}C_0(.1)^0(.9)^{12}$ = .28

p(1 correct|guessing) = ${}_{12}C_1(.1)^1(.9)^{11}$ = .37

p(2 correct|guessing) = ${}_{12}C_2(.1)^2(.9)^{10}$ = .23

p(3 correct|guessing) = ${}_{12}C_3(.1)^3(.9)^9$ = .09

P(>= 3 correct|guessing) = 1 - .97 = .03

p(>= 2 correct| guessing) = .12

Therefore, minimum acceptable score set at 3

Working Memory latencies

Guessing rate = $.1^3$ = .001

number of responses = 15

p(0 correct|guessing) = ${}_{15}C_0(.001)^0(.999)^{15}$ = .99

P(> 0 correct|guessing) = 1 - .99 = .01

Therefore, minimum acceptable score set at 0 (i.e., no minimum)

Single Word Categorization Latencies

Guessing rate = .5

number of responses = 16

p(11 correct|guessing) = ${}_{16}C_{11}(.5)^{11}(.5)^5$ = .07

p(12 correct|guessing) = ${}_{16}C_{12}(.5)^{12}(.5)^4$ = .03

p(13 correct|guessing) = ${}_{16}C_{13}(.5)^{13}(.5)^3$ = .009

p(14 correct|guessing) = ${}_{16}C_{14}(.5)^{14}(.5)^2$ = .001

p(15 correct|guessing) = ${}_{16}C_{15}(.5)^{15}(.5)^1$ = .0002

p(16 correct|guessing) = ${}_{16}C_{16}(.5)^{16}(.5)^0$ = .00001

p(>= 12 correct|guessing) = .04

P(>= 11 correct|guessing) = .11

Therefore, minimum acceptable score set at 12

Continuous Recognition latencies

Guessing rate = .5

number of responses = 18

p(12 correct|guessing) = ${}_{18}C_{12}(.5)^{12}(.5)^{6}$ = .07

p(13 correct|guessing) = ${}_{18}C_{13}(.5)^{13}(.5)^{5}$ = .03

p(14 correct|guessing) = ${}_{18}C_{14}(.5)^{14}(.5)^{4}$ = .01

p(15 correct|guessing) = ${}_{18}C_{15}(.5)^{15}(.5)^{3}$ = .003

p(16 correct|guessing) = ${}_{18}C_{16}(.5)^{16}(.5)^{2}$ = .0006

p(17 correct|guessing) = ${}_{18}C_{17}(.5)^{17}(.5)^{1}$ = .00007

p(18 correct|guessing) = ${}_{18}C_{18}(.5)^{18}(.5)^{0}$ = .000004

P(>= 13|guessing) = .04

P(>= 12|guessing) = .11

Therefore, minimum acceptable score set at 13

Synonym-Antonym and Same-Different latencies (Secondary Memory Access Rate)

See Single Word Categorization Latencies

Movement Time Latencies

Guessing rate = .5

Number of responses = 20

p(13 correct|guessing) = ${}_{18}C_{13}(.5)^{13}(.5)^{7}$ = .07

p(14 correct|guessing) = ${}_{20}C_{14}(.5)^{14}(.5)^{6}$ = .04

p(15 correct|guessing) = ${}_{20}C_{15}(.5)^{15}(.5)^{5}$ = .01

p(16 correct|guessing) = ${}_{20}C_{16}(.5)^{16}(.5)^{4}$ = .005

p(17 correct|guessing) = ${}_{20}C_{17}(.5)^{17}(.5)^{3}$ = .001

p(18 correct|guessing) = ${}_{20}C_{18}(.5)^{18}(.5)^{2}$ = .0001

p(19 correct|guessing) = ${}_{20}C_{19}(.5)^{19}(.5)^{1}$ = .00002

p(20 correct|guessing) = ${}_{20}C_{20}(.5)^{20}(.5)^{0}$ = .000001

P(>= 14|guessing) = .06

P(>= 13|guessing) = .13

Therefore, minimum acceptable score set at 14

APPENDIX IV - Factor analysis of the Standardized Memory Assessment's subscales

Primary Memory Capacity II

Item #	Location of Missing Digit	Factor I	Factor II
3	2	**0.57**	-0.04
5	3	**0.56**	0.09
2	9	**0.52**	0.02
11	8	**0.52**	-0.29
9	2	**0.49**	0.13
10	6	**0.46**	-0.09
8	7	**0.43**	0.10
12	1	**0.37**	0.04
6	5	-0.11	**0.69**
4	7	-0.09	**0.61**
7	4	0.22	**0.51**
1	4	0.24	**0.47**
Factor Correlations			
Factor I		1.00	
Factor II		0.13	1.00

Working Memory

Triad #	Factor I
9	**0.65**
2	**0.58**
6	**0.58**
3	**0.53**
7	**0.52**
8	**0.49**
13	**0.48**
1	**0.47**
5	**0.46**
4	**0.44**
15	**0.42**
10	**0.39**
12	**0.39**
11	**0.37**
14	**0.36**

Free Recall

Item #	Imagery	Frequency	Oblimin rotated factor		Unrotated Factor	
			Factor I	Factor II	Factor I	Factor II
1	high	low	-0.32	0.23	-0.07	**0.38**
2	low	high	**-0.42**	0.32	-0.07	**0.51**
3	low	low	**-0.43**	**0.42**	-0.00	**0.59**
4	low	high	-0.08	**0.37**	0.21	**0.31**
5	high	high	0.23	**0.50**	**0.52**	0.19
6	high	low	0.07	**0.64**	**0.51**	**0.40**
7	high	high	**0.51**	-0.00	**0.36**	**-0.35**
8	low	low	-0.01	0.31	0.21	0.22
9	high	high	0.29	-0.21	0.06	**-0.35**
10	high	high	**0.45**	0.22	**0.49**	-0.16
11	high	low	0.06	**0.52**	**0.41**	0.32
12	low	low	**0.52**	0.08	**0.43**	-0.30
13	low	high	**0.40**	0.21	**0.44**	-0.13
14	high	low	0.31	0.03	0.24	-0.19
15	low	low	**0.36**	0.16	**0.37**	-0.14
16	low	high	0.11	0.25	0.26	0.10

Factor Correlations				
Factor I			1.00	
Factor II			0.02	1.00

Cued Recall

Item #	Factor I
13	0.59
3	0.55
10	0.55
11	0.54
12	0.51
15	0.45
5	0.43
2	0.41
16	0.40
8	0.39
14	0.38
4	0.37
9	0.31
6	0.30
7	0.28
1	0.17

Continuous Recognition Hits

Item #	Location in List	Factor I	Factor II
18	78	**0.76**	-0.26
14	63	**0.73**	-0.16
13	57	**0.67**	0.02
11	55	**0.66**	0.01
15	66	**0.61**	0.08
17	74	**0.56**	0.18
16	71	**0.55**	0.08
12	56	**0.51**	0.03
7	32	**0.49**	0.18
6	29	**0.48**	0.05
10	41	**0.44**	0.07
2	10	0.07	**0.71**
8	38	0.10	**0.67**
4	15	0.06	**0.60**
5	23	0.12	**0.57**
1	9	-0.20	**0.54**
3	13	**0.35**	**0.51**
9	39	0.33	**0.48**
Factor Correlations			
Factor I		1.00	
Factor II		0.35	1.00

Primary Memory II Latencies

Item #	Factor I
1	0.65
9	0.64
12	0.62
7	0.60
3	0.59
6	0.58
5	0.58
2	0.56
8	0.41
4	0.41
11	0.39
10	0.37

Working Memory Latencies

Triad #	Factor I
9	0.84
5	0.84
6	0.83
13	0.80
4	0.75
11	0.75
10	0.75
12	0.74
15	0.74
14	0.70
8	0.69
2	0.68
1	0.67
3	0.65
7	0.65

Working Memory Study Time

Triad #	Factor I
9	0.90
12	0.90
11	0.85
4	0.83
5	0.83
14	0.82
13	0.81
10	0.80
7	0.77
15	0.76
6	0.74
2	0.70
8	0.68
3	0.68
1	0.68

Single Word Categorization Latencies

Item #	Factor I
6	0.80
7	0.78
12	0.75
16	0.74
11	0.73
9	0.72
10	0.71
4	0.70
5	0.67
2	0.66
3	0.63
1	0.63
13	0.62
8	0.58
14	0.57
15	0.47

Secondary Memory Access Rate

Synonym-Antonym task

Item #	Factor I
7	0.73
4	0.72
16	0.71
2	0.65
8	0.65
15	0.64
5	0.64
13	0.61
11	0.60
3	0.59
12	0.56
14	0.56
1	0.54
9	0.50
10	0.49

Continuous Recognition Latencies

Item #	Factor I
13	0.77
15	0.74
29	0.74
66	0.73
55	0.73
63	0.73
57	0.72
23	0.72
74	0.68
39	0.67
32	0.65
71	0.63
38	0.63
10	0.62
41	0.62
78	0.58
56	0.52
9	0.45

Movement Time

Item #	Factor I
10	0.64
4	0.63
9	0.63
6	0.62
2	0.61
5	0.58
18	0.58
12	0.57
19	0.56
8	0.55
3	0.55
11	0.54
17	0.54
20	0.52
13	0.52
16	0.51
15	0.47
14	0.45
1	0.44
7	0.39

Typing Speed

Item #	Factor I
7	0.90
14	0.88
13	0.87
1	0.84
15	0.84
5	0.83
10	0.83
9	0.82
11	0.80
4	0.78
8	0.78
12	0.76
3	0.75
6	0.74
2	0.72
16	0.68

APPENDIX V - Correlation matrix of the Standardized Memory Assessment's subscales.

Subscale	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 -Primary Memory Capacity I	1.00													
2 -Primary Memory Capacity II	0.25	1.00												
3 -Working Memory	0.03	0.04	1.00											
4 -Primacy Free Recall	0.13	0.25	-0.05	1.00										
5 -Nonprimacy Free Recall	0.09	0.22	0.11	0.17	1.00									
6 -Cued Recall	0.08	0.08	0.15	0.09	0.25	1.00								
7 -Continuous Recognition Hits	0.09	0.12	0.29	0.08	-0.04	-0.04	1.00							
8 -Continuous Recognition False Alarms	-0.05	-0.13	-0.08	0.04	-0.23	-0.15	0.00	1.00						
9 -Primary Memory II latencies	-0.24	0.06	-0.16	0.16	-0.01	-0.05	0.02	0.14	1.00					
10 -Working Memory Latencies	-0.14	-0.08	-0.35	-0.09	-0.11	-0.26	-0.22	0.13	0.42	1.00				
11 -Working Memory Study Time	-0.11	-0.01	-0.03	0.14	0.00	0.09	-0.02	-0.06	0.32	0.29	1.00			
12 -Single Word Categorization Latencies	0.05	0.10	0.01	-0.15	-0.15	-0.05	0.17	0.10	0.13	0.14	-0.02	1.00		
13 -Secondary Memory Access Rate	0.10	0.08	-0.07	-0.07	-0.04	-0.08	-0.09	-0.03	0.17	0.18	-0.04	0.50	1.00	
14 -Continuous Recognition Latencies	0.11	-0.04	-0.01	-0.06	0.00	-0.09	0.06	-0.03	0.24	0.26	-0.03	0.20	0.30	1.00