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Transcendental meditation as an intervention in the aging of neurocognitive function: Reduced age-related declines of P300 latencies in elderly practitioners

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Maharishi International University, 1992

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TRANSCENDENTAL MEDITATION AS AN INTERVENTION IN THE AGING OF NEUROCOGNITIVE FUNCTION: REDUCED AGE-RELATED DECLINES OF P300 LATENCIES IN ELDERLY PRACTITIONERS

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A Dissertation

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in partial fulfillment of the requirements for the degree of

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Dissertation Supervisor: Professor Frederick T. Travis

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CERTIFICATE OF APPROVAL

PH.D. DISSERTATION

This is to certify that the Ph.D. dissertation of

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has been approved by the Examining Committee for the dissertation requirement of Doctor of Philosophy degree in Psychology at the July 1992 graduation.

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ABSTRACT

Two cross-sectional experiments were conducted to test the hypothesis that long-term practice of Transcendental Meditation (TM) would preserve the speed of neurocognitive processes in elderly practitioners compared to non-meditating elderly, as measured by P300 latency of the event-related brain potential and choice reaction time (RT). In Experiment 1, 13 TM subjects, group matched with 13 non-TM subjects on age (mean 65.7 yrs.) and gender (9 females in each group) participated in two oddball tasks (visual and auditory). Group t-tests indicated the TM group showed faster P300 latencies than the non-TM group in the visual task, while no differences were found in the auditory task for P300 latency or RT.

In Experiment 2, TM and non-TM subjects from both young (6 in each group, mean 20 yrs.) and older (10 in each group, mean 69 yrs.) age ranges, matched on age, gender, IQ, exercise level, and self-health ratings, were compared in a task intended to manipulate stimulus discriminability and stimulus-response compatibility; 2 variables demonstrated to affect stimulus evaluation and response-related stages of processing, respectively.

Repeated measures ANOVAs indicated, 1) within young subjects, while P300 latency and RT increased additively with difficulty in discriminabiilty and stimulus-response compatibility, the magnitude of change was substantially greater for RT than for P300 latency when an incompatible response was required, 2) P300 latencies were longer in older than young subjects in all conditions, while RT differences between young and older subjects became significant when task difficulty increased, indicating a centrally mediated age effect with complexity effects confined to response-related stages of processing and, 3) P300 latencies were faster for older TM than non-TM subjects across all conditions, while RT was faster in older non-TM than older TM subjects. Evidence suggests faster RT in older non-TM compared with TM subjects may be partially due to strategy differences indicated by a greater error rate and significantly greater CNV amplitude in the older non-TM compared to older TM and young subjects across all conditions.

The results suggest neurocognitive processing speed may be preserved with age as a result of long-term practice of TM and potential mechanisms are discussed in terms of models of adult cognition, as well as in terms of Maharishi's Vedic Psychology.

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INTRODUCTION

The importance of health maintenance in promoting a higher quality of life, particularly in later adulthood, is both a very old and a very new idea. We find it expressed, for example, in our western philosophical roots in the following essay by Cicero written in 44 B.C. (Bashore, 1990):

> One must fight against old age ... and its faults must be outweighed by carefulness; just as one fights a disease, you must resist old age; you must take stock of your health; you must engage in moderate exercises; you must consume only enough food and drink so your strength is restored, not overburdened. And in truth you must not come to the aid of your body only, but much more to that of the mind and spirit. For these are snuffed out by old age unless you drop in oil as into a lamp; and bodies, of course, grow heavy with the fatigue of exercise, but spirits are lightened by exercising. (p. 18)

Modern testimony to the insights of Cicero are reflected in the increasing number of studies in the area of the psychology of aging which have demonstrated the potential benefits of interventions, such as exercise, on reducing age-related declines in mental and physical functions. Of particular relevance to this study are those investigations attempting to assess the degree to which the well-documented behavioral slowing that accompanies growing old can be reduced or recovered. Several studies suggest, for example, that exercise may be one effective means by which this slowing in the rate of mental processing speed can be ameliorated (Bashore, 1990; Spirduso, 1980; 1990). Evidence such as this not only has important practical consequences, but may have important theoretical implications.

The purpose of the present study was to assess the extent to which long-term practice of Transcendental Meditation (TM) would preserve mental processing speed in the elderly. TM is a form of meditation that has been researched extensively, thus permitting easy comparison of results with findings from other related studies (for a thorough review see Chalmers, Clements, Schenkluhn, & Weinless, 1990; Orme-Johnson & Farrow, 1975; Wallace, Orme-Johnson, & Dillbeck, in press). It is taught in a standard format, and a sufficient number of elderly subjects with long-term practice are available. Regular practice of this program, in alternation with ordinary activity, has been shown to result in a number of psychophysiological changes both during the practice and as a result of cumulative practice (Dillbeck & Orme-Johnson, 1987). Beneficial effects on health (Orme-Johnson, 1987; Wallace, 1986; Wallace, Dillbeck, Harrington, & Jacobe, 1982) and reduction in a number of age-related declines have been reported in long-term practitioners (Alexander, Langer, Newman, Chandler, & Davies, 1989).

The decision to emphasize age-related changes in the dimension of mental processing speed in this study is based on the following. First, there are no reports to date which have assessed the effects of TM on age-related behavioral slowing. Second, age-related slowing is one of the three most commonly reported affects of age on mentation (along with memory loss and selective attention) making it important from a practical standpoint. Third, there is a large body of research, both from cognitive psychology using reaction time (RT) and cognitive psychophysiology using event-related brain potentials (ERP), which suggest that an age-related decline in the rate and efficiency of central nervous system (CNS) processing underlies the behavioral and cognitive changes evident in people as they age (Bashore, 1990; Birren & Renner, 1979; Birren, Woods, & Williams, 1980). From this perspective, response time, or psychomotor speed, is regarded by many as a useful index of the integrity of the CNS and a marker of aging (Birren et al., 1980; Borkan & Norris, 1980). As such, when interventions, such as exercise, are found to have a significant impact on maintaining mental processing speed, this can be taken as evidence for a modulation of aging effects at higher levels of the nervous system, levels which have been considered unamenable to intervention.

Chapter 1 briefly reviews research that has led to the development of theories attempting to explain the nature of behavioral slowing. This includes an overview of current approaches to the problem that use information-processing models adopted from cognitive psychology. In addition, the cognitive psychophysiological approach to the study of mental processing speed is introduced with the intention of highlighting the ways in which ERPs compliment and extend current understanding of the locus of declines in processing speed.

Having surveyed the research and current models of behavioral slowing, Chapter 2 discusses what has been done to answer the following question: to what extent can slowing-with-age be modulated? Factors which have been found to minimize age differences in response speed are reviewed, each adding understanding to the nature of the phenomenon. Also introduced is the intervention of interest in this study, TM, and the research which suggests that TM may be one means by which mental processing speed can be preserved in the elderly.

Chapter 3 serves as the core of this report, describing the results of two experiments designed to test the hypotheses of this study.

Finally, Chapter 4 presents a discussion of these results with the aim of providing a larger context in which to evaluate the role of meditation both with regard to its practical and theoretical relevance, and in integrating our understanding of the effects of aging on neurocognitive functions.

CHAPTER I: A RESEARCH REVIEW OF AGING OF NEUROCOGNITIVE FUNCTION

The psychology of aging, as a discipline within the field of psychology, attempts to understand changes in the organization of behavior that occur during late adulthood (Birren & Birren, 1990; Birren & Cunningham, 1985). Perhaps the most frequently cited cognitive change with age is the slowing of mental processing speed which is inferred from the observed differences between young and old subjects on various measures of response or psychomotor speed; the so-called slowing-with-age phenomenon (Salthouse, 1985). Comprehensive reviews are available which summarize the extant literature on this topic (Salthouse, 1985; Welford, 1977).

In the study of the cognitive slowing that accompanies advancing age, approaches from cognitive psychology, in particular the mental chronometric approach, have been utilized to address issues regarding the nature of the slowing in information processing terms. Cognitive psychophysiological studies employing ERPs have provided additional information about the character of the slowing (Bashore, 1989, 1990; Ford & Pfefferbaum, 1985; Miller, Bashore, Farwell, & Donchin, 1987). The current theoretical emphasis is to determine if the slowing is manifest at all levels of mental processing (globally) or at some levels and not at others (locally) (Birren & Birren, 1990; Birren & Cunningham, 1985; Botwinick, 1984; Cerella, Poon & Williams, 1980; Cerella, 1985, 1990; Salthouse, 1985). In combination, the cognitive and cognitive psychophysiological approaches provide complimentary methodological tools that may help achieve this end, as well as help elucidate the effects of interventions designed to preserve functions that normally decline with age or to restore functions that have already declined.

This chapter begins with a short review of studies assessing age differences in mental processing speed by measuring response time in age-contrasted groups. Subsequent research is then discussed that has led to the development of theories regarding the nature of the slowing. The cognitive psychophysiological approach is then introduced, with emphasis being given to the P300 component of the ERP since it has been used most frequently in assessments of changes that occur in mental processing speed with age.

Cognitive Slowing as Engendered in Measures of Reaction Time

Simple RT

In a simple reaction time task the subject is required to make a repetitive, simple response (e.g., button press with the right index finger) to every presentation of a stimulus (e.g., flash of light) that occurs on every trial. Early studies conducted on human speeded performance in young and old adults showed simple reactions to be slower with age. On the basis of reviews of this work, Welford (1977) and Birren et al. (1980) concluded that a slowing of 20-26% was evident between young and old subjects. For example, Birren and Botwinick (1955) conducted a study in which young subjects (19-36 yrs. of age) were compared to old subjects (61-91yrs.) on simple reaction time to a 1000 Hz tone indicated by a response with either the foot, jaw, or finger. In all three responses the older were slower by approximately 29% (e.g., 182 vs. 232 ms difference in finger response). Several different investigators have replicated this effect using different sensory modalities and measuring different types of motor responses (Birren et al., 1980; Salthouse, 1985; Welford, 1977).

Among the conclusions that Welford (1977) made in his review of 21 studies on simple RT differences between young and old subjects was (1) that the percentage of change with age does not appear to differ systematically with the sense organ stimulated, implying that the changes are either common to all sensory and perceptual mechanisms or are concerned with mechanisms of perception and response lying beyond the point at which the various sensory modes converge, and (2) slowness with age is not due to a lack of motivation, since administering electric shock to subjects on slow RT trials (Weiss, 1965) or providing instructional or monetary incentive for fast responses (Salthouse, 1979; Salthouse & Somberg, 1982a) decreased RT for young and old subjects equally. In a more recent review of RT studies by Salthouse (1985) the relationship between age and simple RT from 11 studies were presented in the form of correlation coefficients. All of the correlations were positive with a range between .19 to .47. A larger correlation indicated a greater contribution of the age variable.

However, more recent research has questioned this conclusion (e.g., Gottsdanker, 1982). Gottsdanker (1982) has pointed out that many of the earlier studies were confounded by the effects of variables other than the primary aging process, such as lack of practice and requirement of highly coordinated movements. In addition, inadequate screening would disadvantage subjects of all ages where secondary factors such as poor health, inactivity, unease in the laboratory setting and low motivation could contribute to difference in response speed. When simple reaction time is reduced by experimental manipulation, extensive practice, and/or careful subject selection to extremely short reactions, age differences can be greatly minimized (e.g., Gottsdanker, 1982; Spirduso, 1990). Any studies done comparing groups on response time must consider these factors as potentially mitigating influences.

Choice Reaction Time

Choice RT (CRT) requires the subject to map a stimulus onto a response. That is, the subject must discriminate the imperative stimulus and select one appropriate response. As such, CRT requires greater computational demands of the subject than simple RT.

This is reflected in the common observation that age differences in RT become more evident as the task becomes more complex (e.g., Kausler, 1982). This has been referred to by some as the "complexity effect" and is described more below (Cerella et al., 1980). In Salthouse's review (1985), correlation coefficients for 19 studies using choice reaction time (CRT) indicated larger positive correlations between CRT and age than simple RT, ranging between .22 and .64.

The Information Processing Approach to Speeded Performance

In discussing the effects of age on simple RT and CRT, it is important to diverge for a moment and discuss the recent approaches to the study of human cognition in terms of information processing models (e.g. Lachman, Lachman, & Butterfield, 1979). The information processing approach to the study of mental processes has resulted in a substantial amount of research and theory on the computational nature of speeded performance tasks. Several different models exist concerning the nature of the human information processing system, but a common assumption of all models is that human cognitive performance is mediated by way of processing levels or stages, each performing its own set of operations (Sanders, 1990). Mental chronometry, a paradigm within cognitive psychology which dates back to the work of Donders (1868/1969), is concerned with the structure and timing of mental processes using RT as a dependent variable. Donders is recognized as being the first to hypothesize that RT could be used to estimate the speed of internal cognitive processes (Lachman et al., 1979). Donders distinguished three kinds of RT tasks. The simple RT task, which he labeled the A task, consists of a single stimulus and a single response. The CRT task, labeled the B task, is a more complex task, in which the subject is presented two or more stimuli, and has two or more potential responses. The subject is required to make a decision regarding which stimuli has occurred and which appropriate response is to be given. The time it takes one to make the correct response is the choice RT. Finally, the C task has multiple stimuli, but only one response. For example, one may be asked to respond only if one of three different lights appear. Donders proposed that the 3 tasks differentially engage stages of mental processing. The B task, he proposed, involves 3 processes: (1) the simple reaction (i.e., the time to respond to the stimulus); (2) stimulus categorization (i.e., the time taken to decide which stimulus had been presented); and (3) response selection (i.e., the time taken to select the right key). Donders reasoned that the A reaction was a component of the B reaction and that the B reaction added two additional cognitive processes (i.e., stimulus categorization and response selection). He also reasoned that the C reaction is similar to the B reaction in that it requires the process of stimulus categorization, but differs from the B reaction in that is does not require response selection processes. Donders proposed that the time required for different stages of processing could be assessed through a decoupling process referred to as the "subtraction method" (Lachman et al., 1979). For example, the time required for stimulus evaluation could be attained by subtracting the time taken for a simple reaction (A) from the time taken for a C reaction (commonly referred to as a disjunctive reaction (e.g., van der Molen, Bashore, Halliday & Callaway, 1991)). Response selection could be attained by subtracting the C reaction from the B reaction.

The stages of mental processes outlined by Donders is nicely summarized in a model taken from Welford (1977) in which he identified the main functional mechanisms of human motor performance (see Figure 1). A simplified version is presented here. On the left are the sense organs which receive data from external (eyes, ears, etc.) and internal (receptors in muscles, tendons, etc., and sensors which monitor bodily conditions) sources. At the far right are the effectors which include the hands, feet, and other voluntary muscles, as well as various reactors of the autonomic system, which are not normally under voluntary control. To quote Welford: "Between these lies a chain of three main central mechanisms which it seems intuitively obvious should be distinguished from each other in function: it is one thing to perceive that an event has occurred, another to decide what to do about it, and still another to carry out the action decided upon (p. 450)". According to Welford (1977), the perceptual mechanism analyzes, coordinates, and supplements data received with data from memory stores. This processed data is then fed to the translation mechanism which translates the data into action by triggering a decision and computing a response. The orders for this response are passed to the central effector mechanism which programs a phased sequence of muscular actions to execute them. In this context, the A reaction of Donders would effectively bypass the stimulus evaluation and response selection stages of processing, requiring only adequate perception of the presence of a stimulus, and execution of a preprogrammed response. The B reaction, however, would require full perceptual evaluation of the stimulus allowing a decision to be made as to what stimulus occurred, and what the appropriate response would be. In addition, the selected response would have to be organized and executed. Finally, the C reaction would require the same stimulus evaluation processes of the B reaction, however, while response decision processes would be comparable to those of choice RT (since a decision to withhold a response also requires processing), translation and execution of a response would be preprogrammed for a single response.

An important aspect of the Welford's model is the diffuse activation system which he describes not only as the basis of arousal (mediating differences between sleep and wakefulness), but providing subtle changes in the level of general activation of the organism from moment to moment. According to Welford (1977):

> "It (the DAS) has its center in the brain stem and generates diffuse impulses which increase the sensitivity and responsiveness of the cortex. The center receives inputs from the various sensory channels so that it responds to external situations. It also seems to have connections from the perceptual mechanism so

> that it reacts to any situation seen as requiring effort or threatening departure from optimum conditions. It is thus the mediator of generalized reactions to stress and motivation. Subjectively its activities are associated with emotions and feelings. It appears to have connections to all the main central stages, enhancing their activity at times of high demand and reducing it under monotonous conditions. It also has connections with the autonomic nervous system, whose activities are commonly used as indices of arousal."

As Welford (1977) points out, the model suggests that human motor performance does not depend on motor factors alone but on activities of the whole system. Welford's model (1977) is somewhat unique in that it includes conceptually "deeper" structures which have important input in the "computational" stages of processing, though more recent models have attempted to elaborate on this approach as well (e.g. Sanders, 1983).

Also important to this discussion of models of cognitive function is the great contributions to the area of mental chronometry of Sternberg (1969) and his additive-factors method. Sternberg's additive-factors method is commonly associated with a memory scanning task in which subjects are shown a list of stimuli, such as digits 1 to 9, one stimulus at a time. This list constitutes a memory set which typically varies from 1 to 4 items. Following the presentation of the memory set the subject is presented a single stimulus, the test item, and is required to make a manual response indicating whether the test item was in the memory set for that trial. Sternberg demonstrated that RT to the test item is a linear function of the number of items in the memory set with an increase of approximately 38 ms per item in young adults. The slope of this function is considered to reflect the time needed to compare the test item with the items held in memory, which he labeled serial comparison time. The intercept of the regression function is considered to reflect the sum of all the other stages comprising stimulus encoding, binary decision, and response translation and organization times. Sternberg assumed that the four processing stages engaged in the memory scanning task occurred in a serial and successive fashion in which a particular process in the sequence is not engaged until it had received its input from the preceding one. Based on this assumption, Sternberg (1969) developed the additive-factors method to isolate the stages influenced by different experimental manipulations. He proposed that experimental manipulations are inferred to activate different stages of processing if they produce main effects (i.e., are additive) and to activate the same stage if they produce interactive effects. In this way, the relationship of different stages could be ascertained, giving important experimental and theoretical power to the investigator.

The information processing approach to mental processes from cognitive psychology made it possible to better characterize the effects of cognitive slowing with age in terms of stages of processing. For example, Salthouse and Somberg (1982b) used the memory scanning task of Sternberg (1969) to assess the effects of age on the encoding, serial comparison, binary, and response selection and execution stages of processing. The major finding of their study was that increased age affected all of the stages, indicated by longer RTs, larger intercepts, and steeper slopes in the older subjects compared to young. In addition they concluded that the slowing evident in the old could not be localized in any one particular stage. Similar findings have been reported by others investigators (e.g. Anders & Fozard, 1973; Anders, Fozard & Lillyquist, 1972; Madden, 1982). Thus the conclusion drawn from these studies is that with age comes a global slowing of all cognitive processes.

Theories Regarding the Nature of Cognitive Slowing

As the body of research on behavioral slowing with age has grown, theories regarding the nature and organization of the phenomenon have changed significantly. Initial theories up to the turn of the century regarded behavioral slowing to be primarily a result of changes in peripheral sensori-motor processes while thought processes were considered to be spared (Bashore, 1990). Studies have been conducted to assess the relative contribution that peripheral sensory-motor changes and central (cognitive) changes make to changes in RT with age. Recall the aforementioned study by Birren & Botwinick (1955). In this study, a difference between the young and the old on simple RT was reported with no differences in response between the groups for the foot, jaw or finger. This study provided a test of the relative contribution that peripherally mediated changes in neural conduction velocity made to behavioral slowing with age. The hypothesis was that if age effects are a result of loss of neural transmission speed, then the greater the transmission distance the more apparent should be the slowing of RT in the old. As the results indicated, the difference between young and old as a function of distance of the neuromuscular pathway was insignificant. Other studies directed at determining whether the loss of speed with age can be explained on the basis of alterations in the sense organs (Botwinick, 1971) or motor factors (Botwinick & Thompson, 1966) have concluded that RT slowing with age cannot be explained by these peripheral factors.

While there does appear to be consensus as to the predominance of a central contribution to the cognitive slowing, the question remains as to what kind of central changes are responsible and to what extent the changes are diffuse or isolated to specific processing activities (Salthouse, 1985). Botwinick has classified theorists as subscribing to one of two different orientations which he characterized as the consequence view and the determinant view. The consequence view, the more traditional of the two views, argues that age-related decrements in response speed are produced by declines in sensory-perceptual mechanisms and/or in the power of cognitive abilities (e.g., Hartley, Harker, & Walsh, 1980). In this view, speed of performance is only one of several response measurements; it may be the best one in some instances and not in others. Advocates of the determinant view, which is gaining in support, argue that age-related slowing is a manifestation of CNS slowing, and as such, produces perceptual and cognitive deficits

(Birren et al., 1980; Cerella et al., 1980; Cerella, 1985; 1990; Salthouse, 1985). In this view, it is loss in the integrity of the CNS, reflected by speed of performance, which determines ability in tasks of perception, cognition, and others. If the aged are slower than the young, it is because the CNS of the older person is less capable of handling the task, particularly as the demands of task increase.

The most compelling behavioral evidence in support of centrally mediated, generalized slowing factor in processing speed with age, comes from the aforementioned "complexity effect" (Cerella et al., 1980). The complexity effect refers to the fact that when young are compared to old on RT across tasks of increasing complexity (holding input/output factors constant), the older RT is slower than the young by constant proportion, while the absolute magnitude of the difference between young and the old subject increases.

Cerella et al. (1980), Cerella (1985), and Salthouse (1985) have provided quantitative support for a centralist theory of slowing using meta-analytic techniques. Their work employed regression analyses on RT data comparing young and old from many different studies utilizing tasks of varying degrees of complexity. The assumptions on which these meta-analyses were based rests on the following logic. If the slowing of speeded performance is due to peripheral changes, then there should be a constant difference between young and old across tasks of increasing complexity, provided sensori-motor requirements are held constant. This is based on the assumption that more complex task requirements engage centrally mediated cognitive processes. If these processes are unaffected by age then, the difference between young and old associated with age should be a constant; the constant contributed to by peripheral factors which is additive across tasks of differing complexity.

This can be represented formally by the equation:

$$Y_i = X_i + c$$

where Y is RT for the old, X is RT for the young, c is the age deficit, a constant reflecting the peripheral slowing factor which is a constant *increment* across tasks (i) (see Figure 2).

On the other hand, if the age effect is primarily centrally mediated then as the demands of central processing are increased, the difference between young and old associated with age should be constant; the constant associated with central factors which is *multiplied* across tasks of increasing complexity. This can be represented formally by the equation:

$$Y_i = X_i \ (m)$$

where Y is RT for the old, X is RT for the young, m is the age deficit, a central factor increasing the older latency by a constant *proportion* across tasks (i) (see Figure 2).

In the meta-analytic studies (Cerella et al., 1980; Cerella, 1985; Salthouse, 1985) RTs of the old (plotted on the Y axis), when regressed against those of the young (plotted on the X axis) across tasks of increasing complexity (defined operationally by increases in RT), indicated that as processing complexity increased, the absolute difference in RT increased by a constant proportion. This was expressed as a function with an intercept of approximately zero and a slope significantly greater than 1. According to the logic that motivated these meta-analyses, this multiplicative function would be evident only if the slowing was mediated by central, as opposed to peripheral processes.

Cerella, Poon, and Fozard (1981) have distinguished between strong and weak versions of the determinant view. The weak form simply predicts that age-related slowing will be evident in all mental processes; in its strong form the hypothesis predicts that the extent of the slowing will be the same in all mental processes. Both Botwinick (1984) and Salthouse (1985) agree that the weak form of the hypothesis is supported substantially by the data. The strong form, however, is much more difficult to test as it requires considerable knowledge of mental processes and much greater precision in the data then has been available (Salthouse, 1985).

Summary

This brief review of the literature on RT and aging has indicated that slowing with age is (1) a robust phenomenon, (2) increases as the complexity of the task increases, (3) is mediated primarily in the CNS, (4) may be either a fundamental effect that determines changes in all behavior (determinant view) or only one expression of a series of changes in peripheral and central functions that are affected by age (consequence view), and (5) current theoretical efforts are aimed at characterizing the precise nature of the slowing.

The research presented thus far has made use of psychophysiological terms such as "peripheral" and "central" or "CNS" processing which refer to systems which in fact have not been directly measured. The use of these terms in these behavioral studies refers more to concepts than anatomical structures or physiological functions. However, psychophysiological studies have been conducted which measure CNS processing in the interest of understanding the nature of age-related changes in speeded performance. In particular, ERPs have proven fruitful as measures of the timing of mental processes. The following section introduces the methodology of ERP research and the P300 component which has been used as a marker of the aging process. It is suggested that ERP components, such as the P300, may provide a valuable window into CNS functioning which allows more precise tests of the validity of the different views on the cause and organization of age-related behavioral slowing.

ERPs in the Analysis of Mental Processing Speed:

The Cognitive Psychophysiological Approach

In the previous section it was pointed out that mental chronometric techniques base inferences about the timing and structure of mental processes by experimentally decomposing the composite reaction time. Over the last 30 years, research on ERPs has indicated that these measures may provide useful information for the mental chronometrician which adds to the understanding of ongoing cognitive events. Cognitive psychophysiology, an offspring of psychology and neurology (Bashore, 1990), has been directed at understanding the significance of ERPs as indices of cognitive processes in young adults. The ERP is a voltage/time phasic brain potential taken at the scalp in humans and elicited in response to sensory, cognitive, or motor events. The ERP is a series of positive and negative deflections in polarity inherent within the on-going electroencephalogram (EEG) that are time-locked to the presentation of the stimulus or to the execution of a movement (e.g., Donchin, Bashore, Karis, Gratton, & Coles, 1986). These fluctuations in polarity are generally considered to be manifestations of synchronous activity within large neuronal populations whose spatial orientations allow their propagation to the scalp. Because these signals are smaller in amplitude relative to the ongoing EEG, signal averaging is the most widely practiced methodology for detecting the changes consistently associated with the processing of a stimulus or the execution of a response. However, a variety of techniques are now available for determining the morphological characteristic of interest in single trial waveforms (e.g., Fabiani, Gratton, Karis, & Donchin, 1987). Components elicited by a stimulus event are labeled on the basis of their electrical polarity (positive or negative) and the approximate latency at which the maximum amplitude of the component is achieved (e.g., Fabiani et al., 1987). Since most early components are sensitive to variations in physical stimulus parameters and show little change as a function of processing demands, they have been termed "exogenous". In contrast to the exogenous components, those potentials which vary as a function of higher order processes, such as attention, memory, mental workload, and semantic processing, are regarded as being "endogenous" in nature. As such, in the investigation of endogenous ERPs, the subject is often challenged with complex tasks, and the subject always has some task to perform.

The task of the cognitive psychophysiologist is to analyze the variance in the ERP, so that the share of variance attributable to specific experimental manipulations can be ascertained. Several attributes of the task are manipulated and serve as the independent variables. The term "component" refers to those attributes which vary as a function of the independent variables, and these variations can be considered to reflect changes in the "strength" and "timing" of the underlying psychological process (Donchin et al., 1986).

Fabiani et al. (1987) make the important distinction between the theoretical and operational definitions of a component. They point out that the theoretical definition of a component is based on a wealth of observations that suggest variance in the data can be interpreted by assuming the existence of a component. This component is interpreted in terms of its functional significance and represents some essential psychological construct. Studies are driven by the view one has of its likely functional significance. The observational definition refers more to the operations one undertakes when acquiring data about the component. Therefore, the label P300 for example, may observationally occur at P250 or P800. However, one assumes that all these observational components are realizations of the unique theoretical process referred to as the P300 (Fabiani et al., 1987).

Of particular interest in this study is the endogenous P300 (a positive-going component occurring 300 ms or more after stimulus presentation). According to Donchin, Ritter, & McCallum (1978), there are four defining features to characterize P300: (a) its polarity (positive), (b) its latency (in excess of 275 ms), (c) its scalp distribution (maximum positivity at centro-parietal scalp locations, and (d) its response to experimental manipulations (larger for rare and task relevant stimuli than for frequent and unattended stimuli).

P300 Latency as an Index of Stimulus Evaluation Processes

According to the logic put forth by Kutas et al. (1977), as P300 commonly appears as a discriminative response to specific stimuli within in a series, its elicitation must be preceded by an adequate evaluation of the stimulus at some level of processing. Kutas et al. (1977) point out that several investigators have suggested that P300 is associated with stimulus evaluation processes rather than response selection and, if so, then P300 latency should be related to the time required for stimulus evaluation.

Kutas et al. (1977) conducted a study in which choice reaction times and the latency of P300 were compared under speed-maximizing and under accuracy-maximizing instructions. The results indicated that the correlation between P300 latency and RT for all trials was low when response speed was emphasized and higher when accuracy was emphasized. Kutas et al., (1977) concluded these data support the notion that at least two processes are initiated by a stimulus, a response selection and execution process indexed by the overt response and a stimulus evaluation process indexed by the P300 component. Under accuracy instruction where response selection is contingent on stimulus evaluation the two processes are tightly coupled, with RT frequently longer than P300 latency. When subjects operate under speed instructions, stimulus evaluation is more loosely coupled with response selection; responses may be generated before the stimulus has been fully evaluated.

The most convincing evidence in support of the hypothesis that P300 latency serves as an index of stimulus evaluation processes comes from a study by McCarthy and Donchin (1981). They manipulated two variables, stimulus discriminability and S–R compatibility, whose effects on RT have been demonstrated by a substantial body of research affect stimulus evaluation and response selection processes, respectively. The additive effect of these two manipulations on RT was a critical prerequisite to testing the effect of these manipulations on P300. In this study, the stimulus consisted of a matrix in which a target word (RIGHT or LEFT) appeared embedded in varying degrees of "noise" using various sets of characters from the alphabet (see Figure 3). The response selection stage was varied by changing the compatibility between the target and the response required. Subjects indicated the identity of the target word by pressing a response button with the left or right thumb. A cue word, SAME or OPPOSITE presented in the center of the screen, preceded the exposure of each matrix. SAME indicated that a compatible response (e.g., RIGHT signal the right thumb) while OPPOSITE indicated an incompatible response (RIGHT signal the left thumb). All factors varied randomly within a block of trials.

McCarthy and Donchin (1981) hypothesized that if the P300 reflects stimulus evaluation processes necessary for the categorization of the target, then both RT and P300 latency should increase as the difficulty in discriminating the target increases. However, if P300 is sensitive to stimulus evaluation processes, while being insensitive to variations in demands on response selection processes, then manipulations of S–R compatibility should not affect P300 latency. Rather, these manipulations should only affect RT. These predictions were supported. The results indicated that, although RT was affected by both stimulus discriminability and S–R compatibility (i.e., longer RTs were found across conditions of stimulus discriminability, as well as across conditions of S–R compatibility), P300 latency was affected only by stimulus discriminability (i.e., P300 latency increased when stimulus discriminability was more difficult, whereas it was not altered by changes in S–R compatibility) (see Figure 4). A subsequent study by Magliero et al. (1984) replicated and extended these results. In this study, P300 latency was found to increase systematically with variations in stimulus discriminability.

P300 in the Study of Aging of Mental Processing Speed

As Bashore et al. (1989) point out in their review, there are three reasons to place emphasis on the P300 component of the ERP in the study of aging of mental processes. First, there is evidence to suggest that the latency of the P300 reflects the time taken to evaluate and categorize stimulus events and is relatively independent of the time required to select and execute a response (Kutas et al, 1977; Magliero, Bashore, Coles, & Donchin, 1984; McCarthy, & Donchin, 1981). Second, there are observations that P300 latency, unlike RT, does not vary significantly with changes in speed/accuracy trade–offs (Kutas et al., 1977; Pfefferbaum, Ford, Johnson, Wenegrat, & Kopell, 1983; Strayer, Wickens, & Braune, 1987). And third, there is a growing literature which demonstrates that the latency of this component increases systematically with age (Bashore, 1990; Ford, & Pfefferbaum, 1980, 1985; Miller et al., 1987; Polich & Starr, 1984).

There are a number of studies using the P300 component to investigate age–related declines in the rate and efficiency of CNS processing (comprehensive reviews include Bashore, 1990; Bashore, Heffley & Osman, 1989; Ford & Pfefferbaum, 1980, 1985; Marsh & Thompson, 1979; Miller et al., 1987; Polich & Starr, 1985). The following is a brief summary of results from studies measuring P300 latency, amplitude and scalp distribution.

P300 latency

A growing body of literature indicates that P300 to an improbable auditory or visual stimulus increases in latency with age (Beck, Swanson, & Dustman, 1980; Donchin, Miller & Farwell, 1986; Goodin, Squires, Henderson, & Starr, 1978; Pfefferbaum, Ford, Roth, Hopkins, & Kopell, 1979; Pfefferbaum, Ford, Wenegrat, Roth, & Kopell, 1984; Picton, Stuss, Champagne, & Nelson, 1984; Smith, Michalewski, Brent, & Thompson, 1980). Although there have been some reports of failures to find age-related latency effects (Michalewski, Patterson, Bowman, Litzleman, & Thompson, 1982; Picton et al., 1984; Podlesny & Dustman, 1982), the majority of studies have demonstrated age-correlated slowing, and none have reported a decrease in P300 latency with age (Miller et al., 1987).

Thus a large majority of studies suggest that P300 latency becomes prolonged with increasing age suggesting that those processes engaged prior to, and in conjunction with, the P300 component (e.g., stimulus evaluation processes) are sensitive to the affects of age.

P300 amplitude

While the latency of P300 indexes the duration of stimulus evaluation stages of processing, P300 amplitude has been suggested to index the degree of activation of those neural processors engaged in relation to the stimulus evaluation process which serve in the updating of contextual aspects of short-term memory (see Appendix A). The findings on P300 amplitude and aging are less consistent. Whereas reductions in P300 amplitude with age have been reported in a number of studies (Brown, Marsh, & LaRue, 1983; Donchin et al., 1986; Goodin et al., 1978; Mullis, Holcomb, Diner, & Dykman, 1985, Picton et al., 1984; Podlesny & Dustman, 1982; Polich. Howard, & Starr, 1985), several studies dispute P300 amplitude decline with age (Beck, Swanson, & Dustman, 1980; Ford, Pfefferbaum, Tinklenberg, & Kopell, 1982; Pfefferbaum, Ford, Roth, & Kopell, 1980) especially when an overt response is required (Ford, Duncan-Johnson, Pfefferbaum, & Kopell, 1982).

P300 scalp distribution

It has been suggested that reduced P300 amplitude may be the result of a shift in the scalp distribution of P300 with age (Miller et al., 1987). Several studies report that P300 amplitude appears to be reduced at the parietal lead and maintained or increased at the frontal lead with advancing age (Donchin et al., 1986; Ford & Pfefferbaum, 1985; Goodin et al., 1978; Mullis et al., 1985; Pfefferbaum, Ford, Roth, & Kopell, 1980; Pfefferbaum, Ford, Wenegrat, Roth, & Kopell, 1984; Picton et al., 1984; Smith, Michalewski, Brent, & Thompson, 1980; Strayer et al., 1987). Ford and Pfefferbaum (1985) have suggested that differences in slow wave scalp topography between young and old subjects may be account for the equipotential distribution of P300 amplitude in older subjects. The slow wave and the P300 overlap temporally, with the slow wave continuing much longer than P300. The slow wave is negative at the frontal site and larger in younger subjects than older subjects. A frontally reduced slow wave negativity in older subjects may account for a concomitant increase in P300 amplitude at Fz, making the distribution of the P300 more equivalent across electrode sites.

Form of the decline

Although some have reported an increased rate of delay after age 60 (Beck et al., 1980), or even after 45 (Brown et al., 1983), others have found a fairly constant latency prolongation of 1 to 1.5 ms/year (Goodin et al., 1978; Syndulko, Hansch, Cohen, Pearce, Goldberg, Montana, Tourtellottee, & Potvin, 1981). Thus controversy about the linear relationship between age and P300 latency exists (Miller et al., 1987).

Theories of Mental Slowing Using P300 Latency

As Bashore et al. (1989) point out, the conclusion of both Cerella et al. (1980) and Salthouse and Somberg (1982b) is that the complexity effect is the result of a centralized slowing, and the slowing appears to be generalized in character, affecting all mental processes equally. While in agreement with the centralist view arrived at through the regression analyses based on RT measures, Bashore et al. (1989) take issue with the conclusion of a generalized or proportional slowing across all central processes. They present evidence using similar meta-analyses on regression functions using both behavioral and electrophysiological data which suggest that not all components of central processing are equally affected by aging. This evidence comes from two sources; (1) studies using the memory scanning task of Sternberg (1969) to assess age-related declines in the speed of memory search (Ford et al., 1979; Ford et al., 1982; Marsh, 1975; Pfefferbaum et al., 1980; Strayer et al., 1987) and, (2) meta-analytic studies using P300 latency as a measure of stimulus evaluation time (Bashore, 1990; Bashore et al., 1989).

Recall that in the context of Sternberg's memory scanning task (Sternberg, 1969), several studies using RT have shown that older subjects have longer RTs, larger intercepts (indicative of an aggregate time comprising stimulus encoding, binary decision, and response translation and organization times, independent of comparison times), and steeper slopes (indicative of the time required to compare the test item with each item held in memory, or, "serial comparison time") than do young adults (e.g., Anders & Fozard, 1973; Salthouse & Somberg, 1982a, 1982b) leading to the conclusion that mental processing speed is slower at all stages of processing in older adults.

However, different conclusions can be drawn from ERP studies of age-related changes in memory scanning (Bashore, 1990; Bashore et al., 1989; Miller et al., 1987; Ford & Pfefferbaum, 1985). These innovative studies were based on the reasoning that the slope of the P300 latency-memory set size function, rather than that of the RT-memory set size function, provides a purer estimate of serial comparison time (Miller et al., 1987), based on previous studies suggesting a relationship between P300 latency and stimulus processing (e.g., Kutas et al., 1977). These analyses indicated that the slope of the RT-memory set size function was steeper and the intercept larger in the old than the young, replicating previous findings (see Figure 5). However, the slope of the P300 latency-memory set size function was comparable in the two groups, whereas the intercept of this function was larger in the old than in the young. Using the additive factors logic of Sternberg, Ford et al. (1979) suggested that age-related slowing in memory scanning occurs at both stimulus encoding (elevation of P300 latency intercept) and response-related stages (steeper slope and elevation of intercept RT-P300 latency difference regression function) while the speed of serial comparison processes appears to be maintained with age (no difference in P300 latency slopes).

The second line of evidence comes from Bashore (1990) and Bashore et al. (1989) who conducted a meta-analysis on the slowing of mental processing speed with age using P300 latency data gathered from several studies. The results replicated findings of steeper slopes of the RT and RT-P300 latency regression function for older subjects than young adults under tasks of increasing complexity, suggesting that the age-related decline in mental processing speed is multiplicative (see Figure 6).

However, when P300 was plotted as a function of age over tasks of increasing complexity, the result was additive (see Figure 6). Bashore (1990) and Strayer et al. (1987) suggest that differences in response strategy may account for why P300 latency showed an additive affect with age while RT and RT-P300 latency functions suggest that age-related decline in mental processing speed is multiplicative. The authors suggest that this may be a result of another factor associated with aging, the tendency towards more conservative response strategies. They suggest that because P300 has been found to be relatively insensitive to response strategy (e.g., Strayer et al., 1987), whereas RT has been found to be extremely sensitive (Miller et al., 1987), the slope effects for RT and

RT–P300 latency may reflect changes in response strategy as processing complexity is increased.

Summary

This section introduced the research using ERPs to investigate age–related changes in speeded response. The use of the P300 component of the ERP has allowed the following conclusions to be made: (1) P300, like RT, indicates that the older people are slower than young in processing rates, (2) age–related slowing of P300, as a direct measures of the CNS, provides strong support to the theory of CNS changes with age, (3) P300 as an index of only a subset of processes which affect RT has allowed more precise conclusions to be made regarding the affect of age on different computational stages suggesting that (4) not all stages of mentation are affected by age (e.g., memory scanning rate) and (5), that the complexity effect is accounted for by processes occurring after stimulus evaluation processes, implicating response decision and execution stages.

In conclusion, these approaches highlight how mental processes can be articulated utilizing ERP/RT measures and applied to clarify such issues as the specification of those aspects of information processing which are or are not affected by the aging process. It is has been demonstrated that this combined RT/P300 approach lends itself nicely to the investigation of the effects of interventions on age–related declines in mental processing speed (e.g., Bashore, 1990). In the following chapter the effects of some interventions on mental processing speed are reviewed and the intervention of interest in this study, TM, is introduced.

CHAPTER II: POTENTIAL INTERVENTIONS IN AGING OF NEUROCOGNITIVE FUNCTION

Historically, neuroscientists have tended to share the opinion that little can be done to slow the rate at which central nervous system integrity is compromised with age (Bashore & Goddard, in press). Not surprisingly, the view was also held that once CNS loss had been sustained there was nothing that could be done to restore the functions mediated by the compromised structures. Research in the past twenty years has begun to debunk the old myths, held both by lay public and scientists, about aging and its consequences. This chapter begins with a discussion of the kinds of factors that have been found to minimize age differences in mental processing speed. TM is then introduced as a potential intervention in reducing age differences in CNS processing speed.

Factors that Minimize Age Differences in Response Speed

A useful framework in which to discuss factors which have been found to minimize age differences in RT is provided by Salthouse (1985), in which a computer metaphor is used to organize, conceptually, the research and theory regarding age differences in speeded performance. A computer, as an information processing system, takes a certain amount of time to process information between input and output. Salthouse (1985) considered hypothetically that if two computers are given the same input, there are several reasons why the output of one computer, relative to the other, might take longer. Among the alternative explanations he considered were: (1) peripheral input/output devices may be slower at bringing information to and from the central processor, (2) the software, or set of instructions, that are carried out on the slower computer may be less efficient or may simply use a different, less efficient processing algorithm and (3) there may be differences in the hardware such that the central processor is simply slower, thereby preventing it from processing information at a comparable rate. As has been discussed in Chapter 1, and as Salthouse (1985) concluded in his review of studies using RT, the only explanation that can be safely eliminated is (1), -- slower peripheral input/output mechanisms produce the differences in RT among the young and the old.

Software Differences

With respect to explanations based on software differences, Salthouse (1985) suggested that examples in this category would include any differences between young and old subjects in processing strategy. Two fundamentally important differences between the young and the old that fall under strategy differences are variations in response preparation, and greater concern for accuracy than for speed. Salthouse suggested that the influence of strategy differences on age-related slowing could be determined by designing tasks that minimize or eliminate these variations. If age differences in speed are eliminated under these conditions, then the conclusion is supported that they play no role in the slowing-with-age phenomenon.

Salthouse reviewed two studies conducted in his laboratory (Salthouse, 1979; Salthouse & Somberg, 1982a) which indicated that age differences persist, even when accuracy rates are comparable between young and old. With regard to the poor-preparation hypothesis, the strongest support for this comes from recent work by Gottsdanker (1982). Gottsdanker (1982) eliminated age differences in simple reaction time by matching young and old subjects with comparable performance levels. He then varied the interval between the warning and the imperative stimulus to determine the effect of differing levels of difficulty in preparation. He found that simple RT of older subjects was longer than young subjects in the condition where preparation was most difficult (longer fixed intervals), suggesting that age negatively influences anticipatory processes. Other studies, using psychophysiological measures of arousal or preparation (e.g., the CNV) indicate that older subjects do not manifest the same type of preparation responses, as indicated by a less responsive CNV, as young subjects (e.g., Loveless & Sanford, 1974).

An alternate interpretation of the aging differences is that they reflect the need for greater amounts of practice in older persons. One effect of providing sufficient practice is that it helps the subject acquire an optimal strategy for the task, which should eliminate age differences. Studies have revealed that age differences in speed persist through at least 50 hours of experience (Salthouse & Somberg, 1982a). However, studies on the development of automaticity suggest that older subjects do not develop automaticity in the same way as young subjects (Madden & Nebes, 1980).

Hardware Differences

The explanation based on hardware differences is synonymous with the determinant view which theorizes that changes in the overall processing efficiency of the CNS is responsible for the slowing found across a wide range of performance. Belonging to this group is Welford (1977) and the neural-noise theory. The neural-noise theory suggests that the effect of age is to reduce the signal-to-noise ratio in the nervous system. The neural noise concept suggests that if the strength of the signal is diminished relative to the background noise, the older nervous system is slower because of its need to integrate information samples for a longer time. Birren et al. (1980) have also persuasively advocated the fundamental role of the CNS in slowing. They proposed two speed factors: (1) a primary factor of aging at a subcortical level reflected in all or most processes mediated by the CNS, and (2) a second factor of cortical integrity which may be influenced by disease, particularly those resulting in local cell loss, interference with circulation, and ischemia.

Figure 7 is intended to summarize the ideas conveyed by Birren et al. (1980), Welford (1977) and others. The processing in the computer is driven by the computer at the speed of the central processor (e.g. 20 MHz). The operations that the computer can perform are mapped in the hardware design of the computer (logic circuits, etc.) and determine the kinds of operations the computer can be programmed to perform (software). With this view, it is theorized that while the software or set of operations that the cognitive system performs remains structurally intact with age, the CNS undergoes a loss of integrity which expresses itself in a general slowing of processing capacity. This reflects itself in the "complexity effect" , a constant proportional slowing across tasks of increasing complexity (see Chapter 1).

There are other theories which characterize age-related changes in task performance with a different emphasis. Marsh and Thompson (1977) have suggested that much of the behavioral impairment found with age may be the result of a lack of congruence between CNS and ANS functioning. This suggestion was based on evidence that alignment of CNS-ANS activity may be a significant factor in preparatory set. Podlesny and Dustman (1982) found that elderly showed less of a correlation between CNS (P300 and contingent negative variation (CNV)), ANS (heart rate deceleration), and cognitive (RT) measures than young adults. Other studies evidence a breakdown in the functional autonomy of CNS processes, as indicated by increased EEG coherence, decreased power variability and reduced alpha reactivity in the elderly (Dustman et al. 1984). As Miller et al. (1987) point out, the value of coherence may be more or less problematic depending on the task at hand. The Dustman et al. (1984) results could be confounded by the lack of a task requirement, which may promote the onset of sleep, a tendency which is known to be heightened in the elderly due to a breakdown in the waking-sleep cycle. They point out that studies remain to be done which address whether the increased coupling is related to a loss of functional capacity in the elderly.

The common view is that the changes in neural transmission presumed to mediate mental slowing in the elderly are inevitable and cannot be delayed or reversed. Studies are beginning to show that these declines are alterable. RT and ERP studies have been done which suggest that mental processing speed is faster in older exercisers than it is in older nonexercisers (Bashore, 1990; Bashore et al., 1988; Spirduso, 1980), and comparable to those of young non-exercisers (Botwinick & Thompson, 1966). Bashore (1990) and Bashore et al., (1988), using the S-R compatibility task of McCarthy and Donchin (1981), have reported faster P300 latencies and RT in elderly exercisers compared to elderly nonexercisers. Dustman, Emmerson, Ruhling, Shearer, Steinhaus, Johnson, Bonekat, & Shigeoka (1989) reported a study of 30 young and 30 older adult males whose fitness levels were either high or low. The results indicated that, in a visual task, high fitness level was associated with shorter P300 latencies for both the old and the young. Despite a 30-year difference in age, P300 latency for the aerobically fit older adults was not different from latencies for the young adults.

Although the mechanisms responsible for improvements through exercise remain unclear, altered physiological status has been proposed as one explanation. Exercise may serve to maintain an optimal cerebral physiology. It is known that mental activity results in increased regional blood flow, reflecting the dynamic needs of the cerebral tissue for glucose and oxygen. If the supply of these nutrients is cut off, mental function can decrease (Sokoloff, 1981). Poor circulatory status, such as hypertension or mild to moderate cardiovascular disorders, have been reliably associated with slower performance on psychomotor tasks (e.g., Light, 1978; Spieth, 1964). As such, changes in the brain's capacity to receive and utilize vital nutrients would be considered in the category of hardware intervention. Bashore (1990) concludes, "...the rate at which declines in brain processing efficiency occur with age may be alterable and that aerobic exercise may be one means by which this decline can be delayed well into later life." This a particularly important finding, since most researchers have conceded that CNS changes were inevitable and unamenable to remedial intervention.

Summary

The studies suggest that the change in the rate of mental processing speed with age may be associated with the health of the cerebral and cardiovascular systems. People who maintain high levels of fitness (i.e., high levels of cerebral/cardiovascular system efficiency) appear to preserve mental processing speed. In addition, it appears that the differences between young and old cannot be explained in terms of differences in what Salthouse (1985) refers to as software differences. When these processes are controlled speed differences remain. In the next section research on TM is discussed which suggests that the benefits that accrue the long-term practitioner may, indeed, be due to benefits at the level of both the CNS and ANS (i.e., the hardware) and the rate of decline in CNS processes may be slowed in those who practice TM.

Transcendental Meditation as a Potential Intervention

The first series of articles by Keith Wallace and colleagues at UCLA and Harvard (Wallace et al, 1970; Wallace et al., 1971; Wallace & Benson, 1972) suggested that during TM, meditators exhibited a unique style of physiological functioning as evidenced by pronounced sympathetic de-excitation (i.e., significant decreases in oxygen consumption, carbon dioxide elimination, respiration rate, minute ventilation, heart rate and marked increases in skin conductance) along with electrophysiological evidence of restful alertness (i.e., increased alpha and theta wave activity spreading to central and frontal areas of the brain). These findings led Wallace and colleagues (1970; 1971; 1972) to propose that TM produces a fourth major state of consciousness, uniquely different from waking, sleeping, and dreaming.

Since those early studies several investigators have sought to elaborate or substantiate these initial findings. Although consensus regarding the characterization of a unique style of physiological functioning during TM has yet to be reached (Dillbeck & Orme-Johnson, 1987), there is strong evidence indicating that TM has beneficial effects on alleviating the effects of stress and in reducing the negative consequences of aging.

A few studies have addressed the effects of TM on the aging process directly. Wallace, Dillbeck, Jacobe, & Harrington (1982) evaluated the effects of the TM and TM-Sidhi program on the aging process using a standardized test of biological aging (Morgan Scale; Morgan & Fevens, 1972) measuring near point vision, auditory threshold, and systolic blood pressure. Controlling for age (mean age of 55 yrs. for all groups) and diet, three groups were compared: long-term meditators (over 5 years practicing TM), short-term meditators (less than 5 yrs. TM), and non-meditating controls. When each groups biological age was compared to that of the population norm at the chronological age of 55, the controls were found to have a biological age 2.2 years younger than the norm, short-term practitioners of TM were 5.0 years younger; and long-term practitioners were 12.0 years younger. These results have been replicated and extended by showing that further reductions occur longitudinally in the same meditating subjects (Toomey, Chalmers, & Clements, 1990).

Another study on biological aging involved the measurement of serum dehydroepiandrosterone sulfate (DHEAS) by Glaser, Brind, Eisner, Vogelman, Dillbeck, Chopra, & Wallace (1987). DHEAS declines progressively with age. Peak levels occur in one's mid-twenties and by the eighth and ninth decades of life, one's DHEAS level may have declined 80 percent. In this study DHEAS levels were measured in experienced meditators (256 men, 74 women) and non-meditators (981 men, 481 women) who were compared according to gender across different age groups. Mean DHEAS levels were significantly higher in the TM group compared to the controls in all the 5 age groups measured in women, and in eight of the eleven age groups for men. Further, the difference was more pronounced in the older subjects: the mean percentage of DHEAS elevation over control values was higher for the older age groups, with mean differences of 23 percent for men over 45, and 47 percent for women over 45. This effect was independent of identifiable contributing factors including diet, exercise, obesity, or use of alcohol, and is another indication of younger biological age in TM participants.

In another study, Alexander, Langer, Newman, Chandler, & Davies (1989) investigated cognitive performance in elderly subjects instructed in TM. In this study, 73 elderly nursing home residents were randomly assigned to one of the following four treatment conditions: TM, mindfulness training, relaxation and no-treatment control. The conditions were selected to foster equal expectations about anticipated results and to have a common structure and follow-up program. After three months of practice results showed the TM group improved most, followed by mindfulness, in comparison to relaxation and no-treatment for the following cognitive, health and personality measures: paired associate learning; two measures of cognitive flexibility; systolic blood pressure; mental health; self-ratings of behavioral flexibility and aging; and multiple indicators of treatment efficacy. The mindfulness group improved most, followed by TM, on perceived control and word fluency. After three years, survival rate (longevity) for TM was 100% and mindfulness 87.5% in contrast to lower rates for the other conditions. These findings could not be attributed to simple relaxation or expectation. Alexander et al. (1989) suggest that, " while TM is designed to induce a more settled state during the practice, it also appears to be an effective procedure for enhancing alertness and general preparedness for engagement in more adaptive and potentially mindful interaction after the practice." (p. 952).

Cognitive Changes in Young Adults

Because prevention of age-related declines in CNS processing speed is presumably a cumulative phenomenon, it seems relevant to discuss studies on response speed in young adults practicing TM. These studies indicate that TM may enhance both short-term and long-term speeded response. One approach has been to measure the short-term effects of TM on RT immediately before and after TM practice. Findings include faster simple reaction time (Orme-Johnson, Kolb, & Hebert, 1973) and choice reaction time (Holt, Caruso, & Riley, 1978) with less variability in response (Apelle & Oswald, 1974) after TM practice compared with before the practice. Researchers have also reported long-term cumulative effects from TM (Orme-Johnson et al., 1973) with faster reactions associated with length of practice of TM. Similar effects were found in practitioners of the TM-Sidhi program, in which length of time practicing was negatively correlated with response speed (Jedrczak, Toomey, & Clements, 1986). Long-term practitioners have been found to be faster than controls both at pre-test (Apelle & Oswald, 1974) and after the practice (Cranson, 1988; Cranson, Orme-Johnson, Dillbeck, Jones, & Alexander, 1991; Orme-Johnson et al., 1973; Rowe, Neuschatz, & Nidich, 1980). Cranson (1988) and Cranson et al. (1991), in a longitudinal study, reported significantly greater improvement in CRT and greater reduction in CRT variability over a 2-year period in college students practicing TM compared to a non-meditating control group. This finding was accompanied by an increase in IQ in the TM group, while no change in IQ was found in the non-meditating group.

Orme-Johnson et al. (1973) interpret faster response speed in TM practitioners as an indication of increased alertness. Orme-Johnson (1973), measuring skin conductance response (GSR), found TM meditators adjusted more quickly to environmental stresses (faster GSR recovery), displayed a more stable reaction (fewer multiple fluctuations during the recovery cycle) and had an overall lower resting arousal level (fewer spontaneous skin conductance responses). Orme-Johnson et al. (1973) state that, "the long-term effect of the TM technique may be to lower internal "noise" and agitation levels and thereby enhance cue utilization." (p. 316).

In another study on young adults, Dillbeck (1982) investigated the effects of the regular practice of TM on habitual patterns of visual perception and verbal problem-solving. It was specifically hypothesized that the TM technique involves a reduction of habitual patterns of perceptual and conceptual activation, resulting in more effective application of schemata to new information and less distracting mental activity during performance. After a two-week period, the TM group showed improvement both on task conditions in which habitual perceptual schemata aided performance and on task conditions in which they either did not aid or actually hindered performance.

ERP Changes in Young Adults

In studies combining ERPs with visual CRT meditators have displayed shorter RTs than resting controls both before and after their respective practices, with fewer mistakes after TM compared to resting controls (Banquet & Lesevre, 1978; Banquet, Bourzeix, & Lesevre, 1979; Banquet & Lesevre, 1980). Latencies for N120 and P200 were shorter in meditators before and after the practice for a go-stimulus task. Banquet & Lesevre (1980) interpreted this overall difference in RT performance as indicative of improved capacity of focalized attention and vigilance levels resulting from TM practice. P300 amplitude was found to increase after TM practice compared to resting controls whose P300 amplitude tended to decrease. The RT-P300 relationship indicated meditators consistently emitted their response before the P300, suggesting adoption of a strategy which favored speed over accuracy (cf. Kutas et al. 1977). However, accuracy was better in meditators at pre-and post-test, with TM improving at post-test. The authors suggest the meditating subjects may have given more importance than the controls to the frequent (90%) target stimulus and pre-selected their response.

Wandhoefer and Plattig (1973), and Kobal, Wandhoefer, and Plattig (1976), using an auditory task with different levels of intensity, found meditators to have shorter P200 and N200 latencies both in an awake state and during TM compared to resting controls before and during rest. They also reported greater amplitudes for P2 and N2 in the TM group, while N100 amplitudes were smaller than the controls.

Cognitive Changes Associated with EEG Changes

Another potentially related area of research on TM has been electrophysiological (EEG) studies on adult meditators. Studies assessing EEG coherence during task performance have found a positive correlation between task performance and frontal EEG coherence but only in the meditating subjects (Dillbeck & Veseley, 1986).

Frontal coherence during TM has been found to increase with 2 weeks of TM practice (Dillbeck & Bronson, 1980) and positive psychological factors, such as creativity and moral reasoning have been found to correlate with this increase (Orme-Johnson et al, 1981). However, this positive correlation is unique to meditating subjects and to the frontal areas. As such, these findings necessitate greater specification in current models which propose global coherence to be a index of neural redundancy (Thatcher & Walker, 1985), or loss of CNS functional capacity (Dustman et al., 1984). These models will need to account for individual differences brought about, for example, by TM as reflected in the increase in frontal-central coherence and it's relationship with positive psychological growth.

The finding of greater hemispheric asymmetry in meditators during cognitive tasks (Bennett & Trindler, 1984) might be the result of an induced state of integration in brain functioning during TM which may provide for a more optimal platform of functional differentiation during active processing. This hypothesis, supported partially by Dillbeck et al., (1981), needs further testing.

The findings of increased EEG coherence in meditation accompanied by changes in autonomic stability are also relevant, based on studies suggesting a relationship between CNS-ANS integration and response speed. Because research suggests a unique integrated state of CNS-ANS functioning occurs during subperiods of TM (single subject study of Farrow & Hebert, 1982), as evidenced by EEG coherence and autonomic stability, and these effects seem to persist outside the practice (Orme-Johnson, 1973), it seems plausible that reduced age-related affects in mental processing speed may be associated with cumulative exposure to this style of neurophysiological functioning. As such, coherence as a predictor of age-related declines in information processing, proposed by the theory of Dustman et al. (1984), remains to be tested, and may be dependent upon (1) the conditions under which EEG coherence is measured (resting vs. active), (2) on what population of subjects is under investigation (meditating or non-meditating), (3) how coherence is measured (Dustman used power variability, while TM studies in general have used phase relationships), and (4) where EEG is measured (i.e., the scalp distribution, e.g., anterior/posterior)

In summary, the studies reviewed have shown TM to have beneficial effects on cognitive and physiological processes in elderly adults. Young adults practicing TM have also shown increased perceptual and cognitive flexibility and increased processing speed compared to controls. Also evident are unique changes in EEG which have been found to correlate with positive psychological variables. If these effects are cumulative, then the benefits of TM may be more pronounced in the later years of life where the effects of age, and the advantages of good mental and physical health, are potentially more dramatic.

CHAPTER III: TESTING THE EFFECTS OF TRANSCENDENTAL MEDITATION ON NEUROCOGNITIVE AGING

As outlined in the first 2 Chapters, several studies indicate that neurocognitive changes that take place with age are, for the most part, accompanied by a slowing of behavior across a wide range of tasks, with the greatest differences occurring in those tasks which place the greatest demands on central/cognitive processes. The combined approaches of behavioral (RT) and psychophysiological (ERP) methodologies have provided more direct evidence for centralized slowing.

While most neuroscientists regard the age-related slowing of behavior as inevitable and irreversible, evidence is beginning to accumulate which suggests that the latency of life at which these changes occur and the rate of change may be modulated through behavioral interventions. For example, regular aerobic exercise has been found to reduce age-related slowing as measured by traditional RT tasks as well by ERP analyses. The present study was designed to assess if regular practice of Transcendental Meditation (TM) may be another means by which age-related slowing may be reduced. While there are currently no studies reported which have assessed TM's effects on age-related slowing using the cognitive psychophysiological approach, there are several studies which suggest TM practitioners evidence a younger biological age, as measured by blood pressure, sensory thresholds and acuity, hormonal profiles, and cognitive flexibility (Alexander et al., 1990; Glaser et al., 1987; Wallace, 1986).

This chapter serves as the core of this report by introducing two studies which were conducted to test the hypothesis that long-term practice of TM would reduce age-related declines in mental processing in the elderly. In both studies the combination of RT and P300 were employed to assess the effects of TM on speeded performance in the elderly.

Experiment 1

In the first experiment, two oddball tasks were employed which have been standard tasks in P300 research (Kutas et al., 1977) for the purpose of testing the effect of long-term practice of TM in the elderly in preserving mental processing speed as measured by CRT and P300 latency. The hypotheses were that the elderly TM group would evidence shorter CRT and P300 latencies on both the visual and auditory oddball tasks.

Method

Subjects

The non-meditating subjects were selected from a data base at the Cognitive psychophysiology laboratory at the University of Illinois, Champaign-Urbana. Only subjects between 61-69 years of age were included for matching purposes, totalling 13 subjects with a mean age of 66.5 (9 females). The meditating subjects were solicited by advertisement from the community at Maharishi International University. Thirteen of those tested were selected on the basis of age and gender to match the non-meditating group. The mean age of the meditating group was 65.8 years (9 females) and they had practicing TM for an average of 11 yrs.

The non-meditating subjects, as part of the previous study, received extensive medical screening prior to inclusion in that study. The meditating subjects were only required to fill out a brief self-report of health status. Results from both screening procedures indicated subjects to be free from neurological disorders and in good health. All data from this experiment was collected in a 2.5 hr. session.

Stimuli

Visual Stimuli. Visual stimuli were presented on a video monitor under computer control. Male and female names (see Kutas et al., 1977) appeared one at a time, at an interstimulus interval of 1500 ms.

Auditory Stimuli. Auditory stimuli were presented through headphones. High and low tones consisted of 1000 Hz and 500 Hz frequencies, respectively, presented for 200 ms at an inter-stimulus interval of 1500 ms.

Procedure

Subjects sat in a chair in front of the monitor. In the visual task, names were presented to the subject in the center of the display in random order with the male names occurring with a probability of .20 and female names occurring with a probability of .80. Subjects were instructed to keep a mental count of the male names. Four blocks of 100 presentations occurred with the subject giving a report of the count at the end of each 100 trial block. All subjects counting performance was above 95% accuracy (i.e., 20 +/- 2), typical for this task.

In the auditory task, high and low tones were presented in random order with the high and low tones occurring with a probability of .20 and .80, respectively. Subjects were required to make a right button press to the low tone and a left button press to the high tone, using buttons on a rectangular box which rested in their lap. Thumbs rested on the respective buttons during the task. Four blocks of 100 presentations occurred in sequence. One meditating subject and his matched control were dropped from the RT analysis due to arthritis in the thumbs, leaving 12 in each group. Each subject received all 4 blocks of one task before performing the other task.

Data Collection

Beckman silver silver-chloride electrodes were affixed with EC-2 electrode cream at Fz, Cz, and Pz (international 10-20 system) and with stomaseal adhesive collars to the reference sites (linked mastoids), the ground (forehead), and the electrooculogram (EOG) sites (sub- and supra-orbital). Electrode impedance did not exceed 10 Kohms. The electroencephalogram (EEG) signals were amplified with Grass Model 12 amplifiers using an 8-sec time constant and a low-pass filter with a 35-Hz cutoff (3-dB/octave roll-off). The EEG signals were digitized every 10 ms beginning 100 ms prior to stimulus onset. All aspects of experimental control and data collection were controlled by a custom built, Pearl 2 computer system. Data were collected whenever a test stimulus was displayed and stored on magnetic tape for subsequent quantification and analyses. The EOG activity was corrected off-line (Gratton, Coles, & Donchin, 1983a). The latency of the P300 component was assessed on a single trial basis by identifying the largest positivity in the parietal electrode within a 300-1000 ms window. The design was a static group comparison.

Results

Visual task

Results for P300 latency and amplitude are presented in Table 1.

Because P300 is maximal at Pz, all discussion which follows concerning the P300 is based on signals from this electrode. ERP averages for both groups, for target and non-target trials, at Pz are shown in Figure 8. P300 latencies to the target stimuli were significantly shorter in the meditating group compared to the non-meditating group (543 vs. 703 ms), $t = 4.36$, $p < .0002$. P300 amplitudes were not significantly different between the groups, $t = 1.56$, $p < .14$.

TABLE 1. Older TM group compared to older non-TM group on average P300 Latency (Pz) in a visual oddball task (mental count).

Group	TM (n=13)	Non-TM (n=13)	t-value	prob
Age	65.8	66.5	.57	.57
s.d.	2.9	3.3		
P300	543	704	4.36	.0002
Latency	80.8	105.2		
P300	96	130	1.56	.14
Amplitude	35.3	69.2		

Auditory task

The results for RT and P300 latency are presented in Table 2. T-tests were performed on four dependent variables; Pz latency and amplitude, and CRT for target and non-target stimuli.

TABLE 2. Older TM group compared to Older non-TM group on average P300 latency (Pz) in an auditory oddball task (choice reaction time).

Group	TM	Non-TM	t-value	prob
P300	427	413	-.68	.505
Latency	48.9	55.1		
P300	85	122	1.85	.08
Amplitude	36.7	62.4		
Target RT	485	428	-1.91	.07
s.d.	82	63		
Non-Target	395	374	-.84	.41
RT	59.8	63.7		

RT for the target and non-target stimuli were not significantly different between the groups. However, the non-TM group tended toward faster responses to the target stimuli (428 vs. 485), t = -1.91, p < .07. Accuracy rates between the groups were comparable (95%).

ERP averages for both groups for target and non-target trials at Pz are shown in Figure 9. P300 latencies (t = -.68, p <.50) and amplitudes (t = 1.85, p <.08) were not significantly different between the groups. However, P300 amplitudes tended to be larger in the non-meditators.

Discussion

The results partially support the hypothesis that long-term TM practice may reduce age-related declines in CNS processing speed. While no significant differences were found between the meditating and non-meditating groups in P300 latency or reaction time in the auditory task, the meditating group showed significantly shorter P300 latencies than the non-meditating group in the visual task. One possible explanation for the interaction between group and task may be due to the response requirement. Auditory oddball tasks that require a manual response have been found, in some cases, to modulate age differences in P300 amplitude (Picton et al., 1984). P300 latency, however, has proven to be considerably unresponsive to response demands. Another possible explanation may be made with reference to the relationship between stimulus modality and the complexity effect. If TM is affecting cognitive processes, then differential benefits associated with TM would become more apparent as cognitive demands increased. It is not unreasonable to argue that the visual task involved a greater cognitive demand than the auditory task, especially on stimulus encoding, evaluation and categorization processes, those processes known to affect P300 latency. Fabiani et al. (1987) report that a consistent majority of studies using both auditory and visual stimuli have found that P300s elicited by visual stimuli are both larger and later than those elicited by auditory stimuli. They suggest that many of the differences reported between auditory and visual stimuli may be related primarily to the complexity of the stimuli and the difficulty of the discrimination required (Fabiani et al. 1987). It is possible that the difference due to meditation found in the visual task reflects benefits to cognitive processes which were not sufficiently engaged in the auditory task.

This experiment has a number of potential confounds. First, due to the cross-sectional nature of the design, the most salient confound is subject-selection. Meditators, having self-selected themselves into this group, and having practiced it for several years, constitute a unique group. This makes any firm conclusions about differences between the groups due to TM difficult. The findings of no difference in RT suggests that whatever differential benefit TM may have on mental processing speed, reflected in shorter P300 latencies, is compensated for in response selection processes, reflected in equal CRT. Indeed, the trend toward faster RT in the non-TM group would argue against a differential benefit associated with TM. Since accuracy rates were comparable between the groups this difference does not seem attributable to differing response strategies between the groups.

There is another alternative hypothesis regarding the lack of control for intelligence levels. While no studies to date have reported a systematic relationship between IQ and P300 latency, there is evidence for a positive relationship between IQ and RT in young adults, with faster RT related to higher IQ (Eysenck, 1987; Jensen, 1982; Jensen & Munro, 1979). Since P300 and RT have been found to covary when factors affecting strategy controlled, it is possible that P300 may show a similar relationship. The lack of a measure of IQ in this study prevents any differences between the groups to be interpreted without possible confounds associated with IQ. It could be argued that people inclined to practice meditation are more intellectually oriented and possibly have higher IQs. Though the groups were not significantly different in CRT, the trend toward faster CRT in the non-meditating group weakens this potential argument. However, studies have shown TM practice to increase IQ levels (Cranson, 1990), and without controlling for possible differences due to IQ, this remains a potential confound.

One factor which may support the conclusion of TM benefits concerns health status. While the non-meditating control group consisted of subjects who had successfully passed medical screening for neurological and health disorders, the meditating group was less thoroughly screened through the use of a self-report health questionnaire. It is possible the non-meditating group was biased toward a more healthy sample than the meditating group. However, this would only support the hypothesis of an effect due to meditation. Finally, the lack of a young group to serve as a point of reference for differences between the elderly groups in the study prevents one from discussing the age effect more directly.

Therefore, while findings of shorter P300 latency in the TM group for visual stimuli is significant and suggestive, there is need for better control of confounding factors known to affect processing speed. Experiment 2 was conducted for the purpose of providing these controls.

Experiment 2

Experiment 2 was conducted to further investigate the hypotheses of Experiment 1 and to control for some of the confounds. With regard to individual differences, all comparison groups were matched on age, gender, IQ, reported involvement in exercise, and health status. The task used by McCarthy and Donchin (1981) was chosen for Experiment 2. This task allows the investigator to systematically vary task complexity, and provides the ability to manipulate, independently, stimulus evaluation and response related-stages of information processing. Therefore, validity for the interpretation of results of Experiment 1, with reference to differential effects of meditation practice across levels of cognitive complexity, could be assessed.

A prerequisite to the central research question of preservation of processing in older subjects with long-term practice of TM, was the replication (to the extent that it could be possible) of both the experimental findings of McCarthy and Donchin (1981) within a young subject population, as well as in the pattern of age-related slowing of processing speed that would be predicted by previous studies. The addition of a young subject population was not only important for replication purposes, but also provided a reference point from which the magnitude of differences as a result of age, and potentially, the TM practice could be assessed. In addition, the inclusion of a TM comparison within young subjects was desirable, since little work had been done on this population using the cognitive psychophysiological approach. However, for practical reasons the number of subjects included in this comparison was kept very small since it was not the main comparison of interest.

There were four research questions in Experiment 2: a) replication of experimental findings within a group of young adult subjects in the McCarthy and Donchin (1981) task, b) an assessment of the effects of TM on mental processing speed within this young group, c) assessment of age-related declines in mental processing speed as evidenced by a contrast between young and old subjects, and d) assessment of the degree of preservation of mental processing speed in long-term elderly TM practitioners.

With reference to replication of findings of McCarthy and Donchin (1981) in young adults, it was predicted that, 1) both RT and P300 latency would be prolonged with increased difficulty in discriminability, 2) the effects of discriminability and stimulus-response compatibility would have independent effects on both RT and P300 latency (i.e., they would show additive effects), 3) RT to the target word in the matrix would be faster when the word was in the middle two rows relative to the outer two rows, and 4) RT would be prolonged under conditions of stimulus-response incompatibility, while P300 latency would be relatively unaffected by stimulus-response incompatibility.

With reference to the second question of differences in mental processing speed in young adult practitioners of TM compared to non-meditators, it was predicted that the TM group would exhibit faster RT and P300 latencies when compared to the non-meditating control group. On the basis of the results of Experiment 1 it was predicted that differences in processing speed would be greatest when processing demands were highest (i.e, increased stimulus noise and incompatible response).

With regard to third question, the effects of age on mental processing speed, it was predicted that the effect of age would be expressed in the following two ways: 1) Older subjects would have longer RTs than young subjects and the differences between the groups would be greatest under conditions of stimulus noise and stimulus-response incompatibility (i.e., there would be a proportional increase in RT with increases in task complexity), 2) P300 latency would be longer in the old subjects than the young subjects, but the effect of age would not interact with task complexity (i.e., the difference in P300 latency between young and old would be additive with increases in task complexity) and, 3) the same within-subject experimental effects found in the young (mentioned above) would be found in the old subjects.

The fourth question assessed the extent to which long-term TM practice was associated with a preservation of mental processing speed. For this, a contrast between elderly meditators, elderly non-meditators, and young subjects was conducted. It was assumed the McCarthy and Donchin task (1981) would provide the opportunity to assess whether the effect of TM is to reduce the differences between young and old in RT and

P300 latency across tasks of increasing complexity. The hypotheses were: 1) that the elderly TM group would evidence shorter RTs compared to elderly non-meditators and this difference would be most pronounced under conditions of increased task complexity (i.e., stimulus noise and stimulus-response incompatibility), 2) the TM elderly group would evidence shorter P300 latencies compared to elderly non-meditators overall, with the most pronounced differences between the groups found in conditions of increased task complexity (i.e., stimulus noise and stimulus-response incompatibility), 3) length of time practicing TM would be associated with the degree to which the preservation of processing speed in RT and P300 latency is expressed, and 4) the elderly TM group would evidence more comparable RT and P300 latencies with the young subjects than the non-meditating elderly groups.

Method

Subjects

All subjects were volunteers from the communities of Fairfield and Ottumwa, Iowa, or Philadelphia, Pennsylvania. Subjects were solicited through advertisement, personal recruitment, or referred by other subjects in the study. Non-meditating subjects were introduced to the study as a study designed to assess the extent to which elderly subjects in good health maintained good dexterity of response as measured by reaction time and EEG. Meditating subjects were informed that the purpose of the study was to assess the changes in EEG patterns across the life span. The different instructions for the meditators was intended to minimize possible performance effects due to them knowing they were a part of a TM study. Subjects were screened for inclusion in the study through the use of a comprehensive health questionnaire (see Appendix B). Individuals with any current or past medical disorder that could affect the central nervous system (CNS), taking any medication that acted on the CNS, or with a history of drug or alcohol abuse were eliminated by this initial screen. Bashore (personal communication, 1990) reports that 98% of all subjects screened by the questionnaire were determined to be in good physical health in a subsequent medical examination and exercise stress test.

All of the young volunteers were accepted into the study on the basis of their responses to the health questionnaire. Four of the non-meditating elderly and four of the meditating elderly volunteers were excluded from the analysis on the basis of this screen. Only those volunteers who had been practicing TM for at least 10 years were included in the study.

All subjects were administered the WAIS-R using the abridged version of the test recommended by Adams, Smiglielski, and Jenkins (1984). One subject from the young non-meditating group was not included in the study due to a low score on this test.

Tables 3, 4, and 5 summarize the composition of the groups in terms of the factors on which they were matched (discussed in detail below). The young non-meditating group comprised 6 subjects (3 females). The young meditating group comprised 6 subjects (3 females) from Maharishi International University, with average length of time practicing TM of 14.5 yrs. The elderly non-meditating group comprised 10 subjects (7 females), 7 of whom were referrals from the senior employment office of the AARP, in Ottumwa, Iowa, on the basis of their high degree of involvement in the community. The remaining 3 subjects were solicited through advertisement or referred by other subjects in the study from the Philadelphia area. The elderly meditating group comprised 13 subjects (10 females), 12 from the community of Maharishi International University, and one from the Philadelphia area. The elderly TM group had a mean length of time practicing TM of 16.1 yrs. Ten of these subjects had received training in the TM-Sidhi program. Six of these subjects were also teachers of TM.

Stimuli

The stimuli were generated according to the rules described by McCarthy and Donchin (1981) as modified by Magliero et al. (1984). Each matrix contained the word RIGHT or the word LEFT. The matrices were composed of 4 rows and 6 columns of characters arranged as a rectangle which subtended a horizontal angle of approximately 2.5 degrees from the viewing distance of 70 cm. The stimulus words, RIGHT or LEFT, were written horizontally from left to right and appeared with equal probability in each of the four rows. Both the row and the starting column (columns 1, 2, 3 for LEFT and 1 or 2 for RIGHT) were randomly chosen on each trial. Approximately one-third of the trials were no-noise trials on which the background positions of the matrix were filled with the "#" symbol. Approximately one-third of the trials were medium noise trials on which the background positions of the matrix were filled with the letters chosen randomly from a subset of the alphabet, A-G. The remaining one-third of the trials were high noise trials on which the background positions were filled with letters chosen randomly from the entire set of the alphabet, A-Z (see Figure 10). The assumption of Magliero et al. (1984), supported by their findings, was that the larger the set from which the letters of the alphabet are chosen, the greater the "noise" in the matrix.

Procedure

All subjects completed two 2 to 2.5 hour test sessions. In the first test session, the subject filled out the health questionnaire and was administered the WAIS-R. In addition, the subject practiced 3 blocks (288 trials) of the variant of the McCarthy and Donchin (1981) task implemented in this study. No quantitative analysis was done on the practice RTs to assess performance asymptote, however all subjects reported performance stability had been achieved by the end of the practice session.

During the task subjects sat comfortably in a chair with a light plastic handle in each hand on which was mounted reaction time buttons. Subjects were allowed to hold the handles such that the thumb or the index finger rested on the button, whichever was more comfortable. Subjects indicated the identity of the target word by pressing the buttons on which the thumb or index finger rested. A cue word, presented in the center of the screen, preceded the exposure of each matrix. The cue SAME indicated that the right button (right thumb or index finger) was the appropriate response for the target RIGHT, while the left button was correct for LEFT. The cue OPPOSITE indicated a crossed mapping: the right button (right thumb or index finger) was now appropriate for LEFT, and the left button for RIGHT. Cue words were presented for 750 ms, a 250 ms interstimulus interval (ISI) followed, and then the matrix was presented for 400 ms (see Figure 11). The ITI (matrix offset to cue onset) was fixed at 3000 ms. Probability of cue word (SAME vs. OPPOSITE), and target (RIGHT vs. LEFT) was .50 within each block. Probability of each level of stimulus discriminability (no-noise, AG, and AZ) was .33 within each block. Position of target within the matrix (row and column) were selected randomly and independently. Each block consisted of 96 presentations. Because there were four factors on which the computer randomly generated the stimuli, the overall combination of these factors created an unequal amount of stimuli within the two factors of stimulus discriminability and S-R compatibility. This inequality was constant and fixed across subjects however, with every subject presented 99 compatible # stimuli, 111 compatible A-G stimuli, 87 compatible A-Z stimuli, 87 incompatible # stimuli, 96 incompatible A-G stimuli, and 96 incompatible A-Z stimuli, in the same invariant order.

In Session 1, subjects practiced 3 blocks to allow the opportunity for performance stability to be achieved. The experimenter monitored performance and coaching was provided to facilitate compliance with the instructions. No EEG recordings were done during Session 1. Session 2 occurred on a subsequent day, during which the subject performed 6 blocks of the task, with a short practice block of 30-40 trials. Each block lasted approximately 10 minutes. Short breaks of 1-2 min. were taken between each block with a longer break of 5 min. after the third block.

Subjects were instructed to balance speed with accuracy. The instruction from the experimenter was to "give your fastest response, while maintaining accuracy."

Data Collection

Grass gold-cup electrodes were affixed with EC-2 electrode cream at Fz, Cz, and Pz (international 10-20 system) and with skin tape to reference sites (linked mastoids), ground (forehead), and electrooculogram (EOG) sites (sub- and supra-orbital). Electrode impedance did not exceed 10 Kohms. The electroencephalogram (EEG) signals were amplified with Grass Model 12 amplifiers using an 16-sec time constant and a low-pass filter with a 100-Hz cutoff, (3-dB/octave roll-off). The EEG signals were digitized every 10 ms for the entire length of the block. EEG acquistion was controlled by a Quatech 12-bit A/D converter interfaced with a CODAS waveform display and recording system installed on an 286-AT IBM compatible. Stimulus presentation, and monitoring of subject response was controlled by custom software. This separate, dual-monitor, system was also installed on an 286-AT IBM compatible with stimuli presented via a SONY TRINITRON Character Display, model CPD-1302. Data were stored on hard disk and magnetic tape for subsequent quantification and analyses. The EOG activity was corrected off-line (Miller, Gratton, & Yee, 1989).

To quantify the latency of P300, each single trial waveform for all channels was subjected to an optimal linear phase finite impulse response filter (Farwell, Bashore, Martinerie, Rapp, & Goddard, in press) with a pass band of 6 Hz and a stop band of 8

Hz (i.e., a transition band of 6-8 Hz) designed to allow slower components like the P300 to pass while reducing the distribution of higher frequency activity to these later components. The window in which the latency of the P300 component was assessed was selected on the basis of each condition of stimulus discriminability. That is, in identifying the largest positivity at Pz for all subjects, a window of 300-800 ms was selected for the no-noise condition (#'s), and 300-1250 ms for the 2 noise conditions (A-G and A-Z), and P300 latency was assessed on a single trial basis.

Design

The general design was a cross-sectional, static group comparison. The independent variables were age (2 levels), TM participation (2 levels), discriminability (3 levels), and stimulus-response compatibility (2 levels), totalling 4 independent variables. The dependent variables were RT, accuracy rate, and P300 latency, totalling 3 dependent variables.

Results

The results of Experiment 2 are presented according to the 4 research questions addressed: a) replicability of the McCarthy and Donchin (1981) findings within the young subjects, b) assessment of differences in processing speed as a result of TM participation within the young subjects, c) assessment of differences in processing speed between the young and the old, and d) preservation of processing speed associated with TM participation within the old subjects.

Experiment 2a. Replicability of findings of McCarthy and Donchin (1981) within young subjects

The first question of Experiment 2 assesses the replicability of findings in this laboratory of those reported by McCarthy & Donchin (1981). For this purpose, the young TM (n = 6) and non-TM (n = 6) groups were combined to assess the effects of discriminability and stimulus-response compatibility on RT, accuracy rate, and P300 latency. The results of a repeated measures MANOVA on the set of 3 variates showed the main effect of discriminability was significant, $F(6,5) = 29.85$, $p < .001$. All 3 variates contributed to this overall effect showing univariate significance individually (discussed below). In addition, the main effect of stimulus-response compatibility was significant, $F(1,10) = 44.65$, $p < .001$. Again, all 3 variates contributed a significant univariate effect to this overall significance (discussed below). However, there was a significant interaction between discriminability and stimulus-response compatibility, $F(6,5) = 5.10$, $p < .05$. The main contribution to this overall effect was a significant effect on accuracy rate, with a lesser effect on RT (discussed below). Table 3 summarizes the F statistics for the univariate repeated measure ANOVAs which are discussed now.

Reaction time. Mean reaction times plotted as function of the main effects of discriminability and stimulus-response compatibility are presented in Figure 12. For this and all figures that follow, vertical bars represent standard error bars. A repeated measures ANOVA showed the main effect of discriminability to be significant, $F(1,10) = 98.8$, $p < .001$, indicating a slowing of RT as a function of stimulus noise. Post-hoc planned contrasts between the 3 levels of discriminability showed significant increases in RT between #'s (731 ms, sd 133) and A-G (864 ms, sd = 139), $F(1,11) = 196.7$, $p < .001$, between A-G and A-Z (951 ms, sd 167), $F(1,11) = 64.6$, $p < .001$, and between #'s and A-Z, $F(1,11) = 175.4$, $p < .001$. The increase in RT was 133 ms between the #'s and A-G condition and 87 ms between the A-G and A-Z conditions, indicating a 50 ms greater effect from the "no-noise" to the A-G condition than from A-G to A-Z.

TABLE 3. F statistics for effects of stimulus discriminability and stimulus-response compatibility on the 3 variates; Reaction time, accuracy rate, and P300 latency for the young subjects.

Variable	Reaction time	Accuracy rate	P300 latency
stimulus discriminability	98.8 (2,9)**	11.9 (2,9)**	90.4 (2,9)**
stimulus-response compatibility	110.3 (1,10)**	70.14 (1,10)**	11.60 (1,10)**
discriminability X s-r compatiblity	2.54 (2,9)	4.20 (2,9)*	.94 (2,9)

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

The main effect of stimulus-response compatibility was also significant, F(1,10) = 110.4, p <.001, indicating that incompatible responses (918 ms, sd = 159) were slower than compatible responses (781 ms, sd = 157). These effects were additive, for the interaction was not significant, F(2,9) = 2.54, p <.13 (see Figure 13).

An additional finding by McCarthy and Donchin (1981) was that RT to the noise matrices was affected by the position of the target word within the matrix. RT was slower when the target word was in one of the center rows than when the target word was in one of the outer (first or fourth) rows. When the average of the two center rows (804 ms, sd = 128) was compared to the average of the two outer rows (884 ms, sd = 127), collapsed across main effects of discriminability and stimulus-response compatibility, this effect was replicated, F(1,11) = 115.2, p <.001 (see Figure 14).

Magliero et al. (1984) reported that the cost of incompatibility was larger for the no-noise matrices, indicated by an interaction between stimulus noise and stimulus-response compatibility (though the magnitude of this interaction was small). The results of this study did not find this interaction to be significant, $F(2,9) = 2.54$, $p < .13$ (see Figure 13).

Accuracy Rate. Accuracy rate, presented in Figure 15, was analyzed to assess the effects of potential speed/accuracy trade-offs on RT (Pachella, 1974). A repeated measures ANOVA showed the main effect of discriminability was significant, $F(2,9) = 11.98$, $p < .003$, indicating that accuracy decreased as difficulty in discriminability increased. Post-hoc planned contrasts between the 3 levels of discriminability showed significant decreases in accuracy between #'s (92 %, sd 1.1) and A-G (88 %, sd = 1.0), $F(1,11) = 18.7$, $p < .001$, and between #'s and A-Z (86 %, sd = 6.2), $F(1,11) = 21.3$, $p < .001$. However, no significant difference was found between A-G and A-Z, $F(1,11) = 2.44$, $p < .15$, suggesting that the main contribution to the overall effect of discriminability on accuracy was between the #'s and A-G conditions.

The main effect of stimulus-response compatibility was significant, with incompatible responses (14%) resulting in more errors than compatible responses (4%), $F(1,10) = 70.1$, $p < .001$. There was, however, a significant interaction between discriminability and stimulus-response compatibility, $F(2,9) = 4.20$, $p < .05$. Inspection of Figure 15 suggests that this interaction may be accounted for by greater differences in accuracy between compatible and incompatible conditions in the #'s and A-Z conditions than the A-G condition. While the effect of increasing stimulus noise in the incompatible response condition results in an approximately linear decrease in accuracy rate, the same effect is not found in the compatible response condition. Virtually all of the decrease in accuracy rate in the compatible condition is accounted for by the difference in the #'s and A-G condition, with no additional decrease in the A-Z condition.

Event-Related Potentials. ERP superaverages at Fz, Cz, and Pz in young subjects for each discriminability condition are presented in Figures 16, 17, and 18. The cue stimulus elicited a positivity followed by slow increase in negativity. The presentation of the matrix resulted in an ERP characterized by an N100-P200 complex. A negative peak was present at 300-400 ms with a fronto-central distribution, the amplitude and duration of which increased with the addition of noise. The negativity was followed by a broad positivity with a parieto-central distribution. This positivity was strongly influenced by the amount of noise in the stimulus; increasing noise resulted in reduction of amplitude (see Figure 19). On the basis of its scalp distribution (Pz>Cz>Fz), and its variance as a function of discriminability, this was labeled the P300.

Examples of waveforms for single subjects are shown in Figures 20 and 21. As expected there are large individual differences in the morphology of the waveforms and in the relative expression of the scalp distribution. In some cases, the effect of incompatibility was to add a double peaked positivity. As previous studies have shown, it was the latency of this second peak which increased as the noise increased. Other subjects displayed only one broad positivity, which increased in latency with increasing noise. Both cases were labeled a P300.

P300 Latency. Results for P300 latency are presented in figure 13. The main effect of discriminability was significant, $F(2,9) = 92.7$, $p < .001$, indicating that as stimulus noise increased P300 latency increased. Post-hoc planned contrasts between the 3 levels of discriminability showed significant increases in P300 latency between #'s (473 ms, sd = 33) and A-G (688 ms, sd = 61), $F(1,11) = 182.7$, $p < .001$, between A-G and A-Z (739 ms, sd 68), $F(1,11) = 93.1$, $p < .001$, and between #'s and A-Z, $F(1,11) = 216.3$, $p < .001$. The difference between the #'s and the A-G condition was 215 ms, while the difference between the A-G condition and the A-Z condition was 51 ms. Therefore, the addition of stimulus noise did not result in a linear increase in processing time for P300 latency. The difference between the #'s trials and the noise trials (averaged over A-G and A-Z) was 240 ms.

The main effect of stimulus-response compatibility was also significant, $\underline{F}(1,10) = 11.6$, $\underline{p} < .007$, indicating that P300 latency increased from a compatible (621 ms, sd = 123) to an incompatible (646 ms, sd = 135) response requirement. The overall increase in P300 as a result of the incompatible response, collapsed across discriminability, was 25 ms. The interaction between discriminability and stimulus-response compatibility was not significant, $\underline{F}(2,9) = .94$, $\underline{p} < .44$, indicating that the effect of discriminability was not significantly different for compatible and incompatible responses. However, visual inspection suggests the average increase in P300 latency as a result of the incompatible response became more pronounced with increased difficulty in the discriminability factor. Analysis of the simple effects of stimulus-response compatibility showed a 16 ms difference in the #'s trials (compatible: 465 ms, sd = 29 vs. incompatible: 481 ms, sd 35), $\underline{F}(1,11) = 7.43$, $\underline{p} < .02$, a 29 ms difference in the A-G trials (compatible: 674 ms, sd = 51 vs. incompatible: 703 ms, sd = 69), $\underline{F}(1,11) = 13.51$, $\underline{p} < .004$, and a 32 ms difference in the A-Z trials (compatible: 723 ms, sd = 61 vs. incompatible: 755 ms, sd = 74), $\underline{F}(1,11) = 4.84$, $\underline{p} < .05$.

Discussion

In general, the results support the main predictions and suggest a similar pattern of effects to those reported by McCarthy and Donchin (1981). The results indicated that RT was significantly increased across each level of difficulty in discriminability. In addition, RT was significantly slower for an incompatible response compared to a compatible response. Also, these two experimental effects were additive, suggesting that discriminability and stimulus-response compatibility were affecting different stages of processing. Consistent with results of McCarthy and Donchin (1981) discriminability had a larger impact on RT (220 ms) than did stimulus-response compatibility (140 ms). The effect of target position on RT was also replicated, with RT faster to rows 2 and 3 then rows 1 and 4.

Overall accuracy rate was less in this study (88.9%) than reported by McCarthy and Donchin (1981) (91.7%) suggesting that there was some factor making the present task more difficult. Personal experience of the actual stimuli used by McCarthy and Donchin (1981) after this task was set up, indicated that the size of the stimulus matrix used in this experiment was smaller overall, and the selection of font more complex, than that used by McCarthy and Donchin (1981).

P300 latency was significantly prolonged with increased difficulty in discriminability. However, the significant effect of stimulus-response compatibility on P300 latency did not replicate the findings of McCarthy and Donchin (1981) or Magliero et al. (1984). Nevertheless, the magnitude of effect of stimulus-response compatibility on P300 latency, relative to discriminability, suggests that P300 latency was primarily influenced by manipulation of discriminability and much less influenced by stimulus-response compatibility. This is in agreement with McCarthy and Donchin (1981) and Magliero et al. (1984).

Among the possibilities that might account for the unpredicted effect of stimulus-response compatibility on P300 latency are differences in stimulus characteristics, and technical assessment of P300 latency. As previously mentioned, the stimuli used in this study constituted a smaller and more complex array of characters by virtue of the font limitations on the computer. The fact that RT was approximately 60 ms slower and accuracy rate was approximately 4% less in this study, compared with those reported by McCarthy and Donchin (1981), suggests that the discriminability factor may have been more difficult. In this study, the #'s condition had a 16 ms difference on P300 latency associated with the incompatible response, comparable to the overall difference of 16 ms in McCarthy and Donchin (1981) and 12 ms effect in Magliero et al. (1984). Greater difficulty of discriminability may have prolonged completion of stimulus evaluation processes to such an extent that response selection processes began to interact. While stimulus-response compatibility effects on P300 latency reported by McCarthy and Donchin (1981) and Magliero et al. (1984) were not significant, there have been consistent reports of small magnitude effects, with some studies finding significant effects (Pfefferbaum & Ford, 1988; Ragot, 1984; Ragot & Renault, 1981). It is possible that this interaction would become more apparent under sufficiently difficult conditions.

Another potential explanation concerns the way in which P300 latencies were determined. Window selection is capable of altering the outcome of peak picking of P300. Since the window setting initially used for single trial peak picking in this study (300 - 800 ms for #'s, 300 - 1250 ms for A-G and A-Z) was different than that used by McCarthy and Donchin (1981) (200 - 1500 ms), P300 latency was re-calculated using the same window settings (200 - 1500 ms). This did not change the observed stimulus-response compatibility effect on P300 latency. Also, an additional re-analysis using a boxcar filter similar to that used by McCarthy and Donchin (1981) (-3 dB at 3.52 Hz) did not significantly change the results.

Experiment 2b. Assessment of differences in processing speed as a result of TM participation within young subjects

In this section, the results of a comparison between the young TM and non-TM groups on RT, accuracy rate, and P300 latency is presented. Table 4 shows the results of a one-way MANOVA comparing the two groups on 4 matching variables: age, full-scale IQ (FIQ), exercise level, and health status.

The groups were comparable on all 4 variables (F's < 1). The results of a repeated measures 3-way MANOVA on the set of 3 variates (RT, accuracy rate, and P300 latency) indicated no significant main effect of TM participation, $F(3,8) = .09$, $p < .96$. Main effects and interactions of discriminability and stimulus-response compatibility are reported in section 2a.

Reaction time. RT data for the 2 groups are presented in Figure 22. A univariate repeated measures ANOVA indicated that the TM (835 ms, sd = 146) and non-TM (863 ms, sd = 194) groups were not significantly different overall (F < 1). The effect size of this result, calculated as d = (m1 -m2)/sd, (Cohen, 1977; Stevens, 1986) is .16, a small effect. Since power is heavily dependent on sample size (Cohen, 1977), it is likely that inadequate sample size contributed greatly to inadequate power to detect significant differences (see discussion). As was discussed above, the main effects of both discriminability and stimulus-response compatibility on RT were significant. The mean difference in RT between the groups as a function of discriminability, collapsed across stimulus-response compatibility, was 48 ms for #'s (TM = 708(103), non-TM = 756(160)),

TABLE 4. Matching factor statistics for young TM and young non-TM subjects.

	TM (n=6)		Non-TM (n=6)				
	mean	sd	mean	sd	F	df	P
age	21.2	4.40	19.5	1.80	.73	1,10	.41
FIQ	112.8	10.20	110.2	12.60	.16	1,10	.70
exercise	1.8	.41	1.8	.41	.0	1,10	1.00
health	3.3	.33	3.3	.52	.0	1,10	1.00

25 ms for A-G (TM = 852(106), non-TM = 877(170)), and 12 ms for A-Z (TM = 945(122), non-TM = 957(208)). The interaction between TM participation and discriminability was not significant (F < 1), indicating that the effect of discriminability on RT was similar for the two groups. The mean difference in RT between the groups as a function of stimulus-response compatibility, collapsed across discriminability, was 23 ms for the compatible response (TM = 769(132), non-TM = 792(181)) and 35 ms for the incompatible response (TM = 900(132), non-TM = 935(184)). The interaction between TM participation and stimulus-response compatibility was not significant (F < 1), indicating that the effect of stimulus-response compatibility was similar for the two groups. The interaction of discriminability and stimulus-response compatibility was not significant, as discussed in the previous section. The 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant (F < 1).

Accuracy rate. Accuracy rate data is presented in Figure 23. A univariate repeated measures ANOVA on mean accuracy rate indicated that the TM (m = 88.8% ms, sd = .94) and non-TM (m = 88.9% ms, sd = 1.1) groups were not significantly different overall, (F < 1). As was discussed in the previous section, the main effects of both discriminability and stimulus-response compatibility on accuracy rate were significant. The mean difference in accuracy rate between the groups as a function of discriminability, collapsed across stimulus-response compatibility, was 1.6% for #'s (TM = 91.4% (5.9), non-TM = 93% (5.1)), .07% for A-G (TM = 87.3 % (4.1), non-TM = 88.8% (5.5)) and 2.6% for A-Z (TM = 87.7% (6.1), non-TM = 85.1% (6.3)). The interaction between TM participation and discriminability was not significant, F(2,9) = 2.65, p, <.12), suggesting that the patterns of effects of this factor were not different between the groups. The mean difference in accuracy rate between the groups as a function of stimulus-response compatibility, collapsed across discriminability, was .03% for the compatible response (TM

= 92.4% (132), non-TM = 92.1% (4.0)) and .07% for the incompatible response (TM = 85.1% (4.5), non-TM = 85.8% (6.2)). The interaction between TM participation and stimulus-response compatibility was not significant (F < 1), suggesting that the pattern of effects for this factor were not different between the groups. The interaction of discriminability and stimulus-response compatibility on accuracy rate was discussed in the previous section. Finally, the 3-way interaction (TM participation x discriminability x S-R compatibility), was not significant (F < 1).

Event-related brain potentials. ERP superaverages at Pz as a function of group for the 3 discriminability conditions are presented in Figures 24, 25, and 26. Visual inspection suggested the groups displayed a similar waveform morphology overall. One possible exception was a consistently larger positivity in the TM group following the cue word, which was identified as the P300 on the basis of its latency and scalp distribution. The greater positivity to the cue word for the TM group seems to result in a temporary shift of the waveform to a more positive position, relative to the non-TM group, resulting in a smaller initial negativity (N1) to the onset of the matrix, and a greater positivity (P2).

P300 latency. P300 latency data are presented in Figure 27. A univariate repeated measures ANOVA on mean P300 latency from single trial measurement indicated that the TM (m = 628 ms, sd = 131) and non-TM (m = 639 ms, sd = 128) groups were not significantly different overall, (F < 1). This translates into an extremely small effect size of .08. As was discussed in the previous section, the main effects of both discriminability and stimulus-response compatibility on P300 latency were significant. The mean differences in P300 latency between the groups as a function of discriminability, collapsed across stimulus-response compatibility, were 21 ms for #'s (TM = 463(28), non-TM = 484(35)), 1 ms for A-G (TM = 688(63), non-TM = 689(62)) and 9 ms for A-Z (TM = 734(63), non-TM = 745(76)). The interaction between TM participation and discriminability was not significant ($\underline{F}$ < 1), indicating that the pattern of effects for this factor was the same for both groups. The mean differences in P300 latency between the groups as a function of stimulus-response compatibility, collapsed across discriminability, were 6 ms for the compatible response (TM = 618(127), non-TM = 624(123)) and 16 ms for the incompatible response (TM = 638(138), non-TM = 654(135)). The interaction of TM participation and stimulus-response compatibility was not significant ($\underline{F}$'s < 1), indicating that the pattern of effects of this factor was similar for both groups. The interaction of discriminability and stimulus-response compatibility on P300 latency was discussed in the previous section. The 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant.

Discussion

The results indicated that the young TM and non-TM groups did not significantly differ on any of the 3 variates: RT, accuracy rate, or P300 latency. This is at odds with the predictions of this study and with previous studies which have indicated that, in young adults practicing TM, RT is generally faster than controls. However, the results did indicate that for all 3 variates, the TM group tended to perform faster and with greater accuracy, though this did not reach multivariate significance. Overall differences between the two groups resulted in an effect size of .16 for RT and .08 for P300 latency, both very small effect sizes. A multivariate power estimation based on 2 dependent variables with a sample size of 15 subjects per group (Stevens, 1986, p. 141), indicates that an effect size of .25 results in a power value of .26 at $\underline{p}$ = .05. Since an acceptable power level is generally .70 or greater, this sample size was quite inadequate. However, the effect size of .16 for RT found in this study is much less than those reported by others. For example, Cranson et al. (1990), using Hick's 8-choice RT task, reported effects sizes on the order of .67 (pretest) and .98 (posttest) with an average of

.80. Because power is heavily dependent of sample size and because Cranson et al. (1990) had larger sample sizes, it is clear that larger samples are required to provide adequate power. Differences in speed/accuracy tradeoff can not account for the finding of no difference since comparable accuracy rates suggest similar strategies between the groups. With regard to P300 latency, while there have been reports of shorter latencies prior to P300 (i.e., N100, P200, N200), in young meditating subjects compared with controls, the two reports on P300 latency prior to this study (Banquet & Lesevre, 1980), found no differences in P300 latency in young adults as a result of TM practice. These studies did not report P300 latencies so effect size could not be ascertained. Therefore, the results of this study do not show differences in processing speed in young adults as a function of TM practice. However, the small effect size suggests that significant differences might be apparent if samples sizes were larger. Since this comparison was less central to the major question of this study, the sample size was kept to a minimum and this may account for the lack of significance found here.

Experiment 2c. Assessment of differences in processing speed between the young and the older subjects

In this section, the effect of age on RT, accuracy rate, and P300 latency is presented. The 12 young subjects were compared to 10 old non-meditating subjects to assess the effects of age independent of the effects of TM. While the initial analysis combined the old TM and old non-TM groups into one group for the age comparison, it was found that the TM and non-TM elderly subjects differed significantly on 2 of the 3 dependent variables (see section 2d below), confounding age with TM participation. Therefore, for the analysis of the effects of age, the old TM group was excluded. Table 5 shows the results of a MANOVA conducted on the young and old groups on 4 matching factors: age, FIQ, exercise, and health status.

The results indicated that the groups were not significantly different in FIQ, F(1,20) = 3.4, p <.08, although there was a trend with older subjects having higher IQ (120) than young subjects (112). Any differences as a result of age would only be strengthened by this finding, since higher IQ is associated with faster RT (Eysenck, 1988; Jensen, 1987). The older subjects reported less exercise activity than the young, F(1,20) = 13.4, p <.002. Interestingly, the older subjects reported being in better health than the young, F(1,20) = 3.8, p <.07. These results suggest that the older subjects were a relatively high functioning group who considered themselves to be in good health.

TABLE 5. Matching Factor statistics for young compared to older non-TM subjects.

	Young (n=12)		Older (n=10)				
	mean	sd	mean	sd	F	df	P
age	20.3	3.3	68.7	4.40	854.2	1,20	.0001
FIQ	111.5	11.1	119.7	9.50	3.4	1,20	.08
exercise	1.8	.39	1.0	.67	13.4	1,20	.002
health	3.3	.65	3.8	.42	3.8	1,20	.07

A repeated measures multivariate ANOVA for the set of 3 variates (RT, accuracy rate, and P300 latency), was significant for all 3 main effects: age, F(3,18) = 7.01, p <.003, discriminability, F(6,15) = 90.86, p <.001, and stimulus-response compatibility, F(3,18) = 3.52, p <.04. In addition, the two-way interactions between age and discriminability, F(6,15) = 4.32, p <.01, age and stimulus-response compatibility, F(3,18) = 3.52, p <.04, and discriminability and stimulus-response compatibility, F(6,15) = 10.33, p <.0001, were significant. Finally, the 3-way (age x discriminability x stimulus-response compatibility) interaction was also significant, F(6,15) = 3.09, p <.04. Table 6 summarizes the results of repeated measure ANOVAs for each experimental factor on the 4 variates discussed below: reaction time, accuracy rate, P300 latency, and CNV amplitude.

Reaction time. Reaction times for the young and old subjects are presented in Figure 28. A univariate repeated measures ANOVA found a non-significant main effect of age, F(1,20) = 3.50, p <.08, indicating that young (849 ms, sd = 171) and old (970 ms, sd = 218) subjects were not significantly different in RT overall, though the older subjects tended to be slower. This overall difference, however translates into a moderate effect size of .62, an effect that may be real had power been greater through larger samples size. Both the main effects of discriminability, F(2,19) = 164.92, p <.001, and stimulus-response compatibility, F(1,20) = 283.50, p <.001, were significant, consistent with results within the young subjects alone. The interaction between age and discriminability was significant, F(2,19) = 5.08, p <.02. Inspection of Figure 29 suggests that increased difficulty in the discriminability factor, particularly between #'s (young = 732(133), old = 821(172)) and A-G (young = 864(139), old = 1018(214)) had a larger effect of slowing RT in the old (197 ms) than the young (133 ms). Analysis of simple effects of age at discriminability found a non-significant difference of age at #'s (young = 732(133), old = 821(172)), F(1,20) = 2.20, p <.15, a significant difference at A-G (young = 864(139), old = 1018(214)), F(1,20) = 5.10, p <.04, and a non-significant difference at A-Z (young = 951(167), old = 1072(189)), F(1,20) = 3.03, p <.10. These results are consistent with the prediction that as processing demands increase, the difference in RT between young and old increase, with the caveat that the addition of background characters from noise condition A-G to A-Z does not result in a proportional increase in RT for the old.

TABLE 6. F statistics for effects of age, stimulus discriminability, and stimulus-response compatibility on the 4 variates; Reaction time, accuracy rate, P300 latency, and CNV amplitude.

Variable	RT	Accuracy	P300 latency	CNV amplitude
age	3.5 (1,20)	3.34 (1,20)	18.6 (1,20)**	23.8 (1,20)**
stimulus discriminability	164.9 (2,19)**	43.4 (2,19)**	6.2(2,19)**	1.53 (2,19)
stimulus-response compatibility	283.5 (1,20)**	47.4 (1,20)**	42.2 (1,20)**	2.36 (1,20)
age X discriminability	5.08 (2,19)*	8.0 (2,19)**	1.59 (2,19)	.1 (2,19)
age X s-r compatibility	.9 (1,20)	6.2 (1,20)*	3.49 (1,20)	3.0 (1,20)
discriminability X s-r compatibility	10.13 (2,19)**	9.40 (2,19)**	7.0 (2,19)**	.4 (2,19)
age X discriminability X s-r compatibility	5.76 (2,19)**	.12 (2,19)	3.38 (2,19)	.2 (2,19)

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

The interaction of age and stimulus-response compatibility was not significant (F < 1), indicating that the effect of stimulus-response compatibility was the same for the young and the old. The interaction of discriminability and stimulus-response compatibility was significant, F(2,19) = 10.13, p <.001, unlike the additive effect found in the young subjects alone. Inspection of Figure 29 suggests that the increase in RT from #'s to A-G was greater in the incompatible response condition (178 ms) than in the compatible response condition (145 ms), largely attributable to the differential effect of increased difficulty in discriminability in the older subjects. This is complicated by a significant 3-way interaction (age x discriminability x stimulus-response compatibility), F(2,19) = 5.76, p <.01, indicating that the 2-way interaction profiles for discriminability and stimulus-response compatibility were different for the young and the old subjects. Figure 29 suggests that at least one contribution to the 3-way interaction is in the greater increase in RT in the older subjects between the #'s and A-G discriminability conditions from the compatible (171 ms) to the incompatible (224 ms) response condition, compared to the increase in RT in the young subjects between #'s and A-G in compatible (125 ms) and incompatible (140 ms) response conditions. The 3-way interaction is made more complicated when young and old are compared on differences in the increase in RT from the A-G to A-Z discriminability conditions across the two stimulus-response compatibility levels. In this case, the difference in older subjects' RT between compatible (79 ms) and incompatible (28 ms) response conditions still remains greater than the differences in young subjects' RT between the compatible (77 ms) and incompatible (96 ms) response conditions. However, while in the #'s to A-G comparison it was the incompatible response that added to the overall difference in RT between young and old, in the A-G to A-Z comparison, it was the compatible response that added to the overall difference in RT between the young and the old.

Accuracy rate. Accuracy rates are presented in Figure 30. A univariate repeated measures ANOVA indicated no significant difference between the young and the old in accuracy, F(1,20) = 3.34, p <.08, however the young subjects tended to have greater accuracy overall (88.8 %) than the old subjects (85.3 %). Both the main effect of discriminability, F(2,19) = 43.45, p <.001, and stimulus-response compatibility, F(1,20) = 47.29, p <.001, were significant, indicating that increased difficulty in discriminability and incompatible responses resulted in decreases in accuracy. The interaction of discriminability and stimulus-response compatibility was significant, F(2,19) = 9.40, p < .002, explained in part by the relatively greater decrease in accuracy between #'s and A-G discriminability conditions for the compatible response, compared to more linear decrease across all 3 discriminability conditions for the incompatible response. The interaction between age and discriminability was significant, F(2,19) = 8.03, p <.003, attributable to the fact that as difficulty in discriminability increased, the decrease in accuracy rate for the old became greater than the young. Analysis of simple effects of age at disciminability found a non-significant difference of age at #'s (young = 92.2%(5.5), old = 93.9%(4.5)), F(1,20) = 1.56, p <.23, a moderately significant difference at A-G (young = 88%(4.8), old = 82.8%(8.3)), F(1,20) = 5.0, p <.06, and a significant difference at A-Z (young = 86.4%(6.2), old = 79.4%(7.9)), F(1,20) = 3.03, F(1,20) = 7.81, p <.01.

In addition, the interaction between age and stimulus-response compatibility was significant, F(1,20) = 6.24, p <.02. However, in this case, the decrease in accuracy as a result of the incompatible response was greater for the young (6.8 %) than the old (3.1 %). The accuracy rate began at a higher rate for the young than the old, and even in the incompatible condition, the young always maintained a level of accuracy higher than the old. Analysis of simple effects showed a significant difference between young and old subjects at the compatible response (young = 92.3%(4.5), old = 86.9%(9.9)), F(1,20) = 7.64, p <.01. The age groups did not differ significantly in accuracy at the incompatible response condition (young = 85.5%(5.3), old = 83.8%(8.7)), F < 1. There was no significant 3-way interaction (age x discriminability x stimulus-response compatibility), (F < 1).

Event-related brain potentials. ERP superaverages at Fz, Cz, and Pz in the old subjects for the 3 discriminability conditions are shown in Figures 31, 32 and 33. The older subjects exhibited comparable patterns of effects as the young, most notably the prolongation of P300 latency and reduction in P300 amplitude with increasing levels of stimulus noise. Note in these waveforms the large negative shift (referred to as the contingent negative variation, or CNV) at Cz in the interval preceding matrix onset (referred to as the S1-S2 interval in protocols interested in motor preparation or anticipatory processes, where S1 represents a warning stimulus and S2 represents an imperative stimulus to which the subject responds). Figures 34, 35 and 36 superimpose the young and old subjects across experimental conditions at Pz. Note that although the peak of the P300 looks larger in the young compared to the old relative to baseline at matrix onset, this difference is more than made up for by the relatively greater negative shift in the S1-S2 interval in the older subjects. If P300 amplitude measures were taken from the peak of the N200, then differences between the groups would be substantially diminished.

P300 latency. P300 latencies are presented in Figure 37. A univariate repeated measures ANOVA indicated a significant main effect of age, F(1,20) = 18.46, p <.001, with older subjects showing longer P300 latencies (715 ms, sd = 135) than the young subjects (634 ms, sd = 129). The main effects of discriminability, F(2,19) = 226.21, p <.001, and stimulus-response compatibility, F(1,20) = 47.29, p <.001, were significant, indicating that both increased difficulty in discriminability and incompatible responses prolonged P300 latencies. The interaction between age and discriminability was not significant, (*F* < 1), indicating an equivalent effect of discriminability on P300 latency for young and old subjects. The interaction between discriminability and stimulus-response compatibility was significant, $F(2,19) = 7.03$, $p < .005$, with slowing of P300 latency to stimulus noise being greater in the incompatible response condition. The interaction between age and stimulus-response compatibility was not significant, $F(1,20) = 3.49$, $p < .08$, indicating that the effect of stimulus-response compatibility on P300 latency was not significantly different for the young and the old, though the old subjects tended to show greater slowing in the incompatible response condition. The 3-way interaction (age x discriminability x stimulus-response compatibility) was nearly significant, $F(2,19) = 3.38$, $p < .055$, indicating that the two-way interaction profiles of discriminability x stimulus-response compatibility were different for the young and the old. Inspection of Figure 38 suggests a similar interpretation to that of the RT data. That is, the main contribution to the 3-way interaction is in the greater increase in P300 latency in the older subjects (71 ms), relative to the young (14 ms), between the #'s and A-G stimulus condition from the compatible to the incompatible response condition.

Contingent negative variation (CNV). Because of the large CNV differences apparent in the ERP averages between the young and the old in the S1-S2 interval, the amplitude of the CNV was quantified and subjected to statistical analysis. Quantification of the CNV was determined on a single trial basis by taking the difference in the average amplitude of the EEG at the vertex electrode (Cz) 100 ms prior to onset of the cue word and 100 ms prior the onset of the matrix. The difference between these two averages represented the CNV and these averages were then averaged separately for each experimental condition. These data are presented in Figure 39. The results of a repeated measures ANOVA showed a significant main effect of age, F(1,20) = 23.82, p <.0001, with the old subjects exhibiting a larger CNV than the young subjects across all conditions. There were no main effects for discriminability, F(2,19) = 1.53, p <.24, or stimulus-response compatibility, F(1,20) = 2.36, p, <.14, indicating that CNV did not vary as a function of these experimental manipulations. The 2-way interactions of age and discriminability, age and stimulus-response compatibility, and discriminability and stimulus-response compatibility were not significant (F's < 1; except age and stimulus-response compatibility, F(1,20) = 3.02, p <.10). Inspection of Figure 40 suggests that the trending interaction of age and stimulus-response compatibility is due to a consistent increase in CNV amplitude, across all levels of discriminability, in the incompatible response condition for the old compared to the young. The 3-way interaction (age x discriminability x stimulus-response compatibility) was not significant (F < 1).

Discussion

The third research question of Experiment 2 concerned age differences in mental processing speed as measured by RT, accuracy, and P300 latency. Contrary to the predictions, the young and old did not differ in RT overall. However, in general, the effects of age were in the predicted direction with differences between young and old being expressed as interactions between age and task complexity. When difficulty in discriminability increased, the RT of the older subjects became significantly slower and less accurate than the young. The incompatible response requirement caused greater slowing for the old than the young, also consistent with the predictions. However, the additive effect of discriminability and stimulus-response compatibility found in the young was not found in the old subjects, or in the two groups combined. This suggests that the difficulty in discriminability had an effect on response-related processes in the older subjects.

Consistent with the predictions, P300 latencies were significantly longer in the old compared to the young. However, when the young and old subjects were combined the effect of discriminability on P300 latency interacted with stimulus-response compatibility. This suggests that for the older subjects, when discriminability was more difficult, the stimulus evaluation processes began to effect response-related stages of processing. This is also suggested by the different pattern of interaction between discriminability and stimulus-response compatibility between the young and the old. This difference is explained in part by the fact that the difference in slowing of P300 latency between the old and the young became greater when noise stimulus and incompatible responses were required. Therefore, while the complexity effect was not predicted for P300 latency it was found in the older subjects.

An unanticipated finding was the significantly larger CNV in the older subjects compared to the young across all experimental conditions. The fact that this difference was not associated with any of the experimental conditions suggests that this was a tonically elevated state in the old subjects. Since late components of the CNV have been associated with motor preparation (Rohrbaugh & Gaillard, 1983), it may be speculated that the older subjects were more primed to respond than the young subjects. This would be supported in part by the lower accuracy rate found in the older subjects, since research has indicated that CNV is greatly attenuated when attention is directed toward accurate rather than speedy response (Loveless & Sanford, 1974; Gaillard & Perdok, 1980; Gaillard, Perdok, & Varey, 1980).

The explanation for this priming effect may be associated with a different motivational set produced by the recruitment procedures. The recruitment procedure explicitly informed the elderly that the study was looking for the effects of good health in the elderly on maintaining dexterity of response. This may have induced a state within the older group to fulfill the experimenters expectations. It should be noted that the old group was an intellectually high functioning group, and in good physical health. The fact that the overall difference in RT was not significant between the groups suggests that this group was exceptional.

Experiment 2d. Preservation effects in processing speed associated with TM participation within the older subjects

The effect of TM on preserving mental processing speed in the elderly is now addressed. For purposes of this comparison, the 10 elderly practitioners with the longest practice of TM and the advanced TM programs (17.5 yrs.) were group matched to the 10 non-meditating elderly on the basis of 4 factors: age, FIQ, reported exercise level, and health status. The results of a MANOVA on these 4 factors is presented in table 7.

A univariate ANOVA indicated the groups did not differ significantly on age, F(1,29) = .01, p <.90, Full Scale IQ, F(1,29) = 1.45, p <.24, exercise level, F(1,29) = .77, p <.39, or reported health F(1,29) = 2.10, p <.16.

TABLE 7. Matching Factor statistics for older TM compared with older non-TM subjects.

	Old TM (n=10)		Old Non-TM (n=10)				
	mean	sd	mean	sd	F	df	P
age	68.5	3.20	68.7	4.40	.01	1,18	.91
FIQ	125.3	9.90	119.7	9.50	1.67	1,18	.21
exercise	1.2	.42	1.0	.67	.64	1,18	.43
health	3.4	.70	3.8	.42	2.40	1,18	.14

A repeated measures MANOVA on the set of 3 variates (RT, accuracy rate, and P300 latency) indicated the main effect of TM participation was significant, $F(3,16) = 3.89$, $p < .02$, with significant contributions from RT and P300 latency. The main effect of discriminability was significant, $F(6,13) = 91.3$, $p < .001$, with significant contributions from all 3 variates. The main effect of stimulus-response compatibility was significant, $F(3,16) = 117.6$, $p < .001$, with significant contributions from all 3 variates. The interaction between TM participation and discriminability was not significant, $F(6,13) = 1.42$, $p < .28$. The interaction between TM participation and stimulus-response compatibility was significant, $F(3,16) = 5.03$, $p < .01$, with main contributions from RT and P300 latency. The interaction between discriminability and stimulus-response compatibility was significant, $F(6,13) = 9.34$, $p < .001$, with contributions from all 3 variates. Finally, the 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, $F(6,13) = 1.35$, $p < .31$. Table 8 summarizes the results of repeated measure ANOVAs for each experimental factor on the 4 variates discussed below: reaction time, accuracy rate, P300 latency, and CNV amplitude.

Reaction time. Reaction time data are presented in Figure 41. A repeated measures ANOVA indicated the main effect of TM participation was significant, $F(1,18) = 4.62$, $p < .05$. However, the results were opposite to those predicted with the non-TM group (970 ms, sd = 218) showing faster RTs than the TM group (1129 ms, sd = 209). Consistent with results reported in the previous sections, both the main effect of discriminability, $F(2,17) = 156.3$, $p < .001$, and stimulus-response compatibility, $F(1,18) = 179.9$, $p < .001$, were significant. The interaction between TM participation and discriminability was not significant, $F(2,17) = 1.44$, $p < .26$, indicating that the effects of discriminability were similar for the two groups. However, the interaction between TM participation and stimulus-discriminability was significant, $F(1,18) = 6.59$, $p < .02$, attributable to the fact that the cost of the incompatible response was greater for the non-TM group (154 ms) than the TM group (104 ms). The interaction between discriminability and stimulus-response compatibility was significant, F(2,17) = 9.64, p <.002. Finally, the 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, F(2,17) = 1.69, p <.21.

Accuracy rate. Accuracy rates are presented in Figure 42. A repeated measures univariate ANOVA indicated the main effect of TM participation was not significant, F(1,18) = 1.28, p <.27, with overall accuracy for the TM group at 88.1 % and the non-TM group at 85.4 %. Consistent with results in the previous sections, both the main effect of discriminability, F(2,17) = 41.21, p <.001, and stimulus-response compatibility, F(1,18) = 12.1, p <.002, were significant. There were no significant interactions between TM participation and discriminability, F(2,17) = .84, p <.45, or TM participation and stimulus-response compatibility, F(1,18) = .21, p <.65, indicating the effects of these factors were similar for both groups. Finally, the 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, F(2,17) = 1.14, p <.34.

Event-related brain potentials. ERP superaverages at Fz, Cz, and Pz in the old TM group for the 3 discriminability conditions is presented in Figures 43, 44, and 45. ERP averages at Pz with the TM and non-TM groups superimposed are presented in Figures 46, 47, and 48. P300 latencies appear consistently shorter in the TM group to the cue word, and in the #'s discriminability condition. In the A-G and A-Z conditions, though significant differences are found in signal trial peak-picking of P300 latencies, visual inspection find group differences in P300 latency are difficult to determine in the average. This could be due at least 2 sources: 1) the increased variability in the latency of the P300 in the more difficult conditions (latency jitter), also found in the young subjects,

TABLE 8. F statistics for effects of TM participation, stimulus discriminability, and stimulus-response compatibility on the 4 variates; Reaction time, accuracy rate, P300 latency, and CNV amplitude.

Variable	RT	Accuracy	P300 latency	CNV amplitude
TM participation	6.88 (1,18)**	1.28 (1,18)	8.98 (1,18)**	9.72 (1,18)**
stimulus discriminability	156.3 (2,17)**	41.2 (2,17)**	171.4 (2,17)**	2.8 (2,17)
stimulus-response compatibility	179.9 (1,18)**	12.1 (1,18)**	48.7 (1,18)**	4.7 (1,18)*
TM participation X discriminability	1.44 (2,17)	.8 (2,17)	1.79 (2,17)	.3 (2,17)
TM participation X s-r compatibility	6.6 (1,18)*	.2 (1,18)	9.3 (1,18)**	2.8 (1,18)
discriminability X s-r compatibility	9.6 (2,17)**	9.4 (2,17)**	8.6 (2,17)**	.2 (2,17)
TM participation X discriminability X s-r compatibility	1.7 (2,17)	1.1 (2,17)	2.8 (2,17)	.8 (2,17)

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

which results in an average that appears to flatten out the late positivity and make peak picking on the average extremely unreliable, and 2) the group averages are a composite of only 10 individual averages, any one of which has a significant impact on the overall composite. Note, again the differences in CNV between the groups, with the TM group showing a smaller CNV than the non-TM group, similar to the differences found between the young and old non-TM subjects.

P300 latency. P300 latencies are presented in Figure 49. A repeated measures univariate ANOVA indicated the main effect of TM participation was significant, $F(1,18) = 8.98$, $p < .008$, with the TM group showing shorter P300 latencies (645 ms, sd = 120) than the non-TM group (715 ms, sd = 135). Again, both the main effects of discriminability, $F(2,17) = 171.42$, $p < .001$, and stimulus-response compatibility, $F(1,18) = 48.7$, $p < .001$, were significant. The interaction between TM participation and discriminability was not significant, $F(2,17) = 1.79$, $p < .20$, indicating that the effect of discriminability was similar for both groups. However, the interaction between TM participation and stimulus-response compatibility was significant, $F(1,18) = 9.25$, $p < .007$, attributable to the fact that the cost of the incompatible response was greater in the non-TM group (46 ms) than the TM group (18 ms). The 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, $F(2,17) = 2.27$, $p < .13$.

It was predicted apriori that the largest differences between the old TM and non-TM subjects would be found as the cognitive demands of the task increased. This prediction was supported by the interaction between TM participation and stimulus-response compatibility. Analysis of simple effects indicated that while the old TM group showed significantly shorter P300 latencies than the non-TM group in the compatible (TM: 636 ms, sd = 117, non-TM: 692 ms, sd = 120, $F(1,18) = 5.25$, $p < .03$) and incompatible

(TM: 654 ms, sd = 125, non-TM: 738 ms, sd = 147, _F_(2,17) = 13.17, _p_ <.002) response conditions, the differences between the groups became more pronounced when the response demands were greater. Although the interaction between TM participation and discriminability was not significant, analysis of simple effects also indicated that the difference between the two groups became more pronounced when difficulty in discriminability was high. The TM group showed shorter P300 latencies in the #'s condition (TM = 507(44), non-TM = 547(38), _F_(1,18) = 5.05, _p_ <.04), the A-G condition (TM = 694(73), non-TM = 782(74), _F_(1,18) = 8.83, _p_ <.008), and the A-Z condition (TM = 735(80), non-TM = 816(67), _F_(1,18) = 7.07, _p_ <.02). Therefore, the difference between the groups was greatest with the addition of the first noise condition (A-G), followed by the A-Z condition. This points out again that the effect of adding the A-G condition had a greater impact in slowing P300 latency than did the effect of adding A-Z.

CNV. Differences in CNV amplitudes between the groups are presented in Figure 50. A repeated measures ANOVA indicated that the main effect of TM participation was significant, _F_(1,18) = 9.72, _p_ <.006, indicating that the non-TM group had larger CNV amplitudes (-17.5 uV, sd = 9.0) than the TM group (-7.1 uV, sd = 5.0). The main effect of discriminability was not significant, _F_(2,17) = 2.75, _p_ <.09. However, the main effect of stimulus-response compatibility was significant, _F_(1,18) = 4.67, _p_ <.04, attributable to the fact that the incompatible cue resulted in a larger CNV (-12.6 uV, sd = 9.3) than the compatible cue (-11.9 uV, sd = 8.6). The interaction between TM participation and discriminability was not significant (_F_ < 1), indicating that the effect of discriminability was similar for both groups. The interaction between TM participation and stimulus-response compatibility was also non-significant, _F_(1,18) = 2.81, _p_ <.11. The small effect found in this interaction is due to the fact that the difference between the compatible and incompatible cue was greater in the non-TM group (compatible: -16.9 uV, sd = 8.8, incompatible: -18.0 uV, sd = 9.3) than in the TM group (compatible: -7.0 uV, sd = 4.9, incompatible: -7.2 uV, sd = 5.2). The interaction between discriminability and stimulus-response compatibility was not significant ($F < 1$). Finally, the 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant ($F < 1$).

Length of Time Practicing TM Associated with Differences in Mental Processing Speed

It was possible to specify further the effect of TM by virtue of a natural division which existed within the TM group on the basis of length of time practicing TM, participation in advanced programs, and regularity of practice. Three subjects who were excluded from the main comparison constituted a group with no participation in advanced programs, but had been practicing TM for an average of 11 yrs. One of the three subjects had not practiced TM regularly. Within the group of 10 subjects included in the main comparison were 2 subjects who had participated in the advanced TM-Sidhi program but had not been practicing for as long as the other 8 subjects in the group. Therefore, the 3 TM subjects excluded from the main comparison were combined with the 2 subjects from the main comparison to constitute a "medium-term" practice group, for purposes of comparing the possible cumulative effect of TM. The long-term TM group (LTM: 18.9 yrs. TM with advanced programs), medium-term TM group (MTM: 11.6 yrs. TM with less or no advanced programs) and the non-TM group (non-TM) included 8, 5, and 10 subjects respectively.

Results showed the main effect of TM experience on the set of 4 variates (RT, accuracy rate, P300 latency, and CNV) was significant, $F(8,34) = 2.63$, $p < .02$, with significant contributions from P300 latency and CNV. The main effect of discriminability was significant, $F(8,13) = 66.29$, $p < .001$, with significant contributions from all 4 variates. The main effect of stimulus-response compatibility was also significant, $F(4,17) = 66.14$, p

$<.001$, with significant contributions from RT, accuracy, and P300 latency. The interaction between TM participation and discriminability was not significant, ($F < 1$). However, the interaction between TM participation and stimulus-response compatibility was significant, $F(8,34) = 3.13$, $p <.009$. Finally, the 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, $F(16,26) = 1.50$, $p <.17$.

Reaction Time. Reaction time data for the 3 groups plotted as a function of the main effects of discriminability and stimulus-response compatibility are presented in Figure 51. The main effect of TM experience was not significant, $F(2,20) = 1.90$, $p <.18$, indicating that the three groups did not differ overall in RT and suggests that the addition of the 3 MTM subjects reduced the differences originally found between the groups. Both the main effect of discriminability, $F(2,19) = 109$, $p <.001$, and stimulus-response compatibility were significant, $F(1,20) = 193$, $p <.001$, indicating that RT increased with increased difficulty in discriminability and with incompatible responses. The interaction between TM participation and discriminability was not significant, ($F < 1$), indicating the effect of discriminability on RT was similar for the groups. However, the interaction between TM participation and stimulus-response compatibility was significant, $F(2,20) = 4.93$, $p <.02$, consistent with the comparison of the TM and non-TM groups cited above, and mainly attributable to the fact that the cost of the incompatible response was greater for the non-TM group (154 ms) than the LTM group (104 ms). The 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, ($F < 1$).

The planned comparison between the LTM (1122 ms, sd = 217) and MTM (985 ms, sd = 202) groups indicated no significant difference in RT, $F(1,20) = 1.95$, $p <.18$. The planned comparison between the LTM group and the NTM group (970 ms, sd = 218) was not significant, $F(1,20) = 3.43$, $p <.08$, (effect size = .70) indicating that the 2 MTM subjects taken from the original LTM group removed the difference between the LTM and NTM groups. This is accounted for by the slight decrease in RT and increase in the standard deviation in the new LTM group, relative to the original group. There was also no difference between STM and NTM groups, (F < 1). The interaction between the MTM and non-TM groups and discriminability was not significant (F < 1), nor was the interaction between these groups and stimulus-response compatibility, F(1,20) = 2.41, p <.14, indicating that the MTM and non-TM groups showed similar patterns of effects on these two factors.

Accuracy rate. Accuracy rate data for the 3 groups plotted as a function of the main effects of discriminability and stimulus-response compatibility are presented in Figure 52. The main effect of TM experience was not significant, (F < 1), indicating that the 3 groups did not differ in accuracy overall. The main effect of discriminability was significant, F(2,19) = 40.2, p <.001, as was the main effect of stimulus-response compatibility, F(1,20) = 15.62, p <.001, consistent with results reported in the previous sections. Also, neither the interaction between TM participation and discriminability, F(4,38) = 1.27, p <.30, or TM participation and stimulus-response compatibility was significant, (F < 1), indicating that the addition of the MTM group did not result in a different pattern of effects between the groups. The 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, F(4,38) = 1.26, p <.30.

The planned comparison between the LTM (88.4 %, sd = 8.4) and MTM (86.8 %, sd = 8.7) groups showed no significant difference, (F < 1). The planned comparison between the LTM and non-TM (85.4 %, sd = 9.4) groups showed no significant difference, F(1,20) = 1.53, p <.23. The planned comparison between the MTM and non-TM groups also showed no significant difference, (F < 1). There were no significant 2-

way interactions at each paired group comparison, nor was the 3-way interaction significant, indicating that the addition of the MTM group did not result in different patterns of effects between the groups on the experimental factors.

P300 latency. P300 latency data for the 3 groups as a function of the main effects of discriminability and stimulus-response compatibility are presented in Figure 53. Consistent with findings from the previous section, the addition of the MTM group showed the main effect of TM experience was significant, F(2,20) = 4.49, p <.02. Both the main effects of discriminability, F(2,19) = 151.1, p <.001, and stimulus-response compatibility, F(1,20) = 36.2, p <.001, were significant, consistent with the findings reported in the previous sections. The interaction between TM participation and discriminability was not significant, F(4,38) = 1.1, p <.37, indicating that the effect of this factor was comparable between the groups. However, the interaction between TM participation and stimulus-response compatibility was significant, F(2,20) = 5.12, p <.02, mainly attributable to the fact that the cost of the incompatible response was greater in the non-TM group (46 ms) than the LTM group (18 ms). The 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, F(4,38) = 2.20, p <.09.

The planned comparison between the LTM (646 ms, sd = 128) and MTM groups (662 ms, sd = 105) indicated no significant difference, (F < 1). The planned comparison between the LTM and the non-TM groups (715 ms, sd = 135) was significant, F(1,20) = 8.2, p <.01, with the LTM group showing shorter P300 latencies. The planned comparison between the MTM and non-TM group was not significant, F(1,20) = 3.67, p <.07, though the MTM group also showed shorter P300 latencies. None of the interactions between each paired-group comparison and discriminability were significant, indicating that the pattern of effects due to discriminability were similar for the groups. The interaction between the paired-group comparison MTM and non-TM and stimulus-response compatibility was significant, F(1,20) = 7.62, p <.01, as was the interaction reported previously between LTM and non-TM and discriminability, F(1,20) = 6.54, p <.02. These interactions are mainly attributed to the larger cost of incompatibility for the non-TM group, compared to both the LTM and MTM groups. Finally, the 3-way interaction between the MTM and non-TM groups with discriminability and stimulus-response compatibility was significant, F(2,19) = 4.61, p <.02, explained in part by the greater increase in P300 latency in the non-TM group from the #'s to the A-G discriminability condition, from the compatible to the incompatible response (71 ms) compared to the MTM group (1 ms).

These results do not allow any firm conclusions to be made about the relationship between length of time practicing TM and the magnitude of the preservation of processing speed. Though, overall the LTM group showed the shortest P300 latencies, followed by the MTM group, and the NTM group, the LTM and MTM groups were not significantly different, and both had significantly shorter P300 latencies than the NTM group. Larger sample sizes and greater control over grouping subjects according to TM participation will be required before to adequately address this question. Average ERPs at Pz for the 3 groups are superimposed for stimulus # (Figure 54), A-G (Figure 55) and A-Z (Figure 56) across conditions of stimulus-response compatibility. Note that the peak of the P300 for the MTM group in the #'s discriminability condition appears longer compared with the NTM group. However, as mentioned previously, the MTM average is a composite of only 5 subjects making peak identification based on the average misleading (see Johnson, 1988).

CNV. CNV amplitude data for the 3 groups plotted as a function of the main effects of discriminability and stimulus-response compatibility are presented in Figure 57. The main effect of TM participation was significant, F(2,20) = 5.12, p <.02, with the non-

TM group showing larger CNVs than both of LTM and MTM groups. The main effect of discriminability was also significant, $F(2,19) = 3.58$, $p < .05$, with larger CNV associated with increased difficulty in discriminability. The main effect of stimulus-response compatibility was not significant, $F(1,20) = 1.12$, $p < .30$, consistent with the findings reported in the previous sections. The interaction between TM participation and discriminability was not significant, ($F < 1$), indicating that the effect of this factor was comparable between the groups. Also, the interaction between TM participation and stimulus-response compatibility was not significant, $F(2,20) = 1.90$, $p < .18$, indicating that the effect of this factor was similar for the 3 groups. The 3-way interaction (TM participation x discriminability x stimulus-response compatibility) was not significant, ($F < 1$).

The planned comparison between the LTM (-6.5 uV, sd = 4.5) and MTM groups (-10.7 uV, sd = 6.2) indicated no significant difference, $F(1,20) = 1.02$, $p < .32$. The planned comparison between the LTM and the non-TM groups (-17.5 uV, sd = 9.0) was significant, $F(1,20) = 9.9$, $p < .005$, with the non-TM group showing larger CNV amplitudes, as presented in the previous section. The planned comparison between the MTM and non-TM group was not significant, $F(1,20) = 2.83$, $p < .11$, though the MTM group also showed smaller CNVs relative to the non-TM group. None of the interactions between each paired-group comparison and discriminability were significant, indicating that the pattern of effects due to discriminability was similar for the groups. Also, the interactions between each of the paired-group comparisons and stimulus-response compatibility were not significant, though there were small effects between the non-TM and each meditating group, suggesting that the effect of the incompatible response tended to increase CNV in the non-TM group, while this was not found in either TM group. Finally, none of the 3-way interactions between the paired-group comparisons were significant, (Fs < 1). Note that CNV did not vary as function of discriminability and only slightly as a function of stimulus discriminability suggesting again that the factors influencing CNV in this task were largely constant across task conditions.

Assessing the Preservation Effect: Comparing the Effect of TM in the Older Subjects with Reference to the Young Subjects

In this final section, the degree to which mental processing speed is preserved in elderly meditators, relative to elderly non-meditators, is assessed by comparing these groups to the young subjects. To accomplish this, planned comparisons were performed between the young subjects (n = 12) and the old TM group (n = 10), and the young subjects and the non-TM group (n = 10) on all the 3 variates (RT, accuracy, and P300 latency).

Reaction time. RT data for the 3 groups, plotted as a function of the main effects of discriminability and stimulus-response compatibility, is presented in Figure 58. As mentioned in section 2c, the overall difference in RT between the young (849 ms) and old non-TM (970 ms) groups was 121 ms. Though this was not significant, the 2-way interaction between age and discriminability, and the 3-way interaction between age, discriminability, and stimulus-response compatibility indicated that with the addition of stimulus noise and the incompatible response, the differences between the two groups became significant. The planned comparison between the young and the old TM group was significant, $F(1,29) = 18.5$, $p < .0002$, indicating the TM group was significantly slower than the young by 280 ms. The planned comparison between the old-TM and the TM groups, as mentioned in the previous section, showed the non-TM group to be significantly faster than the TM group, $F(1,29) = 5.47$, $p < .03$, by 159 ms.

Accuracy rate. Accuracy rate data for the 3 groups, plotted as a function of the main effects of discriminability and stimulus-response compatibility, are presented in

Figure 59. As mentioned in section 2c, the overall difference in accuracy rate between the young (88.9 %) and old non-TM (85.4 %) groups was 3.5 %. Though this was not significant, the 2-way interactions between age and discriminability, and age and stimulus-response compatibility were significant. These were attributable to the fact that with the addition of stimulus noise the old non-TM group became less accurate, and in the compatible response condition, the young began at a higher rate of accuracy than the old non-TM. The planned comparison between the young and the old TM group was also not significant, ($F < 1$), indicating the TM group had comparable accuracy rates as the young. The planned comparison between the old TM and non-TM groups, as mentioned in the previous section, showed the groups were not significantly different, $F(1,29) = 1.72$, $p < .20$. None of the 2-way interactions or the 3-way interaction were significant.

P300 latency. P300 latency data for the 3 groups, plotted as a function of the main effects of discriminability and stimulus-response compatibility, are presented in Figure 60. As mentioned in section 2c, the overall difference in P300 latency between the young (634 ms) and old non-TM (715 ms) groups was 81 ms and this difference was significant. Also, while the 2-way interactions between age and discriminability, and between age and stimulus-response compatibility were not significant, the 3-way interaction (age x discriminability x stimulus-response compatibility) indicated that with the addition of stimulus noise and the incompatible response, the differences between the two groups became more pronounced. The planned comparison between the young and the old TM group was not significant, ($F < 1$), indicating P300 latencies were comparable between the two groups. The planned comparison between the old-TM and the TM groups, as mentioned in the previous section, showed the TM group to have significantly shorter P300 latencies than the non-TM group, $F(1,29) = 9.97$, $p < .004$, by 70 ms.

Finally, the planned comparison between the young and non-TM groups showed P300 latencies were significantly longer in the old non-TM group, F(1,29) = 14.9, p <.0006.

CNV. CNV amplitude data for the 3 groups are presented in Figure 61. As mentioned in section 2c, the overall difference in CNV amplitude between the young (-1.6 uV, sd = 6.1) and old non-TM (-17.5 uV, sd = 9.0) groups was 15.9 uV and this difference was significant. Also, none of the 2-way interactions between age and discriminability, and between age and stimulus-response compatibility, or the 3-way interaction (age x discriminability x stimulus-response compatibility) were significant, indicating that the experimental factors other than age had no main or interactive effect on CNV. The planned comparison between the young and the old TM group was not significant, F(1,29) = 3.48, p <.07, indicating that CNVs were comparable between the two groups, though the old TM group did tend to have a larger CNV (-7.1 uV, sd = 5) than the young (effect size of 1). The planned comparison between the old-TM and the TM groups, as mentioned in the previous section, showed the non-TM group to have significantly larger CNVs than the TM group, F(1,29) = 11.26, p <.002, by 10.4 uV. Finally, the planned comparison between the young and non-TM groups showed CNV amplitudes were significantly larger in the old non-TM group, F(1,29) = 28.82, p <.001.

Discussion

In this section, the preservation effects in processing speed associated with TM participation within older subjects was assessed. First, comparison of the old long-term TM practice group and non-TM group was made with the prediction that the TM group would exhibit faster processing speed reflected in RT and P300 latency, and the difference between the groups would become more pronounced under conditions of greater processing demand.

In general, predictions concerning RT differences between the groups received little support. The older TM subjects were found to be slower in RT overall than the old non-TM group. Since accuracy rates were not significantly different between the groups, speed/accuracy tradeoffs could not account entirely for this difference. However, results did suggest the TM group tended toward greater accuracy and, by inference, a slightly more conservative strategy. Since, the speed/accuracy curve is a non-linear one, and small differences in accuracy can have significant effects on RT, part of this result can be attributed to differences in strategy. Further support for a explanation based on difference in strategy between the groups came from the finding of significant CNV differences between the groups, with the non-TM group displaying larger CNVs than the TM group over all experimental conditions. This tonically elevated state of preparation may have been associated with different motivational sets for the groups induced by different recruitment procedures. While the non-TM subjects were told they would be "participating in a study designed to assess the effects of maintaining good health on preserving good dexterity of response", the old TM subjects were told "they would be participating in a study which looked at EEG changes across the life span". The more neutral solicitation for the TM group was intended to minimize the TM related aspect of the comparison which would result in the TM subjects desire to perform. However, it is possible that the unintentionally non-neutral solicitation for the non-TM group resulted in their attempt to perform, and that this is reflected in the enhanced CNV.

With regard to P300 latency, the predictions were supported. The TM group showed shorter P300 latencies overall compared with the non-meditating group, and the differences became more pronounced under more demanding conditions of discriminability and stimulus-response compatibility.

Secondly, the degree to which length of time practicing TM was associated with preservation of processing speed was assessed. With the addition of 3 older TM subjects the overall differences in RT between the TM and non-TM groups became non-significant. In addition, the differences between the long-term TM group, the medium-term TM group, and the non-TM group were non-significant for RT. This suggests that the differences in RT originally found between the TM and non-TM groups were not robust, and potentially due to a few subjects with exceptionally long RT in the TM group.

With regard to P300 latency, though overall, the long-term TM group had the shortest P300 latencies followed by the MTM group and NTM group, planned comparisons resulted in no significant differences between the LTM and NTM groups. The NTM group showed greater increases in P300 latency between the compatible and incompatible response conditions when compared with both the LTM and NTM groups, suggesting a greater affect of complexity in the NTM group compared to both TM participation groups. However, the results do not permit any firm conclusions to made about the length of time participating TM and the magnitude of the preservation effect. Larger sample sizes will be required for any reliable answers to this question.

Finally, the older TM group and non-TM groups were compared to the young group to assess the degree of preservation of processing speed. With reference to RT it was found that the older non-TM group was not significantly different from the young while the older TM group was significantly slower than the young. Also there were no significant overall differences in accuracy between the young and either of the older groups, though as the task complexity increased the both older groups showed a significant drop in accuracy relative to the young. With regard to P300 latency, the opposite was found. That is, the old TM group showed P300 latencies comparable to the young, while the non-TM group showed significantly longer P300 latencies than the young. Finally, the CNV amplitudes were comparable between the young and the older TM group, while the CNV amplitudes were significantly larger in the older non-TM group relative to both the young and the older TM groups, suggesting that the older non-TM group exhibited an enhanced state of arousal or motor preparation. This may partially account for the lack of difference in RT between the young and the older non-TM group, and the difference between the older TM and non-TM groups.

General Discussion

Two experiments were conducted to test the hypothesis that older subjects with long-term practice of TM would demonstrate a preservation of mental processing speed compared with older non-TM subjects as measured by RT and P300 latency. The results of Experiment 1 indicated that P300 latencies in a visual discrimination task were significantly shorter in older TM subjects, compared to older non-TM subjects matched on age and gender. The fact that no differences were found between the 2 groups in an auditory discrimination task suggested an explanation in terms of the complexity hypothesis. That is, the effects of TM in preserving mental processing speed may only be apparent when cognitive processes are sufficiently engaged, a situation where differences resulting from age are also more pronounced. This interpretation rests on the assumption that TM has its greatest influence on central (i.e., cognitive) as opposed to peripheral processes.

Experiment 2 was conducted to replicate and extend the findings of Experiment 1, by adding a young adult comparison group consisting of both TM and non-TM subjects, in addition to the older TM and non-TM subjects. It was felt that the young subjects would provide a reference point from which to assess the effects of age on processing speed and the potential preservation effects associated with TM. Experiment 2 employed a task introduced by McCarthy and Donchin (1981) designed to manipulate demands placed on stimulus evaluation (discriminability) and response selection (stimulus-response compatibility) stages of processing independently. It was assumed that this task would afford a further test of preservation effects of TM under conditions of systematically increased task complexity. Also, additional attempts to mitigate potential confounds associated with static group comparisons were included by matching the groups on age, gender, intelligence levels, exercise, and self-reported health status.

Four questions were addressed in Experiment 2. Firstly, it was of interest to find out if the experimental dissociation of RT and P300 latency reported by McCarthy and Donchin (1981) could be replicated. In this regard, the results replicated the experimental effects for RT but not for P300 latency. That is, RT increased as a function of both discriminability and stimulus-response compatibility, and the effect of these two factors on RT was additive, suggesting that the factors of discriminability and stimulus-response compatibility were affecting different stages of processing. However, P300 latency also increased as a function of both discriminability and stimulus-response compatibility, contrary to the findings of McCarthy and Donchin (1981) and others who have reported P300 latency to be relatively insensitive to manipulations of stimulus-response compatibility. While the effect of stimulus-response compatibility on P300 latency was significant, it was small in magnitude (25 ms) compared to the effect of discriminability (266 ms). However, the effect could not be accounted for by differences in window specifications for picking P300 latencies, or by differences in filters applied to the signals, since similar analyses were done in this study.

Secondly, young TM subjects were compared to young non-TM subjects to assess if differences in processing speed would be present between the groups. No significant differences were found between the groups in RT, accuracy rate, or P300 latency. The TM subjects were consistently faster and more accurate however, and small sample sizes may have contributed to poor power and this non-significant finding.

Thirdly, a comparison between young and older subjects attempted to assess the effects of age on mental processing speed. The results found the older subjects to have RTs comparable to young subjects overall, though the older subjects became significantly slower as task demands increased. This is in agreement with several studies which indicate that age-related slowing of cognitive processing speed becomes more pronounced under conditions of increased complexity. In addition, though accuracy rates were comparable between the young and older subjects overall, older subjects showed larger decrements in accuracy as a result of increased difficulty in discriminability and in conditions requiring an incompatible response. Therefore, the accuracy data lead to the conclusion that strategy could not account for the slowing of RT found with age.

P300 latencies were found to be significantly slower in older non-TM subjects compared to young subjects, suggesting a age-related slowing of central/cognitive processes associated with stimulus evaluation stages of processing. In addition, the effect of stimulus-response compatibility on P300 latency was also significant when both young and older subjects were taken together. However, the young and older subjects showed similar patterns of prolongation of P300 latency as a function of both discriminability and stimulus-response compatibility, indicating that the effect of increasing task complexity did not result in a differential effect on older subjects. This finding is in agreement with previous research (Bashore, 1990; Ford & Pfefferbaum, 1985) suggesting that the complexity effect has its primary locus in response-related stages of processing (indexed by RT), as opposed to stimulus evaluation processes (indexed by P300 latency). Unanticipated was the finding of larger CNVs in the S1-S2 interval in older subjects compared to younger subjects over all experimental conditions. The fact that this difference was not associated with any of the experimental conditions suggests that this was a tonically elevated state in the older subjects. Since late components of the CNV have been associated with motor preparation (Rohrbaugh & Gaillard, 1983), it may be speculated that the older subjects were more primed to respond than the young subjects. This would be supported in part by the lower accuracy rate found in the older subjects, since research has indicated that CNV is greatly attenuated when attention is directed toward accurate rather than speedy response (Loveless & Sanford, 1974; Gaillard & Perdok, 1980; Gaillard, Perdok, & Varey, 1980). The explanation for this priming effect may be associated with a different motivational set produced by the recruitment procedures.

Finally, the fourth question of Experiment 2 assessed the preservation effects in processing speed associated with TM participation within older subjects. When older long-term TM subjects were compared to older non-TM subjects, contrary to predictions, the older non-TM subjects showed faster RT. Though the two groups did not differ significantly in accuracy rate, the older TM subjects tended to have better accuracy. The finding of larger CNVs in the older non-TM subjects compared to the older TM subjects suggests that the older non-TM subjects were evidencing an enhanced preparatory set compared to both the older TM subjects and the young subjects. This could account, in part, for the differences in RT between the groups.

The older TM-subjects showed significantly shorter P300 latencies overall compared to the older non-TM subjects, suggesting the age-related slowing of central/cognitive processes associated with stimulus evaluation were significantly reduced in the TM subjects. While the effect of discriminability affected P300 latency in a similar way for both older groups, P300 latencies in older non-TM subjects were slowed to a greater degree by the incompatible response condition compared with older TM subjects. As mentioned above, the interaction of discriminability and stimulus-response compatibility on

P300 latency could be attributed to the complexity of the stimulus, such that when the difficulty of discriminability is sufficiently high, stimulus evaluation processes are prolonged to the extent that they interact with response-decision processes. The finding of larger interaction effects within the older non-TM subjects is parsimonious with this interpretation since older non-TM subjects showed significantly longer P300 latencies, suggesting that the effects of discriminability were greater for this group than the older TM subjects.

When the older TM group was subdivided into groups on the basis of length of time practicing TM, with 3 additional older TM subjects added to form a medium-term practice group, RT differences between the older TM and non-TM subjects became non-significant. This suggests that RT differences may not be a robust finding and that initial differences may have been attributed not only to differences in strategy, but also the result of one or two TM subjects performing exceptionally slow. Though overall, P300 latencies suggested a possible relationship between length of time practicing TM and the amount of preservation of processing speed, the finding of no significant difference between the long-term and medium-term TM groups does not allow any firm conclusions to be drawn. Sample sizes will need to be increased before this question can be answered.

Finally, in comparing the older TM and non-TM groups to the young subjects in assessing the degree to which TM may have preserved mental processing speed, aside from the complicated pattern of effects for RT, those cognitive processes indexed by P300 latency are preserved in the older TM subjects and are evidently comparable to the young. Expressed in terms of regression, while older non-TM subjects exhibited a slowing of P300 latency of 1.7 ms/yr., consistent with findings from several other studies (Bashore, 1990), TM subjects slowed at a rate of .22 ms/yr., only a slight reduction from the young subjects. Taken together, the 2 studies conducted here suggest that mental processing speed, as manifest in the latency of P300, is substantially less affected by age-related change in older subjects with long-term practice of TM and comparable to that of young subjects. This suggests the TM technique may have an important contribution to make in supporting a preservation or restoration of integrity of neurocognitive function in the elderly. In the following Chapter, possible mechanisms which may account for the preservation of mental processing speed associated with TM practice are discussed. In addition, results are discussed in the broader context of theories of cognitive potential throughout adulthood as seen by modern developmental psychology and theories of cognition and cognitive development as put forth by Maharishi Mahesh Yogi (1969) and as formalized in his Vedic Psychology (e.g., Alexander et al., 1990; Dillbeck, 1988; Orme-Johnson, 1988).

CHAPTER IV: DISCUSSION OF RESULTS IN THE CONTEXT OF CONTEMPORARY AGING THEORY AND MAHARISHI'S VEDIC PSYCHOLOGY

P300 latency serves as a unique window into information processing as manifest by the electrical activity of the brain and as an index of cognitive processes associated with the timing of stimulus evaluation stages of processing. In the 2 studies conducted here, reduced age-related declines of P300 latencies in elderly practitioners of TM suggests a preservation of speed of neurocognitive function in the older TM subjects. These findings are consistent with previous research which suggests TM promotes a more youthful style of functioning as evidenced in younger biological age (Wallace et al., 1981), younger hormonal profiles (Glaser et al., 1987), greater improvements in cognitive performance and higher survival rates in elderly practitioners (Alexander et al., 1990). Because TM is a mental technique with documented physiological correlates, the mechanisms accounting for these effects can be discussed from both psychological and physiological levels.

In the first section of this chapter, possible mechanisms which may account for a preservation of neurocognitive function in elderly subjects practicing TM are discussed based on the mechanics of the TM practice and in terms of current physiological models. In the second section, the results are discussed in the broader context of models of adult cognition. The role that the speed of processing plays in the context of cognition as whole, as seen by current cognitive aging theorists as well as by Maharishi's Vedic psychology, is reviewed. It is proposed that the model of adult development of Vedic psychology integrates and extends current models of adult cognition, and adds interpretive power to the results of this study.

Preservation of Neurocognitive Function in Elderly Subjects
Practicing TM: Potential Mechanisms

In terms of psychological explanation, during the TM technique mental activity is said to gradually subside as increasingly refined levels of thought and feeling are experienced. This gives rise to the state of transendental consciousness in which awareness is maintained, but all specific objects of attention (percepts, concepts, feelings) are systematically transcended, with the result that awareness becomes self-referral, or directly aware of itself (Alexander et al., 1990). Maharishi (1969) characterizes the experience of transcendental consciousness during the TM technique as follows:

> The Transcendental Meditation technique is an effortless procedure for allowing the excitation of the mind to gradually settle down until the least excited state of mind is reached. This is a state of inner wakefulness with no object of thought or perception, just pure consciousness, aware of its own unbounded nature. It is wholeness, aware of itself, devoid of difference, beyond the division of subject and object--transcendental consciousness. (p. 123)

The experience during TM of a settled and ordered state of mental alertness, has been proposed by many to be responsible for the findings of improved perceptual abilities (e.g., Chalmers, et al. 1990), and cognitive and perceptual flexibility (Alexander et al., 1990; Dillbeck, 1982) associated with both short and long-term practice of the technique (see Chapter 2).

Physiologically, regular experience of transcendental consciousness is said to provide the nervous system deep rest, allowing the internal homeostatic mechanisms of the body to repair chemical and structural abnormalities caused by stress (Orme-Johnson, 1988, p. 131). Alexander et al. (1990) propose that while sleep and dreaming are natural forms of rest which alleviate fatigue and tension, they are not sufficient to neutralize more deep-rooted levels of stress (cf. Wallace, 1986). Consequently, the accumulation of stress may promote the gradual decline of CNS efficiency, reflected in the increased "high-noise" style of functioning found with age (cf. Welford, 1977). Evidence for a state of deep rest, both during and outside of the practice of TM, include biochemical and physiological measures of spontaneous GSR responses, respiration rate, heart rate, and plasma lactate. For example, a meta-analysis of 31 physiological studies found that TM produced greater reduction of plasma lactate and respiration rate, and greater increases in basal skin resistance during meditation than ordinary eyes-closed rest. Moreover, the meditators had lower baseline levels of heart rate, respiration rate, plasma lactate, and spontaneous skin resistance responses outside of meditation (Dillbeck & Orme-Johnson, 1987).

Wallace (1986), in reviewing the literature on TM and the aging process, suggests that an increased ability in meditators to maintain a lower, more stable, internal resting state may be one mechanism accounting for reduced age-related declines in physiological function associated with TM. Wallace (1986) suggests that the physiology of TM meditators operates in a smoother, more orderly and efficient mode, and cites research which links low body metabolism with longer life span.

The description of the effects of TM outlined here are precisely opposite to descriptions of the effects of aging on neurocognitive function. As outlined in Chapter 2, Birren et al. (1980), Welford (1977), Salthouse (1985), and others suggest that centralized declines in processing speed are a result of increased entropy in the older nervous system. It is theorized that while the software or set of operations that the cognitive system performs remains structurally intact with age, the CNS undergoes a loss of integrity which expresses itself in a general slowing of processing capacity. Similar theories have been proposed more recently in terms of information-loss (Myerson, Hale, Wagstaff, Poon, & Smith, 1990). Both the neural noise and information loss models assume that neurobiological changes associated with aging exacerbate errors inherent in the human information processing system and that the result is a decrease in the rate at which information is passed from one level to the next in the nervous system (Myerson et al., 1990). This entropy, expressed by Welford (1977) as neural-noise, serves to reduce the signal to noise ratio in the older nervous system with the effect of requiring the older individual to take longer to perceive information and to respond to it appropriately. The process of transcending to a "least excited" or ordered state of mental experience may serve to maintain a higher signal-to-noise ratio in the CNS with age. Evidence for reduced trial to trial variability in reaction time performance in meditators, such as found in the study of Cranson et al. (1991), as well as findings of increased autonomic stability in meditators as reported by Orme-Johnson (1973), lend support to this hypothesis. The benefit of TM practice may be both short-term normalization of stress and long-term alleviation of age-related declines in CNS integrity associated with accumulation of stress.

Functionally, maintenance of CNS integrity would serve to prolong the systems capacity to adapt and maintain internal stability in the midst of external change. The efficiency with which one maintains homeostasis generally declines with age. Again, findings of greater autonomic stability in meditators, which indicate greater ability to adapt to stress and maintain internal stability (e.g., Orme-Johnson, 1973), suggest another potential mechanism in which TM practice helps to maintain a younger biological age.

Reduced age-related declines of P300 latency in elderly TM meditators provides additional evidence for maintenance of a more youthful psychophysiological state. Moreover, as a direct measure of CNS function, these findings are the first to show that the effects of aging may be mitigated by TM on the level of brain functioning.

In summary, this section has pointed to possible psychological and physiological mechanisms that may account for the maintenance of CNS processing speed in elderly TM practitioners. Alexander et al. (1990) summarize these mechanisms succinctly by stating that, "The apparent beneficial effect on aging of the restful alertness experienced during TM may be jointly due to the role of deep rest in counteracting "wear and tear", and of increased mental stimulation for preventing "atrophy" of functions" (p. 952). In the next section the value of preserving the speed of neurocognitive function later in life is discussed in the context of models of adult cognition. In addition, two theories of Maharishi's Vedic Psychology (1972; 1986) are introduced which may integrate linear stages models of cognitive psychology with models of cognitive development in adulthood.

Speed of Cognition in the Context of Cognition as a Whole

Contemporary Aging Theory

Determinant vs. Consequence Views Revisited

What are the implications of maintenance of faster processing speed later in adulthood? The answer to this question requires that one know the importance of speed of processing to the overall function of cognition as a whole. Recall that this question essentially distinguishes the two theoretical orientations outlined in Chapter 1, namely the determinant and consequence views (Botwinick, 1984). To review, advocates of the determinant view place age-related loss of processing speed as the determinant of many other declines in cognitive function that occur with age. The speed at which information can be processed by the system, as measured by traditional RT and the latency of ERPs, is considered to have implications across all levels of cognition: learning, memory, and attention. This conclusion has led theorists to posit a general slowing factor occurring in the CNS (e.g. subcortical) which impacts all centrally mediated cognitive operations (see Figure 7). In this view, speed of processing is an important window into the integrity of the CNS and plays a fundamental role in cognitive changes associated with aging.

The consequence view, on the other hand, de-emphasizes the value of speed as a fundamental marker of cognitive change with age, and takes a more domain specific orientation to age changes in cognition. Researchers tend to focus on a particular cognitive domain, such as memory function, and attempt to assess structural or functional changes with age occurring in that area. In this view, the speed of information processing is only one dimension of cognition and, in the larger perspective of adult cognition, is not necessarily a limiting factor to other, perhaps more important, cognitive domains.

The determinant vs. consequence views reflect, to a certain degree, another distinction often made in terms of cognitive changes that occur with age, i.e. the difference between fluid and crystallized abilities (Horn & Cattell, 1966; Horn, 1982). Fluid abilities refer to the speed and accuracy of processing information and are thought to be closely linked to the neurological status of the individual. Crystallized abilities refer to facts and information that are accumulated as part of an individual's general knowledge. Fluid intelligence, often measured by performance scales on intelligence tests, declines gradually after young adulthood, a conclusion supported by declines in processing speed found on RT tasks. Crystallized intelligence, in contrast, may follow a different age change trajectory, with maintenance or continued increase throughout adulthood depending on the individuals continued experience in the world (Perlmutter, 1988).

Importantly, Perlmutter (1988) suggests that the view that late life is dominated by an aging process that produces decline, while perhaps reasonable for characterizing biological functions (as reflected in tasks of speeded performance), is not accurate for describing other domains of cognition. Perlmutter (1988) suggests that the negative consequences associated with the loss of processing speed, are only one of many other, often positive changes in cognition that occur with age. Perlmutter's model of cognitive potential will be outlined briefly.

Perlmutter's Model of Cognitive Potential Throughout Adulthood

Perlmutter (1988) has developed a model of cognitive potential throughout life which distinguishes between different types of cognition, each with its own developmental age change trajectory. In brief, Perlmutter (1988) outlines a multi-tiered model of cognition and is simplified in Figure 62. Tier 1 is a cognitive system available at birth which incorporates those processes that have been identified as basic mechanisms, primary mental functions, or fluid abilities. This tier is a fairly closed biological system with little ontogenetic change, and its general structure and function are assumed to be established at a species level. The model posits that development of this cognitive tier parallels development of other largely biological systems, and assessment of performance based on this level will be predicted well by assessment of biological functions and/or health. As such this tier has rapid growth and fine tuning at birth followed by gradual decline throughout adulthood. This tier therefore, is most dependent on the timing of operations performed by the CNS, the efficiency of which is reflected in measures of processing speed such as P300 latency and RT.

The second tier emerges postnatally and is a somewhat open psychological system with potential for ontogenetic change incorporating what has been referred to as world knowledge or crystallized abilities. As such, aspects of this tier are shared by the population, while other aspects are unique to the individual. It emerges only after life begins and slows as the rate of new experiences slows. It is assumed to be a psychological addition to the first biological layer and independent measures of biological functioning or health are not expected to be good predictors of performance involving this level of cognition, except where severe biological breakdowns limit psychological activity.

While more difficult to define, Perlmutter proposes the existence of a third tier which is not in place until later in development and is an extremely open psychological system with potentially substantial ontogenetic change. This tier encompasses the capacities for more complex or higher mental functions including strategies and internally driven goal-directed behavior. Tier 3 is said to emerge out of the organism's cognition about it's own cognitive activity, reflected for example in what Flavell (1977) referred to as "metacognition". The value of this layer of cognitive function is in its ability to allow the system to adapt in a way that is not only responsive to the external world but also to its own apparatus. In the word's of Perlmutter, "while the second tier primes the cognitive system to operate in an ever more environmentally adaptive manner, the addition of the third tier gives the system capacity to adjust its modus operandum to optimize attainment of specified goals" (p. 259). This tier is proposed to be relatively immune to biological fluctuations that may be related to the state of age of the individual.

Perlmutter (1988) suggests that it may be possible to speculate even further tiers, new layers which emerge providing more adaptive regulation and control of the emotional and biological systems. Perlmutter (1988) refers to evidence which suggests better integration of affect and cognition in later adulthood (Labouvie-Vief, 1985) and suggests that these new skills may account for the "as of yet vague quality of wisdom (p. 256)".

Perlmutter (1988) might be considered consistent with a consequence stance in terms of the relative importance of speed of processing to adult cognition as a whole. According to Perlmutter (1988), "while the adult may operate with a slightly slower or less effective biological system, older adult's experientially rich cognitive systems should give them a cognitive advantage over the more agile but less adapted cognitive systems of younger adults (p. 261)".

What role does speed of processing play in the context of cognition as a whole? Figure 63 integrates the two conceptions discussed thus far. As previously suggested, the answer depends on how broadly one defines adult cognition. Many cognitive aging theorists view speed of processing not only as a critical measure of aging, but as a cause of cognitive declines with age. However, because theorists have focused their analyses on cognitive processes which depend critically on the capacity of the CNS to perform speeded operations, speed changes with age are given great importance.

Other theorists consider adult cognition from a broader perspective, discussing changes in processing speed as one dimension of a multi-dimensional system. Perlmutter (1988), in assessing cognitive changes associated with aging, recognizes many positive changes in cognition occurring with age. In order to accommodate for both negative and positive changes in cognition in later adulthood, Perlmutter's model (1988) distinguishes between different domains of cognition. She provides a convincing argument that while slowing of cognitive operations, linked with changes in CNS efficiency, do occur there are other important domains of cognition independent of physiological declines which remain stable or continue of grow throughout adulthood. Interestingly, in accommodating her model to include cognitive domains which show positive change with age, Perlmutter proposes a functional independence of these tiers from the low-level biological changes that occur with age. This assumption is re-evaluated in the following section.

Therefore, the degree of emphasis to be placed on age-related loss of processing speed in developing a theory of changes in cognition in adulthood reveals differences in the way researchers are conceptualizing adult cognition. Currently there does not seem to be a sufficient integration of these theories. In the next section, Maharishi's Vedic Psychology (1969; 1972; Alexander et al., 1990; Dillbeck, 1988; Orme-Johnson, 1988) is introduced and proposed to provide a comprehensive framework of adult cognition which can integrate and extend contemporary theories of cognition and cognitive potential throughout adulthood.

Maharishi's Vedic Psychology

Maharishi's Vedic psychology (referred to herein as Vedic psychology) is a formulation of the theory, practice, and application of Maharishi's theory and technology of the development of consciousness (Maharishi, 1969; Orme-Johnson, 1988; Dillbeck, 1988; Alexander, 1990) as it relates to the field of Psychology. Because Vedic Psychology provides a rich theoretical framework for understanding the mechanics of TM and psychophysiological changes that TM is proposed to induce, Vedic psychology can provide an important context in which to interpret the results of this study. Therefore, this section serves to overview some of the basic theories of Vedic Psychology.

The word "Vedic" derives from the Sanskrit word "Veda" and is defined by Maharishi (1986) in the following quotation:

> Veda means pure knowledge and the infinite organizing power that is inherent in the structure of pure knowledge. Pure knowledge is the state of awareness in which consciousness knows itself alone, when awareness is completely self-referral, when awareness has nothing other than itself in its structure. This state of pure knowledge, when knower, known, and process of knowing are in the self-referral state, is that all-powerful, immortal, infinite dynamism at the unmanifest basis of creation. This is Vedic Science - all about the knower, the known, and the process of knowing; all about consciousness, both in its self-referral, self-interacting state, and as it expresses itself in the infinite variety of the whole creation, that performance of nature which goes on and on eternally in all spheres of time, past, present, and future. The knowledge of this most basic principle of life - the self-interacting dynamics of consciousness - is the science of pure knowledge, the science of the Veda. (p.i)

In Vedic psychology, pure knowledge, the self-referral state of consciousness, is also known as transcendental consciousness. Vedic psychology proposes that the experience of transcendental consciousness lies at the deepest level of the human mind, the experience of which is central to the full development of human consciousness.

There are two theoretical constructs central to Vedic psychology that provide a useful framework in which the different models of adult cognition and findings of this study can be integrated. These constructs are Vedic psychology's levels of mind, and higher states of consciousness. The model of levels of mind provides a structural model of mind consistent with general stage models of cognition from cognitive psychology, such as Welford's model (Chapter 1), while the model of higher states of consciousness has a decidedly developmental perspective which provides a natural extension of the tiers of cognition as outlined by Perlmutter (1988). Both the model of levels of mind and higher states of consciousness are outlined briefly below.

Levels of Mind

Vedic psychology proposes the mind is hierarchically structured in layers from concrete to abstract: the faculties of action and sensation, desire, thinking mind (associative faculty), intellect (discriminative faculty), feelings and intuition, and experiencing ego, respectively (Alexander et al., 1990; Dillbeck, 1988; Maharishi, 1969). Vedic psychology proposes that underlying all these levels is the completely abstract level of "transcendental consciousness" (also referred to as pure consciousness) in which knower, known, and process of knowing are unified. Figure 64 graphically presents the structure of the mind and it's relationship to transcendental or pure consciousness (cf. Dillbeck, 1988; Orme-Johnson, 1988). In brief, the role of each level is described by Maharishi (1972) succinctly as follows:

> The ego is that value of life which is most refined in character. The ego experiences; it is the experiencer in the individual life. The ego feels; the ego enjoys--feeling touches the ego, understanding touches the ego. Ego understands; ego feels; ego thinks. That faculty of the ego which thinks is called the mind. That faculty of the ego which understands, discriminates, and decides is called the intellect. (pp. 19:11-12).

Perhaps more consistent with a linear stage model of cognition is Maharishi's description of the relation of mind, desire, and the level of the senses:

> Experience results when the senses come into contact with their objects and an impression is left on the mind. The impulse of this new impression resonates with the impression of a similar past experience already present in the mind and associates itself with that impression. The coming together of the two gives rise to an impulse at the deepest level of consciousness, where the impressions of all experiences are stored. This impulse develops and, rising to the conscious level of the mind, becomes appreciated as a thought. The thought, gaining the sympathy of the senses, creates a desire and stimulates the senses to action. (1969, p. 284).

These descriptions of levels of mind are generally consistent with cognitive psychology's stage models of cognition and can be integrated quite well with Welford's (1977) model of human performance (Figure 1). Beyond the obvious inclusion of input/output mechanisms (senses and organs of action), both models delineate "computational" stages of perceptual evaluation (mind), based on an interaction between incoming stimuli and a long-term memory (storehouse of impressions) to form a perception, while selection of a response is based on internally generated decisions (intellect). Moreover, both models include conceptually "deeper" structures (e.g. the diffuse activation system representing the state of alertness of the system (Welford, 1977) and desire, ego, and feelings levels of mind representing input from motivational/emotional factors (Vedic psychology)). These deeper structure's input from and output to computational stages clearly has important consequences for the information processing system in the decisions and consequent behaviors that it performs. However, the deepest level of mind, from the perspective of Vedic psychology, is transcendental consciousness. Transcendental consciousness, as a completely self-referral state of consciousness, holds a unique status. Maharishi characterizes transcendental consciousness as "a state of inner wakefulness with no object of thought or perception, just pure consciousness, aware of its own unbounded nature. It is wholeness, aware of itself, devoid of difference, beyond the division of subject and object--transcendental consciousness (Maharishi, 1969, p. 123)". While transcendental consciousness is considered always present at the deepest level of mind, Maharishi points out that if one does not have a systematic means for experiencing it, the deepest level of the mind (Self) is not experienced and the ego or sense of self is restricted (Maharishi, 1969, pp. 338-341). Importantly, the experience of transcendental consciousness is said to have an integrating effect on all the levels of mind by virtue of it being both fundamental to all the levels of mind and being a state of dynamic, yet orderly, wakefulness. The TM technique is designed to accomplish the necessary activity of allowing the mind to settle down and eventually transcend it's own activity, allowing the mind to experience transcendental consciousness.

According to Vedic psychology, the levels of mind form the fundamental structure of the personality while the degree of integration and differentiation of these levels characterizes the state of development. It is the degree of integration and differentiation of levels of mind that characterize the development of higher states of consciousness. The nature of this development is now briefly outlined.

Higher States of Consciousness

The capacity to experience and to culture on a permanent basis the experience of transcendental consciousness is said to gradually unfold in a sequence of stages, referred to as higher states of consciousness (Maharishi, 1969). Vedic psychology identifies seven states of human consciousness, which include four higher states of consciousness psychophysiologically distinct from the three ordinary states of waking, dreaming, and sleeping (see appendix C for psychophysiological evidence). These states are 1) transcendental consciousness, 2) cosmic consciousness, 3) refined cosmic consciousness, and 4) unity consciousness. These four states are outlined briefly below.

Through the TM and TM-Sidhis program, the individual gains and stabilizes the experience of a fourth major state of consciousness, transcendental consciousness. According to Maharishi (1972) the process by which transcendental consciousness becomes a permanent feature of one's consciousness is one of gradual psychophysiological refinement. Through alternation of experience of transcendental consciousness (during TM) and waking state of consciousness there is " a gradual and systematic culturing of the physical nervous system which creates a physiological situation in which the two states of consciousness exist together simultaneously" (Maharishi, 1969, p. 229). It is only when transcendental consciousness is permanently maintained along with waking, dreaming and sleeping, through the gradual refinement and habituation of the nervous system, that the first stable higher stage of consciousness emerges, referred to by Maharishi as cosmic consciousness.

Cosmic consciousness, in contrast to the first four states of consciousness, is a stable state of consciousness, characterized by the permanent experience of transcendental or pure consciousness along with the changing states of waking, dreaming, and sleep. This state and the two later states are also known as states of enlightenment. When the individual comes to identify him/her self with the deepest level of mind, transcendental consciousness, as opposed to the relative states of ego (as defined by thoughts, feelings, emotions, etc.) the first stable higher stage of consciousness is said to be gained. Maharishi states:

> This is the state of cosmic consciousness, where the Self has separated itself completely from the field of activity....When...transcendental absolute Being [the non-changing Self] is found in coexistence with the mind in relative existence, in the field of time, space, and causation, then the mastery of the higher Self is accomplished (Maharishi, 1969, p. 339).

It should be noted that an individual in cosmic consciousness continues to recognize his/her individual status and functions within the normal cognitive domains. This "normal" style of function however, now occurs on the basis of an inner awareness that the Self is nonchanging and complete. Importantly, the emergence of cosmic consciousness is said to require major neurophysiological reorganization. As Alexander et al. (1990) state:

> If stress creates incoherent excited states of psychophysiological functioning that restrict awareness, it would follow that the unrestricted, least excited state of pure consciousness could only be fully maintained when the nervous system is freed from the influence of accumulated stress (Maharishi, 1969). Thus, neutralization of stress (as facilitated by the TM program) is considered critical in the development of higher stages of consciousness. (p. 315).

While in the growth to cosmic consciousness, self identity undergoes a profound shift from the changing values of the knower or ego, to the nonchanging, unbounded state of the Self as pure consciousness, the emergence of the sixth state of consciousness, refined cosmic consciousness occurs as a result of changes on the level of perception. Refined cosmic consciousness is characterized by a profound refinement in perceptual appreciation of the subtlest values of objective reality. On the basis of the stress-free style of functioning afforded by cosmic consciousness the faculties of perception and feeling are said to undergo continued refinement. When the faculties function from their most refined level, then the objects of perception are appreciated for their most refined values as well (Alexander et al., 1990). Maharishi describes this process as follows:

> When only the surface value of perception is open to awareness, then the boundaries of the object are rigid and well-defined--the only qualities that are perceived are those which distinguish the object from the rest of the environment. However, when the unbounded awareness becomes established on the level of the conscious mind...then the perception naturally begins to appreciate deeper values of the object, until perception is so refined that the finest relative is capable of being spontaneously perceived on the gross, surface level (Maharishi, 1972, lesson 23).

Unity consciousness, the seventh state of consciousness, represents the highest stage of human development. In unity, the gap between subject and object is said to be fully bridged, and every object is perceived in terms of pure consciousness, the Self. Maharishi describes unity as follows:

> ...in that state, the ultimate value of the object, *infinite and unmanifest*, is made lively when the conscious mind, being lively in the unbounded value of awareness, falls on the object. The object is cognized in terms of the pure subjective value of unbounded, unmanifest awareness....In this unified state of consciousness, the experiencer and the object of experience have both been brought to the same level of infinite value, and this encompasses the entire phenomenon of perception and action as well. The gulf between the knower and the object of his knowing has been bridged....In this state, the full value of knowledge has been gained, and we *can* finally speak of complete knowledge (Maharishi, 1972, lesson 23, p.9)

In unity, the separation that remains between subject and object in refined cosmic consciousness is brought together and the individual is said to be capable of appreciating that the same consciousness which constitutes the basis of his/her subjectivity is the same dynamic basis of objective creation as well. Unity is the state of development at which human intelligence experiences itself to be identical to nature's intelligence. According to Vedic psychology, unity consciousness constitutes not only the endpoint of development, but the ultimate nature of reality, which exists independently of one's ability to appreciate it (Maharishi, 1972).

Alexander et al's. (1990) Vedic Psychological Life-Span Model

Alexander et al. (1990) suggest that while many developmental theorists postulate the end-point of human development to be a state of *unification* beyond abstract representational thought, the elaboration of this state is not clearly characterized. On the contrary, Vedic psychology delineates a distinct sequence of steps, reflected in the growth to higher states of consciousness, which provide complete unification of the individual and environment. As summarized by Alexander et al. (1990) the steps of unification are as follows:

> (1) temporary experience of a unified Self, which completely transcends the divisions between knower, known, and process of knowing (transcendental consciousness); (2) permanent maintenance of this internal unified Self along with the active, divided levels of mind and changing states of experience (cosmic consciousness); (3) appreciation of the finest value of the object, allowing profound intimacy or integration between Self and non-Self (refined cosmic consciousness); and ultimately, (4) experience of the unmanifest value of pure consciousness underlying and pervading all manifest values of mind and matter, resulting in complete unification of subject and object within the wholeness of the unified field of consciousness. (p. 323)

Alexander et al. (1990) discuss the model of levels of mind and higher states of consciousness in the context of a life-span developmental model. According to Alexander et al. (1990), the repeated process of fully transcending to the silent state of pure consciousness during TM is said to 1) normalize the nervous system, progressively freeing it from the deep-rooted stresses that block development, 2) lead simultaneously to a major functional reorganization of brain processes, and thus 3) "unfreeze" psychophysiological development, which otherwise typically becomes arrested in adolescence or early development.

Alexander et al. (1990) propose that higher stages of consciousness reflect the natural continuation (and culmination) of the developmental process and constitute a postrepresentational tier of development, differing at least as much from the representational tier (which includes postformal representational processes) as the latter does from the prerepresentational, early sensorimotor period. With reference to the model of adult cognition outlined by Perlmutter (1988), the developmental tiers associated with crystallized skills (tier 2) and synthesized skills (tier 3), though distinct, and clearly more adaptive in a developmental sense, remain within the representational domain of cognition. Alexander et al. (1990) propose that the "entire developmental continuum investigated by contemporary psychology--including hypothesized "postformal" stages (and consequently the higher tiers of Perlmutter (1988))--occurs within the psychophysiological confines of ordinary waking consciousness (Alexander & Boyer, 1989; Dillbeck & Alexander, 1989).

On the other hand, higher states of consciousness are said to be as qualitatively distinct from ordinary adult waking as waking is from the states of dreaming and sleep (Alexander et al., 1990). They are considered to meet the criteria for major qualitative advance because among other things, they constitute a "major hierarchical advance beyond the representational tier, because at this stage pure [transcendental] consciousness appears to be fully differentiated from and hierarchically integrated with even the most abstract representational processes involving the intellect, feeling, and ego (Alexander et al., 1990, p. 328)." As such, higher states of consciousness give theoretical and practical concreteness to Perlmutter's (1988) anticipated higher tiers of cognition, where for example, cognition and affect are highly integrated. In fact, recent research on ego development in long-term practitioners of TM has found a significant percentage of these subjects to be responding at the highest level of Loevinger's scale of ego development, characterized by balanced growth of affect and cognition and enhanced self-actualization, domains perhaps closely related to concepts such as wisdom (Chandler, 1990).

Figure 65 represents an attempt to integrate models of cognition (Welford, 1977), and theories of cognitive potential in adulthood (Perlmutter, 1988), in the context of Vedic psychology's model of levels of mind. The 4 main columns differentiated horizontally represent the major models: Vedic psychology's levels of mind, the experimental approach of cognitive psychophysiology (including common experimental factors manipulated and measures used to mark changes in those factors), Welford's (1977) stage model of human performance, and Perlmutter's model of cognitive potential across adulthood (Perlmutter, 1988).

With the exception of psychophysiological methodology, the vertical orientation of these models is intended to indicate that each can be characterized as having a distinct concrete to abstract dimension. As mentioned in the previous section a correspondence exists between levels of models and Welford's (1977) model of human performance. The computational levels of Vedic psychology's levels of mind map well onto Welford's computational stages and logically correspond to Perlmutter's tier 1 (fluid or mechanized abilities) level of cognition. Vedic psychology's storehouse of impressions, while not considered to be a level (said to exist at the deepest level of the mind), is placed at a more abstract level of mind, intended to correspond with Welford's long-term store, and Perlmutter's tier 2 (Crystallized abilities and world knowledge). At a more abstract level, Vedic psychology's ego level corresponds to Welford's diffuse activation system and Perlmutter's tier 3 (strategies and higher mental functions).

At each level of depth the psychophysiological methodology column represents the experimental variables that can be used to manipulate that level of psychological function and provides measures from cognitive psychophysiology which have been used to mark changes due to those manipulations. For example, in experiment 2 of this study, the experimental factor stimulus discriminability, associated with the encoding and stimulus evaluation stage of processing, was manipulated. Changes in RT and P300 latency, measures sensitive to this experimental factor, were used to index the timing of this stage of processing. A similar manipulation was conducted with the experimental factor stimulus-response compatibility. Changes in RT and P300 latency associated with this manipulation suggested that the response choice stage of processing was affected by this manipulation. A few examples are given for each level.

All the models are placed above Vedic psychology's most abstract level of mind, transcendental consciousness. As discussed transcendental consciousness is considered the deepest level of the mind, and as such, is fundamental to each of the models. Transcendental consciousness represents a psychophysiologically distinct state of deep physical rest, and ordered yet alert mental experience, characterized here as a state of zero entropy.

Within transcendental consciousness, the knower, known and process of knowing are said to be unified in one wholeness of consciousness. The different models can be viewed as representing a particular mode of this three-fold structure of knowledge. The knower (Rishi) is best represented by the theory of cognitive potential across adulthood expressed by Perlmutter (1988). The known (Chhandas) is represented by psychophysiological methodology, through which the processes of cognition become observable. Finally, the process of knowing (Devata) has natural correspondence with the information processing approach to cognition, the study of the processes of cognition, as reflected by the linear stage models (e.g. Welford, 1977). Transcendental consciousness also serves as a transition point, the experience of which leads to the development of higher states of consciousness.

Column 4 represents Perlmutter's (1988) model of cognitive potential across adulthood discussed above, Perlmutter's (1988). Perlmutter's tiers of cognition are depicted as a set of increasingly adaptive and complex functions which are built up and to a certain extent based upon previous tiers. However, tier 1 is outlined with a dotted line to represent the distinction made between tiers closely associated with biological function/health (tier 1) and psychologically based tiers which may have an important degree of autonomy from the known biological declines with age (tiers 2 and 3), and which consequently are open to unlimited growth throughout life.

This representation is intended to suggest that the models of levels of mind provide a useful framework in which to place models of cognition and cognitive potential throughout adulthood. In addition, this framework is useful for interpreting the results of this study.

Speed of Processing as an Important Marker of Higher States of Consciousness

What are the implications for preserved CNS processing speed in later adulthood with practice of TM? Having outlined the Vedic psychological model of cognition, both through the discussion of levels of mind and higher states of consciousness a final interpretation is possible.

The pivotal question is the following: for which cognitive domains is maintenance of optimal neurophysiological status critical? As Perlmutter (1988) has pointed out, an impressive range of psychological growth in adulthood can be considered relatively independent of slowing of the hardware of the nervous system. Perlmutter's model inspires a better appreciation of cognitive potential throughout adulthood. In addition, it lends itself to a natural extension through Vedic psychology's model of higher states of consciousness. However, for major qualitative shifts in cognitive development in adulthood associated with the growth of higher states of consciousness, Vedic psychology proposes that concomitant optimization of neurophysiological functioning is considered a prerequisite condition. In contrast, the tiers of cognition outlined by Perlmutter (1988) are capable of open-ended growth relative to the fluid abilities (tier 1) primarily because of their functional independence of age-related changes occurring in the physiology.

Figure 66 is intended to suggest a resolution to this apparent contradiction. It is proposed that those cognitive domains which Perlmutter (1988) associates with enhanced adaptive capacities based on extensive world knowledge (tier 2), and higher mental functions (tier 3), constitute what Vedic psychology would label the "relative" knower. As proposed by Perlmutter (1988), measures of these domains (crystallized abilities, formal operations, etc.) may show little correlation with measures intended to index the general state of physiological status of the adult, perhaps, speculatively, because these domains are not as dependent on the speed of information processing as much as on the association and synthesis of information.

In contrast, in the growth of higher states of consciousness, the individual knower must necessarily become increasingly accustomed to function from the level of transcendental consciousness, the "absolute" knower. These higher states of development are critically based on the ability of the nervous system to function at an optimal state of neurophysiological integration. As such, tier 1 processes associated with mechanized or fluid abilities, because of their dependence on neurophysiological status, would play a critical role in the development of higher states of consciousness. Consequently, not only is maintenance of these mental processing activities important for the growth of higher states of consciousness, but measures of the integrity of these functions could provide an important window into objectifying and characterizing these unique, yet elusive, states. Therefore, by extending Perlmutter's model to include tiers accommodating the growth of higher states of consciousness, the maintenance of CNS processing speed as an index of neurocognitive status, re-emphasizes the value of markers of CNS integrity, such as the P300 latency, as important indicators of the development of full cognitive potential in adulthood.

It is remarkable those levels of cognition most closely linked to the integrity of the CNS which have been considered outside the range of remedial intervention have been preserved in the TM subjects. This finding strongly suggests the experience of TM has a beneficial influence on basic CNS processing efficiency. Precisely how this relates to the development of higher states of consciousness and how such states can be adequately measured is still a matter of much research.

CONCLUSION

In conclusion, Transcendental Meditation has been found to be an important mediating influence in the negative consequences associated with aging of neurocognitive function. At a time when the elderly segment of society is rapidly growing, it is critical to find ways to preserve the quality of life in this, our wisest tier of humankind. The results of this study suggest that much attention in needed to assess the value of these ancient technologies which tap the inner resources of the mind and body. The results of this study speak to the insights of Cicero when he expressed that, "in truth you must not come to the aid of your body only, but much more to that of the mind and spirit." As such, this study provides steps toward building a comprehensive program of preventative interventions.

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APPENDIX A: CONTEXT UPDATING HYPOTHESIS OF DONCHIN AND COLLEAGUES (1986).

One theory of the significance of the P300 component has been put forth by Donchin and colleagues (e.g., Donchin, 1980; Donchin, & Coles, 1988; Donchin et al., 1986). Their theoretical interpretation of the P300 rests on the assumption that the neural activity contributing to the appearance of the potential on the scalp is involved in (is activated in connection with) a specific information processing sub-task or subroutine which is called upon to perform the task of updating the contextual aspects of working memory.

Donchin et al. (1986) state:

> In adopting this concept in the interpretation of the P300, we need concentrate on only one aspect of this Working Memory, namely that the system must continually update and revise this model. If Working Memory, or the Neuronal Model, is to be useful in the performance of the current task under current circumstances, then, even as tasks and circumstances change, so must the model change. Thus, it is plausible to assume that if such a Working Memory exists there must be a set of processes that maintain it. In other words, regardless of our view of the organization and processes that characterize Working Memory, we have to assume that its representations are continually revised. A context-updating process must be included in any system that is context-sensitive. We suggest that it is this updating process which is manifested by the P300.

APPENDIX B. HEALTH QUESTIONNAIRE

1. Do you presently engage in a regular physical activity exercise at least three times a week?

    1.a. Do you exercise with sufficient intensity to produce sweating?
    1.b. If yes, what exercise do you do?
    1.c. If no, have you engaged in regular physical exercise at least three times a week at any time during the past three years?
    1.d. If yes, what did you do? How long?
    1.e. If yes, why did you stop?

2. Are you able to drive a car?

3. When you travel around your community, does someone have to assist you because of your health?

4. Do you have to stay indoors most or all of the day because of your health?

5. Are you in bed or a chair for most or all of the day because of your health?

6. Does your health limit the kind of vigorous activities you can do, such as running, lifting heavy objects, or participating in strenuous sports?

7. Do you have trouble either walking a half mile (about 8 city blocks) or climbing a few flights of stairs because of your health?

    7.a. If yes, what prevents you from doing either or both?

8. Do you have trouble bending, lifting, or stooping because of your health?

9. Do you have any trouble either walking one block or climbing one flight of stairs because of your health?

10. Are you unable to walk unless you are assisted by another person or by a cane, crutches, artificial limbs, or braces?

11. Has a doctor or other health professional ever told you that you had:

    a. A heart attack or myocardial infarction
    b. A stroke
    c. Diabetes for which you now take injections of insulin
    d. Chronic bronchitis or emphasema

12. Are you currently taking any medications prescribed by a physician?

YES NO

13. What medications are you taking and for what reasons?

List:

Names of medication:	Reason:
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

14. How much difficulty, if any, do you have pulling or pushing large objects like a living room chair?

Please check the BEST answer:

1. No difficulty at all
2. A little difficulty
3. Some difficulty
4. A lot of difficulty
5. I just can't do it
6. Don't know

15. What about stooping down, crouching or kneeling? How much difficulty do you have?

Please check the BEST answer:

1. No difficulty at all
2. A little difficulty
3. Some difficulty
4. A lot of difficulty
5. I just can't do it
6. Don't know

16. Lifting or carrying weights under 10 pounds like a small bag of potatoes. How much difficulty would you have doing that?

Please check the BEST answer:

1. No difficulty at all
2. A little difficulty
3. Some difficulty
4. A lot of difficulty
5. I just can't do it
6. Don't know

17. Reaching for things or extending your arms above shoulder level. How much difficulty would you say you have?

Please check the BEST answer:

1. No difficulty at all
2. A little difficulty
3. Some difficulty
4. A lot of difficulty
5. I just can't do it
6. Don't know

18. Writing or handling small objects like picking up coins on a table. How much difficulty would you have with this?

Please check the BEST answer:

1. No difficulty at all
2. A little difficulty
3. Some difficulty
4. A lot of difficulty
5. I just can't do it
6. Don't know

19. Are you able to go shopping for groceries?

Please check the BEST answer:

1. Without help
2. With some help
3. Completely unable

20. Can you prepare your own meals?

Please check the BEST answer:

1. Without help
2. With some help
3. Completely unable

21. Can you do your own laundry?

Please check the BEST answer:

1. Without help
2. With some help
3. Completely unable

22. Can you do your own housework?

Please check the BEST answer:

1. Without help
2. With some help
3. Completely unable

23. Can you do your own handywork around the house?

Please check the BEST answer:

1. Without help
2. With some help
3. Completely unable

Have you ever been told by a doctor, nurse or health professional that you have any of the following medical conditions:

	this month	this year	over a year ago
24. Heart valve problems or murmurs?			
25. An abnormal ECG or electrocardiogram?			
26. Gout, gouty arthritis or high uric acid level?			
27. Irregular heart beat?			
28. Congestive heart failure, weak heart, heart failure, or an enlarged heart?			
29. Any other type of heart trouble?			
30. Hardening of the arteries or arteriosclerosis?			
31. Paralysis of any kind?			
32. Curvature of the spine?			
33. Pleurisy?			
34. Tuberculosis?			
35. Varicose veins or phlebitis?			
36. Gallstones or gall bladder disease?			
37. Disease of the pancreas?			
38. Missing limbs, digits or amputation?			
39. Goiter, low thyroid, high thyroid or thyroid trouble?			

40. Low blood pressure or frequent fainting spells?

41. Diverticulitis, diverticulosis, or problems with the large bowel?

42. Malabsorption?

43. High blood cholesterol, high blood fats, or hyperlipidemia?

44. Weakness of the bone, osteoporosis, brittle bones or low calcium?

45. Pneumonia, lung infections, or lung abscess?

Have you experienced any of the following problems or health-related complaints:

within past month within past year

46. Chest pain or pressure or a squeezing feeling in the chest which came on during exercise or walking any other physical or sexual activity?

47. Palpitations or fluttering in the chest?

48. Fainting of loss of consciousness?

49. Shortness of breath at night when lying in bed?

50. Pain or cramping in the legs during walking?

51. Dizziness?

52. Balance problems?
53. Excessive forgetfulness?

54. Pain, aching, swelling or stiffness of the joints?

55. Weight loss or gain of more than 20 pounds in the past six months?

56. Regular headaches (at least one a day)

57. Heavy cough?

58. Frequent cough?

59. Weakness or paralysis?

60. Tingling or numbness of the skin?

61. Excessive tiredness or fatigue?

62. Do you have tightness or a pressing pain in the chest if you climb a few flights of stairs rapidly?

63. Do you ever get pressure or pain or tightness in the chest if you walk in the cold wind or get a cold blast of air?

Now, you will be asked two questions about how you view your own general state of health. Please think about the answers carefully and answer these questions as best you can:

1. How would you rate your health at the present time?

Please check the BEST answer:

1. Excellent
2. Good
3. Fair
4. Poor
5. Don't know

2. Has there been a change in your health over the past year?

Please check the BEST answer:

1. Yes, improved: my health is better better than it was.
2. Yes, my health is worse than it was.
3. No, my health is about the same.
4. Don't know.

APPENDIX C. EXPERIMENTAL EVIDENCE IDENTIFYING UNIQUE CHARACTERISTICS OF TRANSCENDENTAL CONSCIOUSNESS DURING THE TM TECHNIQUE (DILLBECK, 1988)

1. Decreased respiration rate and minute ventilation during Transcendental Meditation, and respiratory suspension during periods of transcendental consciousness (Badawi, Wallace, Orme-Johnson, & Rouzere, 1984; Dillbeck & Orme-Johnson, 1987; Farrow & Hebert, 1982; Wallace et al., 1971)

2. Increased basal skin resistance during Transcendental Meditation and during periods of transcendental consciousness (Dillbeck & Orme-Johnson, 1987; Farrow & Hebert, 1982; Wallace et al., 1971)

3. Reduction in biochemical indices of stress during Transcendental Meditation (Dillbeck & Orme-Johnson, 1987; Jevning, Wilson, & Davidson, 1978; Jevning, Wilson, O'Halloran, & Walsh, 1983; Wallace et al., 1971)

4. Increased EEG alpha activity in frontal and central regions and increased EEG synchrony and coherence during Transcendental Meditation, increased EEG coherence during periods of transcendental consciousness (Banquet, 1973; Banquet & Sailhan, 1974; Dillbeck & Bronson, 1981; Farrow & Hebert, 1982; Wallace, et al., 1971)

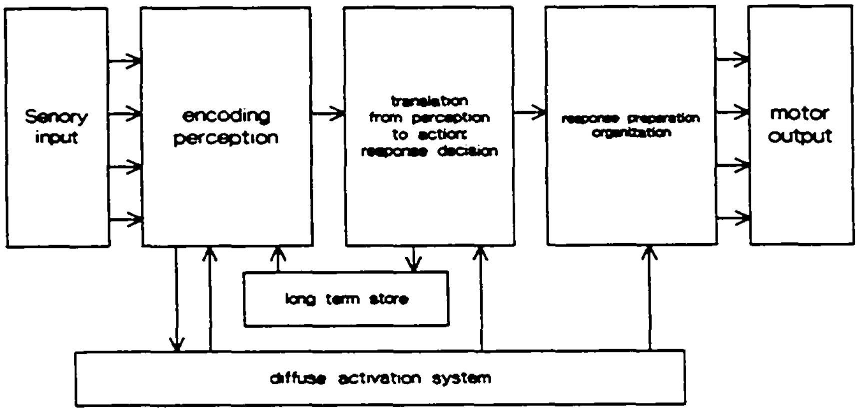


Figure 1. A simplified version of Welford's (1977) model of human performance. Perceptual mechanisms perform a coordinated analysis with sensory data and data from memory stores. Processed data is fed to translation mechanisms which compute an action by triggering a decision and computing a response. Orders are passed to a central effector mechanism which programs a sequence of muscular actions to execute them. The diffuse activation system has connections to all main central stages, regulating the general level of activation and responsivity of the system.

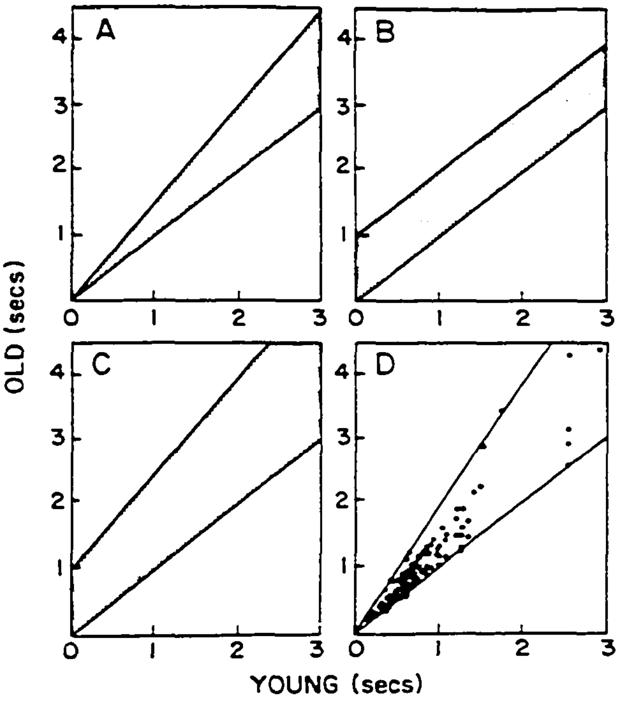


Figure 2. Three hypothesized patterns of results discussed by Cerella (1985) for the meta-analyses of reaction time (RT) in which values for the old are regressed against those of the young. (On the ordinate of each graph is the RT of the old and on the abscissa is the RT of the young [in seconds]). The lines in each graph represent the limits of the space defined by the postulated functions, with the bottom line identifying the diagonal on which changes in RT are compatible for the two groups across tasks of increasing complexity. The scatter of points are distributed equally throughout the space. Shown in panel A is the multiplicative function, in panel B the additive function, in panel C the general linear function, and in panel D the actual distribution of points from the studies analyzed by Cerella, 1985. (reproduced from Bashore, 1990).

```
######
######
##LEFT
######
```

```
KWSMNT
UYRMUD
VTFMZS
ILEFTA
 (A-Z)
```

Figure 3. Stimuli used by McCarthy and Donchin (1981) in which the word "LEFT" or "RIGHT" appeared embedded in varying degrees of noise. # symbols represented the no-noise condition and letters chosen from the alphabet (A-Z) constituted the noise condition.

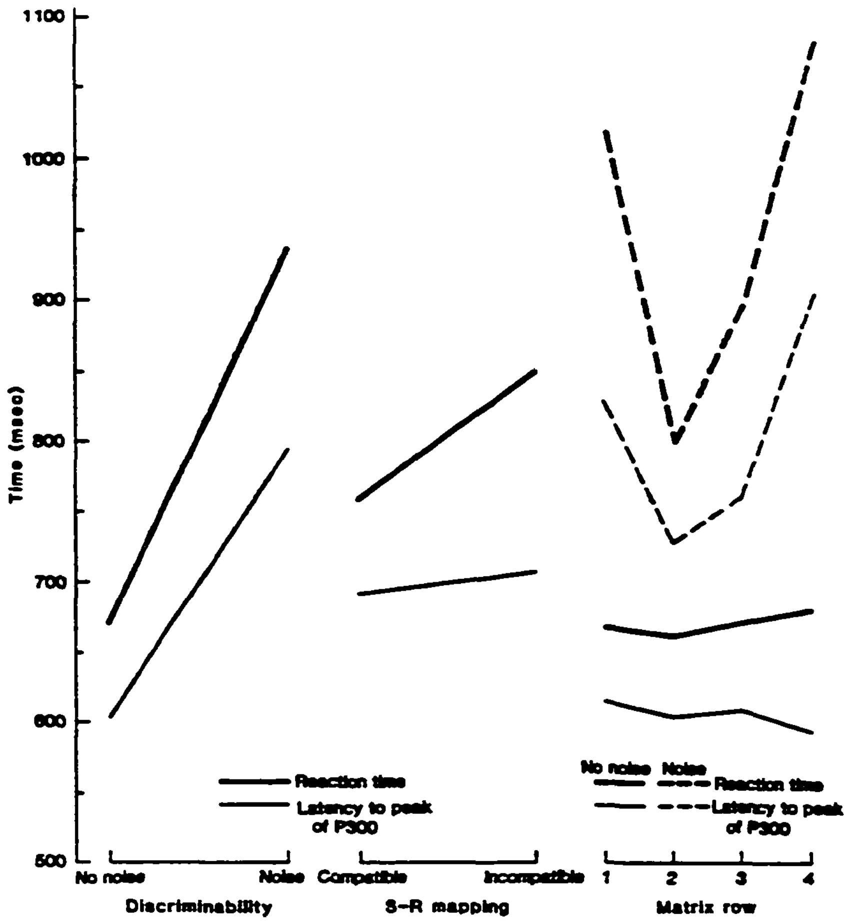
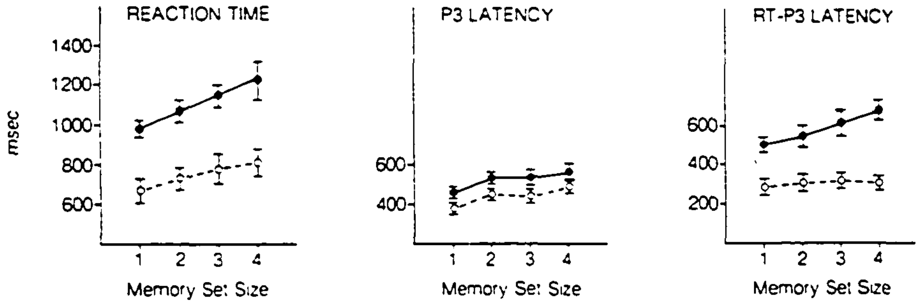


Figure 4. Results of McCarthy and Donchin (1981) for mean RT (thick lines) and P300 latencies obtained from single trial measurement (thin lines) for each experimental factor. The main effects of discriminability condition are shown in the left panel. The main effects of S-R compatibility are shown in the middle panel. The interaction of discriminability an matrix row is depicted in the right panel.



	Slope	Intercept	Slope	Intercept	Slope	Intercept
OLD	80.5 msec/digit	905 msec	27.5 msec/digit	444 msec	53.1 msec/digit	460 msec
YOUNG	43.2 msec/digit	645 msec	27.4 msec/digit	373 msec	15.7 msec/digit	271 msec
	t=3.94, p<.05	t=2.86, p<.05	t= 005, n.s	t=2.57, p<.05	t=2.79, p<.05	t=2.57, p<.05

OLD ●——●
YOUNG ○- - -○

Figure 5. RT, P300 latency, and RT–P300 latency data from the Ford et al. (1979) study of Sternberg memory scanning. Below each figure is a list of the slope and intercept values for the function in old and young subjects. The t-test value is for comparisons of the two groups on the function.

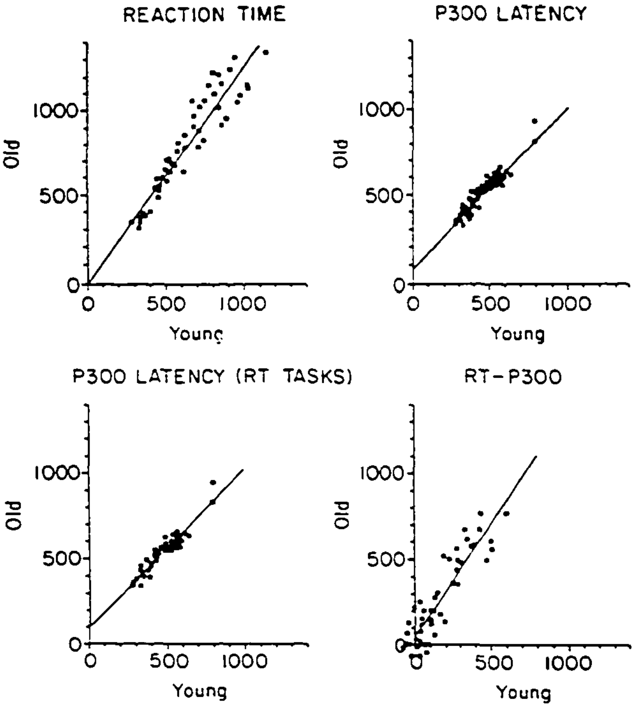


Figure 6. Scatter plot for the regression analyses by Bashore et al. (1989). Each point represents the coordinate of the mean values for the young and the old subjects in an individual experimental condition. The solid line is the calculated regression. Time is given in milliseconds. (Upper left) The derived regression functions for the RT data. (Upper right) The P300 latency data across all experimental conditions. (Lower left) The P300 latency data when manual responses were made. (Lower right) The RT—P300 latency data.

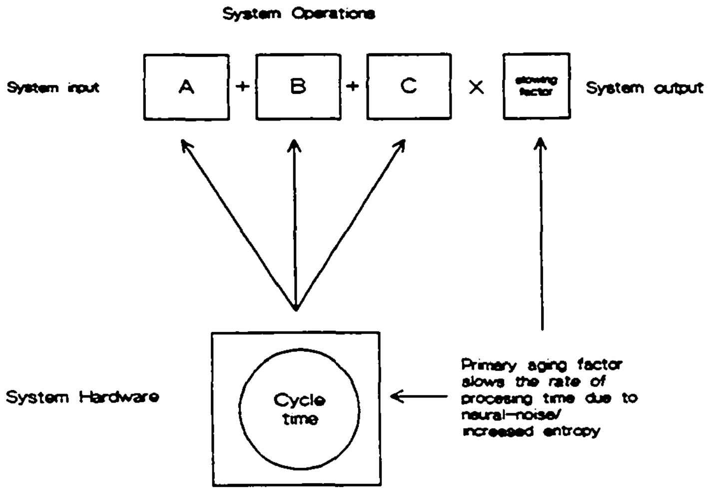


Figure 7. The "cycle time" theory of age-related slowing. Using the computer metaphor, CNS processing rate is analogous to CPU cycle time, with timing of all system operations (e.g. A, B and C) determined by this rate. The effect of age is hypothesized to affect the rate of the CPU, resulting in a constant proportional increase in system response time in direct relation to number of operations performed (the "complexity effect").

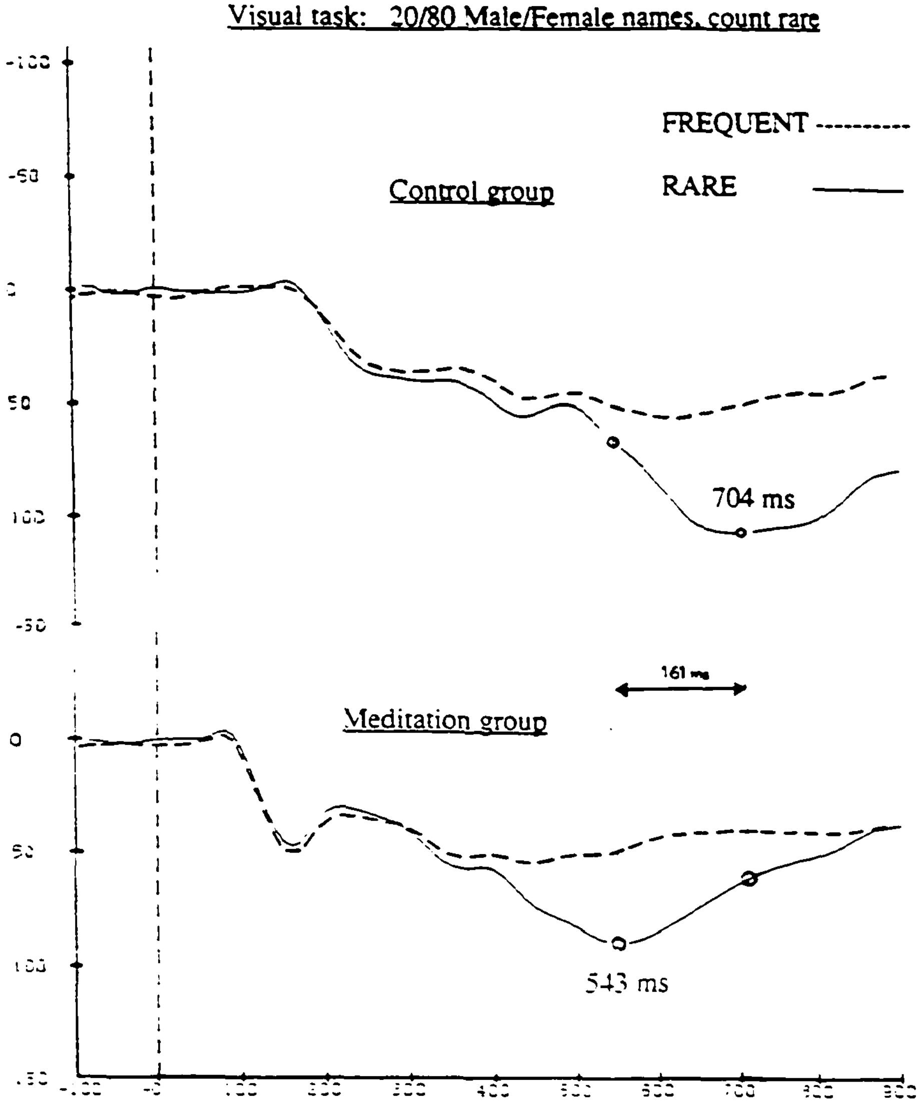


Figure 8. Average ERPs at PZ for older TM and older non-meditating subjects in a visual oddball task. Time in milliseconds in represented on the X axis and digitizer counts is represented on the Y axis (100 counts = 8 microvolts). 0 time represents stimulus onset. Dotted line represents the frequent stimulus (female names, probability 80 %) and solid line represents the rare stimulus (male names, probability 20 %). Positive voltages for this and all figures is plotted down. Note the earlier peak of the positivity in the TM group (lower panel) compared to the non-TM group.

Auditory task: 20/80 Hi/low tone, CRT

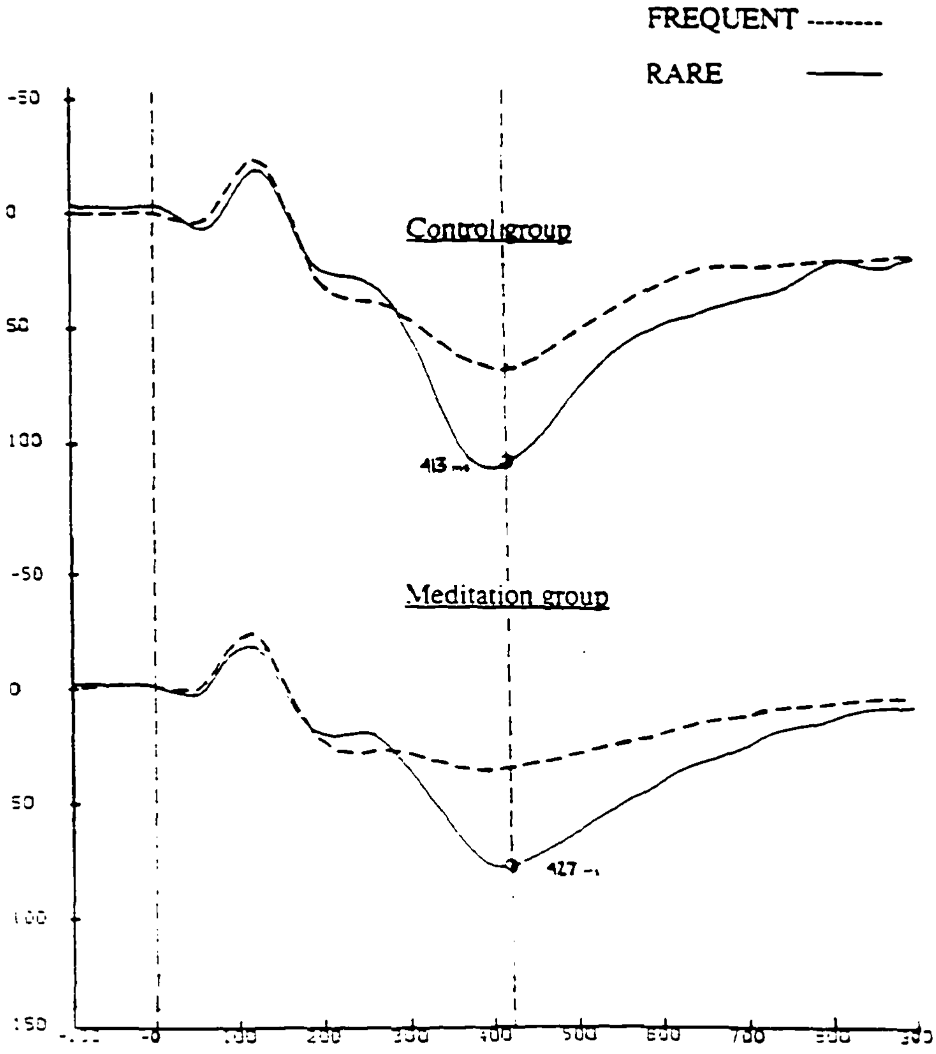


Figure 9. Average ERPs at PZ for older TM and older non-meditating subjects in an auditory CRT oddball task. Time in milliseconds in represented on the X axis and digitizer counts is represented on the Y axis (100 counts = 8 microvolts). 0 time represents stimulus onset. Dotted line represents the frequent stimulus (low tone, probability 80 %) and solid line represents the rare stimulus (high tone, probability 20 %).

#'s condition	X	X	X	X	X	X
	X	L	E	F	T	X
	X	X	X	X	X	X
	X	X	X	X	X	X
A–G condition	B	C	F	G	A	I
	F	L	E	F	T	A
	B	C	E	A	C	E
	G	F	E	A	C	B
A–Z condition	V	R	T	S	O	T
	J	L	E	F	T	O
	O	P	I	O	C	E
	D	E	Q	E	Z	R

Figure 10. Reproduction of matrices of stimuli used in Experiment 2. Discriminability level 1 is shown in top panel (#'s condition), level 2 in the middel panel (A–G condition), and level 3 is shown in the bottom panel (A–Z). All 3 levels display the word "LEFT" for consistency, though "RIGHT" was presented with equal probability and randomly in different rows.

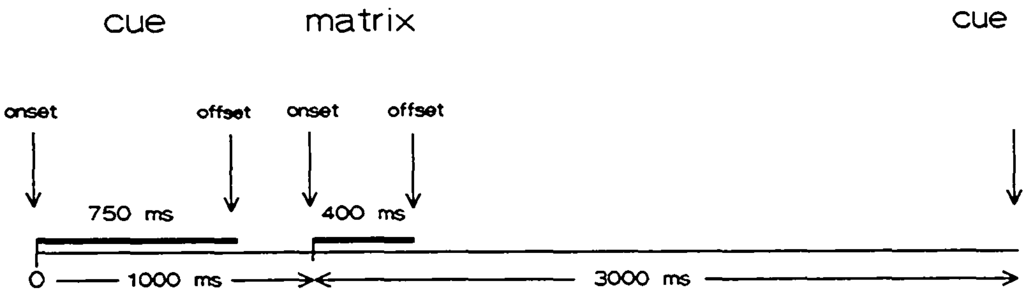


Figure 11. Schematic representation of the recording epoch for a single trial. EEG was digitized continuously throughout the block of trials while the stimulus presentation system marked periods where critical events occurred.

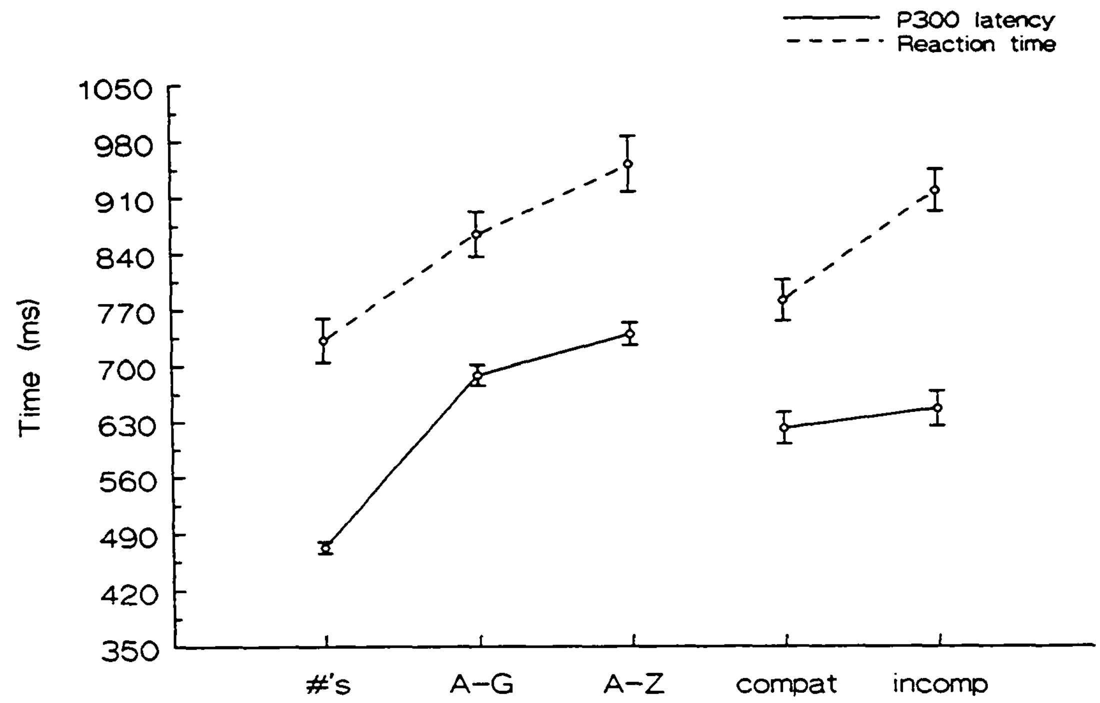


Figure 12. The mean reaction times (dashed lines) and P300 latencies (solid lines) obtained from single-trial measurement for each experimental factor. The main effects of discriminability condition are shown in the left panel (#'s, A-G, and A-Z). The main effects of S-R compatibility are shown in the right panel (compatible vs. incompatible). In this and all figures that follow vertical bars represent error bars.

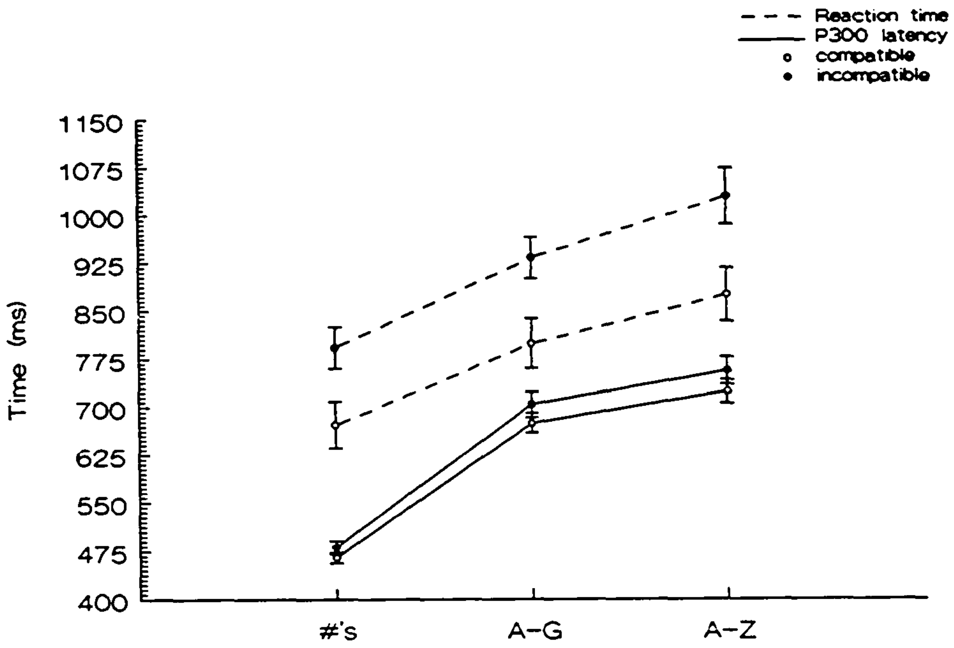


Figure 13. The mean RT (dashed line) and P300 latency obtained from single trial measurement (solid line) for young subjects (n=12) as a function of the interaction between discriminability (#'s, A-G, and A-Z) and S-R compatibility (compatible) (open mark) and incompatible (closed mark)). In this and all following figures vertical bars represent error bars.

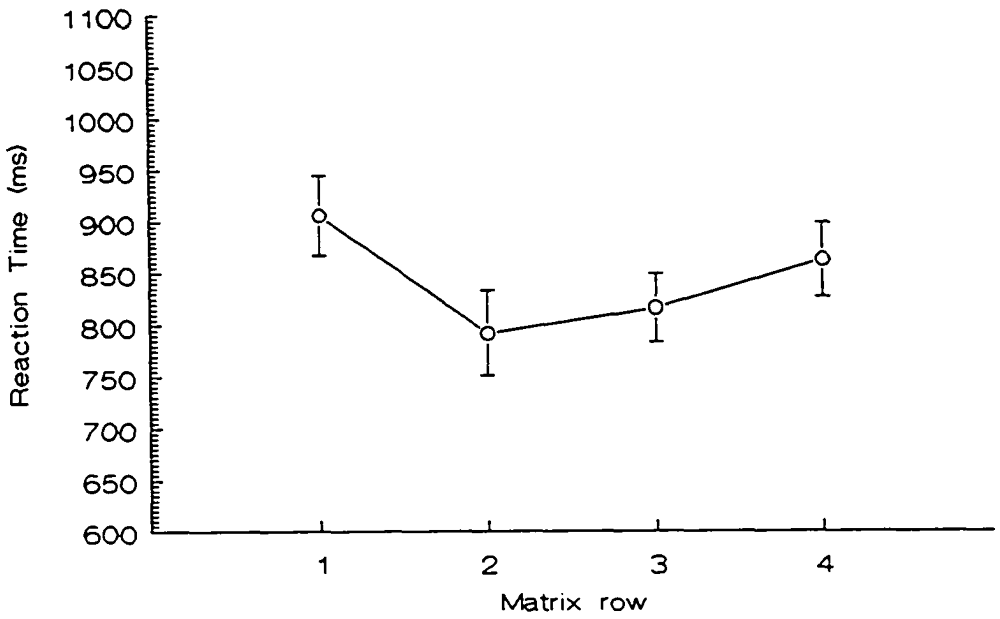


Figure 14. Reaction time for young subjects (n = 12) as a function target word position. Note RT increases when the target word appears in the top row (1) and in the bottom row (4) relative to the middle two rows (2 and 3). RT is collapsed across the two main factors of discriminability and S–R compatibility.

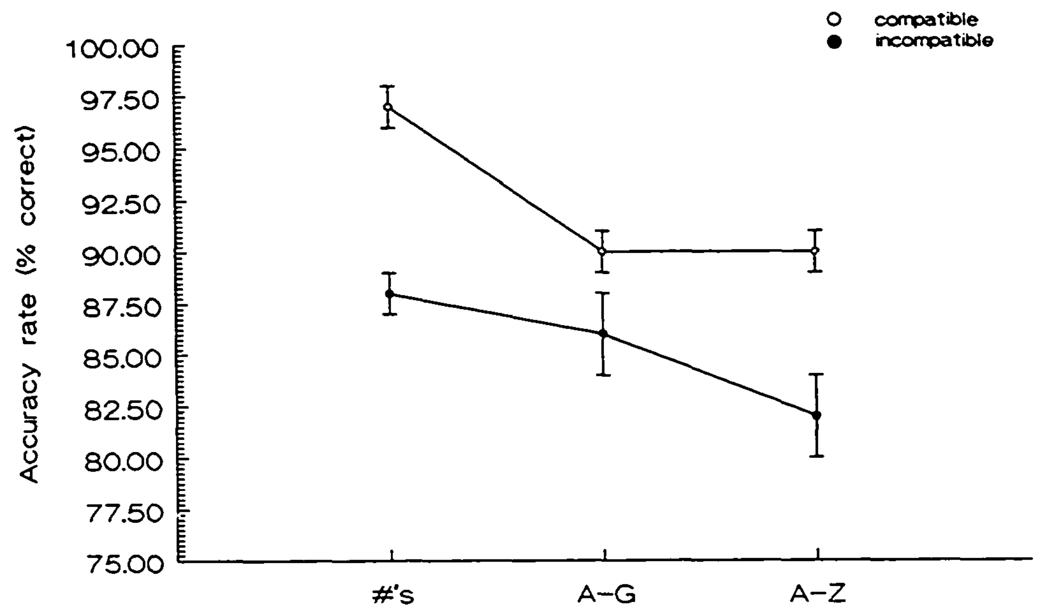


Figure 15. Accuracy rate (% correct) for young subjects (n=12) as a function of discriminability (#'s, A-G, and A-Z) and S-R compatibility (compatible (open mark) and incompatible (closed mark)).

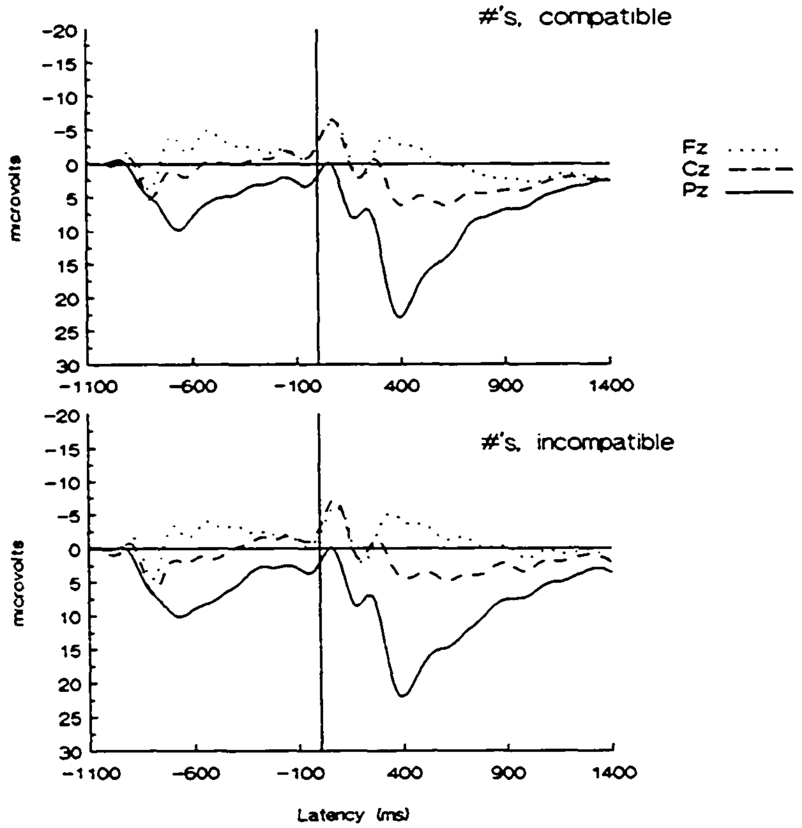


Figure 16. Average ERPs for young subjects (n=12) at Fz, Cz, and Pz in the #'s discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

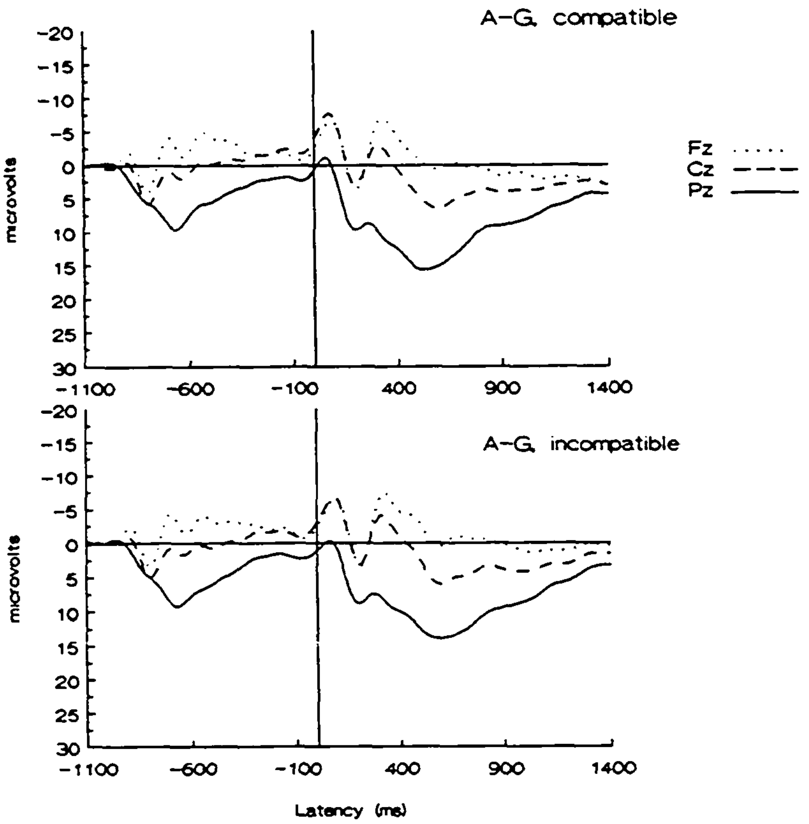


Figure 17. Average ERPs for young subjects (n=12) at Fz, Cz, and Pz in the #'s discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

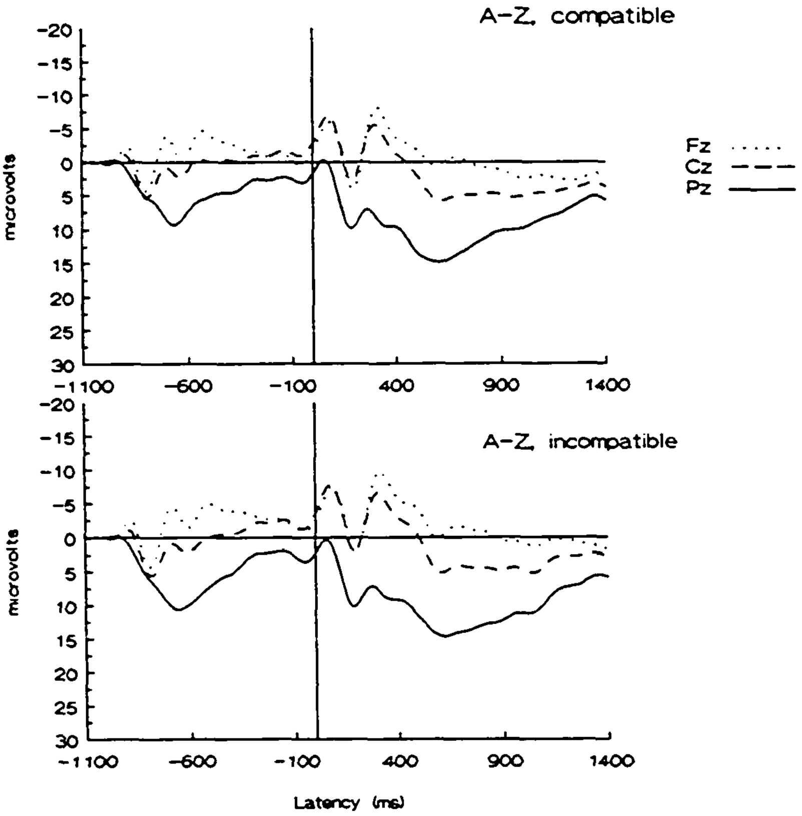


Figure 18. Average ERPs for young subjects (n=12) at Fz, Cz, and Pz in the A-Z discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

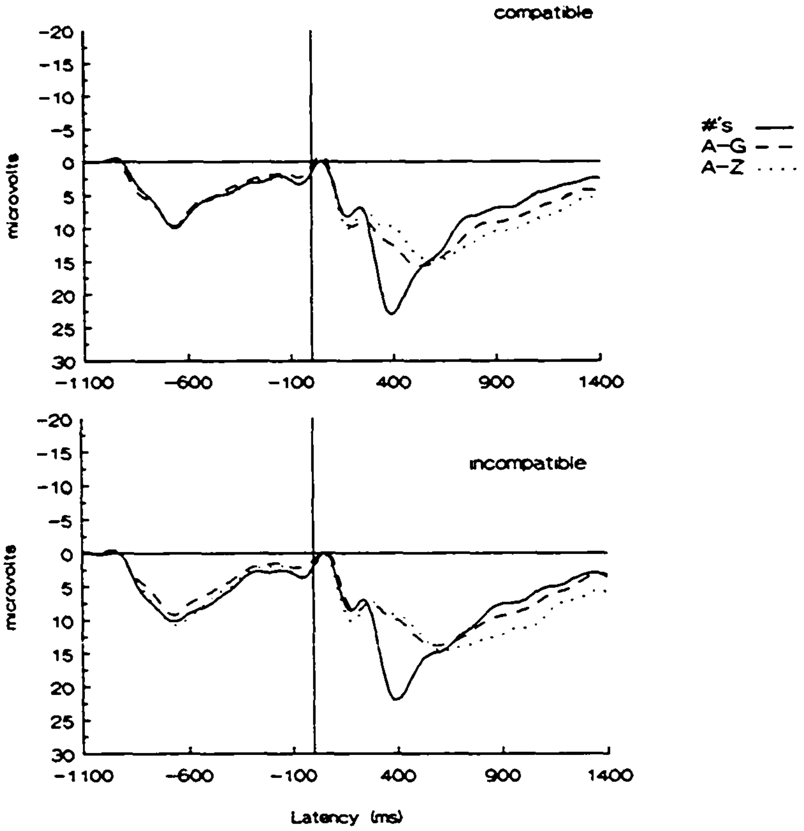


Figure 19. Average ERPs at Pz for young subjects (n=12) as a function of discriminability (#'s, A-G, and A-Z) for the compatible response (top) and incompatible response (bottom) conditions. Y-axis represents cue onset and vertical mark at time point 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

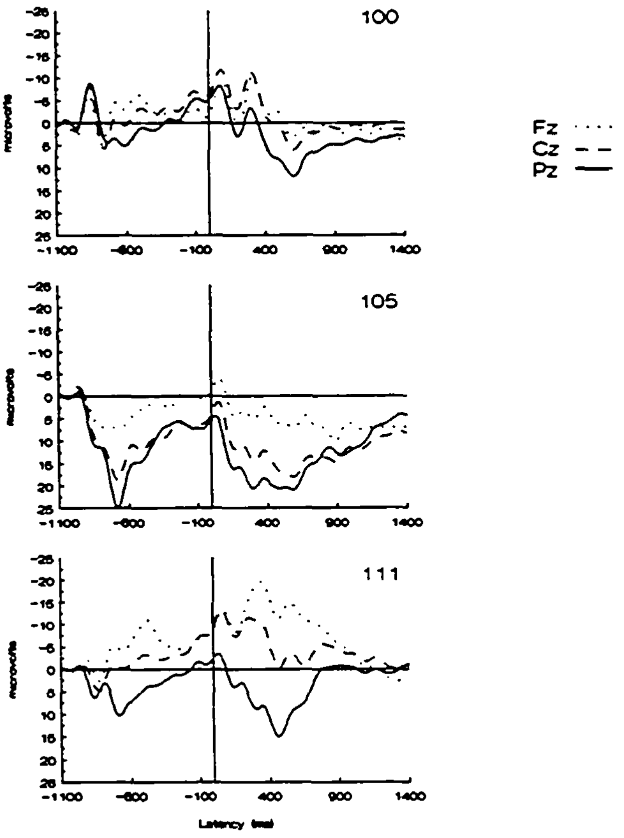


Figure 20. ERP averages at Fz, Cz, and Pz for individual subjects in the A–G discriminability condition requiring a compatible response. Signals are eye-movement corrected and digitally filtered.

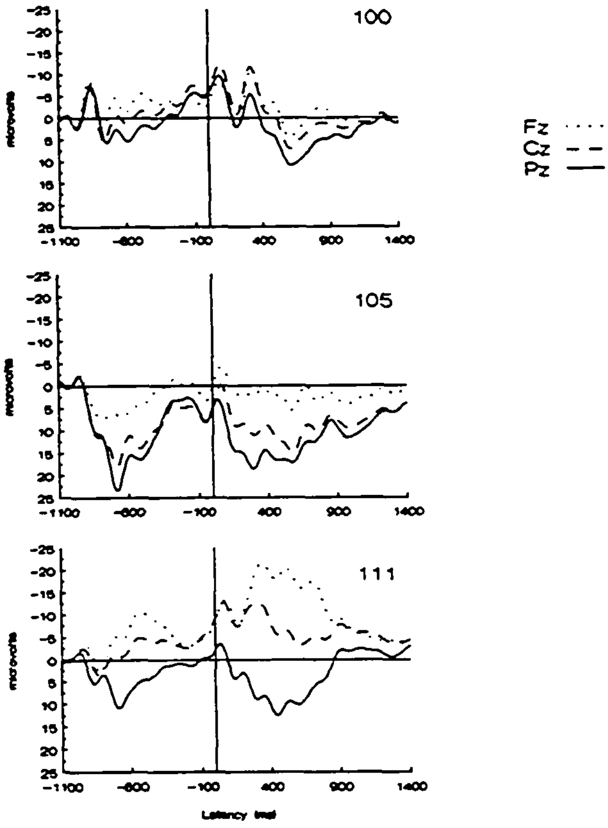


Figure 21. ERP averages at Fz, Cz, and Pz for individual subjects in the A–G discriminability condition requiring an incompatible response. Signals are eye-movement corrected and digitally filtered.

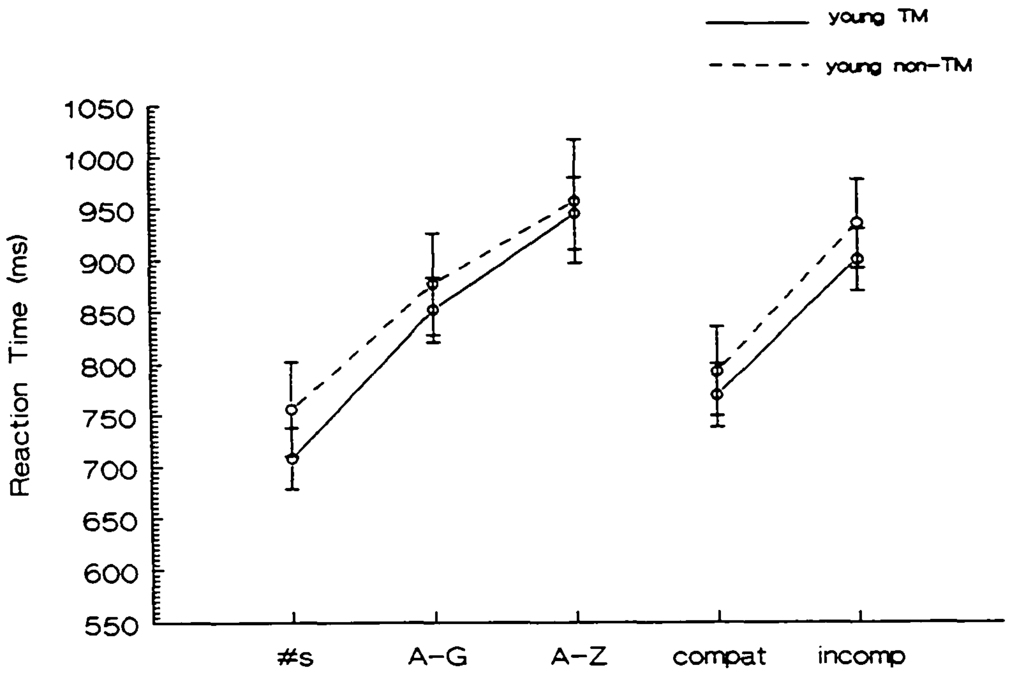


Figure 22. Reaction time for young TM (n=6); solid line) and young non-TM (n=6; dashed line) as a function of stimulus discriminability (#'s, A-G, and A-Z; left panel) and S-R compatibility (compatible and incompatible; right panel).

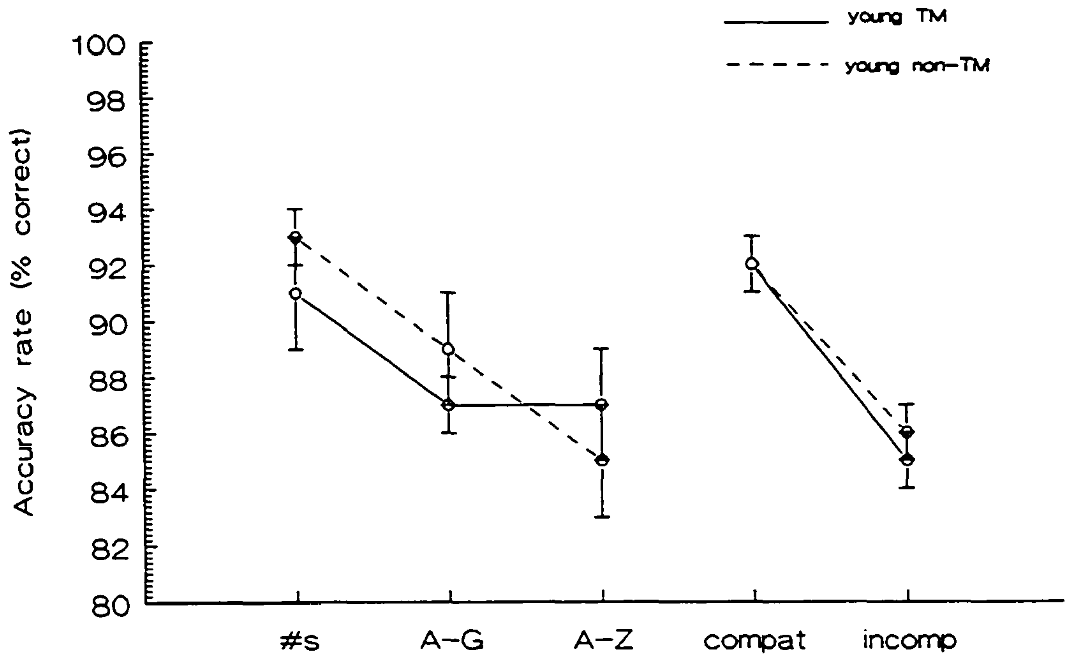


Figure 23. Accuracy rate for young TM (n=6; solid line) and young non-TM (n=6; dashed line) as a function of stimulus discriminability (#'s, A-G, and A-Z; left panel) and S-R compatibility (compatible and incompatible; right panel).

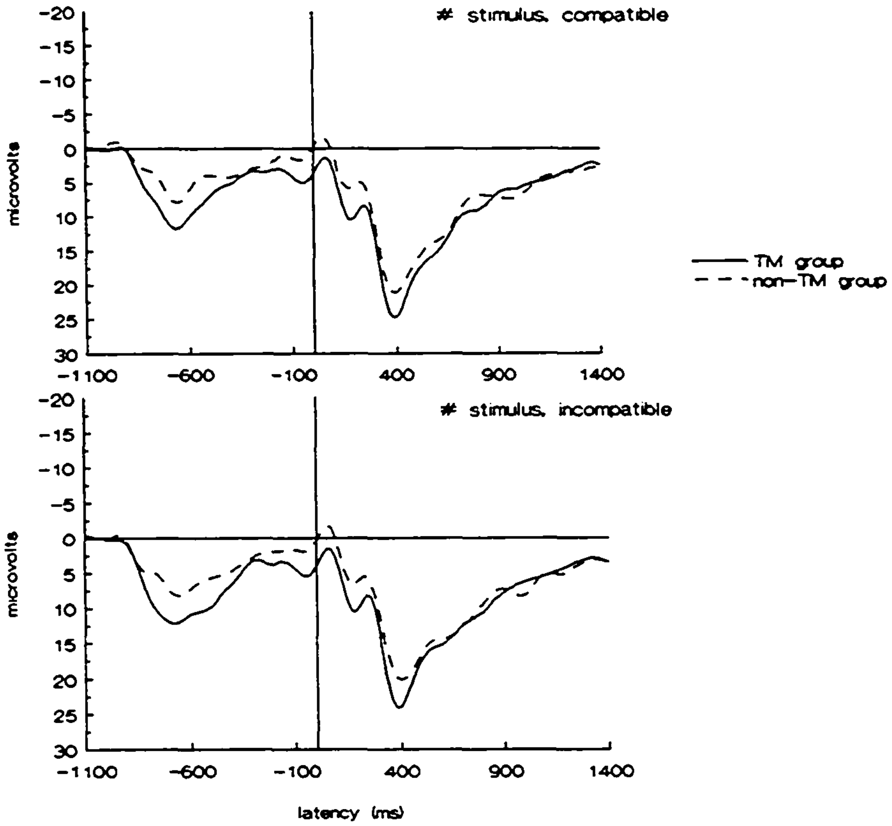


Figure 24. Average ERPs at Pz for young TM (n=6) and non-TM subjects (n=6) at #'s discriminability level for both the compatible (top) and incompatible (bottom) responses. Y-axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

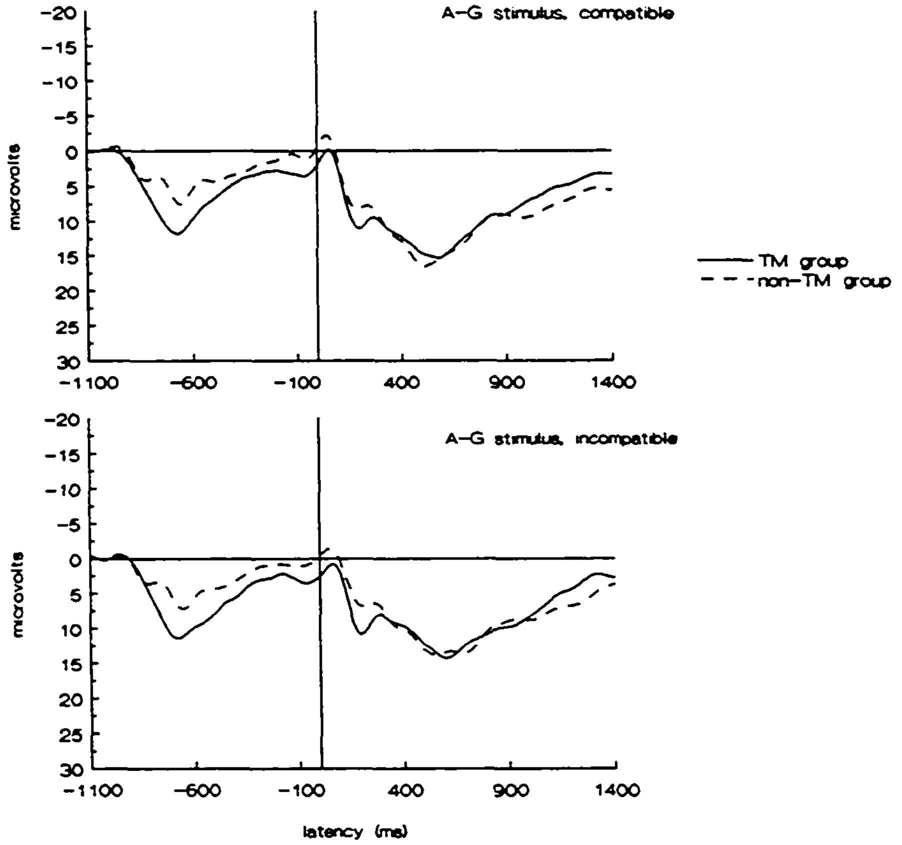


Figure 25. Average ERPs at Pz for young TM (n=6) and non–TM subjects (n=6) at A–G discriminability level for both the compatible (top) and incompatible (bottom) responses. Y–axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

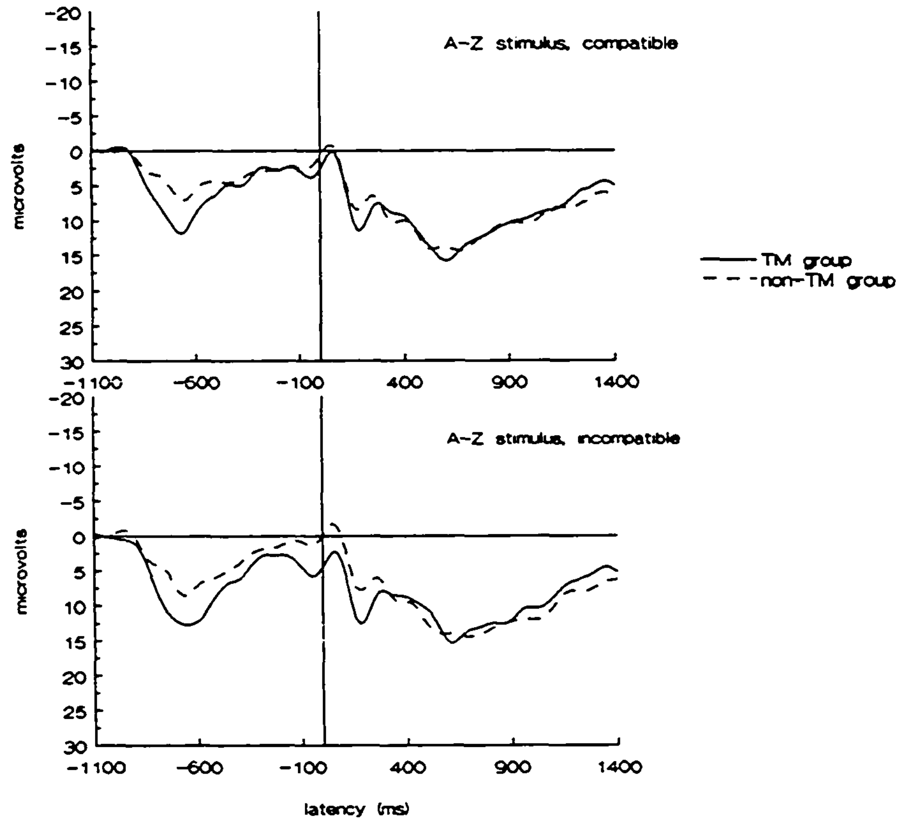


Figure 26. Average ERPs at Pz for young TM (n=6) and non-TM subjects (n=6) at A-Z discriminability level for both the compatible (top) and incompatible (bottom) responses. Y-axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

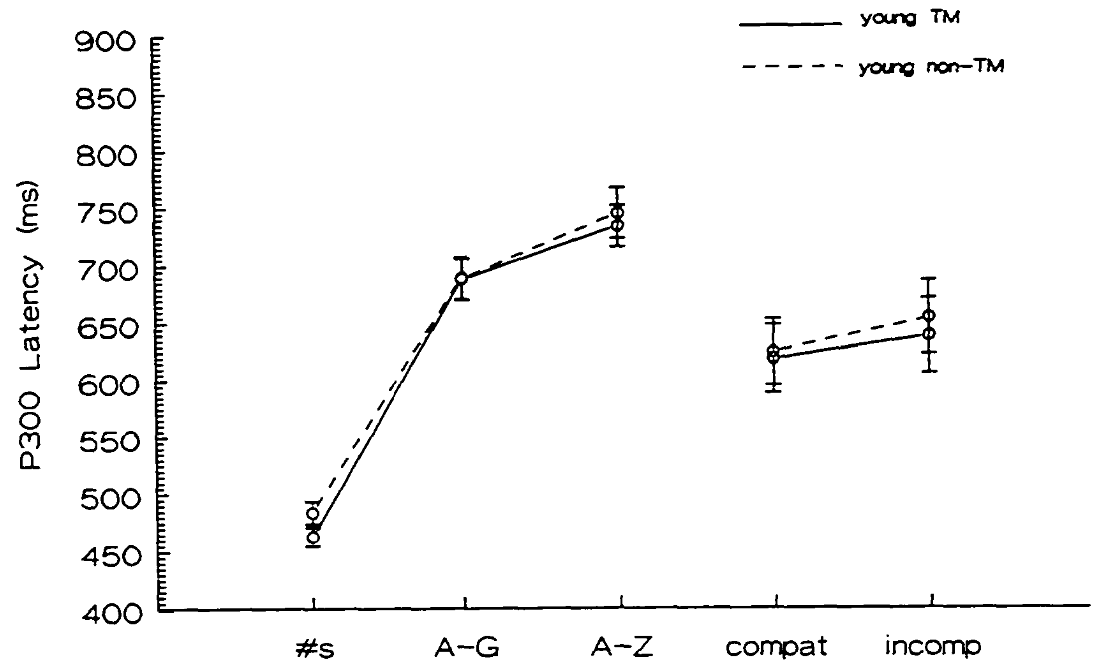


Figure 27. P300 latency for young TM (n=6; solid line) and young non-TM (n=6; dashed line) as a function of stimulus discriminability (#'s, A-G, and A-Z; left panel) and S-R compatibility (compatible and incompatible; right panel).

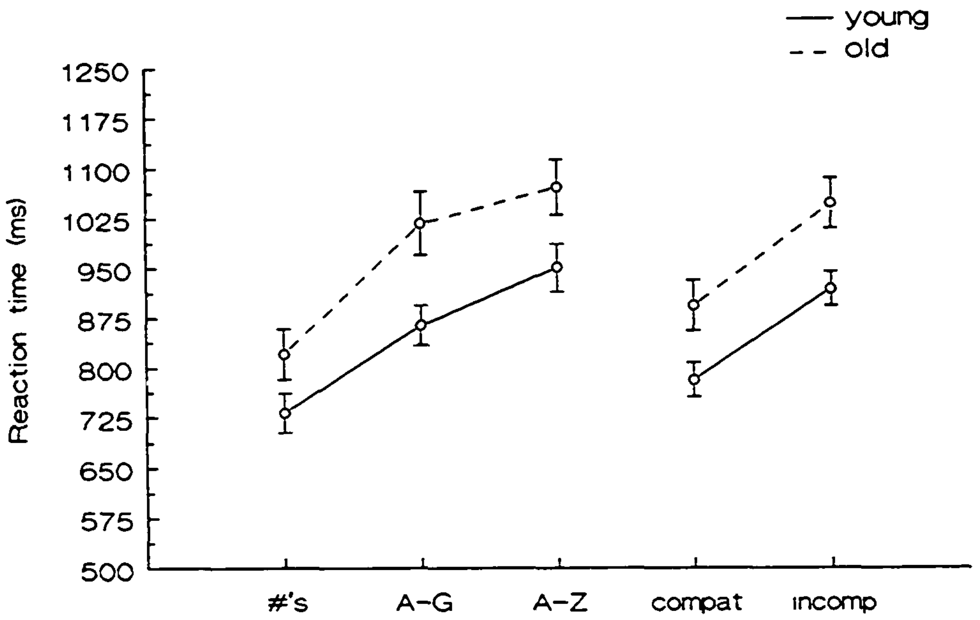


Figure 28. Reaction time for young (n=12) and old (n=10) subjects plotted as a function of the main effects of stimulus discriminability and S-R compatibility. Young subjects are represented by the solid line and old subjects by the dashed line.

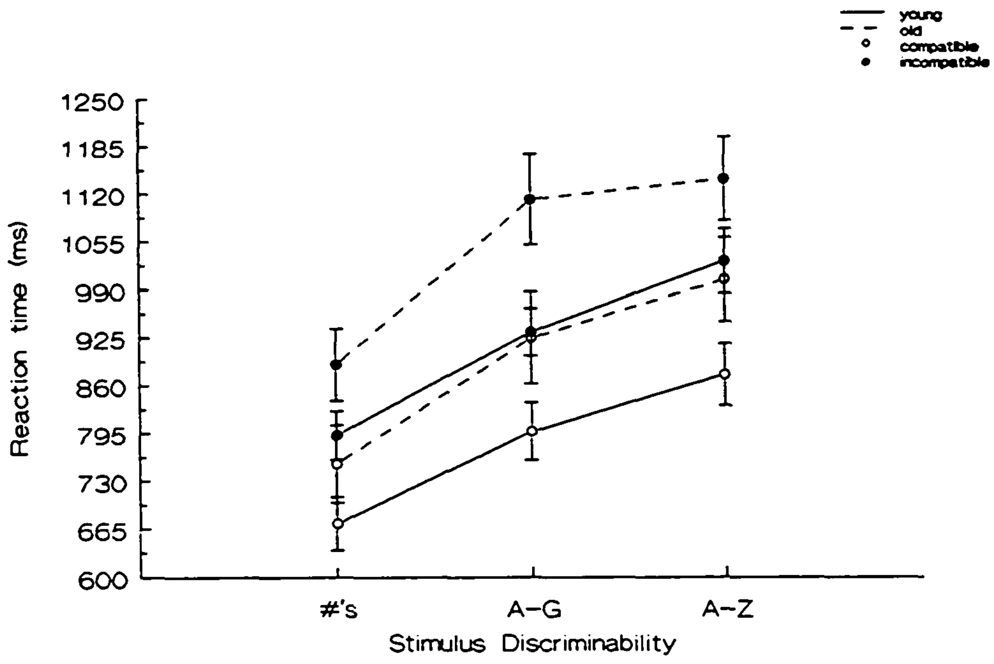


Figure 29. Reaction time for young (n=12) and old (n=10) subjects as a function of the interaction between stimulus discriminability (#'s, A-G, A-Z) and S-R compatibility (compatible (open mark) vs. incompatible (closed mark)).

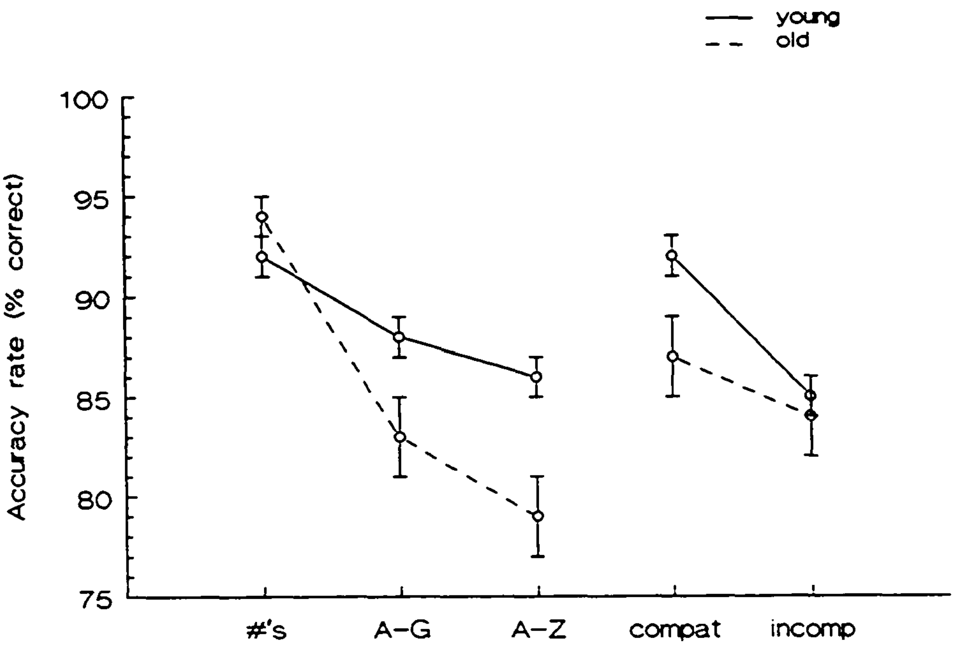


Figure 30. Accuracy rate (% correct) for young (n=12) and old (n=10) subjects plotted as a function of the main effects of stimulus discriminability and S-R compatibility. Young subjects are represented by the solid line and old subjects by the dashed line.

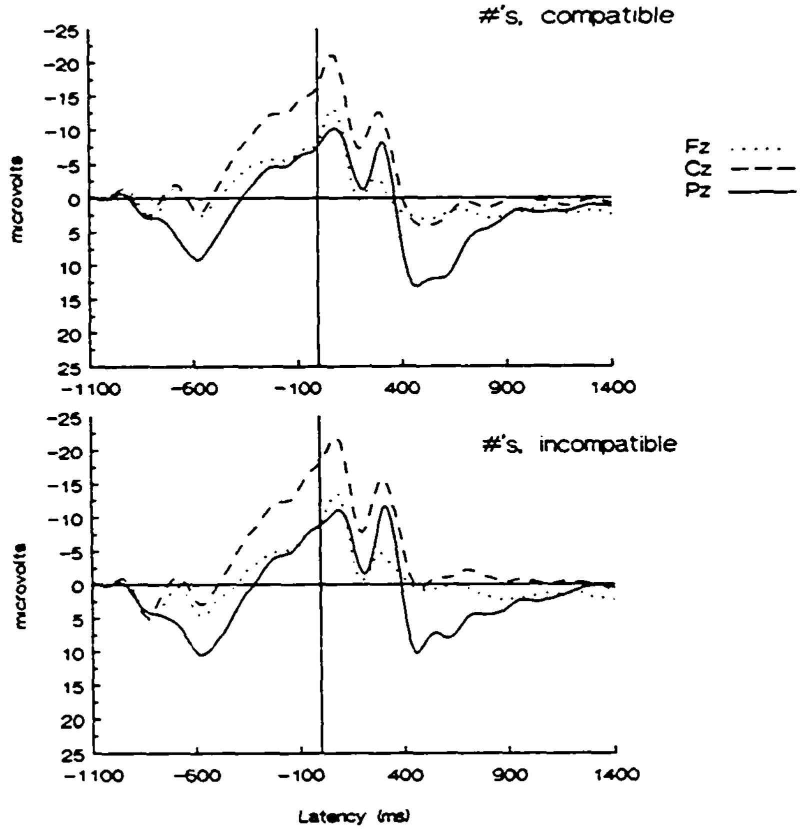


Figure 31. Average ERPs for old subjects (n=10) at Fz, Cz, and Pz in the #'s discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

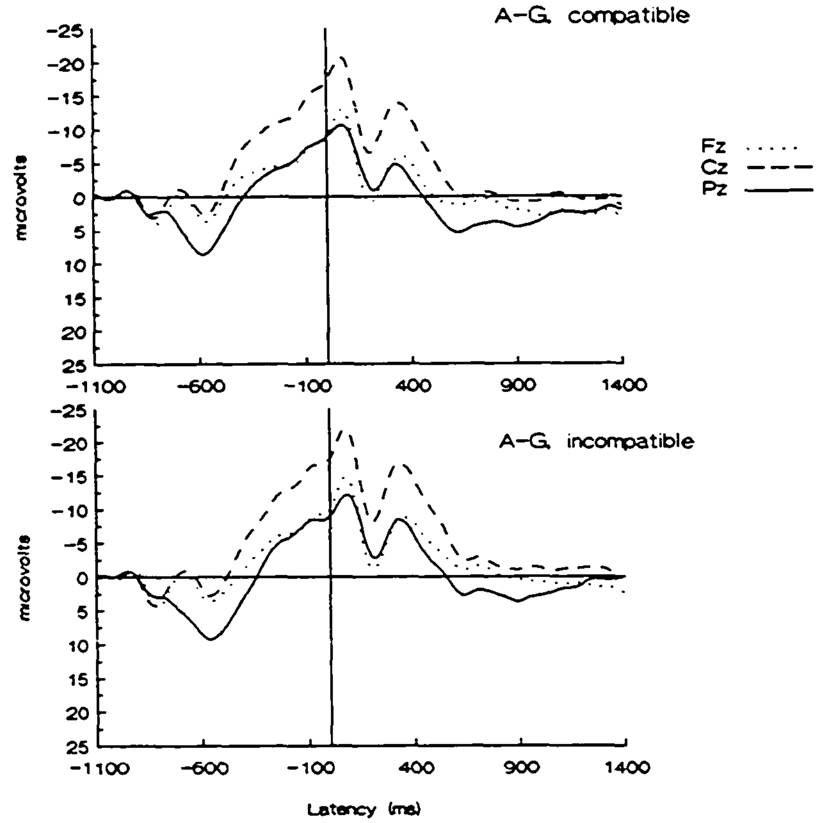


Figure 32. Average ERPs for old subjects (n=10) at Fz, Cz, and Pz in the A-G discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

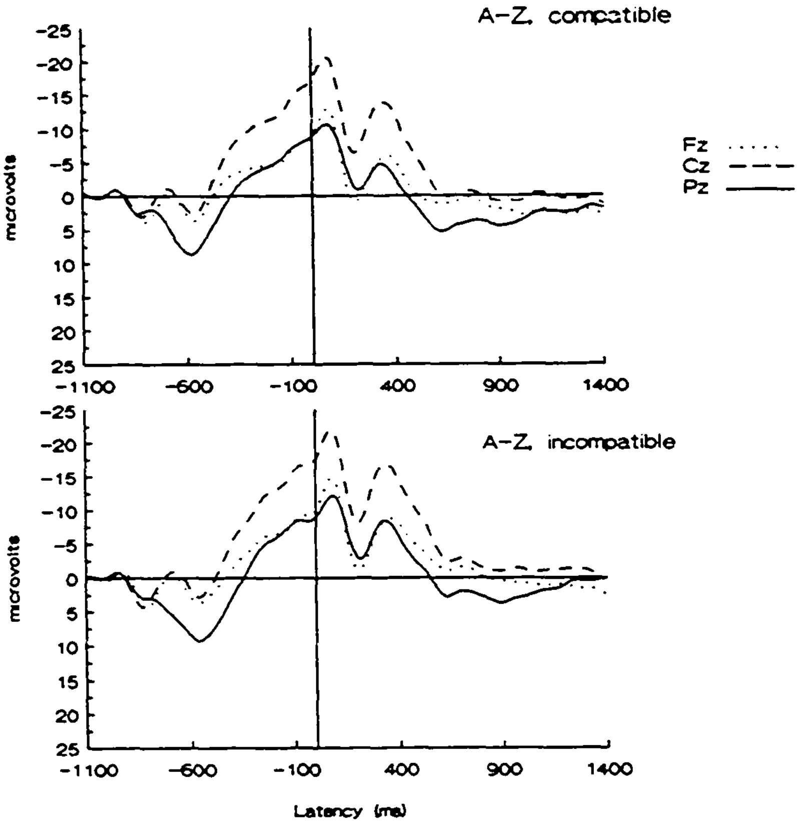


Figure 33. Average ERPs for old subjects (n=10) at Fz, Cz, and Pz in the A-Z discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

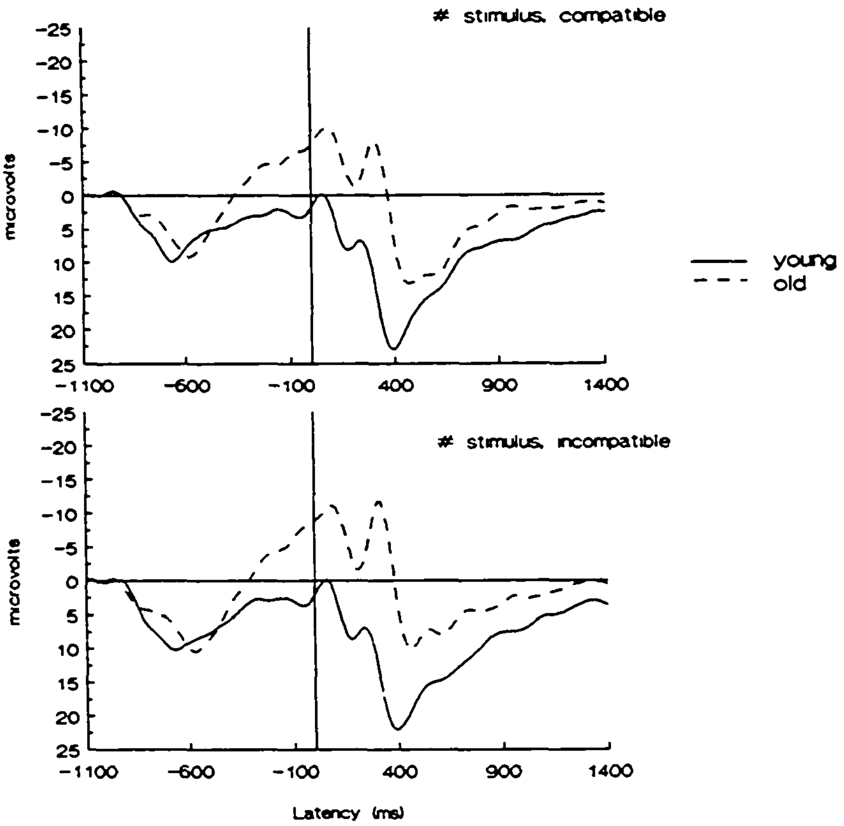


Figure 34. Average ERPs at Pz for young (n=12) and old subjects (n=10) at #'s discriminability level for both the compatible (top) and incompatible (bottom) responses. Y-axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

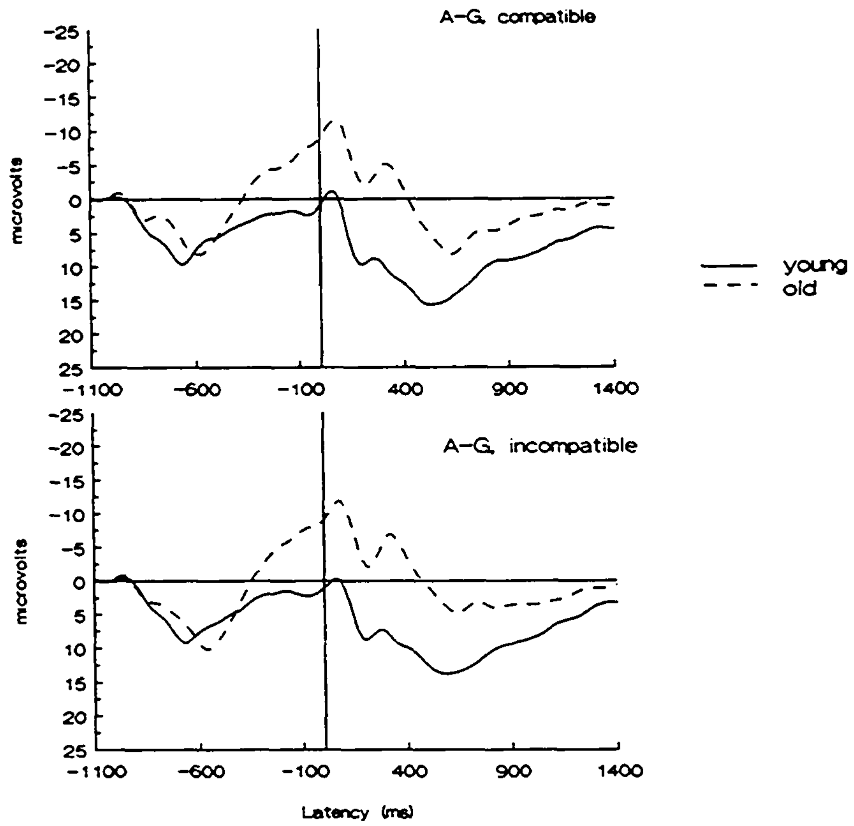


Figure 35. Average ERPs at Pz for young (n=12) and old subjects (n=10) at A-G discriminability level for both the compatible (top) and incompatible (bottom) responses. Y-axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

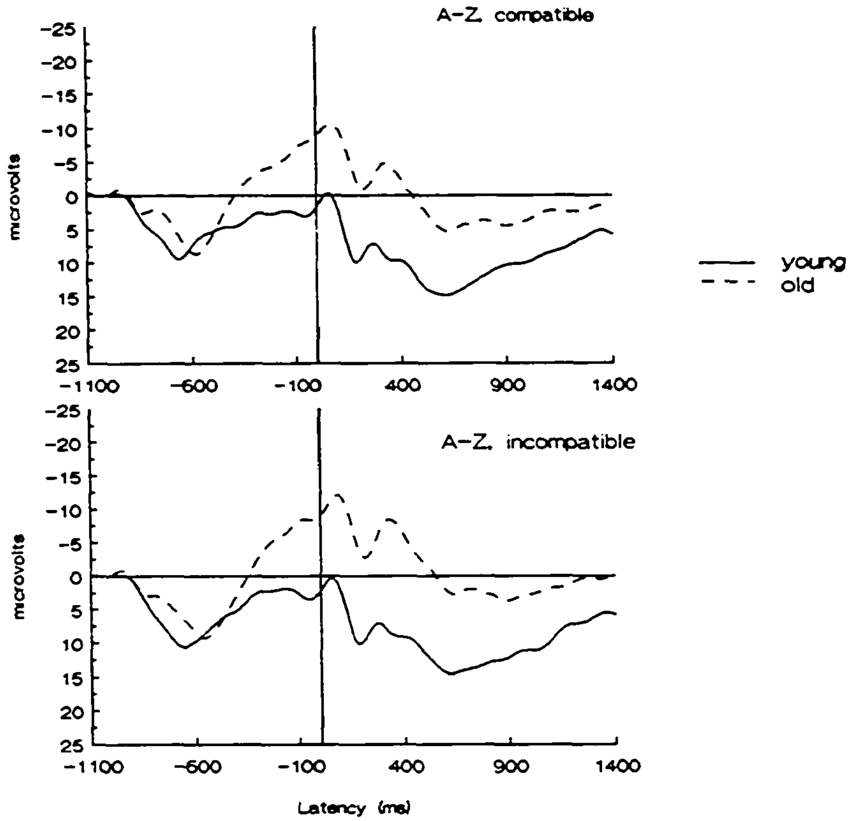


Figure 36. Average ERPs at Pz for young (n=12) and old subjects (n=10) at A-Z discriminability level for both the compatible (top) and incompatible (bottom) responses. Y-axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

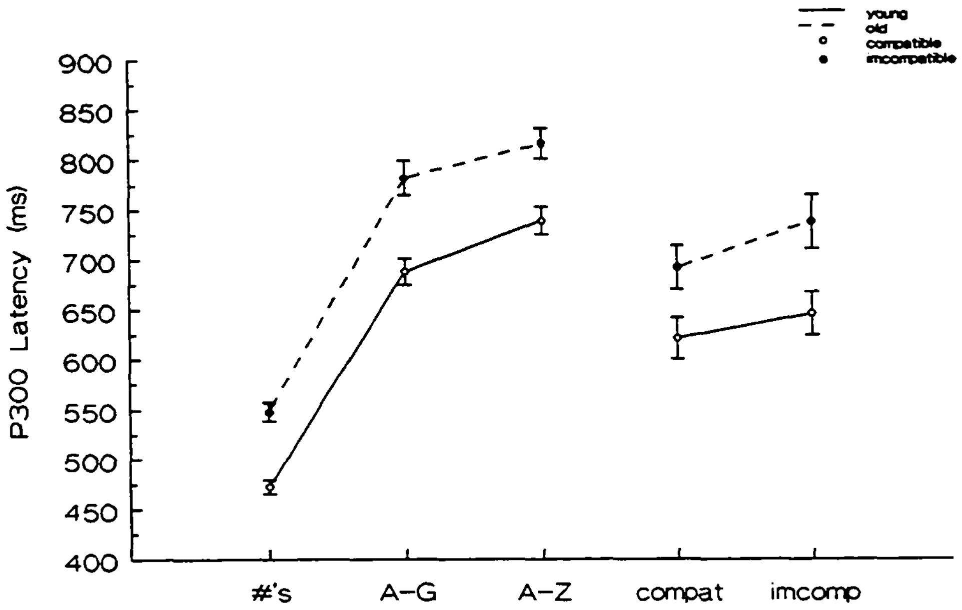


Figure 37. P300 latency at Pz for young (n=12) and old (n=10) subjects plotted as a function of the main effects of stimulus discriminability and S-R compatibility. Young subjects are represented by the solid line and old subjects by the dashed line.

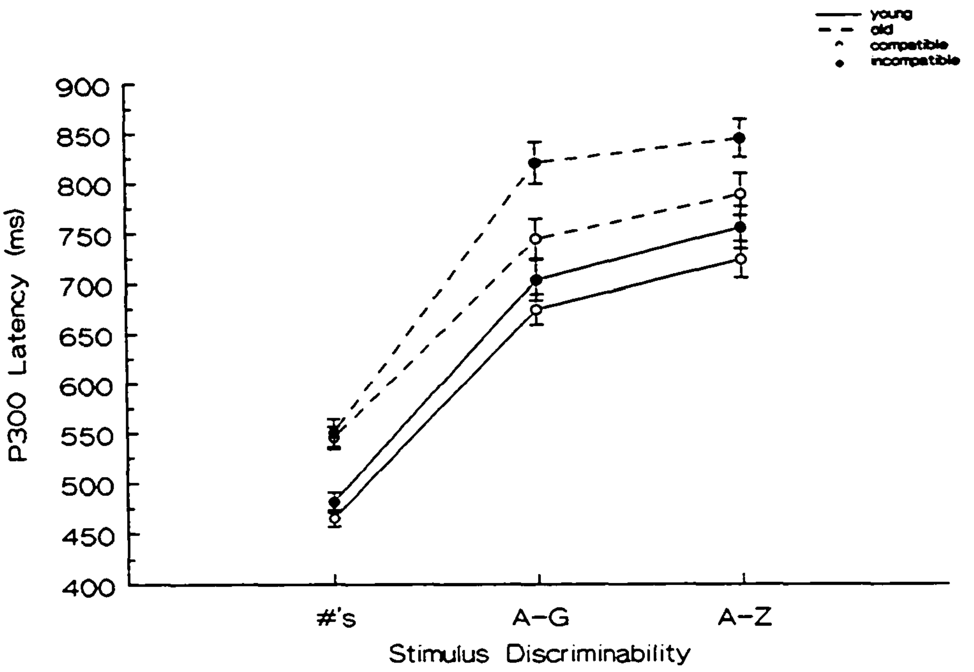


Figure 38. Average P300 latency at Pz for young (n=12) and old (n=10) subjects as a function of stimulus discriminability (#'s, A-G, A-Z) and S-R compatibility (compatible (open mark) vs. incompatible (closed mark)).

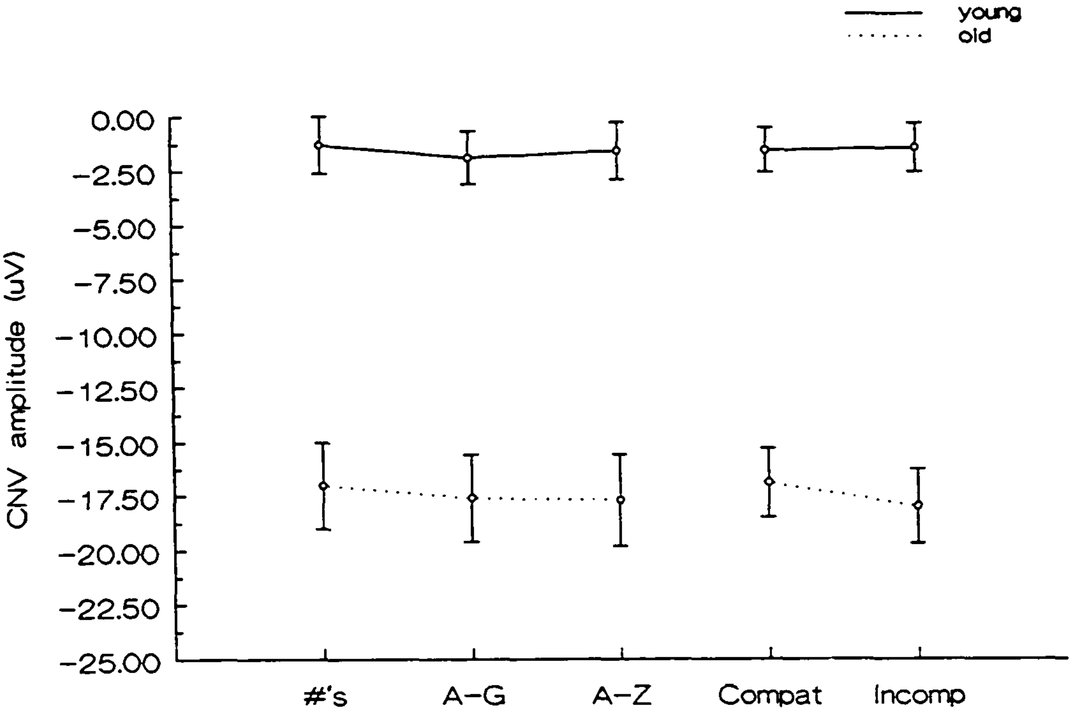


Figure 39. CNV amplitude at Cz for young (n=12) and old (n=10) subjects plotted as a function of the main effects of stimulus discriminability and S-R compatibility. Young subjects are represented by the solid line and old subjects by the dashed line.

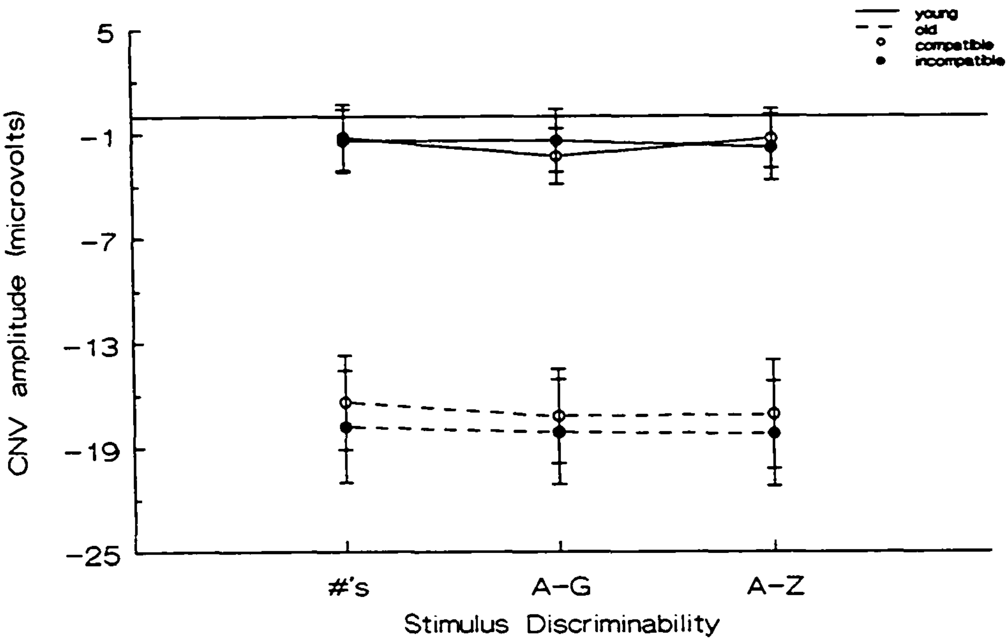


Figure 40. CNV amplitude at Cz for young (n=12) and old (n=10) subjects as a function of stimulus discriminability (#'s, A-G, A-Z) and S-R compatibility (compatible (open mark) vs. incompatible (closed mark)).

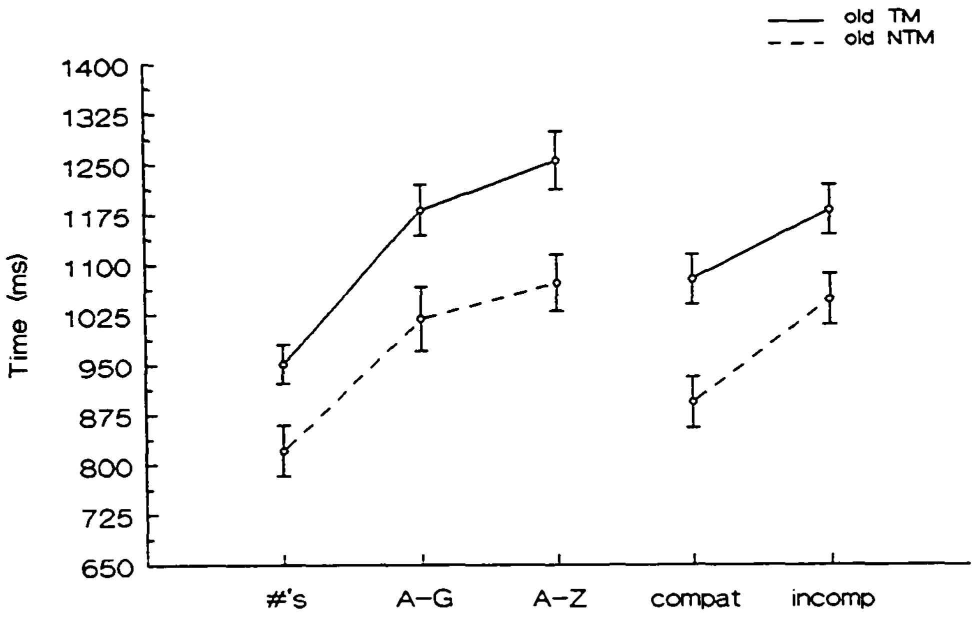


Figure 41. Reaction time for old TM (n=10) and old non-TM (n=10) subjects plotted as a function of the main effects of stimulus discriminability and S-R compatibility. TM subjects are represented by the solid line and non-TM subjects by the dashed line.

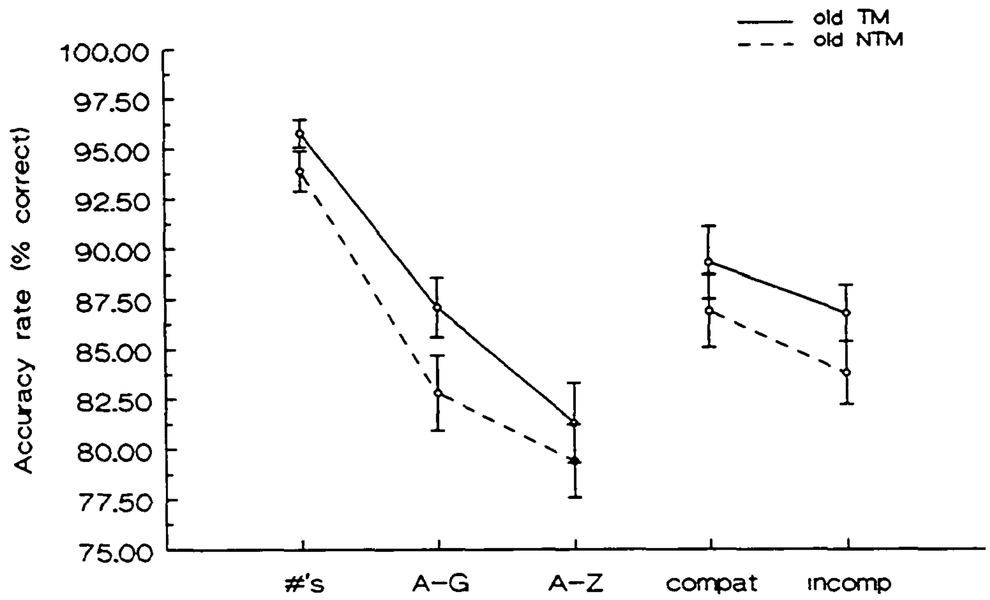


Figure 42. Accuracy rate (% correct) for old TM (n=10) and old non-TM (n=10) subjects plotted as a function of the main effects of stimulus discriminability and S-R compatibility. TM subjects are represented by the solid line and non-TM subjects by the dashed line.

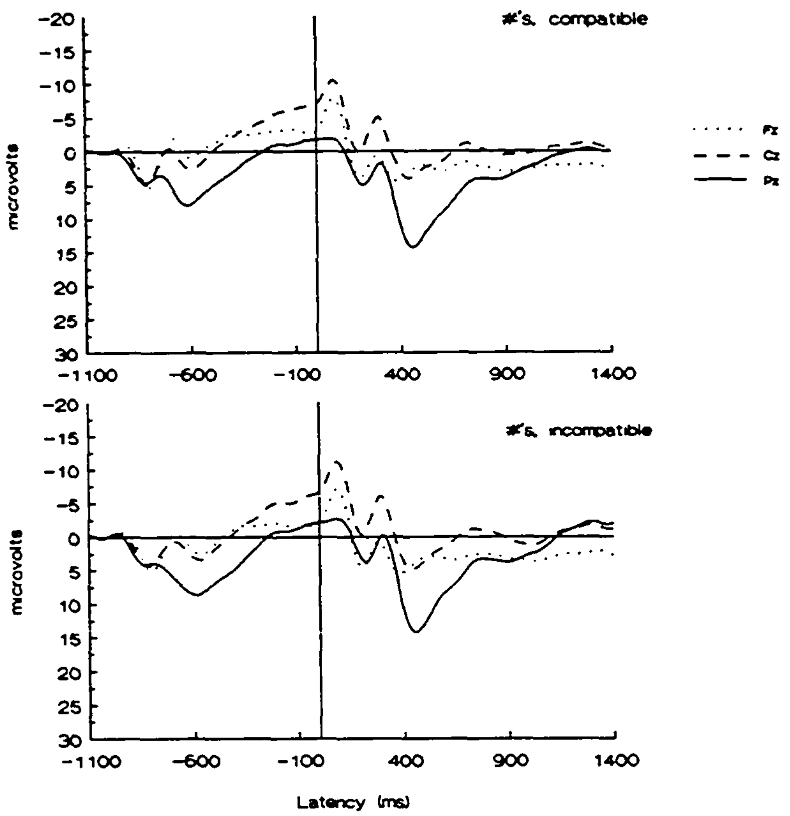


Figure 43. Average ERPs for old TM subjects (n=10) at Fz, Cz, and Pz in the #'s discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

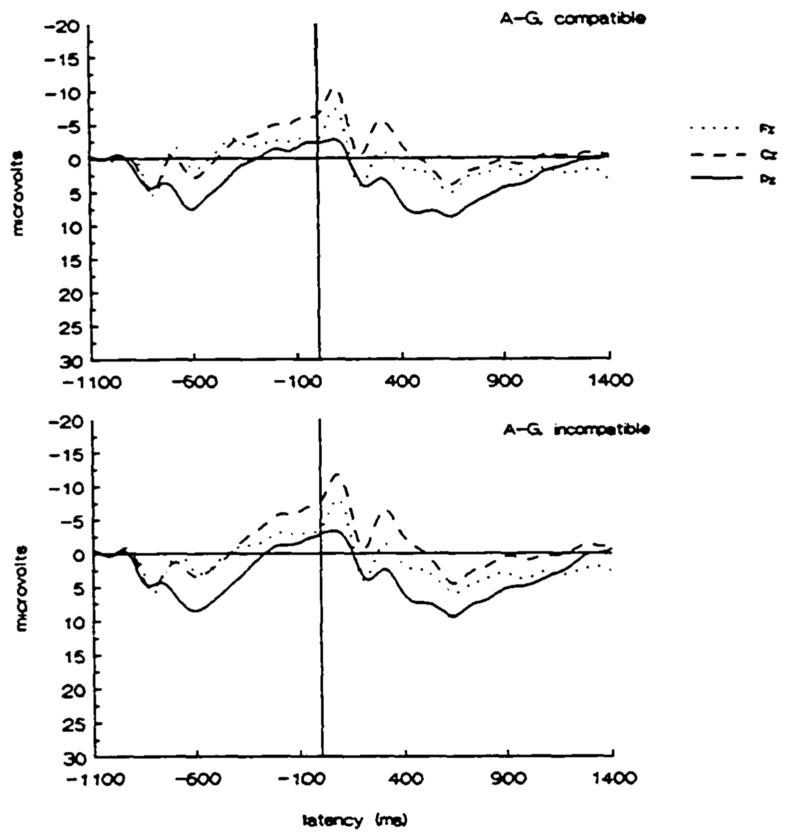


Figure 44. Average ERPs for old TM subjects (n=10) at Fz, Cz, and Pz in the A-G discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

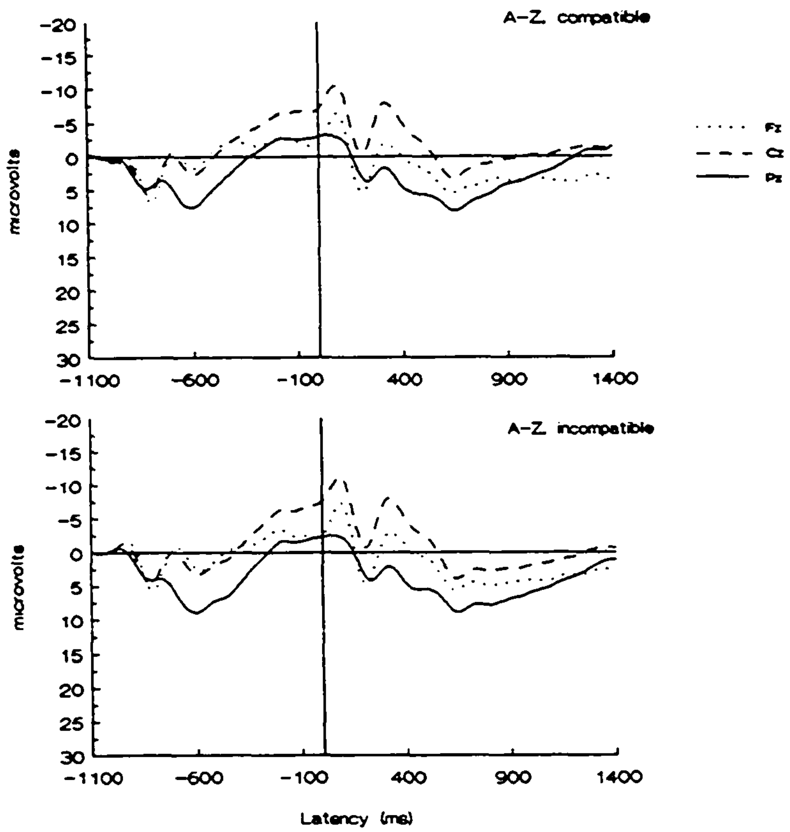


Figure 45. Average ERPs for old TM subjects (n=10) at Fz, Cz, and Pz in the A-Z discriminability level of the compatible (top) and incompatible (bottom) response conditions. Y-axis represents the onset of the cue word and the vertical axis at time 0 represents matrix onset. Signals are eye-movement corrected and digitally filtered.

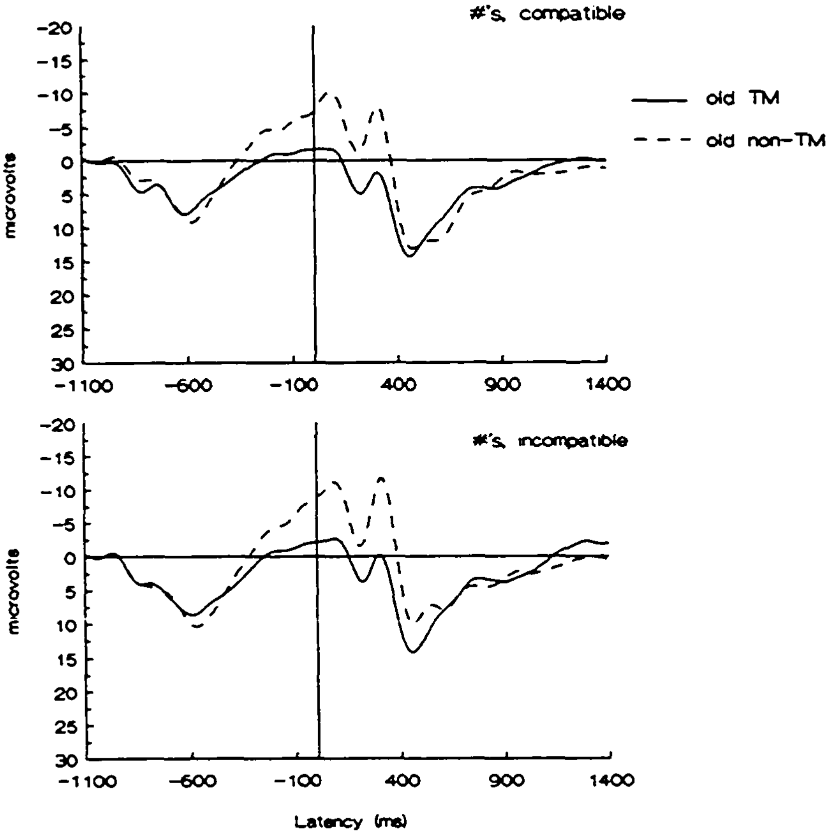


Figure 46. Average ERPs at Pz for old TM (n=10) and old non-TM subjects (n=10) at #'s discriminability level for both the compatible (top) and incompatible (bottom) responses. Y-axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

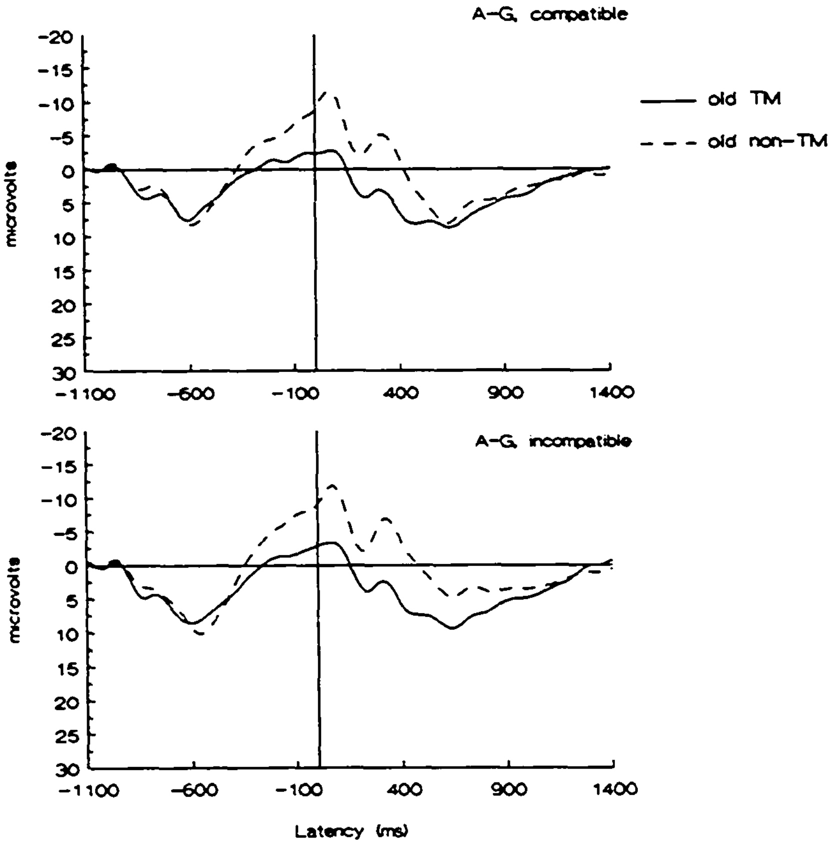


Figure 47. Average ERPs at Pz for old TM (n=10) and old non-TM subjects (n=10) at A-G discriminability level for both the compatible (top) and incompatible (bottom) responses. Y-axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

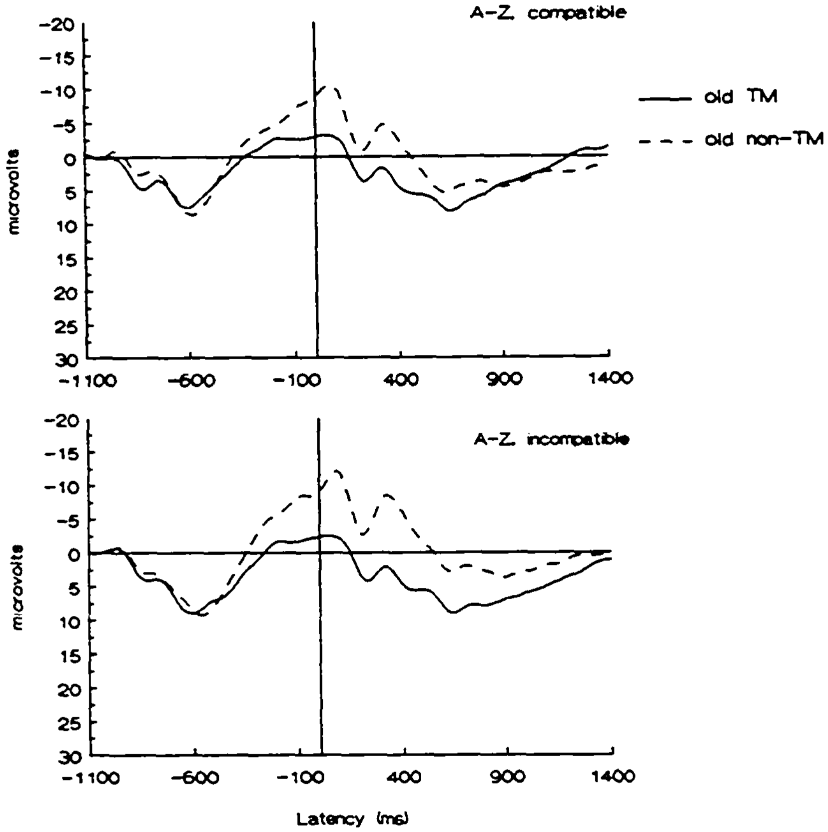


Figure 48. Average ERPs at Pz for old TM (n=10) and old non-TM subjects (n=10) at A-Z discriminability level for both the compatible (top) and incompatible (bottom) responses. Y-axis represents onset of the cue and the vertical line at time 0 respresents matrix onset.

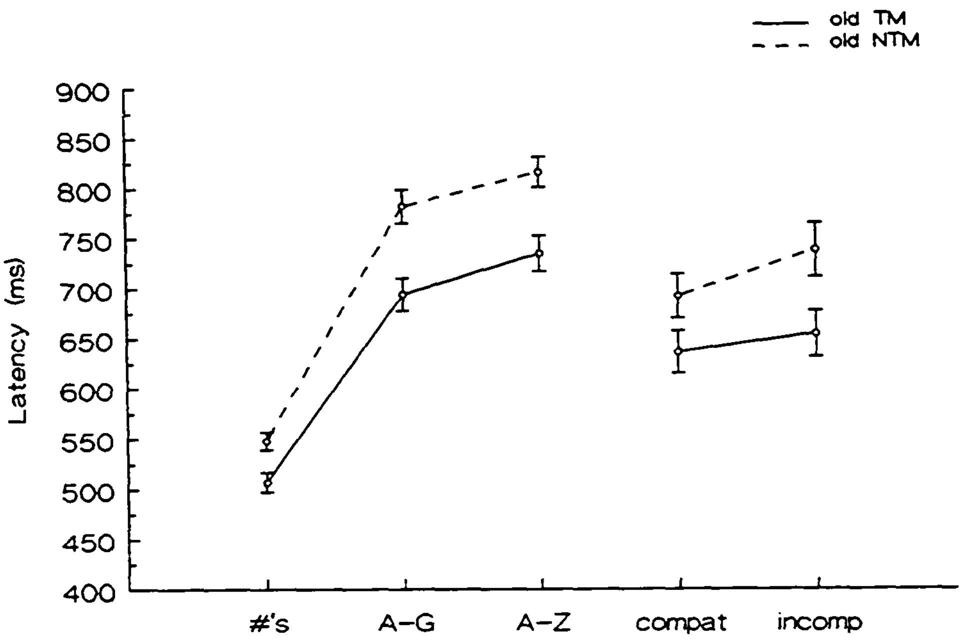


Figure 49. P300 latency at Pz for old TM (n=10) and old non-TM (n=10) subjects plotted as a function of the main effects of stimulus discriminability and S-R compatibility. TM subjects are represented by the solid line and non-TM subjects by the dashed line.

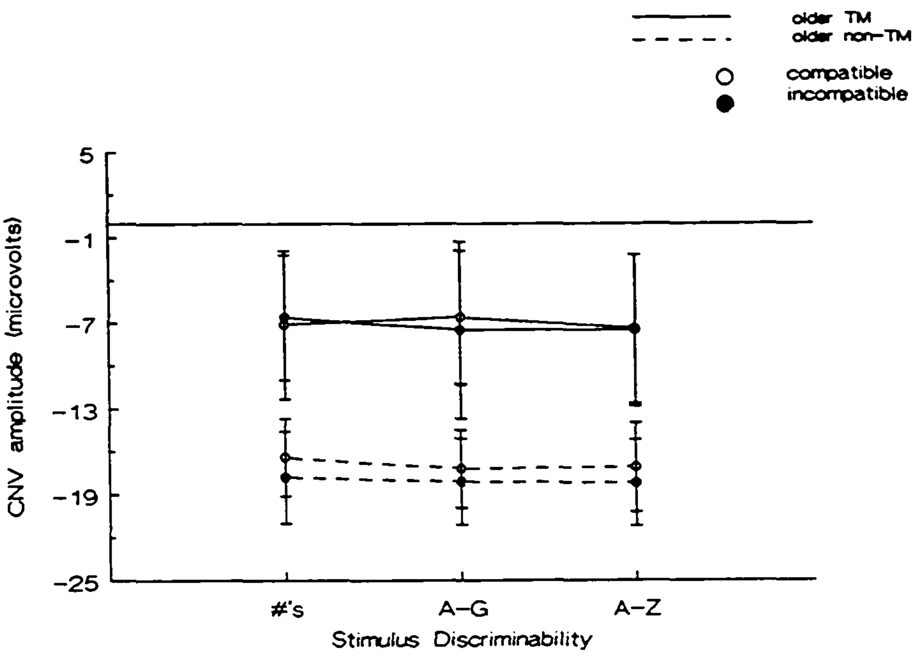


Figure 50. CNV amplitude at Cz for old TM (n=10) and old non-TM (n=10) subjects as a function of stimulus discriminability (#'s, A-G, A-Z) and S-R compatibility (compatible (open mark) vs. incompatible (closed mark)).

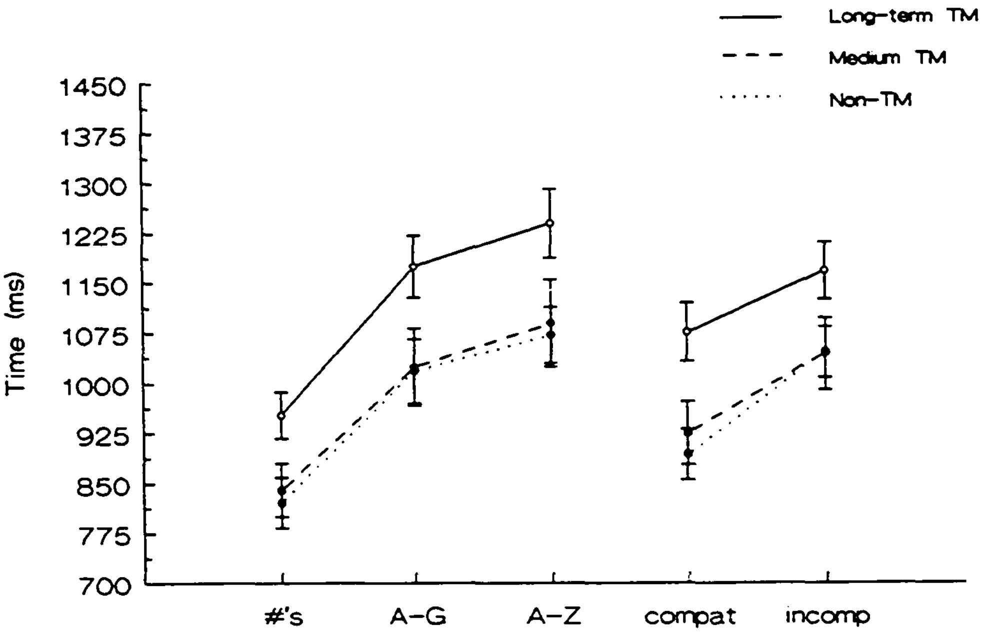


Figure 51. Reaction time for 3 elderly groups: long-term TM (n=8; solid line), medium-term TM (n=5; dashed line) and the non-TM group (n=10; dotted line) as a function of the main effects of discriminability (#'s, A-G, and A-Z) and stimulus-response compatibility (compatible vs incompatible).

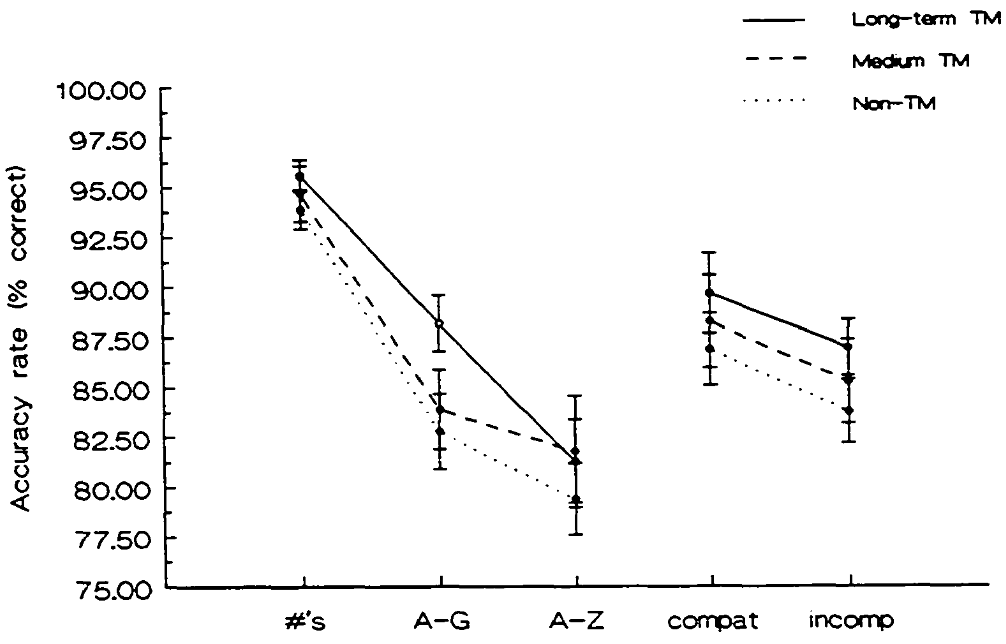


Figure 52. Accuracy rate (% correct) for 3 elderly groups: long-term TM (n=8; solid line), medium-term TM (n=5; dashed line) and the non-TM group (n=10; dotted line) as a function of the main effects of discriminability (#'s, A-G, and A-Z) and stimulus-response compatibility (compatible vs incompatible).

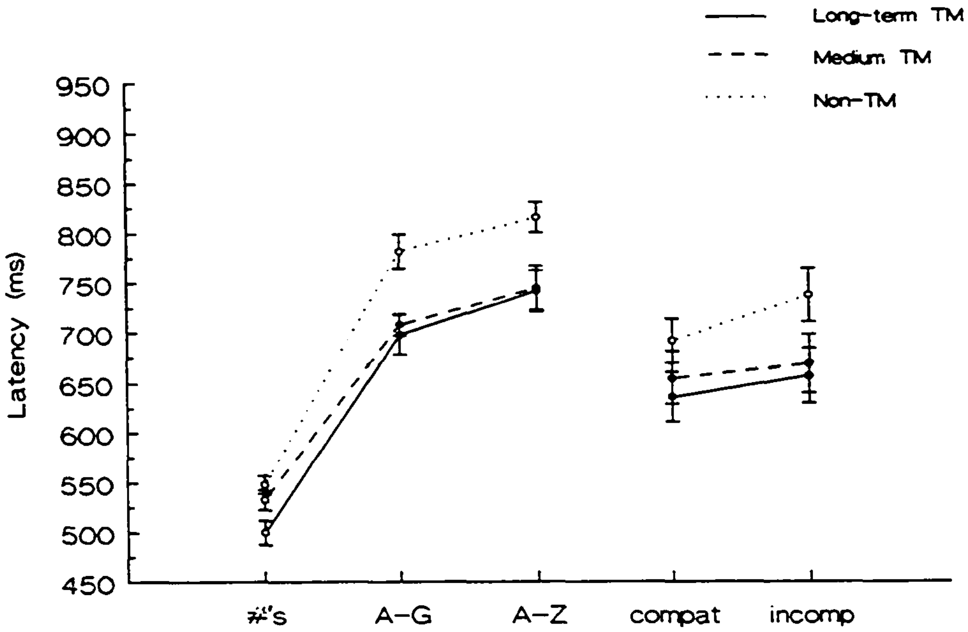


Figure 53. Average P300 latency for 3 elderly groups: long-term TM, (n=8; solid line), medium-term TM (n=5; dashed line) and the non-TM group (n=10; dotted line) as a function of the main effects of discriminability (#'s, A-G, and A-Z) and stimulus-response compatibility (compatible vs incompatible).

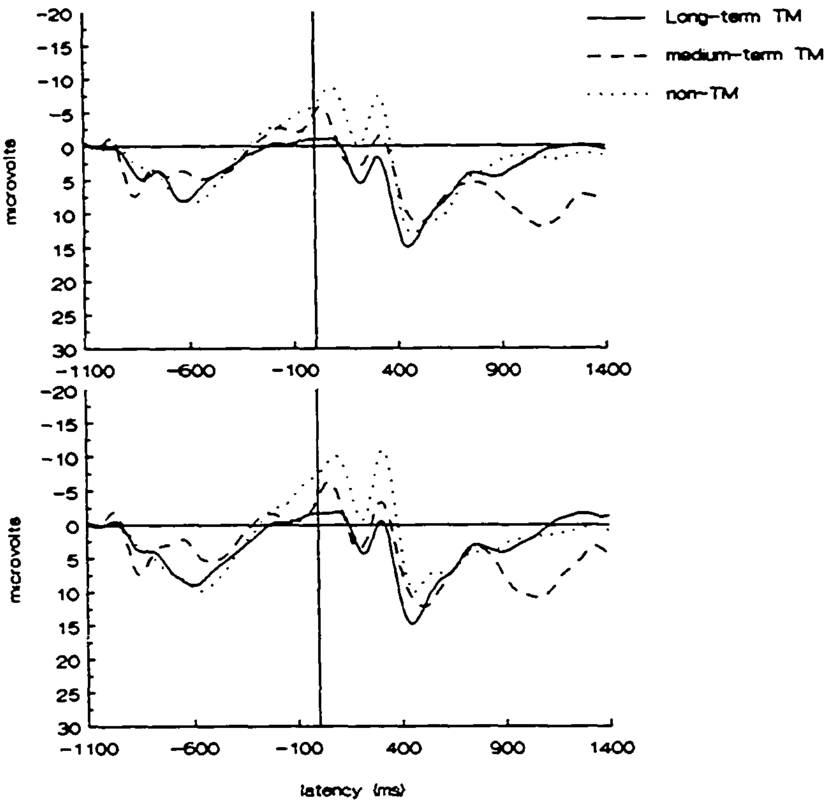


Figure 54. ERP averages at Pz for the 3 elderly groups: Long-term TM (n=8: solid line), medium TM (n=5: dashed line), and non-TM (n=10) plotted in the #'s discriminability condition for the compatible (top panel) and incompatible (bottom) response conditions.

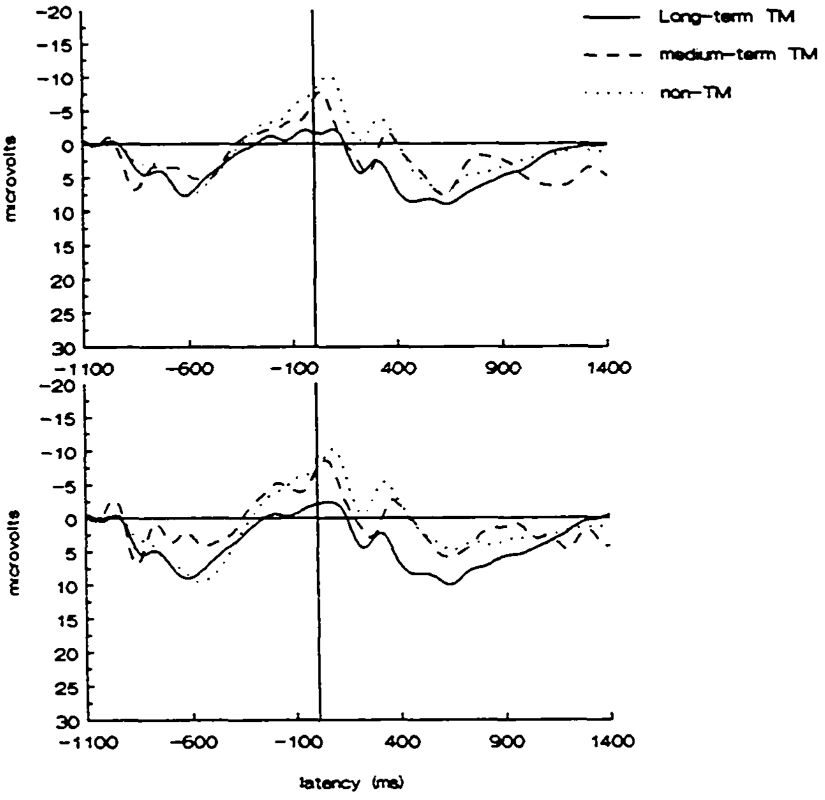


Figure 55. ERP averages at Pz for the 3 elderly groups: Long-term TM (n=8; solid line), medium TM (n=5; dashed line), and non-TM (n=10) plotted in the A-G discriminability condition for the compatible (top panel) and incompatible (bottom) response conditions.

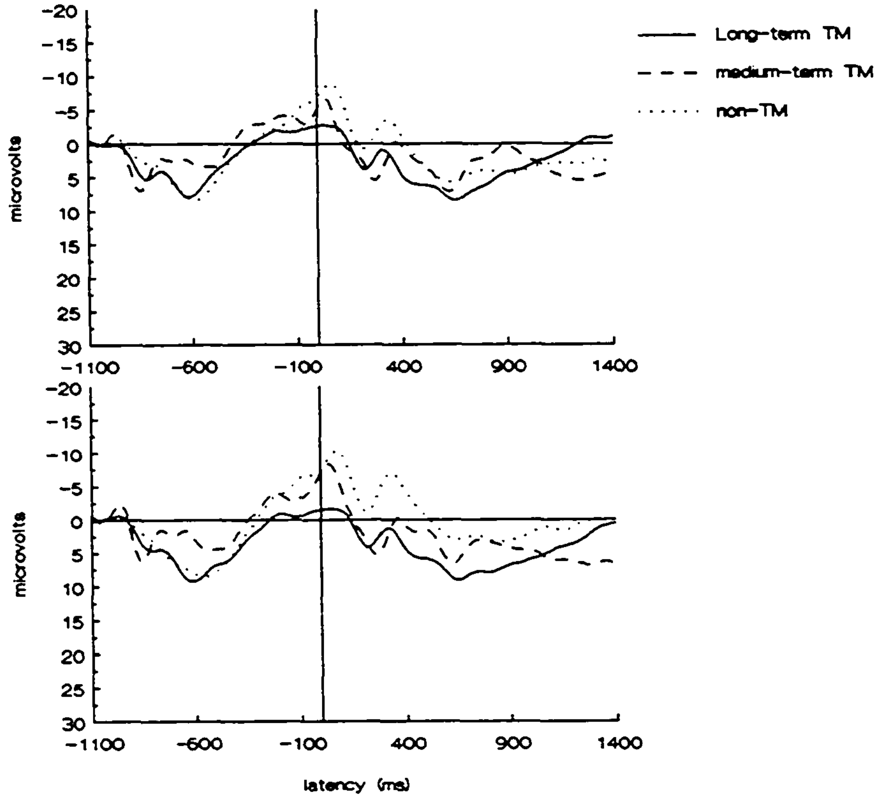


Figure 56. ERP averages at Pz for the 3 elderly groups: Long-term TM (n=8; solid line), medium TM (n=5; dashed line), and non-TM (n=10) plotted in the A-Z discriminability condition for the compatible (top panel) and incompatible (bottom) response conditions.

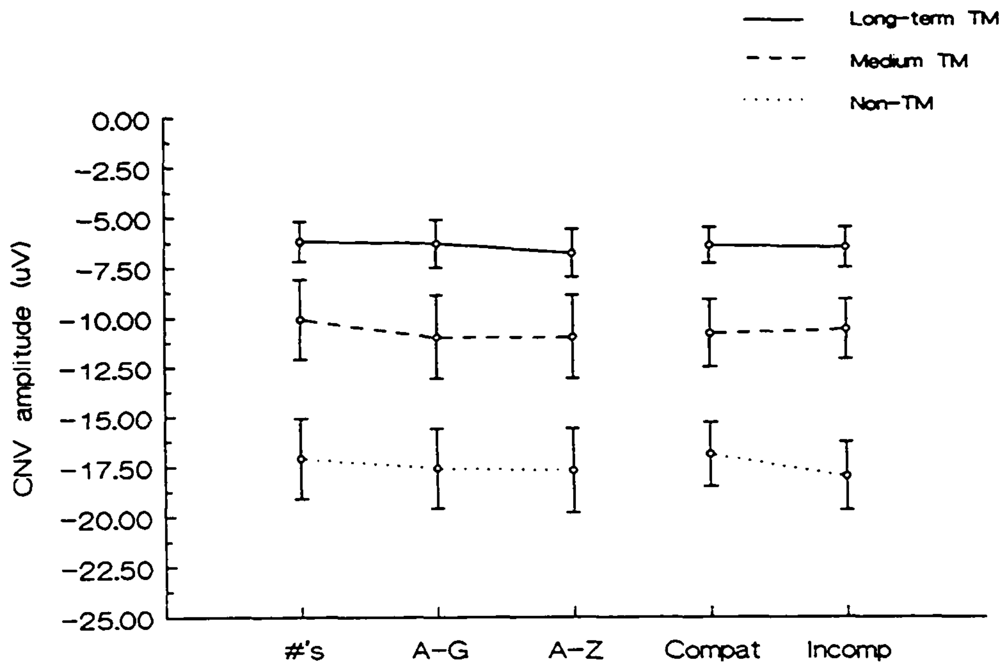


Figure 57. Average CNV amplitude for 3 elderly groups: long-term TM, (n=8; solid line), medium-term TM (n=5; dashed line) and the non-TM group (n=10; dotted line) as a function of the main effects of discriminability (#'s, A-G, and A-Z) and stimulus-response compatibility (compatible vs. incompatible).

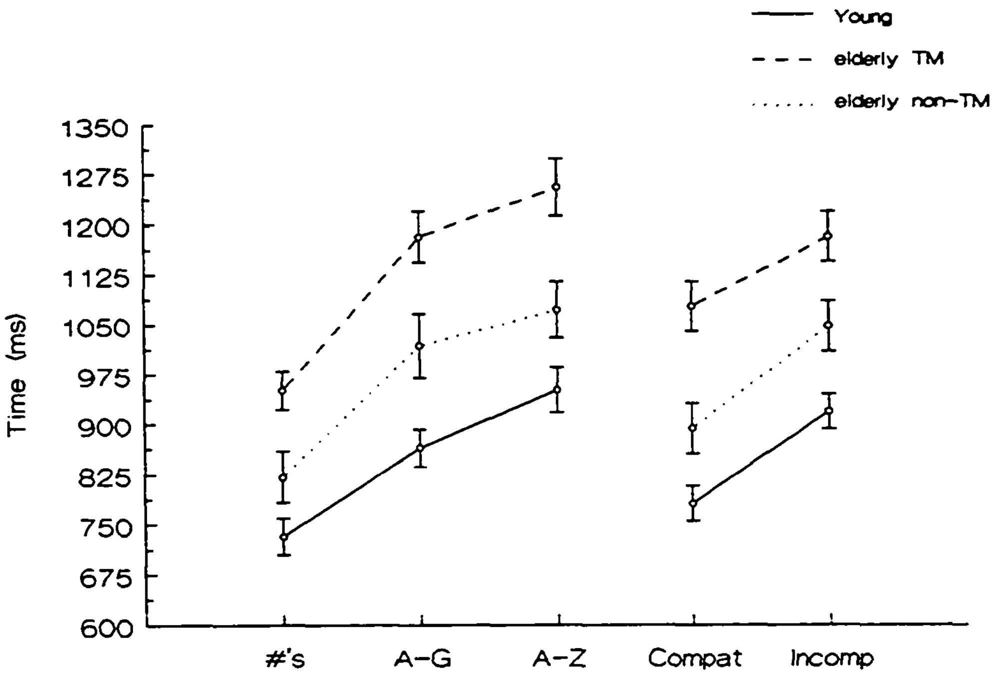


Figure 58. Reaction time for 3 groups: young (n=12; solid lines), elderly TM (n=10; dashed line) and elderly non-TM (n=10; dotted line) as a function of the main effects of discriminability (#'s, A-G, and A-Z) and stimulus-response compatibility (compatible vs. incompatible).

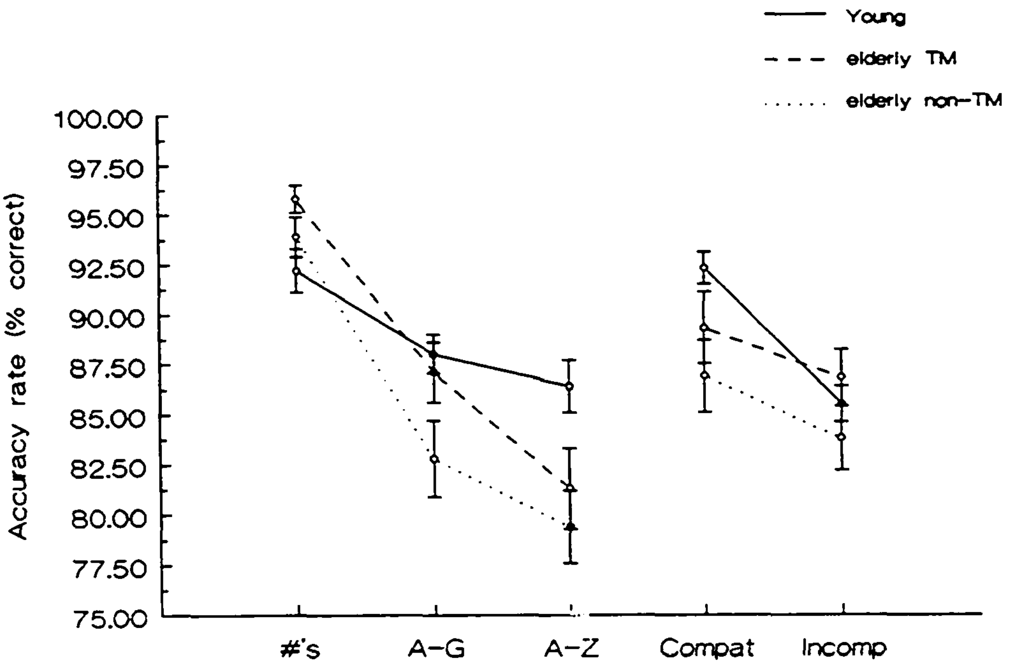


Figure 59. Accuracy rate (% correct) for 3 groups: young (n=12; solid lines), elderly TM (n=10; dashed line) and elderly non-TM (n=10; dotted line) as a function of the main effects of discriminability (#'s, A-G, and A-Z) and stimulus-response compatibility (compatible vs. incompatible).

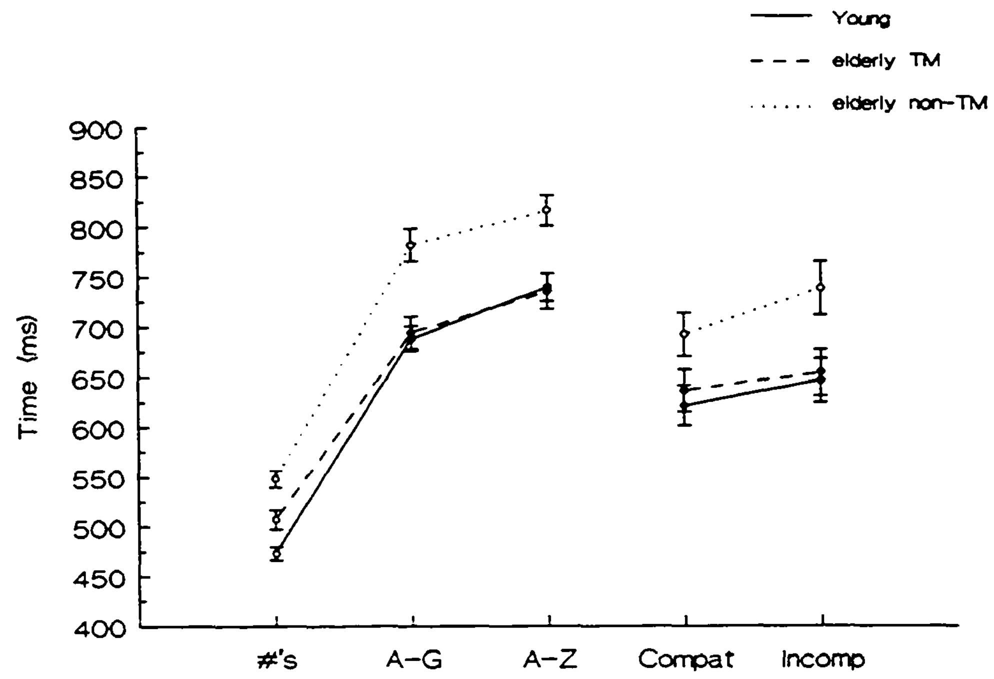


Figure 60. P300 latencies at Pz for 3 groups: young (n=12; solid lines), elderly TM (n=10; dashed line) and elderly non-TM (n=10; dotted line) as a function of the main effects of discriminability (#'s, A-G, and A-Z) and stimulus-response compatibility (compatible vs. incompatible).

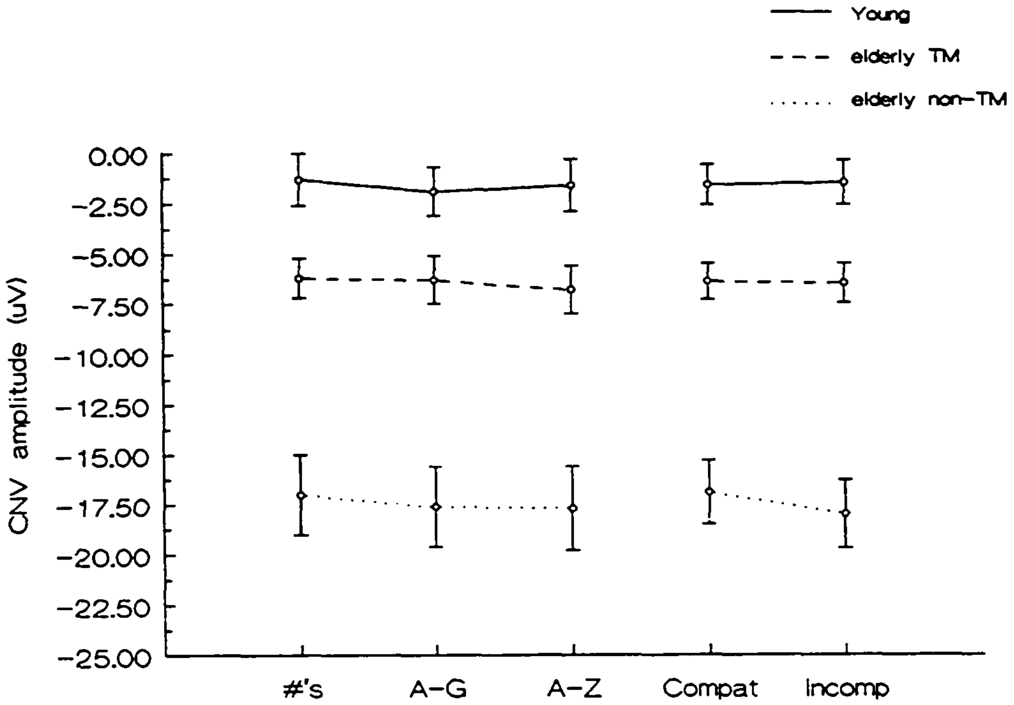


Figure 61. CNV amplitude (uV) for 3 groups: young (n=12; solid lines), elderly TM (n=10; dashed line) and elderly non-TM (n=10; dotted line) as a function of the main effects of discriminability (#'s, A-G, and A-Z) and stimulus-response compatibility (compatible vs. incompatible).

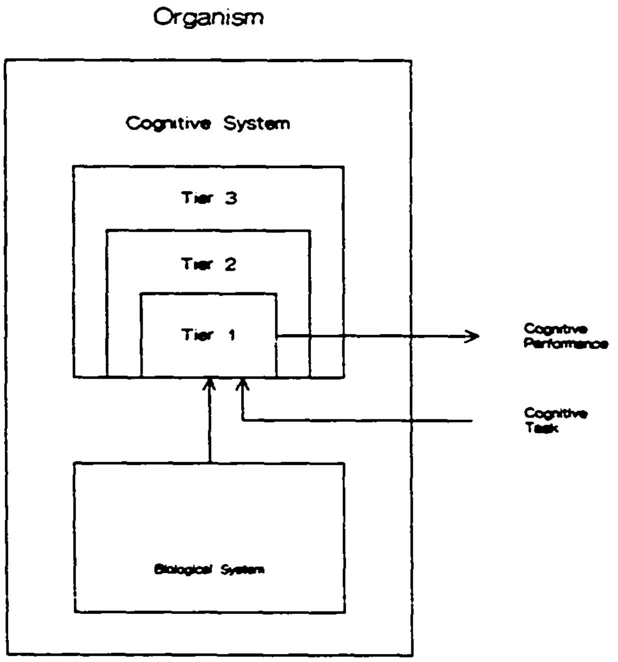


Figure 62. Multidisciplinary framework for considering development from Perlmutter (1988). Reproduction emphasizes the levels of cognition internal to the organism. See Perlmutter (1988) for elaboration of effects of social and physical environment on development.

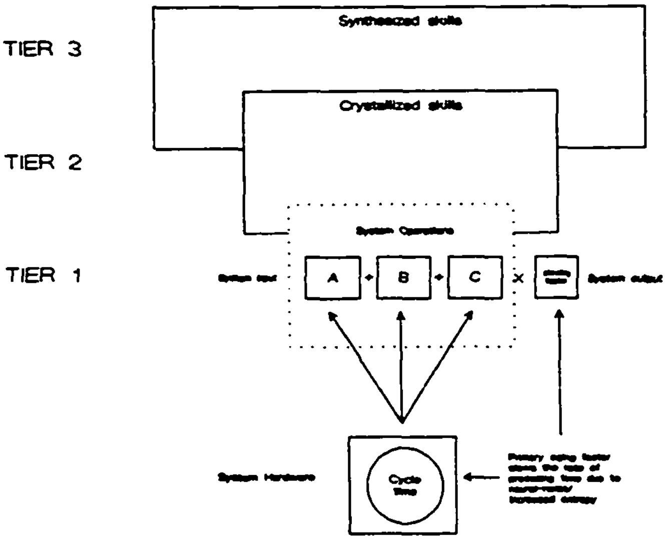


Figure 63. The "cycle time" theory indicating age-related slowing reflects changes in the computational "operations" of cognition, corresponding to Perlmutter's tier 1 (fluid abilities) while tier 2 (crystallized skills) and 3 (synthetic skills) represent cognitive domains functionally unaffected by this slowing and capable of open-ended development.

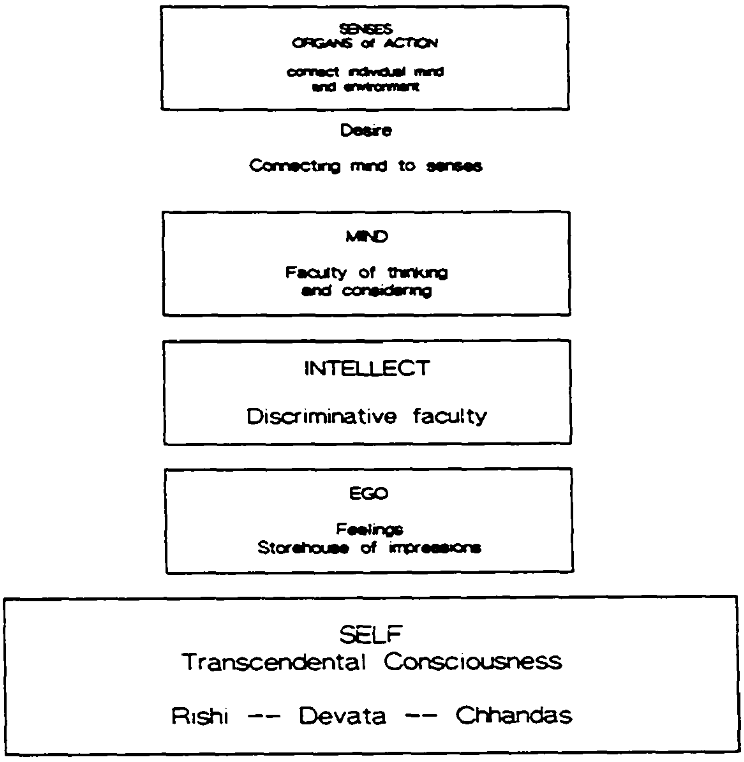


Figure 64. Theory of levels of mind from Vedic Psychology proposing the mind to be hierarchically structured in layers from concrete to abstract: the faculties of action, and sensation, desire, thinking mind (associative faculty), intellect (discriminative faculty), feelings and intuition, and experiencing ego, respectively. Transcendental consciousness underlies all these levels, where the knower, known and process of knowing are said to be unified.

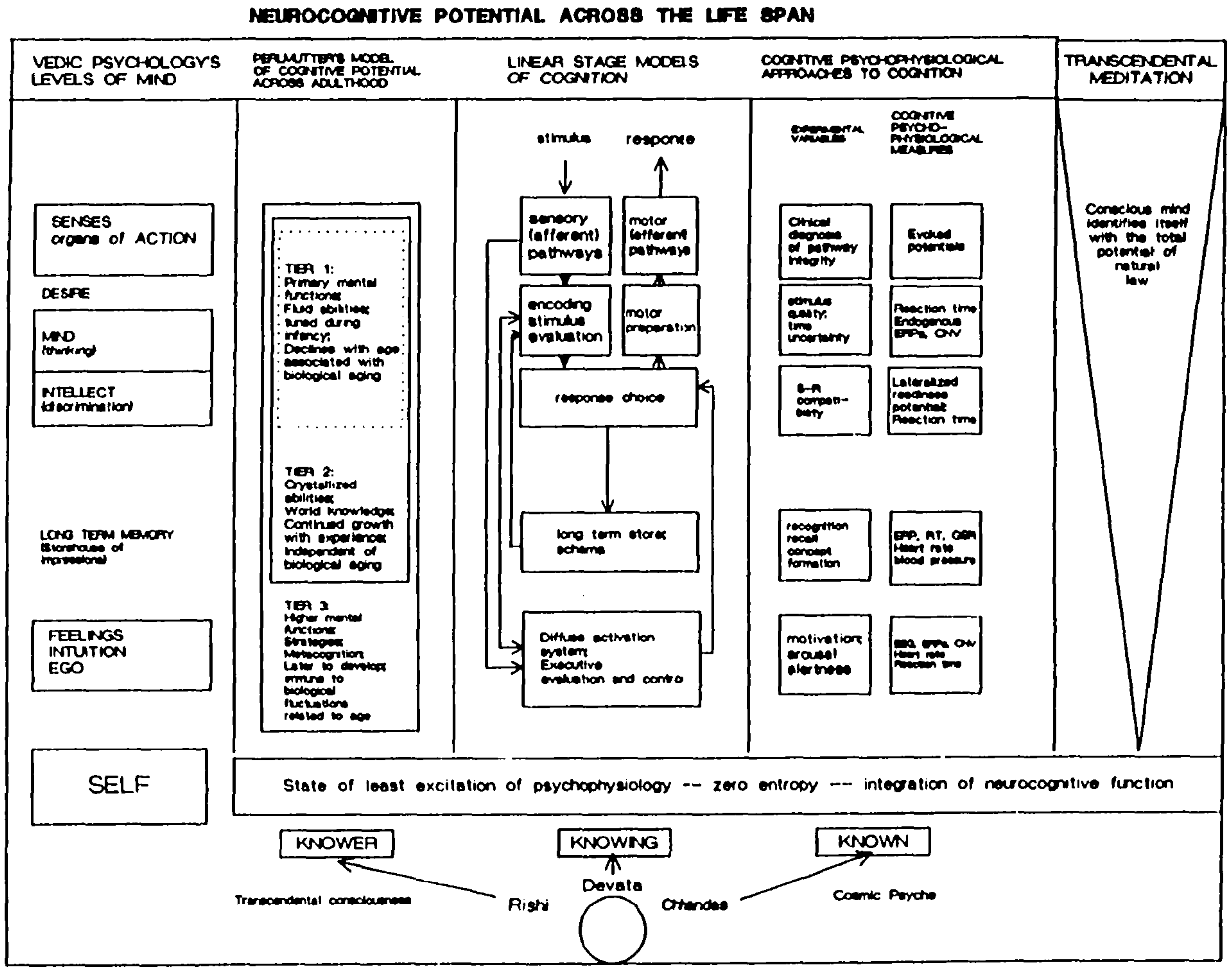


Figure 65. Integration of theories of cognition, cognitive potential in adulthood, and cognitive psychophysiological approaches to the study of cognition in the context of Vedic psychology's theoretical model of levels of mind.

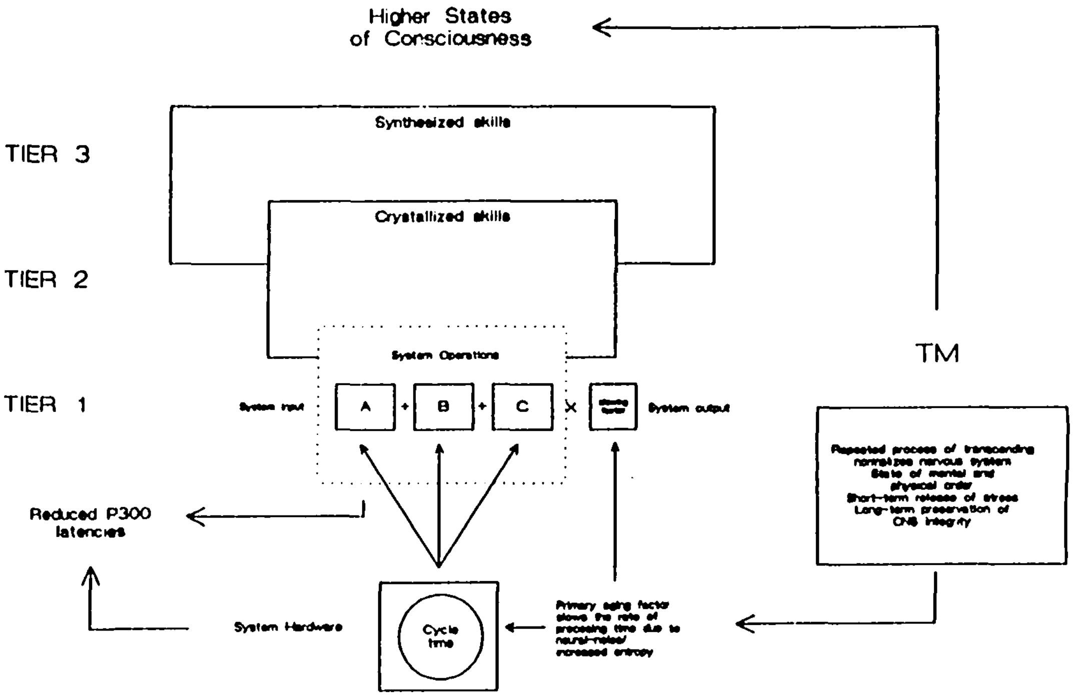


Figure 66. TM is proposed to promote the preservation of the efficiency CNS integrity reflected in maintenance of processing speed, as measured by P300 latency. In addition, the experience of transcendental consciousness is proposed by Vedic psychology to be critical for the development of higher states of consciousness. Note that while Perlmutter's tier's 2 and 3 levels of cognition are independent of biological changes with age, higher states of consciousness are dependent upon optimization of neurocognitive function.