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# THE EFFECTS OF AGE AND PHYSICAL ACTIVITY LEVEL ON ADULT COINCIDENCE-ANTICIPATION TIMING PERFORMANCE

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# ABSTRACT

## THE EFFECTS OF AGE AND PHYSICAL ACTIVITY LEVEL ON ADULT COINCIDENCE-ANTICIPATION TIMING PERFORMANCE

by Darryl D. Michael

The decrement of reaction time with age in adults is a well-documented phenomenon. Recently, however, studies have found that subjects who participate regularly in some forms of physical activity do not exhibit the same degree of psychomotor slowing with age as their sedentary counterparts. The purpose of this study was to evaluate the effects of age and physical activity level on coincidence-anticipation timing performance. Sixty men were grouped on the basis of age (20-30, 40-50, and 60-70 yrs of age) and physical activity level (runners, inactive) for testing on the Bassin Anticipation Timer. All subjects received 100 trials at a stimulus velocity setting of 268 cm/sec (6 mph). A 2 X 3 X 17 (age by activity level by trial blocks) MANOVA with repeated measures on the last factor on absolute constant error and variable error scores revealed no significant interaction or main effects for trials. The age by physical activity level interaction was nonsignificant ($\underline{p} = .071$). The main effects of both age and physical activity level reached significance. As with reaction time, regular participation in running seems to attenuate the performance decrements associated with advancing age in coincidence-anticipation timing.

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# Chapter 1

## Introduction

By the year 2000, as many as 36 million people will be over age 65 (Payne & Isaacs, 1991). Of these 36 million, 5 million will be over age 85. These numbers could double by the year 2040. This increasing number of older Americans carries with it numerous social, economic, and moral implications. For example, the "baby boom" generation will have to prepare itself for the potential health problems, financial hardships, and family care questions that are consequences of living longer than any other generation. In addition, society will have to make adjustments to include this growing population of older adults. For instance, many adults will probably remain in the work force longer, competing with younger people for jobs.

Another consequence of our increasing elderly population, in conjunction with recent fitness trends, is that more older people will be physically active. Much remains to be known concerning the short term and the long term ramifications of a physically active lifestyle. More specifically, there will now be a population of adults who have included physical activity in their lifestyles for forty, fifty, sixty, or more years. There will also be a need to investigate any possible links between participation in movement activities and quality of life, especially as it would apply to older individuals, because such studies could influence the way people perceive the role of physical activity in their lives. If one of the goals of physical education is the inclusion of additional older participants, physical activity must be shown to be appropriate and beneficial at any age.

Many investigators have examined the physiological and psychomotor characteristics of older adults, reporting a variety of findings. Increasing age has been shown to significantly decrease visuospatial perception, reaction times, speed, and tracking (Bohannon, Larkin, Cook, Gear, & Singer, 1984; Downie & Newell, 1961; Gilleard, 1982; Gilliatt, Goodman, & Willison, 1961; LaFratta & Canestrari, 1966; LaFratta & Smith, 1964; Mayer, 1963). However, it has not been found to significantly affect strength or steadiness (Jones, Williams, & Wells, 1986). Although masters runners have demonstrated lower maximum oxygen uptake values than performance-matched younger runners, the older athletes performed as well as the younger athletes because they could work closer to their maximum oxygen uptake for the duration of a race (Allen, Seals, Hurley, Ehsani, & Hagberg, 1985). Also, masters runners did not exhibit the stereotypical decreases in maximal stroke volume and arteriovenous difference seen in their inactive peers (Hagberg et al., 1985). Older subjects on a year long endurance training program increased maximum oxygen uptake an average of 25% (Yerg, Seals, Hagberg, & Holloszy, 1985), suggesting that endurance training can reverse the increased ventilatory response to submaximal exercise normally associated with aging. Female masters swimmers have shown an age-related decline in muscular strength but not in muscular endurance (Dummer et al., 1985). The age-related thermoregulatory response to cold exposures differs between males and females (Wagner & Horvath, 1985). Elderly subjects react significantly more slowly than the younger ones, apparently because of a central nervous system cause of age-related slowing in reaction time, rather than a peripheral cause (Birren & Botwinick, 1955) since age-related decrements in reaction time were found to be independent of peripheral path length. This increase in reaction time with age is seen in females as well (Hodgkins, 1962); however, psychomotor slowing with age may depend on the neural system tested (Nebes, 1978).

This decrement in reaction time with age is reviewed by Birren, Woods, and Williams (1979). Yet Spirduso (1975) was the first investigator to design an experiment to include physical activity level as an independent variable. From this initial study testing racketsports participants, and a subsequent study (Spirduso & Clifford, 1978) including runners, Spirduso concluded that physical activity level is a more significant factor than age in assessing psychomotor speed as measured in reaction time tests.

Another reflection of neuromuscular integrity is coincidence-anticipation timing. Coincidence-anticipation timing is defined as the ability to predict the arrival of a moving object to a particular point in space and coordinate a movement response with that arrival (Payne, 1986). Coincidence-anticipation timing is a basic skill underlying many activities including tennis, baseball, badminton, and even driving. In fact, coincidence-anticipation timing ability is relied upon more heavily than reacting ability in these activities because most stimuli presented have some predictability (Schmidt, 1988). Therefore, this study examined the age and physical activity level effects found by Spirduso (1975) and Spirduso and Clifford (1978) on the coincidence-anticipation timing performance of three groups of runners and three groups of age-matched inactive controls.

Statement of the Purpose

The purpose of this study was to examine the effects of age and physical activity level found by Spirduso (1975) and Spirduso and Clifford (1978) on coincidence-anticipation timing performance of three groups of adult runners and three groups of age-matched inactive controls.

Null Hypothesis

No significant differences between age groups and physical activity levels in performance on a coincidence-anticipation timing task will occur.

Delimitations

This research was delimited in several ways. First, the three age groups tested were 20-30 year-olds, 40-50 year-olds, and 60-70 year-olds. Second, the subjects were assessed on coincidence-anticipation timing performance. Third, the active groups consisted of endurance runners training at least three miles per day, three days per week, between a six and nine minute pace per mile for the five years prior to testing. Fourth, the nonactive subjects averaged one hour or less of physical activity not more than once per week, at a rating of perceived exertion of 5 (50% of maximal effort) or greater on the modified Borg rating of perceived exertion scale.

Limitations

There were several potential limitations of this research. First, since the active individuals were screened by means of a questionnaire, responses regarding the subjects' history of activity may not be truthful. Similarly, subjects classified as inactive with the questionnaire used in this study may represent a wide range of inactivity. In addition, subject motivation to perform the coincidence-anticipation timing task may not have been consistent among all subjects; also, the subjects may not have been at comparable states of alertness at the time of testing. Another limitation related to the subjects is the possibility of self selection of those with inherently better timing ability into physical activities. Further, the subjects might not have displayed a normal distribution with respect to the number of trials reflecting learning and fatigue effects. A final limitation related to the data collection was the use of two different Bassin Anticipation Timers, neccesitated by the testing of subjects at two widely separated locations.

## Definitions and Operational Definitions

Several terms specific to this research, as well as certain statistical measures, are defined for clarity.

Absolute constant error: "the absolute value of the constant error" (Schmidt, 1988, p. 60).

Coincidence-anticipation timing: "the ability to predict the arrival of a moving object to a particular point in space and coordinate a movement response with that arrival" (Payne, 1986, p. 290).

Endurance runner: someone currently running between six and nine minutes per mile a minimum of three miles per day, three days per week for at least the five years prior to testing (Spirduso et al., 1988).

$Eta^2$: an effect size measure calculated by dividing the between subjects sum of squares by the sum of the between subjects and error sums of squares.

Jendrassik maneuver: position in which the hands are clasped at shoulder level with the elbows pointed outward, and the subject pulls away from the midline without unclasping the hands (Hart, 1986).

Nonactive person: someone who, on the average, participates in one hour or less of physical activity per week at a rating of perceived exertion of 5 or greater on the modified Borg scale for at least the five years prior to testing.

Variable error: "the variability of the subject about the mean response" (Schmidt, 1988, p. 58).

Significance of the Study

The proposed study was needed for several reasons. First, many experiments designed to assess neuromuscular functioning have not controlled for the potentially confounding variable of subject physical activity level (Spirduso, 1980). In fact, only recently has fitness level been examined as a factor affecting the neuromuscular decrement in reaction time studies (Botwinick & Thompson, 1968; Spirduso, 1975; Spirduso & Clifford, 1978). Furthermore, the results of these studies should not be used to predict coincidence-anticipation timing performance since little or no correlation exists between reaction time and coincidence-anticipation performance (Haywood, 1977). In addition, analysis of the results including trial blocks as a factor provided support for the use of 85 trials as a consistent measure of coincidence-anticipation timing performance. Finally, Haywood (1989) found that, over a period of seven years, older adults centered their responses significantly better after the first testing session. She felt that the improved performance could be attributed to learning and task familiarity. She further suggested that older adults' anticipatory judgement should be assessed over multiple sessions. All of her subjects, however, were recruited from an exercise program for older adults, and either continued to participate or maintained a physically active lifestyle over the seven year testing period.

She acknowledges that the retention and improvement of skill demonstrated by these subjects in her longitudinal study could have been a product of the subjects' participation in physical fitness programs. Therefore, the inclusion of subject physical activity level as an independent variable helped to assess the degree to which physical activity contributed to the attenuation of age-related neuromuscular deficits.

As our population as a whole continues to grow older, research relating to the effects of regular exercise in the older population has also grown. Participants in masters running and swimming programs have shown attenuated age-related changes in several physiological characteristics (Allen et al., 1985; Dummer et al., 1985; Hagberg et al., 1985; Jones et al., 1986; Yerg et al., 1985). In addition, regular participation in running and in racketsports has been shown to allay the increase in reaction time typically seen with increasing age (Spirduso, 1975; Spirduso & Clifford, 1978). These age and physical activity level effects, however, have not been previously tested in a coincidence-anticipation timing paradigm. In fact, physical activity level could have been an important confounding variable of the results of previous coincidence-anticipation timing research (Haywood, 1989). Therefore, the purpose of this study was to specifically examine the effects of age and physical activity level on coincidence-anticipation timing performance in adults.

## Chapter 2

## Review of Literature

This literature review is divided into three sections. The first topic covered is the neurophysiology of aging. Research concerning the relationship between exercise and neuromuscular integrity is included. The second section covers age-related effects on motor performance, and interaction effects of physical activity. This section also includes those studies that have compared active and sedentary populations as part of the experimental design, because some studies have examined both age and physical activity level effects in a single study. In the third section, the results of previous coincidence-anticipation studies are reviewed. These three topics provided both background information and a theoretical basis for the proposed study. Finally, a summary of this chapter is presented.

Neurophysiology of Aging. Neurophysiological decrements associated with aging include many well documented accounts. LaFratta and Canestrari (1966) studied the effects of age on neural conduction velocities and neural latency periods. These researchers found a substantial decrease in conduction velocity and an increase in latency in sensory nerves of the index finger with age. On the same sample of males aged 23 to 91 years, the latency in motor nerves of the thumb increased with age, though not as dramatically as the latency increase in sensory nerves. This study was an extension of the work of LaFratta and Smith (1964) who found a low negative but significant correlation ($r$=-.22) between motor nerve conduction velocity and age.

Previously, Gilliatt, Goodman, and Willison (1961) found that subjects aged 51 to 80 years had slower popliteal nerve conduction velocities than those aged 20 to 50. Downie and Newell (1961) further calculated a sensory nerve conduction velocity decrease of roughly 0.4 meters per second (m/s) per year, from 35 to 67 years of age. Mayer (1963) also found a significant decrease in sensory nerve conduction velocity, but not until after 50 years of age. Though these authors screened their subjects for history of neurological dysfunction, the subjects' physical activity level was not controlled and could have been a confounding variable.

In an attempt to explain the neurophysiology of aging, Spirduso (1983) asserted that the clinical signs of an aging motor system resemble diseases of the extrapyramidal system in the brain, specifically the basal ganglia. Parkinson's disease, one of the best known basal ganglia diseases, is thought to be a sign of accelerated aging (McGeer, McGeer, & Suzuki, 1977). Parkinsonians exhibit three classic symptoms. The first is postural tremor, which usually diminishes during voluntary movement. Akinesia, slowness in initiation of voluntary movement, is the second symptom. Thirdly, Parkinsonians display rigidity, a constant increase in resistance to passive movement while trying to relax. Loss of dopamine producing cells is considered the major cause of Parkinson's disease. McGeer and colleagues (1977) found that high numbers of dopamine producing cell bodies of the substantia nigra, part of the basal ganglia, showed a significant decrease in number with age. The substantia nigra is the area of greatest loss of dopamine producing cells. Spirduso (1983) further noted that dopamine uptake and dopamine receptor binding affinity are dramatically reduced in both aging and Parkinson's disease. She cautioned that the exact nature of the relationship between the basal ganglia and the control and execution of movement is not yet clear.

With the strong relationship between the dopamine producing cells, age, and Parkinson's disease, Spirduso (1983) examined the link between the dopamine producing cell system and movement initiation. If this link is strong, slowed movement initiation in both aged and Parkinson's subjects would be expected. In a study with conditionally trained rats, Spirduso came to several conclusions. First, blocking dopamine receptors slowed movement initiation. Second, behaviorally "fast" rats have higher dopamine receptor binding. Third, animals lesioned ipsilaterally in the caudate showed slower movement initiation with the contralateral paw. Fourth, complete caudate lesions slowed movement initiation. Fifth, movement initiation is sensitive to small dopamine depletions. In addition, she found that an ipsilateral lesion affected the "uninvolved" paw, and the "involved" paw could be moved if the animal were motivated enough. With these findings, the link between the dopamine system and movement initiation is strengthened, at least in rats.

Next, Spirduso stated that a chronic effect of exercise on brain neurotransmitters would have to be shown in order to determine whether exercise maintains reactive capacity (speed of movement initiation) by postponing the dopamine system deterioration. She proposed two ways exercise may affect brain neurotransmitters. One possibility is that exercise produces acute changes in neurotransmitter levels requiring many hours to return to baseline. Accordingly, consistent exercise would cause fluctuating neurotransmitter levels that would be higher for several hours than in sedentary individuals. Spirduso summarized the results of several studies that found increases in brain neurotransmitters such as norepinephrine and serotonin from one to eight hours after physical activity. She also warned that emotional stimuli, known to activate some neurotransmitter production, could confound these results because physical activity is often associated with an aroused emotional state.

The second mechanism by which exercise could affect brain neurotransmitter production is to produce chronic changes in resting levels of one or more of these neurotransmitters. Higher levels of cerebral norepinephrine and midbrain serotonin have been reported in rats after eight weeks of treadmill running when compared to sedentary controls (Brown & VanHuss, 1973; Brown et al., 1979). Spirduso further suggests that exercise training might also indirectly influence dopamine turnover through endorphin release. Pollard, Llorens, and Schwartz (1977) proposed that substantia nigra cell dopaminergic nerve endings have a high number of opiate receptors, which when activated increase dopamine turnover in the striatum. Also, intraventricular endorphin injections have shown dose-dependent dopamine metabolite elevations (Wood, Stotland, Richard, & Ruckham, 1980). The highest levels of beta-endorphins were recorded in runners who had just completed a 100 mile race (Bortz et al., 1981). These runners also had exceptionally high resting beta-endorphin levels. Male athletes have shown increased beta-endorphin levels above resting levels at least thirty minutes after a maximal treadmill effort (Fraioli et al., 1980). Spirduso (1983) admits the evidence is limited, but there is some basis for arguing that exercise may have both acute and chronic effects on some brain neurotransmitter levels.

Clearly, neurophysiological decrements occur with age. One of the most often reported decrements is the decrease in conduction velocity (Downie & Newell, 1961; Gilliatt et al., 1961; LaFratta & Canestrari, 1966; LaFratta & Smith, 1964; Mayer, 1963). Another sign of an aging neuromuscular system is the lengthening of sensory nerve latency periods (LaFratta & Canestrari, 1966). Functionally, the aging motor system appears to resemble diseases of the extrapyramidal system, such as Parkinson's disease (Spirduso, 1983). The nature of the relationship between the extrapyramidal system and the control of movement, however, is not yet clear. Spirduso (1983) suggests that exercise postpones deterioration of the dopaminergic system, part of the extrapyramidal tracts, and thus maintains reactive capacity. In addition, exercise has been shown to produce both acute and chronic increases in the levels of some neurotransmitters (Bortz et al., 1981; Brown et al., 1979; Brown & VanHuss, 1973; Fraioli et al., 1980; Pollard et al., 1977; Wood et al., 1980) .

Age and Activity Level Effects. Many studies have examined the effects of aging on motor performance or psychomotor speed. Gilleard (1982) tested 140 male and female subjects aged 20 to 89 years on the Gibson Spiral Maze task. Age significantly influenced time scores, while the main effect of gender and the gender by age interaction were not significant. Gilleard also concluded that the declines seen in psychomotor speed and psychomotor accuracy with age are independent of each other. In timed balance tests, subjects over 60 years of age scored significantly poorer than younger subjects on one-leg balance tests, especially in trials with the eyes closed (Bohannon et al., 1984).

Numerous other studies have focused on reaction time and aging. Spirduso (1980) reviewed many such investigations and noted three areas of correlational evidence between physical fitness and psychomotor speed. She first summarized that high physically fit groups have faster reaction times and movement times compared to low physically fit groups, for both athletes and nonathletes. Secondly, she outlined studies indicating that physical training improves reaction time in low physically fit groups. This relationship of physical fitness to psychomotor speed will be explored further in the next section. She then noted that individuals with forms of cardiovascular disease, such as atherosclerosis, have shown decreased psychomotor performance. The proposed hypothesis to explain this link maintains that cardiovascular diseases characteristically lead to decreased cerebral oxygen consumption resulting from decreased cerebral blood flow. This mechanism of oxygen deprivation supports McFarland's (1963) anoxia model. In this model, he proposed that the perceptual and mental decrements associated with aging parallel those decrements seen in oxygen deprived individuals. These decrements might be due to impaired central nervous system functioning caused by decreased oxygen availability. Spirduso warned, however, that some of these studies contained experimental design problems which prevent conclusive interpretation.

The majority of the studies including physical activity level as an independent variable have investigated the relationship between physical activity level and some measure of psychomotor performance, such as reaction time or tracking. Other studies have assessed physical activity level effects on other physiological and behavioral measures.

Hagberg et al. (1985) compared older male athletes to both younger male athletes and older sedentary men on three hemodynamic measures. The three measures were stroke volume, arteriovenous oxygen difference, and the role of heart rate in observed differences in maximal oxygen consumption. Subjects in the older group were 50 to 66 year-olds, while those in the younger group were 22 to 28 year-olds. Subjects were classified as physically active if they had placed in the top 10% of their age group in local 10 kilometer races, and had been consistently training for the three months prior to testing. They found that the older, physically active subjects did not exhibit the decreases in stroke volume and arteriovenous oxygen difference seen in the older, sedentary subjects. In addition, the older, physically active subjects had significantly greater maximal oxygen consumption rates and peripheral vasodilatory responses than their sedentary counterparts.

Physical activity level was also an independent variable studied by Reid (1976) in his investigation of the attitude and personality differences of university instructors. To qualify for the physically active group, subjects reported that they used the activity areas of the university at least twice per week. These activities included squash, swimming, weight training, and running. Of the 16 personality traits scored, the groups only differed on two items. The physically active group was more tough-minded as well as more imaginative than the inactive group. The groups also differed in attitude toward physical activity. The physically active group valued physical activity for its role in health and fitness, for the opportunity to work at something with great intensity, and as an avenue to release energy. The inactive group, however, saw physical activity as a means of social interaction that is also aesthetically pleasing.

Reid and McGowan (1986) reevaluated many of these subjects 10 years later. Those subjects retested had to maintain their respective physical activity level from the time of the previous study. Although both groups declined in predicted maximal oxygen consumption and increased in percent body fat, the physically active group had a significantly higher predicted rate of maximal oxygen consumption and a significantly lower percentage of body fat than the inactive subjects. There were no changes in the personality scores from the previous study, and there was only one change in attitude toward physical activity over this 10 year period. The significantly higher scores of the physically active on the ascetic dimension of physical activity seen in the original study were not present in the reevaluation. Given these findings, the authors supported the idea that youth and early adulthood are the crucial times for establishing interest in physical activity.

Most of the studies assessing the effects of physical activity on psychomotor function have attempted to establish more rigorous definitions of what it means to be physically active. In spite of this, there are still differences among these studies regarding the necessary qualifications for inclusion of subjects in the physically active groups.

As one of the pioneers of studies on the effects of physical activity on psychomotor performance, Spirduso (1975) began by comparing the reaction and movement times of physically active and inactive men of two age groups. Subjects in the younger group were 20 to 30 year-olds, while those in the older group were 50 to 70 year-olds. Inclusion in the physically active groups required regular participation in either squash, racketball, or handball at least three times per week for 2 to 3 years, for younger subjects, or for the past 30 years, for the older subjects. The inactive subjects reported never having regularly participated in any physical activity. Subjects were tested for both simple and discrimination reaction times and simple and discrimination movement times. Analyses of the results revealed significant main effects of age and physical activity level on the four dependent measures. Specifically, the younger groups were faster than the older groups, and the physically active groups were faster than the inactive groups. The significant age by physical activity level interaction for simple and discrimination reaction times pinpointed the significantly slower times of the older inactives as the source of the age effect. In general, the older, physically active subjects performed more similarly to the younger, physically active subjects than their inactive peers. The question remained, regarding the reasons for these differences, as to whether the physically active performed better because their physical activity included reactive movements or because they were in better physical condition.

In order to help determine the underlying mechanism responsible for the faster reaction and movement times of physically active subjects, Spirduso and Clifford (1978) repeated the 1975 study with the inclusion of another physically active group, runners. The runners were chosen since their activity is aerobic and relies very little on reactive movements. The runners in this study reported training a minimum of three miles, four times per week. Again, the main effects of age and physical activity level were significant on the four dependent measures. The four physically active groups displayed similar consistency, and were significantly more consistent than the two inactive groups. This time, however, no significant interactions were present. These results led the authors to conclude that physically active older men experience a much smaller decrement in performance than inactive older men. In addition, since this result was found for both racketsports players and runners, delayed performance decrements appear to be due to the nutritive functioning of a healthy cardiovascular system. Yet these authors added that motivational differences, as well as selective association of those with faster reaction times towards physical activities, could also contribute to the improved psychomotor abilities of older, physically active men.

Clarkson and Kroll (1978) also measured simple and choice reaction and movement times in four groups determined by age and physical activity level. These authors, however, tested these four dependent variables on a right knee extension task, rather than the finger task used by Spirduso (1975) and by Spirduso and Clifford (1978). While subjects in their inactive group were defined by the same terms as Spirduso (1975), the physically active subjects reported participating in physical activity at least three times per week for most of their life. Clearly this definition of physically active is not as rigorous as Spirduso's (1975) or Spirduso and Clifford's (1978). The results of this experiment indicated that for simple reaction time, both older groups demonstrated significant practice effects. For choice reaction time, on the other hand, the two younger groups and the old inactive group improved significantly with practice. For both simple and choice movement times, the two inactive groups showed significant improvement with practice. Yet although the inactive groups improved with practice, the physically active subjects had initially faster times and maintained this superiority through the final trials. Regarding performance consistency, the physically active older subjects had significantly lower variability than the inactive older subjects. Finally, both the mean performance times and interindividual variability of the physically active older subjects were more similar to those measures in the younger inactive group than in the inactive older group. These results led the authors to suggest that a lifestyle of regular physical activity may retard the typical lengthening of reaction and movement times and the increasing interindividual variability seen with aging.

Only recently have researchers directly questioned if the previously described effects of physical activity are comparable for both genders. To research this effect, Rikli and Busch (1986) administered a battery of tests to 60 women assigned to one of four groups based on age and physical activity level. The younger group averaged 21 years of age while the older group averaged 68 years of age. To qualify for inclusion in the physically active groups, subjects had to be involved in vigorous physical activity for at least three 30 minute sessions per week. This schedule had to be maintained over the previous 3 years for the younger subjects, and over the preceding 10 years for the older subjects. These authors defined vigorous physical activity as any activity intense enough to cause rapid heart rate, heavy breathing, and considerable perspiration, such as aerobics, running, and racketsports. The battery of tests used included assessments of choice reaction time, static balance, flexibility, and grip strength. Analyses of the results revealed significant main effects for both age and physical activity level on each of the dependent variables. The significant interactions on choice reaction time, static balance, and shoulder flexibility were traced to the larger performance differences between the two older groups. Overall, the physically active older women performed more similarly to the younger subjects. In fact, the only measure on which the younger inactive subjects scored significantly better than the physically active older subjects was grip strength. To determine if similar results would be found with a moderately physically active group of subjects, these authors then administered the same battery of tests to a group of women who participated in golf (which these authors considered a moderate physical activity) according to the same time schedule used for the vigorously physically active subjects. The golfers also performed significantly better than the inactive subjects on all of the tasks. Yet their scores were not significantly different from those of the vigorously physically active group. These additional results suggest that the diminished age-related decrements in performance associated with regular physical activity may be independent of the type of physical activity chosen, as well as gender.

Hart (1986) also tested four groups of women based on age and physical activity level, but on the dependent variable of patellar reflex time, under both normal and Jendrassik conditions. The younger group consisted of women 18 to 25 years of age, while the older group members had to be over 55 years of age. Hart further restricted her inactive groups to exclude women who performed strenuous work on their jobs. Accordingly, her physically active subjects were those who participated in sport, exercise, or strenuous work for one or more hours at least three times per week over the five years prior to the study. Thus her physically active subjects were of various body types from activities such as running, swimming, tennis, field hockey, and dance. Total reflex time, as well as its components of reflex latency and reflex motor time, were recorded for each subject under the two conditions (normal and Jendrassik). The results showed no significant main effects for age or physical activity level for total reflex time and reflex motor time under both conditions. There was, however, a significant effect of physical activity level on reflex latency times. Curiously, the physically active had shorter latencies than the inactive among the older subjects, while the reverse was seen for the younger subjects. Hart speculated this could be due to the longer and heavier lower legs of the younger subjects. Therefore, any conclusions about the relationship of physical activity level to reflex time and its components must be considered cautiously. The results of this study also suggest that the aging process has little effect on the involuntary neuromuscular functioning of normal myotatic reflexes. The significant age by condition interaction, however, does imply that Jendrassik facilitation is diminished with age.

In an attempt to measure the effects of a more "real-world" exercise program on fine motor performance in socially active older subjects, Normand, Kerr, and Metivier (1987) compared an experimental group of 24 subjects to an equal number of controls on pursuit tracking performance. All of the 57 to 74 year-old subjects received three blocks of 400 trials, with blocks 1 and 2 administered on consecutive days and block 3 given 10 weeks later. Whereas most studies have classified physically active subjects as those who have participated regularly in their chosen activity over at least three years, this study's experimental group met only for one hour, once per week for a low intensity aerobic exercise program, for a total of 10 weeks. These subjects were also encouraged to exercise at home, although subjects did not keep any records of the home exercise sessions. The results indicated that both groups improved with practice over the first two pretest trial blocks. Performance on the pursuit tracking task stabilized for both groups on the third posttest trial block, with no significant difference in performance between the experimental and control groups. The two groups also showed no significant differences in error rate and overshoot rate on the tracking task. These authors concluded that a low intensity aerobic exercise program had no impact on the fine motor performance of a learned task for normal, socially active older adults. These results contradict those of other studies which have reported significant training effects on fine motor performance. Yet in another study on the effects of exercise on neuromuscular function, Gibson, Karpovich, and Gollnick (1961) reported improved simple reaction times after six weeks of aerobic training, which is also a relatively short training period.

Also, Tweit, Gollnick, and Hearn (1963) found that a low physical fitness group improved visual reaction times after a six week conditioning program. But Beise and Peaseley (1937) found no simple reaction time differences among women after seven weeks of a sport training program. Clearly the relationship between physical training and psychomotor speed is not completely understood. Yet if the expected superiority in performance of physically active subjects is due to the nutritive functioning of a healthy cardiovascular system, as Spirduso and Clifford (1978) suggest, perhaps the exercise program described by Normand, Kerr, and Metivier did not significantly improve the cardiovascular health of the experimental group (aerobic fitness was not measured in this study).

Spirduso, McRae, McRae, Prewitt, and Osborne (1988) expanded the psychomotor assessment of physically active and inactive subjects to include tasks believed to rely on different components of psychomotor performance. They also employed a developmental approach to the effects of exercise on motor function by using four age groups of physiclally active and inactive subjects: 20 to 29 year-olds, 50 to 59 year-olds, 60 to 69 year-olds, and 70 to 79 year-olds. The physically active subjects reported to have either walked, jogged, or run at least three miles per day, three days per week, over the five years prior to the study. The battery of psychomotor performance tests used included assessments of simple reaction time, discrimination reaction time, stationary tapping, between target tapping, trailmaking, and digit symbol substitution. Analyses of the results identified the significant main effect of age on all dependent measures. The main effect of physical activity level was also significant, but only for simple reaction time, discrimination reaction time, and discrimination time (the difference between discrimination reaction time and simple reaction time). All groups also improved significantly with practice on each task. Based on these findings, the authors concluded that the relationship between physical fitness and psychomotor performance reflects the speed of sensory input and motor output during simple discriminations and choices. Specifically, physically active subjects seemed to both identify a stimulus and initiate a motor response faster than inactive subjects. This implies that there was a muscular contraction (peripheral) component as well as a central processing component to the improved psychomotor performance in physically active subjects. On the other hand, the lack of significant differences on the remaining tasks suggests that psychomotor performances depending more on scanning, encoding, processing movement-generated error information, and short-term memory were not affected by physical activity level at any age.

Summary of Age and Physical Activity Level Effects. In conclusion, subject age and physical activity level have been examined in a variety of research settings. To begin with, psychomotor speed has been shown to decrease with age (Bohannon et al., 1984; Gilleard, 1982; Spirduso, 1980). Although the exact mechanism through which these performance decrements act is still unknown, neurophysiological experiments on both age and physical activity level effects are expanding the knowledge base in this area. Next, chronically physically active individuals appear to possess measurable differences from inactive people in both physical and psychological dimensions (Hagberg et al., 1985; Reid, 1976; Reid & McGowan, 1986). Psychomotor performance, the most frequently studied subject characteristic in this area, has generally been shown to be superior in physically active subjects (Beise & Peaseley, 1937; Clarkson & Kroll, 1978; Gibson et al., 1961; Hart, 1986; Normand et al., 1987; Rikli & Busch, 1986; Spirduso, 1975; Spirduso & Clifford, 1978; Spirduso et al., 1988; Tweit et al., 1963). This performance difference appears to be a product of a healthier cardiovascular system associated with regular physical activity. More recent research suggests that increased physical activity specifically allays the decrements in speed of sensory input and motor output during simple and choice discriminations (Spirduso et al., 1988).

Coincidence-anticipation Timing. Stadulis (1972) explains that coincidence-anticipation timing implies two aspects of interception behavior. The first aspect involves making a motor response at the same time the moving object arrives at a designated point (coincidence). The second aspect deals with initiating a response before the arrival of the moving object at a designated interception point to avoid a late response caused by reaction time (anticipation). He further divides coincidence-anticipation timing situations into three distinct events. The first phase of a coincidence-anticipation timing response is the prerelease phase. This period includes any events prior to release of the object, for example a wind-up or an approach. The object flight phase of the next component, which obviously begins as the object becomes airborne. The final phase is the response phase. This phase is characterized by the attempt of the subject to intercept the moving object. This classification scheme has implications not only for skill instruction but for research as well.

Studies in coincidence-anticipation timing have proliferated over the past two decades. These studies can be grouped into two general categories. The first group of studies deals with the effects of various environmental task conditions, such as types of practice and stimulus velocity, on coincidence-anticipation timing performance. The second group of studies examined the effects of subject differences, such as age and gender, on measures of coincidence-anticipation timing performance.

From the first category of studies on coincidence-anticipation timing, one of the environmental task conditions that several researchers have investigated is the nature of practice effects on coincidence-anticipation timing performance. Wrisberg and Mead (1981) tested Schmidt's schema theory by varying initial conditions information during practice on a coincidence-anticipation timing task performed by 7 year-olds. Their three groups of subjects either practiced at variable stimulus velocities, practiced at a constant stimulus velocity, or did not practice at all. Of the two experimental groups, only the group that practiced at the constant stimulus velocity showed improved transfer performance over the control group, as measured by absolute error scores. These authors concluded from these results that variability of initial practice conditions may not improve the acquisition of prediction skills in children, contrary to schema theory.

These authors later examined more thoroughly the effects of training on coincidence-anticipation timing development, again in 7 year-old children (Wrisberg & Mead, 1983). In this experiment, the subjects were randomly assigned to one of four testing groups, or a control group, for two days of practice. The experimental groups practiced on the Bassin Anticipation Timer at either one of two constant speed conditions, a randomly presented set of four stimulus speeds, or a blocked set of the same four stimulus speeds. The two testing stimulus velocities used on the test day were outside (one above and one below) the range of practice stimulus velocities. They found that all groups performed more accurately on the transfer trials at the faster stimulus velocity. In addition, their results indicated that the type of training was significant only for the slow speed transfer trials, with the group practicing various speeds presented in blocks showing the most accurate performance. The group that trained at the faster of the two constant stimulus velocities and the group that trained with varied but randomly presented stimulus velocities performed with the least accuracy. These results led the authors to conclude that training sessions for coincidence-anticipation timing development in children should emphasize slow stimulus velocities, supplemented with blocks of faster stimulus velocities.

Weigand and Ramella (1983) also compared the performance of younger and older subjects on a psychomotor task using the Bassin Anticipation Timer. They randomly assigned the 120 younger men and women (average age 23 years) and the 120 older men and women (average age 66 years) to one of six treatment conditions based on different combinations of both knowledge of results delay interval and post-knowledge of results delay interval. The older subjects improved with practice as did the younger subjects, supporting the notion that older adults can benefit from practice on a novel psychomotor task. In addition, they found the ratio of improvement in performance was similar in the two age groups. These authors concluded that biological aging appears to have no significant effect on an individual's ability to reduce response errors with practice. Although the older subjects showed similar performance improvements in magnitude and rate on this task to their younger counterparts, they did exhibit significantly slower task proficiency than the young subjects.

Catalano and Kleiner (1984) also examined whether variable practice would facilitate transfer to novel stimulus speeds on the Bassin Anticipation Timer. Yet they used older subjects, 18 to 24 year-olds, who practiced either at one of four constant stimulus velocities or at the four randomly presented variable stimulus velocities. These results, however, did support Schmidt's schema theory since the group that trained under the variable conditions showed a significantly lower absolute error than the constant practice groups. In addition, those subjects receiving variable practice performed better than the constant practice groups on the trials outside the practice range of stimulus velocities. Although these results appear to conflict with the results of Wrisberg and Mead (1981, 1983) perhaps the key to the differences in these studies lies in the different age groups tested.

Another external task constraint studied by several researchers deals with the effects of knowledge of results on coincidence-anticipation timing performance. Haywood (1975) tested 75 young (18 to 22 year-old) males on a coincidence-anticipation timing task under three different knowledge of results conditions. One group received no knowledge of results while the other two groups received either qualitative or quantitative knowledge of results. The experimental groups did not perform better than the group receiving no knowledge of results, as measured by calculation of constant error. She suggests these findings could be due to the informationally ambiguous nature of the knowledge of results or to the idea that adult subjects have already learned to anticipate because of their many experiences with moving objects. She also found no significant learning effect over the 30 trials in any of the three groups. Cauraugh and Galyon (1989) added to this design by including two different stimulus velocities for the training and transfer trials, on a task using the Bassin Anticipation Timer. Although their results showed equivalent variable error scores among the three groups during training, both experimental groups performed significantly better than the control group on the second of two 10-trial transfer blocks. These studies suggest that, for adults, visual knowledge of results is sufficient to maintain accurate and consistent performance when task requirements are unchanged, but that verbal knowledge of results is important for consistent performance when task requirements change (Cauraugh & Galyon, 1989).

Wrisberg, Paul, and Ragsdale (1979) included subjects' gender as an independent variable in their assessment of the effects of knowledge of results on coincidence-anticipation timing performance. They assigned their 40 male and 40 female subjects to the experimental group, receiving quantitative knowledge of results, or the control group, receiving no knowledge of results. They found that although male subjects anticipated significantly more accurately and with less variability than female subjects, there was no significant gender by (knowledge of results) condition interaction. For both genders, knowledge of results did not significantly influence accuracy of anticipation but did increase within subject variability. As before, knowledge of results did not significantly affect coincidence-anticipation performance on a task with a constant stimulus speed. This seemed to be true for both women and men.

Payne (1986, 1987) examined the effects of two other environmental stimulus conditions on coincidence-anticipation timing performance, stimulus runway length and angle of stimulus approach. In both studies, 18 to 25 year-old subjects were administered 100 trials using the Bassin Anticipation Timer. The study examined the effects of stimulus runway approach using runways positioned at 0, 30, 60, or 90 degrees from the horizontal. Analysis of the results revealed significant main effects of gender and runway angle, as well as a significant gender by runway angle interaction for absolute, constant, and variable error scores. Specifically, male subjects exhibited more error but less variability in the analysis of constant error, yet these subjects also performed with less error in the analysis of absolute and variable error. Also, subjects tested with the stimulus runway at zero degrees to the horizontal performed with the least error. In the study on the effects of stimulus runway length, subjects were tested with either two, three, or four runway sections. Analyses of the absolute, constant, and variable error scores showed significant main effects of stimluls runway length and gender for only absolute and variable error scores, with subjects tested using four sections of runway performing with the least overall error. Male subjects in this study also performed with significantly less error than female subjects.

Payne and Michael (1990) studied the effects of runway occlusion and stimulus velocity on college men and women. The experimental groups had either the far third, middle third, or near third of the runway lights covered, while the controls viewed the entire set of lights. The subjects were tested at 6 or 9 mph. In general, subjects performed with less error at the faster of the two stimulus velocities. For both stimulus velocities, occluding the nearest third of the lights hindered performance the most. On the average, male subjects had lower absolute and variable error scores, yet were not significantly different than female subjects on mean constant error.

Shea et al. (1981) chose to examine the effects of stimulus velocity, stimulus duration, and stimulus uncertainty on coincidence-anticipation timing performance in two experiments. For the first experiment, subjects were assigned to one of four treatment groups designated by movement condition (aimed or ballistic response), and by stimulus condition (known or unknown velocity). The stimulus velocities ranged from 67 centimeters per second (cm/s) to 179 cm/s. The authors found that although the spatial-temporal response structure differed for aimed versus ballistic movements, the response accuracy was comparable for both movement conditions. Furthermore, response accuracy increased as stimulus velocity increased (duration decreased) for those subjects in the known stimulus condition, while the reverse trend was seen for subjects in the unknown stimulus condition. In other words, subjects responded more accurately with faster stimulus velocities only when stimulus velocity was previously determined; when stimulus velocity was unknown, performance decreased as duration decreased. In the follow-up study, subjects were grouped into one of four conditions based on two stimulus durations (335 and 671 milliseconds) and two stimulus velocities (179 and 358 cm/s). The results indicated that for constant stimulus duration, response structure and response accuracy were similar for both stimulus velocities. For constant stimulus velocity, however, response structure and response accuracy were not similar. These results suggest that stimulus duration is more important than stimulus velocity in determining the nature and accuracy of coincidence-anticipation timing responses.

More recently than these studies, Dunham and Glad (1985) have expanded the investigation of factors affecting coincidence-anticipation timing performance to include the plane of movement of the stimulus. They tested 30 women and 30 men at each of two stimulus velocities with the coincident object moving in both the frontal and sagittal planes. Analysis of the results revealed that the plane of motion did significantly affect coincidence-anticipation timing performance, with subjects exhibiting more error when the stimulus approached in the sagittal plane. The authors believed this could be due to fewer visual reference points available in the sagittal plane. The other significant finding in this study was that performance was more variable when the stimulus moved in the frontal plane, which the authors could only attribute to subject inattentiveness or inappropriate performance strategy.

Ball and Glencross (1989) reported the results of one of the few studies to examine the relationship between the target path and the intercepting response. In the first experiment, the target path had either zero, one, or two reversals in direction while the required response was held constant, with one direction reversal. In the second experiment, the target path was constant, with one directional change, while the response varied, requiring from zero to two directional changes. The results indicated that increasing task complexity from a unidirectional response to a unidirectional target path did not produce performance decrements. The overriding factor in determining the accuracy of performance appeared to be the degree to which the perceived target pattern and the required interception response were related. This finding prompted the authors to suggest that an individual may be attempting to integrate the perception and action systems during coincidence-anticipation timing tasks, or simply stated, that moving while perceiving facilitates performance. In addition, the authors found evidence to support the idea that performance becomes more consistent when the response can be linked to an invariant feature of the target pattern.

Gallagher, Polkis, and Del Rio (1989) chose to compare coincidence-anticipation timing performance on two different tasks to determine if the often reported age difference (discussed in the next section) is independent of the nature of the task. The first task the 6 and 19 year-olds performed used a 48 cm runway track and a Bassin Anticipation Timer. The second task, which the authors considered more ecologically valid, involved a baseball moving down a 120 cm track toward a bat. The subjects were tested at four stimulus speeds on each task. The results revealed a significant age by task interaction on all four independent variables of absolute, constant, variable, and absolute constant error. More specifically, the age group performance difference noted using the Bassin Anticipation Timer were not present on the ball and bat task. The authors suggested that this finding could be due to the ball and bat task providing more salient cues for the younger subjects. Yet the longer stimulus pathway in the second task provided a stimulus duration range of 0.93 to 2.73 seconds, while the stimulus duration on the first task ranged from 0.37 to 1.09 seconds. Thus stimulus duration differences could have also accounted for the performance differences, as suggested by Shea et al. (1981).

Summary of Environmental Task Conditions. Several trends have emerged from studies examining the effects of various external practice, stimulus, and response conditions on coincidence-anticipation timing performance. Variablity of practice appears to improve coincidence-anticipation timing performance, at least for older children and younger adults (Catalano & Kleiner, 1984; Weigand & Ramella, 1983; Wrisberg & Mead, 1981,1983). Visual knowledge of results appears to be sufficient to maintain consistent and accurate coincidence-anticipation timing performance when task constraints are held constant, while additional verbal knowledge of results is needed to maintain performance when task requirements change (Cauraugh & Galyon, 1989; Haywood, 1975; Wrisberg et al., 1979). The angle and plane of stimulus approach significantly affect coincidence-anticipation timing performance, with subjects performing with less error when the stimulus approached at an angle of zero degrees with the horizontal, and when the stimulus travelled in the frontal plane compared to the sagittal plane (Dunham & Glad, 1985; Payne, 1986, 1987). Further, some parts of the approaching stimulus path appear to provide more critical timing information than others (Payne & Michael, 1990). Stimulus velocity also significantly affects performance on coincidence-anticipation timing tasks, but this could be more a function of stimulus duration than the velocity itself (Payne & Michael, 1990; Shea et al., 1981). Stimulus duration could also explain the effect of stimulus runway length on coincidence-anticipation timing performance. Also, coincidence-anticipation timing performance seems to improve when response and target patterns are similar, and when perception accompanies the movement response (Ball & Glencross, 1989). Finally, the coincidence-anticipation timing performance may depend on the task setting itself (Gallagher et al., 1989).

The second classification of studies on coincidence-anticipation timing performance deals with such subject variables as age and gender. Stadulis (1972) described the development of coincidence-anticipation in children. In the first stage of his model, young children view the task in parts, instead of as a whole. The only part of the task they direct their attention to first is the object's flight. Next, the children attend to both the object's source and their response, but not the object's flight. Later, as movement becomes more proficient, children add back the information from the object's flight. Finally when the movement response is proficient, the children visually ignore their hands and concentrate on the source and flight of the object. Using this developmental sequence, teachers can structure their lessons accordingly to maximize the chances of success for the students.

Thomas, Gallagher, and Purvis (1981) also examined the development of coincidence-anticipation timing, in particular the relationship between reaction time and coincidence- anticipation time. They tested 7, 9, 11, 13, and 20 year-olds on both simple reaction time and coincidence-anticipation timing. They found that reaction time decreased with age, and that male subjects responded significantly faster than female subjects. They also noted a significant difference in coincidence-anticipation timing performance between the two younger and the three older groups. Reaction time correlated significantly with coincidence-anticipation time for 7, 9, and 11 year-old male subjects only. These authors reasoned that although young male and female subjects do not have a well-developed motor plan in memory for coincidence-anticipation, the more rapid reaction times of the boys allows better coincidence-anticipation timing performance. Further, beginning at 10 or 11 years of age, better motor plans in children's memory leads to less reliance on a quick reaction time for good coincidence-anticipation timing performance. This explains why, from this age on, the correlation between reaction time and coincidence-anticipation timing is very low.

In a coincidence-anticipation timing study reported by Dunham (1977), 7 to 12 year-old boys and girls were tested on a task using a gravity-propelled car on a track, at each of four stimulus speeds. This task differed from most others reported in that the required response involved removing the foot from a switch as the car passed a target flag. The performance of the 7 year-olds was inferior to all other age groups in both magnitude of error (absolute error) and directional bias (constant error). Two additional findings of this study were that boys were significantly more accurate than girls, and that all groups improved with practice.

Dorfman (1977) extended the developmental perspective on coincidence-anticipation timing to include young adults (19 year-olds). He assessed coincidence-anticipation timing using and oscilloscope and a linear slide set-up, like a primitive video game. Analysis of the results revealed that both performance and consistency improved with age. Gender was also a significant variable affecting performance, again with the male subjects performing with less error than the female subjects. Finally Dorfman found, not surprisingly, that on the last 20 of the 60 trials when the final 86% of the stimulus pathway was obscured from view, performance decreased for all subjects.

In her developmental study of coincidence-anticipation accuracy, Haywood (1980) tested four age groups from young childhood to older adulthood: 7 to 9 year-olds, 11 to 13 year-olds, 18 to 32 year-olds, and 60 to 75 year-olds. Each subject was administered two blocks of 30 trials on a Bassin Anticipation Timer at four randomly presented stimulus speeds from 2 to 5 miles per hour. First, the male subjects performed significantly faster than the female subjects, in terms of maximal response time. There was, however, no significant main effect of gender on coincidence-anticipation accuracy. These two findings led Haywood to suggest that coincidence-anticipation accuracy is not just a function of increased processing time. Next, each age group showed significant response time differences. The young adults responded fastest, followed by older adults, older children, and younger children. Analysis of the variable error data indicated that the younger children were significantly less consistent than the three older age groups. This youngest group also performed with significantly more error than the other three groups. as shown in their absolute error scores. In addition, the constant error scores reflect the increased directional bias of the youngest group. Haywood does point out that the oldest group tested had remained physically active, which could have been responsible for the lack of significant performance differences among the older children, younger adults, and older adults. She subsequently tested a second group of less physically active older adults to determine if significant performance differences exist between this group and the younger groups. Not surprisingly, the older adults in the second experiment did perform with significantly more error as well as significantly more variability than the younger adults in the first experiment. These results also suggest that physically active older adults respond faster and with more accuracy and less variability than their inactive counterparts. This relationship will be examined further in the next section (Haywood, 1989).

Mowatt, Evans, and Adrian (1984) included a test of coincidence-anticipation timing in their assessment of the perceptual-motor abilities of a healthy population of older adults. They found a tendency for their subjects to respond late, although they felt that the large individual differences could have obscured any observable trends. They also questioned the validity of their results as a reflection of coincidence-anticipation timing ability since they observed that their subjects did not appear to be tracking the stimulus lights the entire length of the runway. Furthermore, these results on the coincidence-anticipation timing task may be spurious because each subject received only 10 trials. Recall that Payne (1986, 1987) and Payne and Michael (1990) excluded the first fifteen trials on the Bassin Timer as they felt these trials reflected learning due to their marked variability.

Haywood (1977) specifically examined the developmental nature of eye movements during performance of a coincidence-anticipation timing task. More precisely, she sought to investigate the relationship between eye tracking accuracy and response accuracy. She tested 20 male subjects in each of three age groups (5 to 7 year-olds, 8 to 10 year-olds, and 18 to 28 year-olds) on an electronic coincidence-anticipation timing task while recording their eye movements. Subjects were tested at three randomly-presented stimulus speeds. The results indicated that eye tracking error decreased with age, but that coincidence-anticipation timing accuracy was only significantly different between the youngest and the oldest of the three age groups. In addition, Haywood found that the slowest stimulus speed was associated with both the smallest eye tracking error and the largest coincidence-anticipation timing error. These results refuted the expected presence of a simple positive correlation between eye tracking and coincidence-anticipation timing.

Haywood (1982) continued the examination of eye movement pattern during coincidence-anticipation timing performance with young (19-39 year-olds) and old (62-77 year-olds) women and men. In a very similar experimental design using the Bassin Anticipation Timer instead of a video screen, these adults were tested at three randomly presented stimulus velocities, while eye movements were recorded. Eye movement patterns were classified into one of five patterns. The modal pattern (most frequently used) was determined for each subject. Haywood determined that differences existed in the eye movement patterns between the young and old adults and that individuals in both groups tended to be consistent in their use of a certain pattern. Yet since no particular pattern was linked to superior performance, she concluded that the age group differences were not related to eye tracking errors. Nearly one year later, several of these subjects were retested; this time eye movements were hand digitized and compared to the stimulus path. Again, the older adults performed with more error and less consistency though these performance differences did not appear to be due to eye tracking accuracy. Another interesting finding was that the older adults did not tend to use the same modal pattern in the two testing sessions. Again, the relationship between eye tracking and coincidence-anticipation timing performance seems weak.

Finally, in one of the few longitudinal studies on coincidence-anticipation timing performance and as a follow-up to the 1980 study, Haywood (1989) tested 10 subjects over seven years on the Bassin Anticipation Timer. The subjects, who averaged 66 years of age at the first testing session, were administered 20 test trials of radomly presented stimulus velocities of 3, 5, and 7 miles per hour. Analyses of the average absolute, constant, and variable error scores revealed several notable results. First, the subjects significantly improved coincidence-anticipation timing skill from the first session to the final session. Second, the subjects improved their centering of responses significantly by the second testing session, and they maintained this improved level of performance over the remaining testing periods. Third, performance variability increased significantly in the second session but decreased during the last two testing sessions to a level not significantly different from both of the first sessions. These results led Haywood to conclude that older adults could retain and even improve coincidence-anticipation skill. Yet she could not conclusively state that learning took place because the subjects received limited practice with the task over the four testing sessions. She further adds that the results could have been linked to the physical fitness levels of her subjects; the subjects were originally recruited from a university fitness program, and all either maintained or improved their lifestyles of physical activity over the course of the study. That is, exercise could have maintained the integrity of the neurological processes underlying coincidence-anticipation timing performance.

Summary of Subject Effects. Coincidence-anticipation timing appears to be affected by such subject factors as age and gender (Dorfman, 1977; Dunham, 1977; Haywood, 1977, 1980, 1982, 1989; Mowatt et al., 1984; Stadulis, 1972; Thomas et al., 1981). Most studies on the developmental nature of coincidence-anticipation timing have reported an improvement in performance with age through young adulthood (Dorfman, 1977; Dunham, 1977; Haywood, 1977, 1980, 1982; Thomas et al., 1981), with a subsequent decline in performance thereafter. In addition, young children seem to rely heavily on reaction time in their initial exposure to tasks that require a coincidence-anticipation timing component for success (Thomas et al., 1981).

Furthermore, nearly all studies that included gender as a dependent variable reported that male subjects performed with less error than female subjects (Dorfman, 1977; Dunham, 1977; Haywood, 1980; Payne, 1986, 1987; Payne & Michael, 1990; Thomas et al., 1981). Physical activity level also appears to have an effect on coincidence-anticipation timing performance (Haywood, 1980, 1989). Finally, eye tracking movement does not appear to be directly related to coincidence-anticipation timing performance in both adults and children, although the research in this area is limited (Haywood, 1977, 1982).

## Chapter 3

## Methodology

The following section outlines the protocol used to examine the effects of age and physical activity level on adult coincidence-anticipation timing performance. Included in this chapter are sections on the data collection apparatus, subjects, experimental procedures, and data analysis.

Data collection apparatus. Coincidence-anticipation timing performance was assessed using the Bassin Anticipation Timer (model 50-575 manufactured by Lafayette Instrument Company) (Appendix E) which has been employed often in coincidence-anticipation research (Catalano & Kleiner, 1984; Cauraugh & Galyon, 1989; Gallagher et al., 1989; Haywood, 1980; Mowatt et al., 1984; Payne, 1986, 1987; Payne & Michael, 1990; Shea et al., 1981; Thomas et al., 1981; Wrisberg & Mead, 1981, 1983; Wrisberg et al., 1979). Four sections of runway track were linked to the timer as suggested by Catalano and Kleiner (1984), Payne (1987), Payne and Michael (1990), Wrisberg and Mead (1981, 1983), and Wrisberg et al. (1979). This entire length of track houses one yellow warning light and sixty-four 0.6 centimeter (cm) diameter red lights spaced 4.5 cm apart. The subjects sat at the end of the testing table, approximately 18 inches from the end of the runway. Accordingly, the "stream" of stimulus lights approached each subject in the sagittal plane. A stimulus speed setting of 6 miles per hour was used because this speed is roughly the average (1 to 11 mph) reported in coincidence-anticipation timing research (Catalano & Kleiner, 1984; Cauraugh & Galyon, 1989; Gallagher et al., 1989; Haywood, 1980, 1982; Mowatt et al., 1984; Payne, 1986, 1987; Payne and Michael, 1990; Shea et al., 1981; Thomas et al., 1981; Wrisberg & Mead, 1981, 1983; Wrisberg et al.; 1979). The subjects held a push button extension in their preferred hand that was pressed with the first finger for every trial (Payne, 1986, 1987; Payne & Michael, 1990).

Subjects. The subjects for this study were sixty adult males divided into six groups based on three age and two physical activity level classifications. The youngest subjects were aged 20 to 30 years and the oldest groups were 60 to 70 years old, similar to the design employed by Spirduso and Clifford (1978) in measuring the age and physical activity level effects in runners and racketsports players. An additional age division of ten years in length between these two categories (40 to 50 year-olds) was added to expand the developmental component of this study. This third age group was believed to provide further information about how any physical activity level effects change from the youngest to the oldest age group. Subjects were classified as physically active according to the guidelines of Spirduso et al. (1988) which included running a minimum of three miles per day, three days per week for at least the five years prior to testing. The physically active subjects for the proposed study were further restricted to training at a pace between six and nine minutes per mile, to help eliminate extreme scores. Accordingly, the inactive subjects did not participate in any physical activity for more than an average of one hour per week at a rating of perceived exertion of 5 (somewhat strong) or greater on the revised rating of perceived exertion scale (Borg, 1982), for the 5 years preceding the study. A total of 60 subjects (10 subjects per cell) were tested, to build on the protocol of Payne (1986, 1987) and Payne and Michael (1990) and further to protect for power in the multivariate analysis of variance. The subjects for this study were volunteers recruited from the university student body and staff at both San Jose State University and Arizona State University, running clubs, fitness centers, local 5 kilometer (K) and 10K races, and senior citizens' centers. The subjects' appropriateness for the physical activity level groups was determined by means of a questionnaire (Appendices A and B). Each subject read and signed a letter of consent prior to participating in the experiment (Appendix D).

Experimental procedures and data analysis. The experimental procedures closely followed those described by Payne (1986, 1987) and Payne and Michael (1990) for assessing coincidence-anticipation timing performance. All subjects were administered 100 trials at a stimulus velocity of 6 miles per hour (268 centimeters per second). Each trial was preceded by a yellow warning light at the far end of the runway. The duration of the warning light was presented in a counterbalanced manner of 1, 2, or 3 seconds. Payne (1986, 1987) noted that this counterbalancing inhibits the subjects' development of an automatic schema which may improve performance. The subjects were instructed to press the hand held button when they anticipated the arrival of the stimulus light stream at the final runway light (closest to the subject). For each trial, the subjects received both directional (early or late) and algebraic (in thousandths of a second) knowledge of results. The complete set of standardized instructions are attached (Appendix C).

In addition, the first 15 trials were deleted from the analysis since Payne (1986, 1987) found these data showed greater variability and error than the remaining 85 trials; that is, these initial 15 trials were considered warm-up trials. The subsequent 85 trials were blocked into 5 trial groups to allow the calculation of variable error (VE) and absolute constant error (ACE) as suggested by Schutz and Gessaroli (1987) when repeated observations are recorded on the same dependent variable. Absolute error, typically included in coincidence-anticipation timing research, was not included in this analysis because of the potential for multicollinearity when using these three error scores (Thomas, 1977). A 2 x 3 x 17 (activity level by age by block) multivariate analysis of variance was performed on the two related error distributions (dependent variables). Tukey post-hoc tests, relatively conservative tests, were used when age group effects were significant. For all tests of significance, the .05 alpha level was maintained.

Chapter 4

Results

The raw scores for each subject were blocked into groups of five consecutive trials, after the first fifteen trials were discarded from the analysis. The resultant seventeen VE and ACE scores were then averaged by block over the ten subjects in each group to begin the analysis.

Neither the three-way nor the two-way interactions involving the blocks factor reached significance ($p > .09$). In addition, the main effect of blocks was not significant ($p > .20$). In light of these findings, the analysis was rerun collapsing over the seventeen trial blocks (a 2 x 3 activity level by age MANOVA). The multivariate test for the age by activity level interaction was also not significant ($F_{4,106} = 2.22$, $p = .07$); however, while the age by physical activity level data for VE appeared consistent with this result (Figure 1), the ACE data seemed to show a trend toward interaction (Figure 2).

The univariate F-tests for the VE data ($F_{2,54} = 1.48$, $p = .24$) and the ACE data ($F_{2,54} = 3.61$, $p = .03$) support these ideas. A Tukey post-hoc test showed that the physically active and inactive 20-30 year-olds and the active 40-50 year-olds had the lowest mean ACE scores. The 40-50 year-old inactive and the 60-70 year-old physically active subjects had significantly greater ACE scores, while the 60-70 year-old inactives had the largest ACE scores.

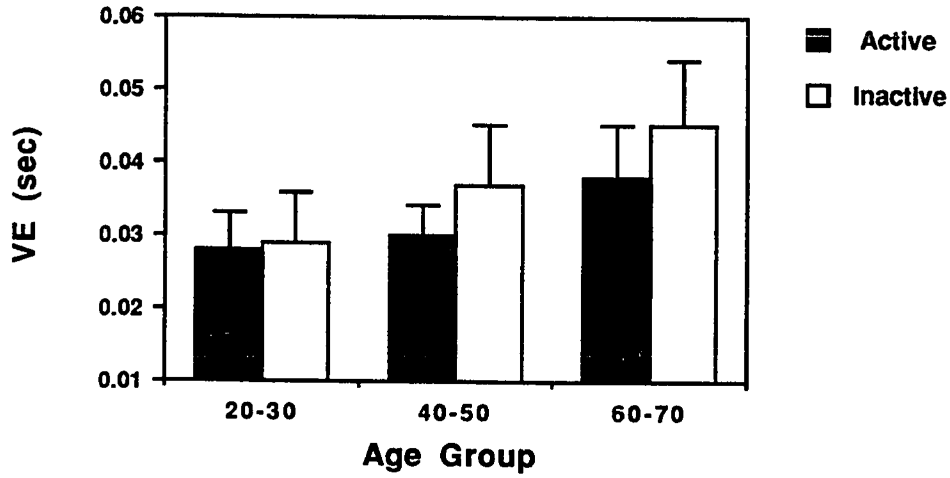


Figure 1. Age group and physical activity level effects on variable error score distribution.

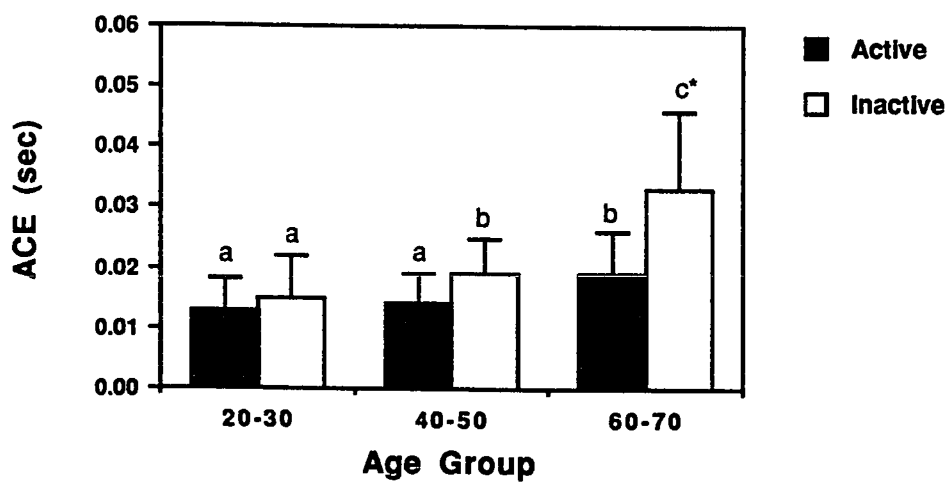


Figure 2. Age group and physical activity level effects on absolute constant error score distribution (* groups with different letters are significantly different at the .05 level).

The multivariate main effects for both physical activity level and age were significant ($F_{4,106} = 11.11$, $p < .001$, and $F_{2,53} = 8.25$, $p < .001$, respectively). The univariate follow-up F-tests for both VE and ACE were significant for the two main effects as well. The analysis of the VE data (Figure 3) showed that the physically active subjects ($M$ = .032 sec, $SD$ = .007) had lower scores than the inactive subjects ($M$ = .037 sec, $SD$ = .010). The physically active subjects ($M$ = .015 sec, $SD$ = .006) also exhibited smaller ACE error scores (Figure 4) than the inactive subjects ($M$ = .022 sec, $SD$ = .012).

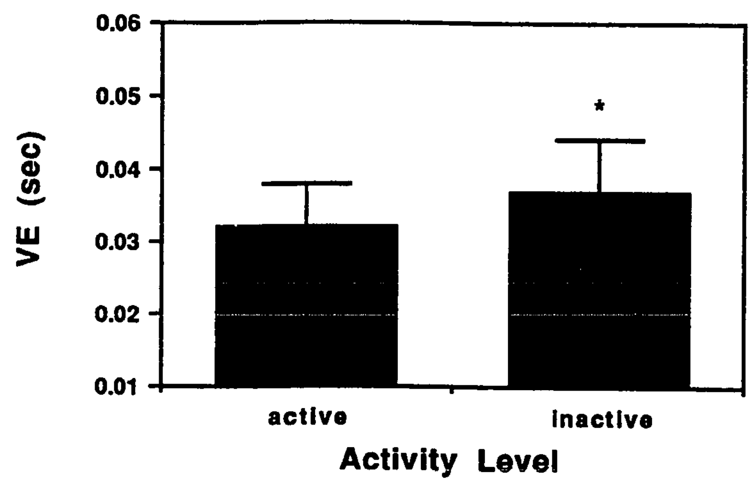


Figure 3. The main effect of physical activity level on variable error (* $p < .01$).

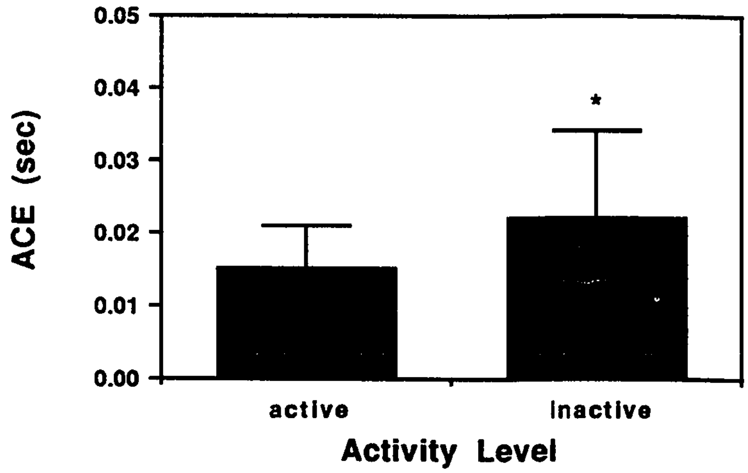


Figure 4. The main effect of physical activity level on absolute constant error (* p < .01).

A post-hoc Tukey test was used to determine differences between the three age groups on the two error distributions. The VE scores increased significantly from the 20-30 year-olds (M = .028 sec, SD = .006) to the 40-50 year-olds (M = .037 sec, SD = .007) to the 60-70 year-olds (M = .041 sec, SD = .008) (Figure 5). For the ACE data, while the 20-30 year-olds and the 40-50 year-olds were not significantly different from each other (M = .014 sec, SD = .006, and M = .016 sec, SD = .006, respectively) both groups had significantly lower scores than the 60-70 year-olds (M = .026 sec, SD = .012) (Figure 6).

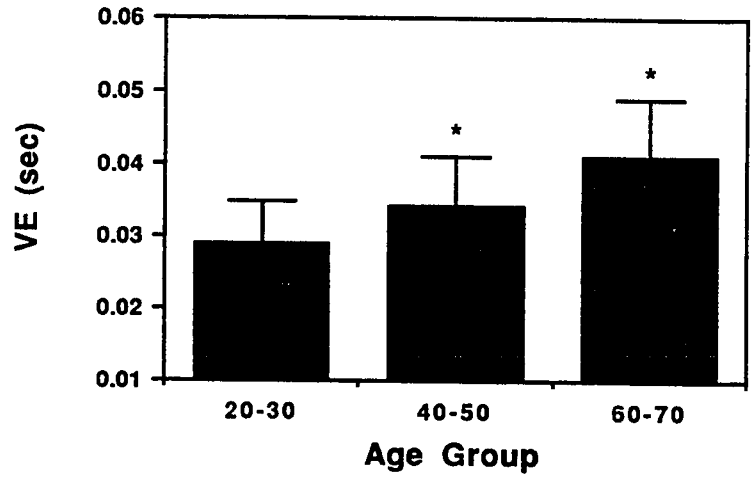


Figure 5. The main effect of age group on variable error (* $p < .001$).

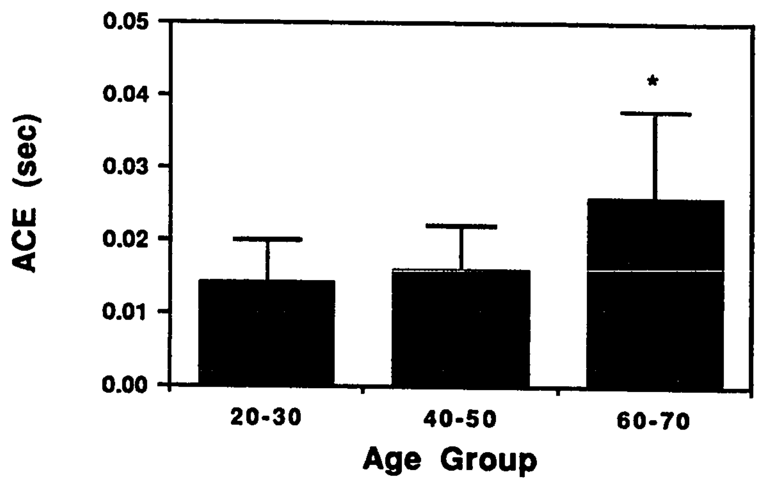


Figure 6. The main effect of age on absolute constant error (* $p < .001$).

Finally, the magnitudes of effect ($Eta^2$) for physical activity level were 0.12 for VE and 0.19 for ACE, and the magnitudes of effect for age were 0.40 for VE and 0.35 for ACE. That is, physical activity level accounted for about 12% of the variance in VE and 19% of the variance in ACE, while age accounted for about 40% of the variance in VE and 35% of the variance in ACE.

The means and standard deviations by age group and physical activity level for both variable error and absolute constant error scores are presented in Table 1.

Table 1

Mean Variable Error and Absolute Constant Error Scores

| | VE | | ACE | |
|---|---|---|---|---|
| | M | SD | M | SD |
| 20-30 Actives | .028 | .005 | .013 | .005 |
| 20-30 Inactives | .029 | .007 | .015 | .007 |
| 40-50 Actives | .030 | .004 | .014 | .005 |
| 40-50 Inactives | .037 | .008 | .019 | .006 |
| 60-70 Actives | .038 | .007 | .019 | .007 |
| 60-70 Inactives | .045 | .009 | .033 | .013 |

(note: all error times are in seconds)

## Chapter 5

## Summary, Discussion, Recommendations, and Conclusions

Summary. The effects of age and physical activity level on coincidence-anticipation timing performance were studied in runners and sedentary controls from 20 to 70 years of age. Performance was measured across the last 85 of 100 trials using the Bassin Anticipation Timer at a stimulus velocity setting of 6 mph. The raw data were analyzed with a 2 x 3 x 17 (physical activity level by age group by trial blocks) MANOVA with repeated measures on the last factor. Since there were no significant main effects and interactions with the trial blocks factor, the analysis was rerun collapsing over trial blocks. For both error distributions, the two-way age by activity level interaction was not significant, althought a trend toward significance was seen in the ACE scores. The main effects of age and activity level, however, were significant for both VE and ACE. Active subjects were more accurate and less variable in their timing than inactive subjects. Response consistency decreased across the three age groups, and the oldest subjects were less accurate in their timing than the two younger groups.

Discussion. In agreement with studies on reaction time (Spirduso, 1975; Spirduso & Clifford, 1987) main effects were found for both age and activity level on this coincidence-anticipation timing task. Specifically, response consistency (VE) decreased with age across the three age groups, while the magnitude of error (ACE) increased significantly only in the oldest subjects. In addition, for the two older age groups, those subjects who were regular runners had more accurate and more consistent responses than their inactive peers. Furthermore, the lack of significant age by activity level interactions in the present study parallels the findings of Spirduso and Clifford (1978). Spirduso (1975) did, however, find significant age by activity level interactions on three of four dependent reaction time measures. This difference in the significance of the interactions may be explained by the subject pools used in these studies. The active subjects in the 1975 study were all racketsports players while the 1978 study combined racketsports players with runners, which more closely resembles the subject pool for this study. The univariate test of the age by activity level interaction for ACE, however, was significant. The 40-50 year-old runners' mean ACE scores were similar to both 20-30 year-old groups, and the 60-70 year-old runners' mean ACE scores resembled those of the 40-50 year-old nonrunners. That is, the two older active groups performed with similar error to, at least, the next younger inactive group.

The lack of a main effect of trial blocks and any interactions with trial blocks indicates that, for all subjects, performance did not significantly change over the 85 trials analyzed. Spirduso (1975) and Spirduso and Clifford (1978), however, did find main effects for trials as well as some interactions with trials. The difference in significance of the trials effects between these two studies and the present one could have been due to the design of the studies. In the 1975 study, only the first five trials were discarded to allow for a learning curve. Then only ten trials were used to measure performance on the reaction time tasks. In comparison, for this coincidence-anticipation timing study the first fifteen trials were excluded for learning effects. This was done based on the findings of Payne (1986, 1987) that the data from the first 15 trials of ten randomly selected subjects showed much greater error and variability than data from the final 85 trials. In the 1978 study, a total of fifty trials were used, but none were omitted as learning trials. This inclusion of early trials could have led to the main effect and interactions with the trials factor.

Although no other studies have reported ACE error scores, several have published VE scores from subjects tested on the Bassin Anticipation Timer. The means and standard deviations of the VE distributions were similar to those obtained by Payne (1986, 1987), Payne and Michael (1990), and Wrisberg, Paul, and Ragsdale (1979). These studies tested subjects at either 6 or 9 mph with the runway in the midsagittal plane. Other studies (Haywood, 1980, 1982) reported mean VE values nearly twice those found in this study. In these two studies, however, the subjects were tested at stimulus velocities between 2 and 7 mph with the runway track positioned horizontally in front of them. Since the mean VE values obtained in this experiment were close to those from other experiments with similar designs, the VE values reported here are presumed to be representative of the population tested.

Recommendations. Further research is needed to assess the activity level effects from participation in other sports besides running to determine whether participation in these other activities would result in similar benefits to the neuromuscular system. Additional classification or inclusion of subjects based on a physiological measure such as maximal oxygen consumption may increase the generalizability of the results. Further, this design should be replicated with female subjects to determine if the age and activity level effects on coincidence-anticipation timing performance are similar in women and men. Although the inactive older subjects in this study reported no regular participation in vigorous physical activity, most stated they attended social activities at a senior citizen center several days per week. Perhaps comparison of these results with those from a more sedentary population than the one used here would help provide a more complete picture of the age and physical activity level effects on neuromuscular integrity, as reflected by coincidence-anticipation timing performance. Along more practical lines, the results presented here would support the idea that participation in physical activity, in this case running, would lead to significantly improved coincidence-anticipation timing performance. A longitudinal training study, with pretraining and posttraining coincidence-anticipation timing measurement, could provide more convincing evidence regarding how much timing would be improved with exercise. Further, although several of the runners tested here probably have been running much longer than five years, it would be interesting to test elite athletes to find out how their performance would compare to the populations tested here.

Conclusions. In summary, the results of this study support the conclusions of others (Clarkson & Kroll, 1978; Hart, 1986; Rikli & Busch, 1986; Spirduso, 1975, 1980; Spirduso & Clifford, 1978) that a lifestyle that includes regular physical activity, in this case running, can allay the typical age-related decrements in neuromuscular function. This concept has now been reported for two different measures of neuromuscular integrity, reaction time and coincidence-anticipation time. The results here, however, cannot support the suggestion that activity level plays a more dominant role than age in its effect on the neuromuscular system (Rikli & Busch, 1986; Spirduso, 1975). The effect sizes for age were larger than those for activity level for both VE and ACE scores.

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# Appendix A

## Subject Background Questionnaire - runners

Subject number________ Age (years)______ (months)______

The following questions pertain to your training schedule for running over the past five (5) years.

1. How many days per week do you train, on the average?

   ____ 1 to 2 days

   ____ 3 or more days

2. How many miles do you train each session, on the average?

   ____ less than 3 miles

   ____ 3 or more miles

3. What is your average training pace per mile?

   ____ less than 6 minutes per mile

   ____ 6 to 7 minutes per mile

   ____ 7 to 8 minutes per mile

   ____ 8 to 9 minutes per mile

   ____ more than 9 minutes per mile

Appendix B

Subject Background Questionnaire - nonrunners

Subject number________ Age (years)________ (months)_______

1. On the average, over the past 5 years, how many hours of physical activity (running, cycling, tennis, etc.) per week have you per week have you participated in that you would rate at an intensity of 5 or greater on the scale below?

____ less than 1 hour per month

____ 1 to 3 hours per month

____ about 1 hour per week

____ more than 1 hour per week

revised Borg RPE scale

| | |
|---|---|
| 0 | Nothing at all |
| 0.5 | Very, very weak |
| 1 | Very weak |
| 2 | Weak |
| 3 | Moderate |
| 4 | Somewhat strong |
| 5 | Strong |
| 6 | |
| 7 | Very strong |
| 8 | |
| 9 | |
| 10 | Very, very strong |

# Appexdix C

## Subject Instructions

After each subject was shown the testing apparatus and seated at the testing table, the following instructions were given.

1. "Hold the pushbutton in your preferred hand. You will use your first finger to press the button instead of your thumb."
2. "A yellow warning light at the far end of the runway will precede each trial. After the yellow light goes out, the stream of red light will approach you."
3. "The goal of the task is to push the button at the same time the light stream arrives at the last light. Do not wait for the last light to go on, or you will always be late."
4. "After each trial, I will tell you whether you responded early or late, and by how many milliseconds. The best possible score is 0.000."
5. "The test will consist of two blocks of fifty trials. We will take a one minute break between blocks."

Qualitative feedback was given as follows:

| | |
|---|---|
| 0.000-0.010 | "Excellent." |
| 0.011-0.050 | "Very good." |
| 0.051-0.099 | no feedback |
| 0.100 + | "That was off a little; concentrate harder on the next one." |

6. "Do you have any questions?"

Once the testing is completed, the subjects were shown their scores and thanked for their participation.

Appendix D

AGREEMENT TO PARTICIPATE IN RESEARCH
SAN JOSE STATE UNIVERSITY

RESPONSIBLE INVESTIGATOR: Darryl Michael

TITLE OF PROTOCOL: Effects of Age and Pyscical Activity Level on Adult Coincidence-Anticipation Timing Performance

I have been asked to participate in a research study that is invertigating factors affecting adult coincidence-anticipation timing performance. The results of this study should further our understanding of how age and physical activity level influence the integrity of the neuromuscular system.

I understand that

1) I will be asked to use a hand-held push button to respond to 100 trials on the Bassin Anticipation Timer, set at a stimulus velocity of 6 mph. This single testing session, lasting approximately 15 minutes, will take place in the Motor Learning Lab at SJSU (SPX 82) or at a location more convenient for me.

2) there are no anticipated risks of this study.

3) the possible benefits of this study to me are an increased understanding of the research process as well as an enjoyable experience.

4) alternative procedures include being tested at a location more convenient for me.

5) the results from this study may be published, but any information from this study that can be identified with me will remain confidential and will be disclosed only with my permission or as required by law.

6) any questions about my participation in this study will be answered by Darryl Michael (408-924-3030). Complaints about the procedures may be presented to Dr. Greg Payne, Graduate Coordinator; Dr. James Bryant, Department Chair. For questions of complaints about research subject's rights, or in the event of research-related injury, contact Serena Stanford, Ph.D. (Associate Academic Vice President for Graduate Studies & Research) at 924-2480.

7) my consent is given voluntarily without being coerced; I may refuse to participate in this study or in any part of this study, and I may withdraw at any time, without prejudice to my relations with SJSU.

8) I have received a copy of this consent form for my file.

I HAVE MADE A DECISION SWETHER OR NOT TO PARTICIPATE. MY SIGNATURE INDICATES THAT I HAVE READ THE INFORMATION PROVIDED ABOVE AND THAT I GAVE DECIDED TO PARTICIPATE.

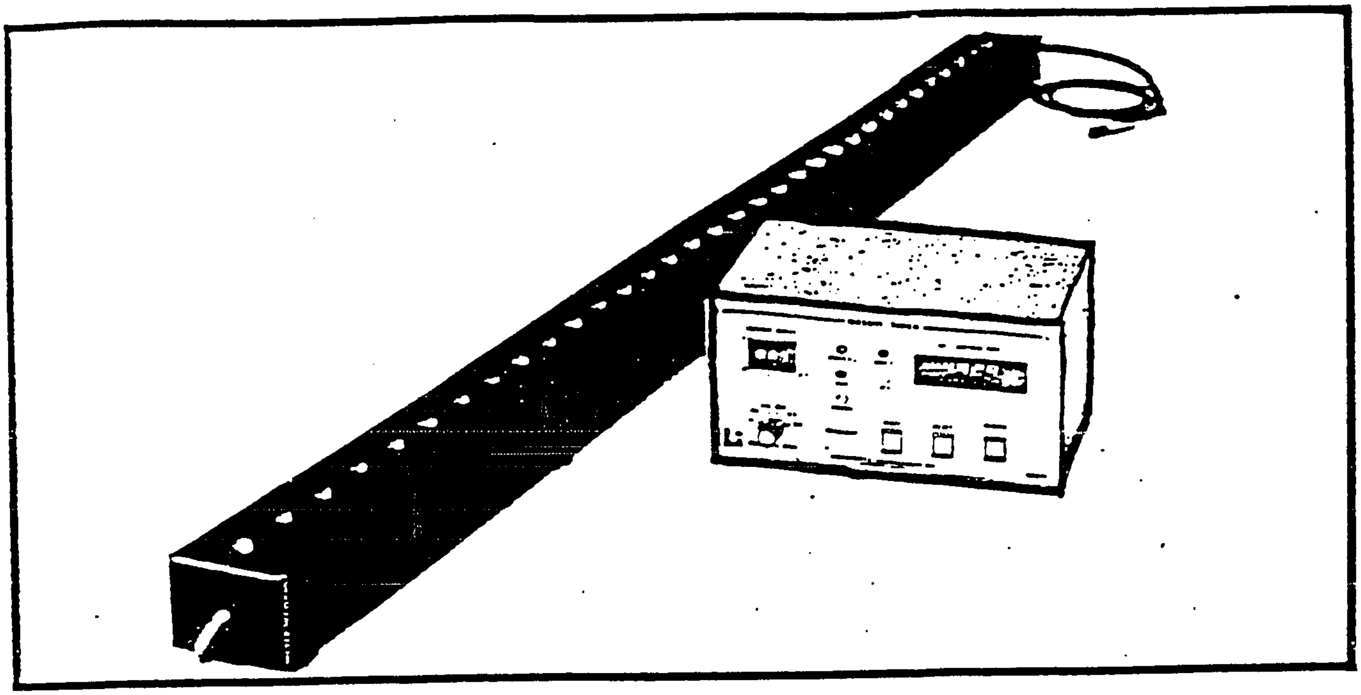
__________ ______________________________

DATE SUBJECT'S SIGNATURE

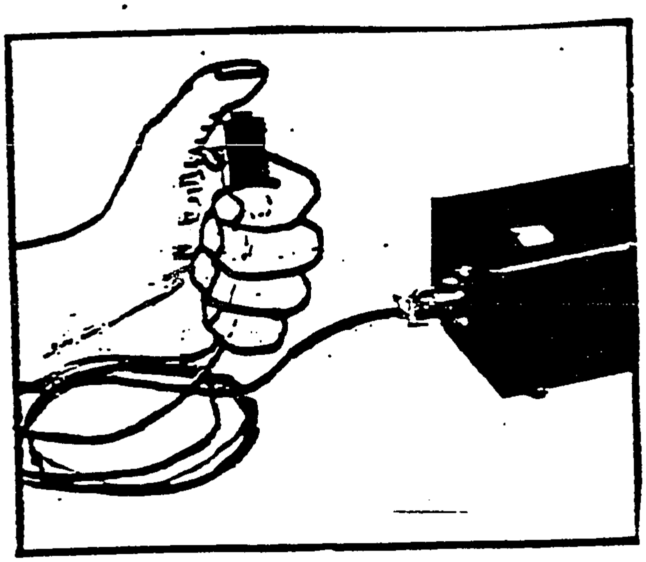
______________________________

INVESTIGATOR'S SIGNATURE

# Appendix E



Bassin Anticipation Timer and runway



push button

# Appendix F

SUBJECT NUMBER______ DATE__________ AGE_________

HAND DOMINANCE______ ACTIVITY LEVEL_________________

TIME OF DAY__________

| | | | | | |
|---|---|---|---|---|---|
| Trial | 1. (1)____ | 21. (2)____ | 41. (2)____ | 61. (1)____ | 81. (2)____ |
| | 2. (3)____ | 22. (2)____ | 42. (3)____ | 62. (2)____ | 82. (1)____ |
| | 3. (2)____ | 23. (1)____ | 43. (2)____ | 63. (3)____ | 83. (3)____ |
| | 4. (2)____ | 24. (3)____ | 44. (3)____ | 64. (1)____ | 84. (2)____ |
| | 5. (3)____ | 25. (1)____ | 45. (1)____ | 65. (2)____ | 85. (2)____ |
| | 6. (1)____ | 26. (3)____ | 46. (1)____ | 66. (3)____ | 86. (3)____ |
| | 7. (3)____ | 27. (2)____ | 47. (3)____ | 67. (3)____ | 87. (1)____ |
| | 8. (1)____ | 28. (1)____ | 48. (2)____ | 68. (2)____ | 88. (1)____ |
| | 9. (2)____ | 29. (2)____ | 49. (1)____ | 69. (1)____ | 89. (2)____ |
| | 10. (2)____ | 30. (3)____ | 50. (3)____ | 70. (1)____ | 90. (3)____ |
| | 11. (3)____ | 31. (3)____ | 51. (2)____ | 71. (3)____ | 91. (3)____ |
| | 12. (1)____ | 32. (1)____ | 52. (1)____ | 72. (2)____ | 92. (2)____ |
| | 13. (3)____ | 33. (2)____ | 53. (3)____ | 73. (1)____ | 93. (1)____ |
| | 14. (1)____ | 34. (1)____ | 54. (2)____ | 74. (2)____ | 94. (1)____ |
| | 15. (2)____ | 35. (3)____ | 55. (3)____ | 75. (3)____ | 95. (3)____ |
| | 16. (1)____ | 36. (2)____ | 56. (2)____ | 76. (2)____ | 96. (2)____ |
| | 17. (2)____ | 37. (3)____ | 57. (1)____ | 77. (1)____ | 97. (1)____ |
| | 18. (3)____ | 38. (1)____ | 58. (3)____ | 78. (3)____ | 98. (2)____ |
| | 19. (3)____ | 39. (2)____ | 59. (1)____ | 79. (1)____ | 99. (3)____ |
| | 20. (1)____ | 40. (1)____ | 60. (2)____ | 80. (3)____ | 100. (3)____ |