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Chronic effects of fitness on the golf putt

Piparo, Anthony John, Ph.D.

The University of North Carolina at Greensboro, 1992

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CHRONIC EFFECTS OF FITNESS ON THE GOLF PUTT

by

Anthony J. Piparo

A Dissertation Submitted to the Faculty of
the Graduate School at
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Approved by

Diane L Gill

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APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro.

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The present investigation examined (1) potential chronic fitness effects on cognitive and motor performance and (2) three theories of attentional interference. Twenty-four golfers, 12 fit and 12 unfit, participated in the study. All golfers were of intermediate level. The fit group consisted of 9 males and 3 females between the ages of 18 and 39 (M = 25.7, SD = 6.17), who had VO_2's between 43 and 68.3 $ml \cdot kg^{-1} \cdot min^{-1}$ (M = 51.5, SD = 7.98), and USGA handicaps between 5 and 24 (M = 13.25, SD =4.14). Fit golfers also reported a history of engaging in vigorous aerobic activity (3 times/wk for the last 6 months). The unfit group consisted of 8 males and 4 females between the ages of 21 and 36 (M = 27.9, SD = 6.00), who had VO_2's between 29.7 and 39.4 $ml \cdot kg^{-1} \cdot min^{-1}$ (M = 35.1, SD = 3.65), and USGA handicaps between 6 and 24 (M = 16, SD = 5.44). Unfit golfers reported they had not engaged in a regular program of vigorous cardiovascular activity for the past 6 months.

Preliminary analyses revealed that the two groups were similar in terms of age, sex, and handicap, but varied significantly with regard to fitness. A (Group (fit/unfit) x Task (RT/Memory) x Condition (Exercise/No Exercise)) (2 x 2 x 2) ANOVA on putting performance with repeated measures yielded a significant main effect for task, F (3, 16) = 5.37, $p < .05$. That is, all golfers had less cm error in the reaction time tasks than they did in the memory perturbation conditions. Further, a significant main effect for

group, F (3, 16) = 19.2, $p < .001$, emerged with fit subjects outperforming unfit golfers across all experimental conditions. These results suggested that performance of the golf putt declined when there was a disruption of the direct, single-step access of information from memory. However, memory theory may need to be modified to account for such extrinsic factors as chronic exercise/fitness effects.

DEDICATION

In loving appreciation, this manuscript is dedicated to my wonderful wife, Kathleen, and my beautiful children, Jennifer Love, and Tony John, for all their patience, love, understanding, and belief in me during this major undertaking. Thank you guys, I love you.

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CHAPTER I

INTRODUCTION

Physiological effects of exercise on physical functioning are relatively well known. Changes occurring in cardiovascular, skeletal, and other organic systems during and after exercise have been described in detail (Fox, 1984; Mathews & Fox, 1976). Less is known of exercise effects on psychological variables. This investigation focused on the psychological effects acute and chronic exercise exerts on physical performance. Specifically, the effects of exercise and nonexercise conditions on one's ability to process information and perform the golf putt were assessed.

Considerable research has examined the acute effects (changes in performance during and immediately after) of exercise on cognitive and motor performance. While some literature (e.g., McAdams & Wang, 1973) reported no exercise effects on cognitive and motor task performance, the bulk of the literature has found exercise either facilitates (e.g., Gliner, Masten-Twisdale, Horvath, & Moran, 1979) or debilitates (e.g., Sjoberg, 1980) mental and physical performance. One of the factors thought to mediate the exercise/performance relationship is the subjects' physical fitness level (Tomporowski & Ellis, 1986). Research evidence consistently demonstrates the superiority of physically fit individuals performing cognitive and motor tasks during and after exercise (Gutin, 1966; Gutin & DiGennaro, 1968a, 1968b; McGlynn, Laughlin, & Bender, 1977; McGlynn, Laughlin, & Rowe, 1979; Sjoberg, 1980; Piparo, Crews, & Hart, 1991; Weingarten & Alexander, 1972). When subjects were recruited based on high physical fitness, positive results were obtained (McGlyn, Laughlin, & Bender, 1977; McGlyn, Laughlin, & Rowe, 1979; Sjoberg, 1980; Weingarten & Alexander, 1972). Similarly, individuals identified as high-fit performed better than low-fit individuals on cognitive and motor tasks after vigorous physical exertion (Gutin, 1966; Gutin & DiGennaro, 1968a, 1968b; Piparo, Crews; & Hart, 1991).

Thus far, research examining fitness effects on the exercise/performance relationship has emphasized acute effects of exercise, that is, how well one performs cognitive and motor tasks during and immediately after exercise. There is some reason to believe that fitness also has a chronic impact on cognitive and motor functioning. Chronic fitness effects would imply that fit individuals outperform unfit individuals on cognitive and motor tasks in non-exercise conditions. In a recent meta-analysis, Salazar, Landers, Petruzzello, and Kubitz (1991) showed that fitness developed through regular physical activity produced a reliable increase in intelligence and memory.

Explaining Fitness/Performance Relationships

While fitness may explain the facilitative or debilitating effects of exercise on mental and physical performance, the reason is unclear. Several hypotheses have been forwarded to explain this phenomenon (Nataanen, 1973; Tomporowski & Ellis, 1986). Tomporowski and Ellis (1986) suggested that differences between fit and unfit performers on vigorous physical activities may be due to fatigue. Because unfit individuals fatigue sooner than fit individuals, vigorous physical activity may impair unfit subjects' performance sooner. However, as Holding (1983) pointed out, the effects of physical fatigue can be modified by incentive variables, citing several studies which indicated that even during extremely physically fatiguing conditions, subjects were able to compensate for fatigue during performance of cognitive and psychomotor tasks. Thus, physical fatigue may not be the discriminating factor for the relationship between fitness and performance.

Second, it has been suggested that performance is directly related to arousal. The inverted-U hypothesis is the model most often cited to describe the arousal/performance relationship (Yerkes & Dodson, 1908). In this model, extremely low and high arousal levels are associated with poor performance while intermediate arousal levels produce optimal performance. The unidimensional nature of the inverted-U hypothesis has recently come under considerable criticism (Hardy & Parfitt, 1991; Hardy, Parfitt, & Pates; 1991; Jones & Hardy, 1989; Neiss, 1988, 1990). Hardy et al. (1991) demonstrated that the arousal/performance relationship is multidimensional, that the arousal/performance relationship varies with cognitive anxiety, and that a three-dimensional model better describes the complex arousal/

performance relationship than two-dimensional, linear or curvilinear models.

While a three-dimensional model may better describe the arousal/performance relationship, other researchers disclaim the direct impact of arousal on performance altogether and suggest a more circuitous route. Nataanen (1973) argued that the arousal/performance relationship was based upon inadequate experimental evidence. He asserted that performance changes during arousing situations are not necessarily the direct result of overarousal. Instead, he stated that the basic paradigm in which the inverted-U was derived involved possible artifact. For example, a typical design involved asking subjects to create increased muscle tension by their own efforts, such as gripping a dynamometer. This was essentially a dual-task design in which increased arousal was produced by using a secondary task source of stimulation. Nataanen provided empirical evidence to support his argument that as subjects increased their muscular tension, they paid greater attention to the arousal, diverting attention from primary task performance.

Mandler (1975) similarly argued that the adverse effects of high arousal upon performance were due to distraction. Arousal, according to Mandler, generated internal cues which became more salient as activation increased so that the individual increasingly attended to the arousal rather than to the task. This resulted in primary task performance decrements.

If unfit performers are distracted by increases in activation, why aren't fit performers similarly distracted? First, physiological responses remain attenuated in the fit performer for a longer period of time. Further, through regular vigorous physical activity, it is more likely that fit individuals' bodies automatically respond to the physical exertion. For these two reasons, physiological changes may not represent as potent a distractor for fit individuals.

This logic suggests that the fitness/performance relationship is affected by the performers' ability to attend to the primary task while processing physiological information. The implication that physical activation influences performance through attentional processes has been accepted as virtually axiomatic by most learning theorists (Tomporowski & Ellis, 1986). Information processing or attention, as defined by Fitts and Posner (1967), is the receiving, coding, and storing of information which results in specific patterns of behavior. Much of the work on information processing has involved the use of dual-task paradigms. Dual-task paradigms, also known as time-sharing, involve adding a cognitive task to a motor task.

Theories of Attentional Processes

Capacity theory. Historically, researchers have viewed time-sharing in terms of supply and demand differences. These theories were based on the assumption that information processing required attention which had a limited or fixed capacity (Kahneman, 1973). If two tasks could be performed as well simultaneously as they could be separately, then at least one of the tasks did not require attention or a portion of the limited capacity. The task or tasks not requiring attention was/were said to be automatic (Fitts & Posner, 1967) or under subcortical control (Shiffrin & Schneider, 1977). Capacity theory further suggests that humans possess a single channel of limited capacity for processing information. An individual can process any amount of information simultaneously as long as limited channel capacity is not exceeded. Performance decrements occur when demands exceed resources. Capacity theory might suggest that processing information related to changes in physiological activation has become automatic for fit performers while unfit performers actively process the physiological information. Performing the cognitive or motor task as well as processing physiological information may exceed the unfit performers' limited channel capacity resulting in performance decrements.

Multiple resource theories. More recent conceptualizations of time-sharing may be categorized under the term structural interference theories (Whittal, 1988) or multiple resource theories (Navon & Gopher, 1979; Wickens, 1984). These theories are based on the premise that resources are multidimensional (McLeod, 1977; Wickens, Mountford, & Schreiners, 1981). In this conceptualization, those tasks which draw upon similar resources will be shared less efficiently than those tasks which do not share the same resources, resulting in decrements in performance of at least one of the tasks. For tasks which draw upon similar resources, decrements in performance occur for those tasks which have not been well-learned. In contrast, decrements in performance will not occur in a primary task if the secondary task taps some other resource, whether or not the secondary task has been well-learned. When a secondary skill is not well-learned and uses the same resource as a primary task, processing information cannot occur simultaneously, but will be sequentially processed with the most well-learned skill processed first. If one is forced to process the information from both tasks simultaneously, disruption in performance will occur in both tasks. Subsidiary tasks which do not tap the same resource as a primary task can be processed concurrently and will not result in performance decrements.

Attention-as-memory. Logan (1988) suggested a third possibility for automatization. He stated that automaticity is a memory phenomenon. Performance is considered automatic when it depends on single-step, direct-access retrieval of solutions from memory. Automaticity occurs only when skills become well-learned through practice under specific conditions. Subsidiary tasks which are not well-learned or are completed simultaneously with primary tasks in novel situations will result in performance decrements of both tasks.

Summary of Attentional Theories

In summary, all three attentional theories are based on automaticity, but they differ in how skills become automatic. According to capacity theory (Kahneman, 1973), skills that are well-learned will be performed equally well, regardless of the situation. Further, even if skills of secondary tasks are not well-learned, they will not interfere with performance of a primary task as long as the total amount of information being processed does not exceed the performer's limited channel capacity. In contrast, multiple resource theory (Wickens, 1984) suggests that performance decrements will occur for skills that are not well-learned and require the same channel for processing. Performance decrements will not occur in tasks performed concurrently that use different channels to process information. Similarly, attention-as-memory suggests that skills performed simultaneously will interfere with one another unless they are well-learned. However, unlike multiple resource theory, the attention-as-memory view does not recognize separate channels for processing different types of information. Therefore, any skill that requires memory and is not well-learned will result in performance decrements when performed simultaneously with another skill or performed in a novel situation. Practice must be specific to that skill in that condition Figure 1 shows predictions for well-learned primary task performance outcomes when completed concurrently with a secondary task that is either well-learned (practiced) or not well-learned (not practiced). For capacity theory, practice of the secondary task is unwarranted as long as the information to be processed does not exceed the performer's limited channel capacity. Multiple resource theory predicts performance decrements in the primary task when completed concurrently with an unpracticed skill using the same channel to process information. Multiple resource theory does not predict performance decrements in execution of a primary task

	Capacity Theory	Multiple Resource Theory		Memory Theory
		Channels		
		Same	Different	
Practice	S+	S+	S+	S+
No Practice	S+	D	S+	D

Primary Task Performance

Figure 1: This figure represents predictions of primary task performance when completed concurrently with practice and unpracticed secondary skills for each of the three attentional interference theories.

Note: S+ indicates stable or improved performance. D indicates performance decrements.

when the subsidiary task uses a different channel, even when the secondary task is unlearned. Finally, the attention-as-memory view predicts performance decrements in primary task performance completed concurrently with any unpracticed secondary task.

Determining potential effects of fitness on cognitive and motor performance may have important ramifications for which attentional interference theory is the best predictor of performance across situations. While all three theories predict similar results for the acute effects of fitness, their predictions differ under nonexercise conditions. First, all three theories might suggest that fit performers may process physiological activation automatically. That is, fit performers process physiological information fast. Processing physiological information for fit performers does not require effort, or attentional control, and will be triggered when the appropriate stimuli are present (during exercise). As intensity and/or duration of exercise increase, concomitant changes do not debilitate the performance of fit individuals. On the other hand, unfit performers may not process physiological information automatically. Active processing requires effort. Unfit individuals may attempt to control their physiological activation, and, because they have very limited practice processing this type of information, their efforts to engage in a cognitive or motor task and simultaneously process physiological information may exceed their ability. The result is a decrement in performance of the primary task.

Because capacity theory is only concerned with the total amount of information to be processed, it might further suggest that chronic exercise, which increases fit performers' capacity to process physiological information, also would increase their capacity to process similar amounts of nonphysiological information. Therefore, one would expect similar differences in performance between fit and unfit individuals when having to perform a cognitive or motor task while processing similar amounts of non-physiological information. That is, fit individuals would continue to perform equally well while unfit individuals would continue to exhibit performance decrements.

In contrast, multiple resource theory and memory theory would not make the same prediction. Multiple resource theory would suggest that both fit and unfit individuals would incur decrements in primary task performance when that task is completed simultaneously with a secondary task that tapped the same channel unless that secondary task was also well-learned. Primary task performance for both fit and unfit individuals would not be affected when performed concurrently with a task that did not require the same channel space even if that secondary task was not well-learned. Finally, the attention-as-memory view would predict primary task decrements for both fit and unfit individuals when the primary task was performed concurrently with an unlearned subsidiary task that required memory. A description of these predictions can be seen in Figure 2.

	Capacity		Multiple Resource				Memory	
			Same Channel		Different Channel			
	Fit	Unfit	Fit	Unfit	Fit	Unfit	Fit	Unfit
Practice	S+	D	S+	S+	S+	S+	S+	S+
No practice	S+	D	S+	S+	S+	S+	D	D

Primary Task Performance

Figure 2: Prediction of Primary Task Performance for Capacity, Multiple Resource, and Memory for Fit and unfit Individuals when a primary task is completed concurrently with a practiced or unpracticed secondary task.

Note: S+ indicates primary task performance remains stable or improves, D indicates primary task performance declines.

To determine if there are any chronic effects of fitness on cognitive and motor performance as well as assessing the ability of the three attentional interference theories to explain the fitness/performance relationship requires that a number of methodological considerations be satisfied. First, fit subjects who exercise as well as unfit subjects who do not exercise need to be recruited. All subjects must be equally well-versed in the primary task. The experimental conditions must include each of two secondary tasks which the subjects are forced to perform simultaneously with the primary task. The information to be processed for one of the secondary tasks should be considered to tap the same resource as the primary task. Information necessary to complete the other secondary task should be considered to use another channel for processing. Also, one of the tasks should require memory while the other does not. If these conditions are satisfied, then one would be able to determine if fitness exerts any chronic influence on performance as well as assessing which theory or view best predicts performance.

Summary

In summary, fit individuals outperform unfit individuals during and immediately after exercise. It has yet to be determined if similar differences in cognitive and motor task performance exist between fit and unfit individuals when performing without the presence of increased physiological activation from exercise. Further, arousal affects performance by altering one's attentional processes. Exactly how this occurs is open to debate. Capacity proponents (Kahneman, 1973) would contend that there is some limited attentional capacity. When one exceeds that capacity, performance declines. Advocates of multiple resource theory (Navon & Gopher, 1979; Wickens, 1984) would suggest that only when two operations require the same channel or tap the same resource will performance decrements occur. Finally, the attention-as-memory view (Logan, 1988a) would suggest that performance decrements occur because there is a disruption of the retrieval of information from memory.

Does chronic exercise/fitness allow fit individuals to process other types of information? That is, can fit individuals process other types of distractions (which is important for successful performance) more automatically than less fit individuals? Answering this question could have great importance for sport, especially for those activities which have not traditionally been associated with high fitness (i.e., golf, archery, bowling, pistol and rifle shooting).

Sport demands that athletes overcome many types of distractions. Common distractions in sport situations are associated with both internal states and external events. For example, too much self-awareness, self-evaluation, and self-doubt may cause an athlete to focus inappropriately during preparation or execution (Singer et al., 1991). Moreover, a sudden auditory or visual external distracter may occur during the preparation for and/or execution of a movement, resulting in impaired performance (Allport, 1989). Physiological changes also may distract athletes.

Overcoming the many potential irrelevant cues and psychological and physiological distractions inherent in sport requires the ability to orient one's attention properly - to remain task-focused from beginning to end.

Purpose

The purpose of this quasi-experimental investigation were (1) to examine potential effects fitness/chronic exercise exerts on performance of the golf putt and (2) to test three theories of attentional interference. The golf putt was selected because it requires a selective attention directed to the task while disregarding ancillary sources of influence. The golf putt is also performed in a stable environment with the golfer able to perceive the situation as well as his/her own intentions. Movements are initiated at the golfer's own pace and, given the situation when the amount of time to prepare the action is limited, attention to the demands of the golf putt is potentially under the control of the golfer. However, as both novice and elite golfers attest, distractions are many, and appropriate focus difficult. In assessing these effects it is assumed that the differences in performance between fit and unfit performers are a result of fit subjects' ability to process physiological information more automatically and to selectively attend to appropriate cues.

Examining chronic effects of fitness as well as adequately testing the three attentional interference theories requires the performance of the golf putt in exercise and nonexercise conditions. Further, subjects must putt while simultaneously performing one of two secondary tasks. The secondary tasks chosen for this investigation include a probe reaction time task and a memory perturbation task. These two tasks were chosen because they appear to require different channels for processing (Wilkens, 1984). Further, the probe reaction time task is not considered to require memory (Kahneman, 1973). Subjects will putt in four experimental conditions; memory perturbation only, probe reaction time task only, exercise with memory perturbation, and exercise with probe reaction time task.

Question 1: Does fitness influence golfers' abilities to perform secondary tasks? Previous work has shown that fitness affects memory with fit subjects outperforming unfit subjects (Salazar, et al, 1991). Fitness has not been found to affect reaction time. However, reaction times have been found to be faster during exercise than during nonexercise conditions for all subjects. Therefore two hypotheses were forwarded. (H1): Fit golfers would outperform unfit golfers on memory tasks during all conditions. (H2): All golfers would have faster reaction times during exercise than nonexercise conditions.

Question 2: What factors influence golfers' abilities to perform the golf putting task? Several hypotheses are forwarded. Because fit golfers have been found to out perform unfit golfers after vigorous physical exercise, (H3): Fit golfers would outperform unfit golfers during the exercise conditions. No differences were predicted for the nonexercise condition. An alternative explanation, based on capacity theory, is that (H4): Fit golfers outperform unfit golfers during the nonexercise condition. However, because the complexity of the task is increased by adding an exercise protocol, no differences were expected to emerge during the exercise condition. Multiple resource theory suggests performance decrements for those activities requiring similar processing resources unless the activities have been well learned under specific conditions it would be expected that (H5): All golfers would experience performance decrements on the probe reaction time task while putting performance was expected to remain constant during the memory task in both exercise and nonexercise conditions. Finally, memory theory, as advance by Logan (1988a), would predict that (H6): All golfers would incur performance decrements on the memory perturbation task, but not on the probe reaction time task during both exercise and nonexercise conditions.

CHAPTER II

REVIEW OF LITERATURE

Fitness Effects on Cognitive and Motor Performance

The primary focus of this investigation concerns potential chronic fitness effects on cognitive and motor performance. Although little research has examined chronic effects of fitness, considerable evidence exists that demonstrates the superiority of fit subjects performing cognitive and motor tasks during and immediately after aerobic exercise. Several hypotheses have been forwarded to account for performance differences of fit and unfit individuals. The most accepted explanation is that exercise affects performance through attentional processes. Further, three attentional interference theories exist that may explain whether or not chronic fitness effects on performance are possible. This chapter will examine present findings on acute and chronic fitness effects on cognitive and motor performance and potential explanations for the fitness/performance relationship. The chapter will then proceed with a review of the three theories of attentional interference. A summary and theoretical and methodological considerations will conclude the chapter.

Research examining the influence of acute bouts of exercise on cognitive and motor performance has produced conflicting results. Basically, studies can be listed in one of four categories; studies that demonstrate positive results; studies that have no effects; studies which show performance decrements; and studies that demonstrate both performance facilitation and performance debilitation. Several studies have shown exercise to benefit cognitive and motor performance (Burgess & Hokanson, 1964; Lybrand, Andrews, & Ross, 1954; McGlynn et al, 1977). For example, Lybrand et al. (1954) found that subjects improved performance on manipulative problem-solving and perceptual organization tasks after completing vigorous physical exercise. Performance of digit-symbol substitution was also enhanced for both males and females following mild exercise (Burgess & Hokanson, 1964). Finally, McGlynn et al. (1977) found that male college students were able to perform a discrimination task, without accuracy impairment, faster while running on a treadmill at increasing speeds and gradients, than before the exercise. All studies used college-aged students in physical education classes which may represent a population of better fit individuals. However, cardiovascular fitness was not measured.

Other investigations have failed to elicit any exercise effects on performance (Flynn, 1972; Gutin & DiGennaro, 1968a; McAdams & Wang, 1967). Gutin and DiGennaro (1968a) found that performance of simple addition was not significantly influenced for 32 male subjects when using a 1 and 5 minute step-up exercise. Similarly, McAdams and Wang (1967) found that a mild run-jog-walk protocol had no impact on a symbol substitution task in 128 male adults. Using a sample of 30 adolescent males, Flynn (1972) found that prior exercise on a bicycle ergometer was not significantly related to numerical speed or accuracy of addition and subtraction. These studies also failed to measure fitness.

Still other studies have shown exercise to be associated with performance decrements (Gutin, 1968b; Stauffacher, 1937). Stauffacher (1937) found that male college students' ability to remember nonsense syllables decreased when they had to simultaneously lift weights. Gutin (1968b) showed that addition performance in male college students worsened slightly following an exhaustive treadmill run than compared to when the subjects were at rest. Again, no attempt was made to assess fitness. Further, the level of exertion in the exhaustive treadmill run conducted by Gutin (1968b) may have exceeded even fit subjects' capacity.

Finally, research has found both beneficial and detrimental effects. Davey (1973) found an inverted-U relationship between exertion and attention in male and female practice teachers. Initial performance was low. As physical exertion increased so did the teachers' ability to attend. However, as the exertion became too strenuous, attention declined. In a study with male and female intermediate-level golfers, Piparo, Crews, and Hart (1991) found that fit subjects made more putts and had less cm error on missed putts after completing an 80% submaximal treadmill walk than before the exercise. The Piparo et al. (1991) study used high and low fit males and females between the ages of 20 and 40 to test golf putting performance. Males were categorized as high fit if they had a VO2 max above 45 $ml \cdot kg^{-1} \cdot min^{-1}$ and low fit if they had a VO2 max below 40 $ml \cdot kg^{-1} \cdot min^{-1}$. Females were categorized as high fit if they had a VO2 max above 42 $ml \cdot kg^{-1} \cdot min^{-1}$ and low fit if they had a VO2 max below 38 $ml \cdot kg^{-1} \cdot min^{-1}$. Subjects walked on a treadmill for 20 minutes at a speed and grade indicative of 80% of their VO2 max as found by a continuous variable speed graded walking protocol. Regardless of gender, all fit subjects improved performance after exercise while low fit subjects experienced performance decrements pre-to-post-exercise. Thus, during and after intense aerobic exercise of moderate length, fit individuals outperformed unfit individuals. Further, Piparo et al. (1991) found that unfit subjects experienced performance decrements pre-to-post-exercise. Based on these studies exercise may facilitate, debilitate, or have no effect on performance.

Some of the differences may be the result of type of exercise (anaerobic or aerobic), intensity of exercise (low to intense), and the fitness level (low or high) of the subjects in the studies. However, abundant evidence indicates that strenuous exercise which does not cause excessive fatigue has a facilitative effect on performance among high fit individuals and a debilitating effect on the performance among low fit individuals. Besides the Piparo et al. (1991) study mentioned previously, several other studies offer similar results (Gutin, 1966; Gutin & DiGennaro, 1968a, 1968b;

McGlynn, Laughlin, & Bender, 1977; McGlynn, Laughlin & Rowe, 1979; Sjoberg, 1980; Weingarten & Alexander, 1970). McGlynn et al. (1979) used highly fit women ($VO_{2\ max}$ above 50 $ml \cdot kg^{-1} \cdot min^{-1}$ as determined by the Sharkey step test, 1979) to test perceptual speed during exercise. Their results showed that these women increased their speed of performance at the most intense exercise level without any adverse effects on accuracy.

Chronic Effects of Fitness

To date, the literature has extensively examined the acute effects of exercise on cognitive and motor performance but has only begun to investigate any possible chronic effects of fitness. Salazar et al. (1991), using meta-analytic techniques, found that fitness, developed through chronic exercise, produced a reliable increase ($ps < .05$) in intelligence (ES= .25) and memory (ES = .41) for an exercise group, but not for a control group ($ps < .05$), (ES = .03) for Intelligence; and (ES = -.02) for memory. Research has not examined chronic effects of fitness on information processing (attention). If performance is disrupted through disruption of attentional processes and fitness provides athletes with the ability to better attend to appropriate cues, then fitness might be of importance to athletes, whether or not the sport requires high levels of fitness.

One of the major concerns of any athlete striving for athletic success is the ability to impose some degree of control over his or her internal states. For athletes engaging in sports with a high degree of vigorous physical activity, fitness is of prime importance.

Fit performers may process changes in physiology better and are thus able to focus on appropriate cues. This may provide them with a greater degree of control over their internal states than performers who are less fit, resulting in better performances for fit athletes. However, in many situations (field goal kicking in football) or sports (golf, archery, pistol and rifle shooting) cardiovascular fitness has not traditionally been thought to play a major role. Vigorous activity represents only one type of 'stressor' or 'distraction' for athletes (Singer, Cauraugh, Tenant, Murphy, Chen, & Lidor, 1991). Common psychological stressors in sport include too much self-awareness, self-evaluation, and self-doubt. These stressors may cause athletes to focus inappropriately during preparation and execution and can be thought of as 'distractions' (Singer et al., 1991). Does fitness help athletes to focus appropriately when being distracted by nonphysiological stressors? And if so, how? The primary purpose of this investigation is to determine if fitness has any chronic effects on athletes' information processing and performance. The secondary purpose is to determine how information processing influences performance. This question is considered in the following section.

Information Processing

While there is sufficient evidence to support the claim that automatic processing of information facilitates cognitive and motor performance, there is some disagreement as to why this relationship exists (Tomporowski & Ellis, 1986). Early hypotheses were based on the inverted-U framework (Yerkes & Dodson, 1908), which states that individuals' current physical arousal levels interact with their ability to perform psychomotor tasks. Performance is low at low levels of physical arousal and increases with increases in arousal to some optimal level. However, as arousal exceeds that optimal level, performance declines. Because fit individuals have attenuated sympathetic activation under even intense physical exertion, they will not have surpassed their optimal arousal level and performance will remain at a high level for a longer period of time. On the other hand, low fit individuals have an increased sympathetic response and so exceed their optimal level far sooner that high fit individuals, resulting in performance decrements much sooner. Although evidence supports the inverted-U relationship when exercise is used to induce physical arousal (e.g., Davey, 1973), the inverted-U hypothesis only describes but does not explain the arousal/ performance relationship. Further, the inverted-U explanation for the arousal/performance relationship has come under recent attack (Hardy & Parfitt, 1991; Hardy, Parfitt, & Pates, 1991; Jones & Hardy, 1989; Neiss, 1988, 1990). Hardy et al. (1991) have found that arousal is multidimensional and that catastrophe theory best describes this complex relationship. The catastrophe theory model is three-dimensional with performance varying according to cognitive anxiety. Performance will not suffer when somatic anxiety is high and cognitive anxiety is low, only when both somatic and cognitive anxiety are high. A complete description of this model is beyond the scope of this discussion and not warranted. It is mentioned merely to point out the concern with the inverted-U model. As with the inverted-U hypothesis however, Hardy, et al. (1991) agree that the catastrophe theory model merely describes the arousal/performance relationship and that research is needed which explains why arousal influences performance.

Attentional Interference. More recently, attentional process theories have been used to help explain how the reception and processing of information influences the execution of cognitive and motor tasks. The contention that physical arousal has an impact on attentional processing has been accepted as virtually axiomatic by most learning theorists (Tomporowski & Ellis, 1986). Attentional processes have been a core topic in psychology and considerable theorizing has been done to explain how attention is influenced by changes in physical arousal levels. Landers (1980) has summarized the major theories of arousal and psychomotor performance suggesting that the model forwarded by Easterbrook (1959) provides the prototype for current theories of attention. Easterbrook's theory proposes that any variation in physical arousal produces concomitant changes in attentional processes. Specifically, an increase in activation results in a "narrowing" of attention to those components of a task that are central to correct response. Attention to those aspects that play limited or no role in correct performance are reduced. As the level of arousal exceeds some optimal arousal state, there is a continued "narrowing" of the attentional field, possibly eliminating relevant stimuli, which results in performance deterioration.

Easterbrook's cue utilization model extended the early work of Yerkes and Dodson's (1908) inverted-U hypothesis, providing a framework for more recent theories of information processing. These more recent frameworks include limited capacity theory (Kahneman, 1973), multiple resource theory (Navon & Gopher, 1979), and attention-as-memory phenomenon (Logan, 1988a). All three of these frameworks are based on automaticity.

Automaticity. Automaticity or automatic processing refers to attentional requirements or the encoding of information into long-term memory. Hasher and Zacks (1979) state that attentional requirements lie on a continuum. Innate automatic processes which are fast, effortless, not open to awareness, consistent, and not subject to disruption by other attentional demands lie on one end of the continuum. At the other terminus are nonautomatic processes. These mental operations are complex, require effort, open to awareness, and subject to disruption by other mental operations. Hasher and Zacks (1979) suggest that other mental operations lie between automatic and nonautomatic processes, and thus share some of the attributes of both automatic and nonautomatic processing.

There is considerable evidence that certain complex operations can become automatic through extensive practice (Hasher & Zacks, 1979). Complex operations which have become automatic through extensive practice are referred to as "learned" automatic processes. Learned automatic processes share some but not all of the attributes of innate automatic processes and are thus thought to lie on the continuum between automatic and nonautomatic processes. Specifically, under stressful conditions, "learned" automatic processes are subject to disruption (Hasher & Zacks, 1979). While the three theories of attention agree that "learned" automatic processes are subject to disruption, exactly how the disruption occurs is the crux of the debate among the theories.

Resource Theories

Capacity Theory. Two existing theories attempt to explain disruption of performance in "learned" automatic processes on the basis of available resources, capacity theory (Kahneman, 1973) or single-resource theory and multiple resource theory (Navon & Gopher, 1979; Wickens, 1984). Both of these theories suggest that performance decrements occur when demands of a task exceed an individual's resources to deal with the distraction. Capacity theory (Kahneman, 1973) suggests the existence of a single "channel" which performs all mental operations. Further, this "channel" has some limited capacity. When the limited capacity of that channel is exceeded, performance disruption occurs. Central to capacity theory is the notion that information is processed simultaneously or in parallel. This differs from earlier information processing theories which assumed sequential processing. Kahneman (1973) referred to these "structural" theories as bottlenecks or filters because they postulated a series of stages through which information passed between input and response, and assumed a particular stage of processing at which selective attention operates. Some theorists (Broadbent, 1958; Triesman, 1960) placed the bottleneck or filter early in the information-processing sequence, prior to perceptual analysis. (See Figure 3). That is, only one stimulus can be perceived

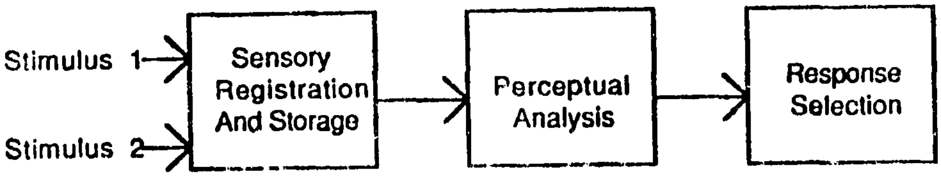

Figure 3: Broadbents (1958) Structural Theory of Attention.

at any one time. When two stimuli are presented at once, one of them is perceived immediately, while the sensory information that corresponds to the other is held briefly as an unanalyzed echo or image (Kahneman, 1973). One can attend to such echoes and images and perceive their content, but only after the perceptual analysis of the first stimuli has been completed. In this model, attention controls perception.

A second model assumes the bottleneck occurs after perception but before response (Deutsch & Deutsch, 1963). (See Figure 4). According to this model, the meanings of all concurrent stimuli are extracted in parallel and without interference. The bottlenecks that impose sequential processing are only encountered later. These bottlenecks or filters prevent the initiation of more than one response at a time, and selects the response that best fits the requirements of the situation.

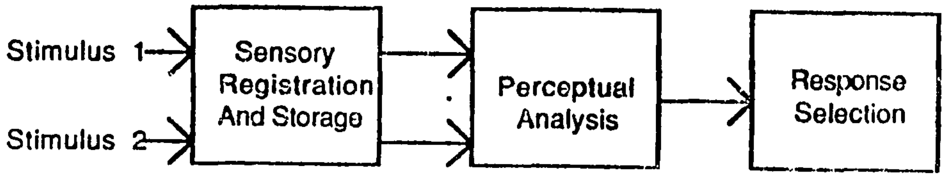

Figure 4: Deutsch and Deutsch's (1963) Theory of Structural Attention.

These two models are also known as structural models of interference because they emphasize structural limitations of the mental system. In a structural model, interference occurs when the same mechanism is required to carry out two incompatible operations simultaneously. Thus, a structural model implies that interference between tasks is specific, and depends on the degree to which the tasks call for the same mechanisms. As you will shortly note, in a capacity model, interference is nonspecific, and depends only on the total demands of both tasks.

Kahneman's capacity theory provided an alternative to these structural theories. Instead of bottlenecks, capacity theory assumes a general limit to one's capacity to perform mental work. Therefore, one can engage in any number of mental operations simultaneously. Performance disruptions occur when the total demand on the system exceeds the capacity of the system to process information or when the available capacity is channelled to other activities. (See Figure 5).

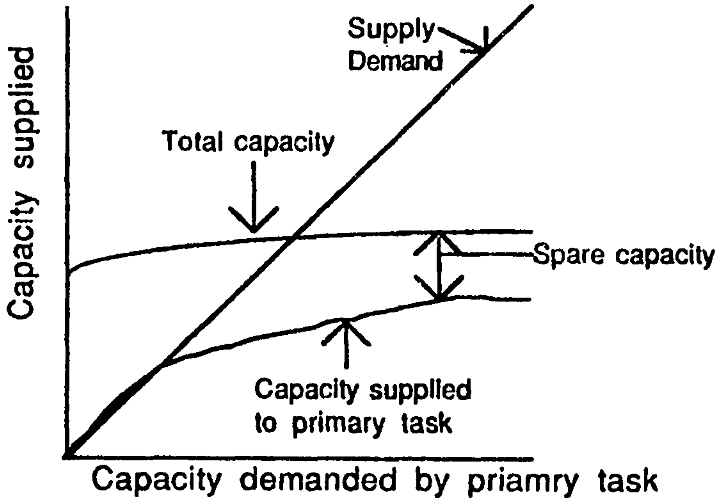

Figure 5: Kahneman's (1973) Single-Resource or Capacity Theory.

Central to capacity theory is the notion that mental activities impose different demands on the limited capacity. Tasks that are automatic require little effort and use only limited amounts of one's capacity. The more complex a task, the more effort is required to complete the operation and the more capacity space used. Thus, any number of automatic tasks can be completed simultaneously because they use up very little capacity. On the other hand, one is limited in the number of operations one can attend to simultaneously when any of the tasks are more complex because complex tasks require more effort and use up more of the limited capacity.

Also important to capacity theory is the idea that limit varies with the level of arousal: more capacity is available when arousal is moderately high than when arousal is low. One can conclude that performance is associated with the allocation of a certain amount of effort. Allocation of sufficient effort does not necessarily result in errorless performance. However, allocating less effort than is necessary will cause performance deterioration. Further, exerting more conscious effort than necessary debilitates performance. Finally, it is assumed that momentary capacity, attention, or effort (Kahneman uses these terms interchangeably) is controlled by feedback from the execution of ongoing operations: a rise in the demands of these activities causes an increase in the level of arousal, effort, and attention.

An additional suggestion is that some effort is exerted even when task demands are at zero. The continuous monitoring of one's surroundings probably occupies some capacity even in the most relaxed conscious states (Kahneman, 1973). Kahneman refers to this as "spare capacity" and suggests that a measure of spare capacity can be obtained by studying changes in performance of two tasks completed simultaneously from when they are completed separately. Failures in performance of the secondary task provides evidence that spare capacity is reduced by task performance.

Figure 5 describes capacity theory in detail and shows that capacity (effort) increases with steadily increasing demands of a primary task. As the demands of the task increase, the discrepancy between effort demanded and the effort actually supplied increases steadily. Also depicted in this representation is the spare capacity available to any secondary tasks. As arousal or effort necessary to complete the primary task increase, less spare capacity is available to complete secondary tasks.

In summary, capacity or single resource theory assumes that only a single reservoir or channel of undifferentiated resources, which is equally available to all stages of mental operations, exists within the human processing system. As such, individuals can engage in any number of mental operations simultaneously as long as capacity demands do not exceed capacity limitations. Automatic processes require little effort and so do not use much channel space. As task complexity increases so does the amount of effort necessary to complete the operation which requires more channel space. Increased task complexity increases physical arousal. Further increases in arousal increase capacity demands which reduce capacity space. Capacity theory also assumes the existence of spare capacity which allows individuals to monitor the environment or engage in secondary tasks. At low levels of arousal or when a primary task is automatic, there is more spare capacity. As primary tasks become more difficult or arousal increases, spare capacity space reduces.

Capacity theory represents an acceptable explanation for the differences in performance between fit and unfit performers during and immediately after exercise. During mild exercise there is sufficient spare capacity to process physiological variables for both fit and unfit performers. Because unfit individuals' physical arousal increases at a faster rate as exercise intensity increases, they exceed their spare capacity limitations sooner, impinging on their channel capacity which results in performance decrements at an earlier stage of exercise than for fit individuals. Using the tenets of capacity theory, it could be argued that through the process of becoming fit, fit individuals have developed the capacity to automatically process information. Since it does not make any difference what kind of information, only the amount of information, fit individuals should be able to automatically process other types of information, as long as the amount of information does not exceed their limited capacity.

Limitations to Capacity Theory. While ample evidence supports capacity theory, enough anomalies exist in the literature to cast doubt on the predictability of capacity theory in many situations. Four phenomena present some difficulty for a single-resource or capacity theory - difficulty insensitivity, perfect time-sharing, structural alteration effects, and difficulty-structure uncoupling related to the structural aspects of the tasks (Wickens, 1984).

An example is cited by Wickens (1984) in which performance of a secondary task did not decrease even when the difficulty of the primary task was increased to a level which supposedly used all available resources. The difficulty of the primary task was measured by continual decrements in performance. In a study by North (1977), subjects time-shared a tracking task with a discrete digit-processing task. The discrete task required subjects to perform mental operations of varying complexity on visually displayed digits, and to indicate their response with a manual switch press. In the simplest condition, subjects merely depressed the microswitch corresponding to the displayed digit. A condition of intermediate demand required the subject to indicate the digit immediately preceding the displayed digit in time - a running memory task. In the most demanding condition, subjects were required to perform a classification operation on a pair of displayed digits. These three operations apparently imposed different demands, as indicated by their single-task performance level and their interference with simple digit canceling. However, when the digit tasks were performed concurrently with the tracking task, all three had equivalent disruptive effects on tracking performance.

An example of perfect time-sharing is provided by Allport, Antonis, and Reynolds (1972), who demonstrated that subjects could sight-read music and engage in an auditory shadowing task concurrently as well as they could perform either task by itself. Wickens (1976) observed a similar finding when an auditory signal detection task was time-shared with a response-based force-generation task. Shaffer (1975) has noted a high degree of efficiency with which skilled typists could time-share typing with auditory shadowing. Although a single-resource theory explanation can, in theory, account for difficulty, insensitivity, and perfect time-sharing, Wickens (1984) argues that the examples just cited did not involve heavily data-limited tasks. As Wickens further explains, neither North's (1977) tasks nor those of Allport et al. (1972) were predictable or repetitive in a manner that might easily give rise to automation. Furthermore, Wickens states that all tasks appeared to involve a relatively heavy time pressure, either through forced pacing or through a self-paced schedule in which performance was measured in terms of the number of responses made per unit time.

Structural alteration effects refer to instances in which the change in a processing structure (modality of display, memory code, modality of response) brings about a change in interference with a concurrent task that has not been altered. Such examples have been observed with regard to input modality (e.g., Isreal, 1980; Martin, 1980; Wickens et al., 1983). If the difficulty of an altered task truly remains unchanged (performance or subjective ratings of single-task controls must guarantee this), then the resource demands should be very similar or identical across tasks. No change in interference with the concurrent task, therefore, should be predicted under the assumption of undifferentiated resources.

The uncoupling of difficulty refers to instances in which the more difficult of two tasks when paired with a third task actually interferes less with the third task than does the easier of the two tasks when it is paired with the third task. This effect was observed by Wickens (1976) in a study in which tracking was paired with an auditory signal detection task and an open-loop force-generation task. The signal detection task was assessed by subjects to be more difficult, and therefore, presumably, it demanded more resources. Yet signal detection interfered less with tracking than did the force task.

It is evident from the examples just cited that some restructuring of the undifferentiated-resource view was required. This has proceeded in two directions. Kahneman (1973), in modifying capacity theory presented in the early chapters of his book, acknowledged the potential of structural factors contributing to interference between tasks. The model which emerged is one in which competition between tasks for the general pool of resources proceeds in conjunction with competition for more or less dedicated structures. An alternative modification postulates the existence of multiple resources (Navon & Gopher, 1979; Wickens, 1984).

Multiple Resource Theory. According to multiple resource theory, there is more than one channel or reservoir within the human processing system that may be assigned resource-like properties. If resources, do in fact, reside in separate channels, then it is important to identify the functional composition of these channels. Examining a large number of dual-task studies that produced structural alteration effects and difficulty insensitivity, Wickens, (1980), has argued that resources may be defined by a three-dimensional metric consisting of stages of processing (perceptual-central versus response), codes of perceptual and central processing (verbal versus spatial), and modalities of input (visual versus auditory) and response (manual versus vocal). It is possible that the response modality dimension is similar to the central-processing code dimension, assuming that manual responses generally tend to be those that are spatially guided and vocal productions are, by and large, verbal (Wickens, 1984).

To summarize, there are not many major differences between multiple and single resource theories. Both predict that time-sharing will be less efficient if two tasks share common demands.

According to Kahneman, this results from direct competition for the structures. According to multiple resource theory, it results from the competition for the resources that enable the operations to function. Perhaps the major difference between the two theories is that the single-resource model assumes only a single channel with resource-like properties, whereas multiple resource theory assumes more than one such channel. This has several implications. First, only when tasks compete for similar resources will there be task interference and second, "learned" automatic processes must be practiced in stable environments. If new stimuli are presented which have not been processed by the learner, interference in the primary task will occur, because the stimuli have to be actively processed increasing the difficulty of the task. In Kahneman's model, learning is undifferentiated. That is, only the amount of information is important, not the nature of the stimuli. New stimuli, therefore, do not necessarily increase the difficulty of the task.

This has tremendous importance for sport. Using the tenets of capacity theory, fit athletes, through the process of becoming fit, should be able to process more stimuli regardless of the nature of the information. Thus, fit athletes should outperform unfit athletes regardless of whether there is an increase in physiological variables because they have learned to process stress-related information through constant exposure to one type of stress - physical stress from exercise. According to multiple resource theory, athletes would have to learn to process specific stress-related information by constant exposure to that specific stressor. In that regard, multiple resource theory would not forward any predictions about the ability of fit and unfit individuals to process distractions which are not physiological in nature.

Attention-as-Memory. According to this view, performance is considered automatized when it depends on single-step, direct-access retrieval of information from memory (Logan, 1988a). The challenge to resource theories lies in the potential, expressed in the more radical theories (Logan, 1988b; Newell & Rosenbloom, 1981) that resources play no role in automatization. These theories propose that novice performers are limited by a lack of knowledge rather than by a lack of resources. Through practice with specific problems novices learn specific solutions, which they can apply when faced with the same problem or generalize when faced with similar problems. At some point they will have learned enough to be able to retrieve solutions for all or most of the problems encountered in a given domain. In other words they will have accomplished automaticity associated with expertise.

Logan (1988a) argues that automaticity can answer four questions which are unanswerable by resource theories. First, automatic processes have certain properties because those properties are characteristic of memory retrieval. Automatic processing is fast, effortless, and unconscious because the conditions that prevail in studies of automaticity are good for memory retrieval. The memory traces that support automaticity are "strong" (Logan, 1988a) in some sense, which allows them to be retrieved rapidly and reliably in a single step. Single-step operations would appear unconscious because there are no intervening steps or stages to consider (Logan, 1988a). Automatic processing is autonomous; attention to an object is sufficient to cause retrieval of whatever information has been associated with it in the past (Keele, 1973; Logan, 1988a).

Logan (1988a) also suggests that attention-as-memory provides several mechanisms by which automaticity can be acquired. The most common is "strengthening", in which a connection between stimulus and response becomes progressively stronger with practice (e.g., LeBerge, 1981; Shiffrin & Schneider, 1977).

Further, Logan states that the memory-view accounts for the emergence of the properties of automaticity with practice. The guiding principle is that properties of memory retrieval may be very different from the properties of the operations upon which novices rely. Early in practice, performance will reflect the properties of inefficient solutions to problems. Later, performance will reflect properties of efficient memory retrieval.

Finally, Logan (1988a) argues that consistency is very important in the attention-as-memory view. The assumption is that subjects learn specific responses for specific stimuli. Thus, transfer to new stimuli is poor. In summary, the attention-as-memory view differs from the resource-view in a number of ways. The resource-view argues that people learn about the processes underlying their behavior, becoming faster and more efficient with practice (e.g., Anderson, 1982; Kolers, 1975). The memory view suggests that people learn about the environment in which they perform, remembering behaviors appropriate to the different states of the environment (e.g., Logan, 1988a). Further, the memory-view predicts narrower transfer because only specific responses to specific stimuli are available to memory.

The attention-as-memory view has several implications for sport. First, those stimuli which have not been internalized will interfere with performance. Fit performers perform better during exercise because they have trained to do so. Unfit performers have not trained to deal with physiological increases and thus incur performance decrements during vigorous physical activity. Second, no predictions can be made about the difference in performance of fit and unfit subjects when placed in situations other than exercise conditions. Only if subjects have practiced relative to the specific stimuli will they be able to perform automatically. Finally, information which interferes with a subject's ability to recall information about the task should result in performance decrements.

Implications for Research and Methodology

Capacity theory would suggest a generalized learning phenomenon across situations, such that fit performers should perform equally well in physiologically and nonphysiologically demanding situations. Both multiple resource theory and the memory-view would suggest that learning is specific to the stimuli present. Therefore, there should be no generalized learning across situations. These theories would not make predictions to other situations which do not involve physiological information. Multiple resource theory would suggest that only those processes which share the same resources would limit performance on a primary task. Information which does not tap similar resources should not interfere with the performance of a primary task even if the tasks are difficult and together would otherwise use more space than available relative to a single-resource view. Finally, the memory-view would suggest that tasks which compete with memory retrieval or are performed in novel situations should interfere with task performance.

Theoretical and Methodological Considerations

To test these theories as well as examining chronic effects of fitness requires that certain methodological considerations are met. First, performance of fit and unfit performers has to be examined in both physically demanding and nonphysically demanding situations. If there are chronic effects to fitness, fit performers should perform equally well in both situations.

Testing the three attentional views requires the use of dual-task paradigms. Secondary tasks must be chosen which (1) are sufficiently difficult to potentially exceed the subjects' limited capacity, (2) tap similar and different resources, one of which does not interfere with memory, and (3) are novel. Subjects must also be forced to process information from both tasks simultaneously.

Probe reaction time tasks have been found to be structurally interfering without affecting memory (Kahneman, 1973), and will be chosen as one of the secondary tasks. Reaction time tasks have not discriminated between the performance of novice and elite athletes in the past (Crews, 1989; Landers, Wang, & Courtet, 1985; Rose & Christina, 1990). However, the reaction time task may not have been sufficiently difficult to exceed the subject's spare capacity and therefore was not a true test of capacity theory. Increasing the difficulty of the reaction time task will hopefully prove fruitful.

The second subsidiary task will be directed at interfering with subjects' ability to recall information about the primary task. All of the subjects will be intermediate-level golfers, thus their putting skill should be fairly well-learned. The secondary task may not interfere with the actual performance of the task but with the processing of distance and accuracy information. Subjects will be presented a series of random numbers just prior to each trial. Upon completion of the putt they will have to recall the numbers recited by the experimenter at the beginning of the trial. Distance and accuracy information may be represented as numerical information in memory (Wickens, 1984). Therefore, having golfers memorize a series of numbers while preparing to putt should interfere with their processing of distance and accuracy information. A complete description of methods employed to examine the questions of this dissertation will ensue in the following chapter.

CHAPTER III

METHOD

Two questions were posed: (1) Does fitness affect performance of secondary tasks, and (2) What factors influence golf putt performance. Answering these questions required the analysis of putting (1) while performing a memory task, (2) while performing a probe reaction time task, (3) while performing a memory task after vigorous physical exercise, and (4) while performing a probe reaction time task after vigorous physical exercise. This chapter will describe the methodology for collecting and analyzing the data, in the following order: subjects, fitness measures, performance measures, cognitive perturbation measures, dependent variables, design and analysis.

Subjects

Twenty-four golfers, 12 fit and 12 unfit, participated in the study. All golfers were of intermediate level or better, having USGA handicaps of between 5 and 18 for men and between 8 and 24 for women. The fit group consisted of 9 men and 3 women between the ages of 18 and 39 ($\underline{M}$ = 25.7, SD = 6.17), who had VO_2's between 43 and 68.3 ($\underline{M}$ = 51.5, SD = 7.98) $ml \cdot kg^{-1} \cdot min^{-1}$, and USGA handicaps between 5 and 24 ($\underline{M}$ = 13.25, SD = 4.14). Fit golfers also reported a history of engaging in vigorous physical activity (3 times/wk for the last 6 months). The unfit group consisted of 8 males and 4 females between the ages of 21 and 36 (M = 27.9, SD = 6.00), who had VO_2's between 29.7 and 39.4 (M = 35.1, SD = 3.65) $ml \cdot kg^{-1} \cdot min^{-1}$, and had USGA handicaps between 6 and 24 (M = 16, SD = 5.44). In addition, unfit golfers reported that they had not engaged in a regular program of vigorous cardiovascular activity for the past 6 months. None of the study participants reported putting while engaging in either of the two secondary tasks prior to this study.

Measures

Physiological. A modified version of the Balke continuous variable speed walking graded exercise protocol was used to determine VO_2 max (Piparo, Crews, & Hart, 1991). Subjects began walking on a treadmill at 3 miles per hour and at 0% grade. Speed was increased .2 mph every 10 seconds while maintaining the 0% grade until subjects begin running. The purpose of this part of the protocol was to determine the fastest walking pace that subjects could maintain for an extended period of time. At this point, speed was decreased .7 miles per hour. Grade was then increased 2% every two minutes until subjects reached volitional exhaustion. Heart rate, oxygen uptake, and respired CO_2 were measured continuously during this protocol. Following the test, data were scrutinized to determine whether a plateau in VO_2 had been achieved (Taylor, Buskirk, & Henschel, 1955). The difference between the last two completed power outputs did not exceed

$2.1 ml \cdot kl^{-1} \cdot min^{-1}$, which suggests that this was a reliable estimate of the subjects $VO_{2\ max}$ (Morgan, Baldini, Martin, & Kohrt, 1989).

For the exercise conditions, golfers walked at the speed and grade which corresponded to 80% of their $VO_{2\ max}$ for 20 minutes. Subjects began walking on the treadmill at 3 miles per hour and 0% grade. Speed was increased .2 miles per hour every 10 seconds until the golfers' optimal walking speed was reached. Grade was then increased 2% every 10 seconds until the subject's optimal grade was achieved. The subject then walked at this speed and grade for 20 minutes.

Putting. Golfers putted 20 balls from a distance of 12 feet. Performance was measured as cm error. Changes in performance were assessed as the difference between experimental conditions and baseline. Golfers used their own putters and balls so there were no discrepancies because of unfamiliarity with equipment.

Memory. Subjects were asked to listen to seven numbers which the experimenter recited just prior to the subject's initiation of the putting stroke (within 2 seconds). At the completion of the putt, subjects were asked to recall the 7 numbers recited by the experimenter for that trial. A random set of numbers from 1 to 9 were selected for each trial. Each subject received the same random set of seven numbers for each trial. Changes in performance were assessed as the difference between experimental conditions and baseline measurement.

Probe reaction time. Subjects were presented with 2 to 4 audio tones prior to each putt. The tones were of 2 different frequencies.

The subjects had to differentiate between the two tones, depressing one of two microswitches located on the their putter. When the low frequency tone was heard the left microswitch had to be depressed and the right microswitch when the high frequency tone was heard. Decrements in performance were defined as slower reaction times during experimental conditions. Initially, performance decrements also were defined in terms of incorrect switch selection. However, very few errors were made in switch selection and only during the first few trials. As such, errors in switch selection were not entered into the analyses. This finding also supports Kahneman's (1973) contention that probe reaction times do not affect memory.

Task difficulty. A subjective measure of task difficulty was included as part of this investigation. Subjects were asked, "On a scale from 1 ('not at all distracting') to 10 ('very, very distracting') how much did the secondary task in this condition distract you from putting".

Heart rate. Heart rate was monitored with a Polar Pacer heart rate monitor continuously during the 20 minute treadmill walk, for 10 seconds just prior to the first putting trial during the exercise condition, and again for 10 seconds at the completion of the final putt of the exercise condition.

Experimental Procedures

Upon entering the Exercise and Sport Psychology laboratory, subjects were instructed about the nature of the investigation, completed a health history form, and signed a consent form approved by the departmental Human Subjects Committee of the

University of North Carolina at Greensboro (see Appendix A). This consent form included a biographical data questionnaire. This questionnaire asked subjects about their exercise history and golfing performance. Subjects classified as fit who had not engaged in vigorous physical activity during the past six months and unfit subjects who had engaged in regular vigorous physical activity during the past six months were eliminated from the study. Also eliminated were males with VO_2 max's ranging from 40.0 to 44.9 $ml \cdot kl^{-1} \cdot min^{-1}$ and females with VO_2 max's in the range of 38.0 to 41.9 $ml \cdot kl^{-1} \cdot min^{-1}$. Eight potential subjects were eliminated for not meeting the requirements of the study. Prior to the putting baseline, golfers completed at least 10 practice putts to acquaint themselves with the experimental putting surface. The putting baseline consisted of 20 golf balls putted from a distance of 12 feet. The cm error each putt finished from the hole was recorded for each trial. After baseline putting had been measured, subjects' fitness levels were assessed as previously described.

Within two weeks, but not less than three days after the VO_2 max test subjects reported to the Exercise and Sport Psychology laboratory to complete one of the experimental conditions. These conditions were counterbalanced to preclude any time or learning effects. Half the fit subjects completed the distraction only tasks first while the other half completed the exercise with distraction tasks. The same was true for the unfit subjects. The conditions were as follows: (1) Memory Perturbation Condition, (2) Probe

Reaction Time Task, (3) Exercise with Memory Perturbation, and (4) Exercise with Probe Reaction Time Task.

Experimental Conditions

(1) Memory perturbation. Subjects were asked to listen to 7 numbers which the experimenter recited within 2s of completion of his or her prestroke routine. At the completion of the putt, the subject had to recall the 7-digit recited by the experimenter for that trial. Errors in memorization were recorded with a mini-tape recorder. (See Table 1).

(2) Probe reaction time task. Subjects were presented with 2 to 4 tones of two different frequencies. Upon hearing the tone, the subject had to depress 1 of 2 microswitches located on the their putter shaft as quickly as possible. They were to depress the left microswitch when the low-frequency tone was emitted and the right microswitch when the high-frequency tone was emitted. These microswitches were connected to the computer which recorded the time between initiation of the tone and the time when the microswitch was depressed. The computer also recorded which microswitch was depressed to determine response errors from the preselected random signals. Each golfer received the same random selection of tones for each trial. Golfers completed both conditions 1 and 2 consecutively on the same day. However, the conditions were counterbalanced for fit and unfit golfers. That is, half the fit and half the unfit group started with the memory task first while the others started with the probe reaction time task first (See Table 1).

Table 1. Experimental Conditions

Day 1	Day 2	Day 3
1. putting baseline	1. Memory only	1. Exercise w/memory
2. VO_{2max} test	2. Probe RT only	2. Exercise w/Probe RT
		3. Probe RT baseline
		4. Memory baseline

Note: Days 2-3 were counterbalanced as well as conditions within each day. Baseline measures for memory and Probe RT were assessed after completion of the last condition.

(3) Exercise with memory perturbation. This condition was the same as Condition 2 except that the subjects performed 20 minutes of walking at 80% of their VO_2 max just prior to putting. (See Table 1).

(4) Exercise with probe reaction time task. This condition was the same as Condition 3 except that subjects walked for 20 minutes at 80% of their VO_2 max just prior to putting. Conditions 3 and 4 were completed during the same visit to the lab. However, the conditions were counterbalanced between fit and unfit golfers. That is, half the fit and half the unfit subjects started with the memory task first while the rest of the subjects started with the probe reaction task first (See Table 1).

Subjects completed baseline measures of each secondary task after completion of all experimental conditions. This was to ensure that the subjects did not habituate to the conditions resulting in learning effects of the secondary tasks. Landers, Wang, and Courtet (1985) found that rifle shooters who completed a difficult time stress task followed by low time stress task shot better than those rifle shooters given the reverse order. Each secondary task consisted of 20 trials. The subjects' baseline memory performance consisted of the average number of 7-digit numbers the subject could recall for each of the 20 trials. For the probe reaction time task the microswitches were attached to the subject's putter in the same manner as in the experimental condition. Subjects then were instructed to listen for two to four tones of differing frequencies, depressing the right microswitch if they heard the high frequency tone and the left microswitch if they heard the low frequency tone. Each trial lasted 5 - 10 seconds. Baseline measurement was the average time subjects were able to respond for each trial. For both baseline measurements, golfers were instructed to assume their normal putting stance to make the baseline conditions as similar to experimental conditions as possible. Baseline memory and probe reaction measurements were counterbalanced among subjects as in the experimental conditions to eliminate any practice or fatigue effects.

Dependent Variables

There were three dependent variables in this investigation.

1. Average cm error. This was defined as the average difference from baseline measures in distance putts finished from the hole during experimental conditions.

2. Memory. The difference from baseline conditions in golfers' ability to correctly recite the entire 7-digit number during experimental conditions.

3. Probe reaction time. Average differences from baseline measures in the time it took golfers respond to the audiotones during experimental probe RT conditions.

Performance was assessed as a function of change because the theories deal with change, not with level of ability. Individual differences in performance may vary. Change scores would consider any individual differences. This would be especially true for the secondary tasks. Some subjects may have better memories than others, while others reaction times may be faster or slower than others. Thus change scores were selected as the most appropriate measure.

Design and Analysis

The following designs and analyses were undertaken for each of the experimental conditions.

Question 1: Does fitness influence golfer's performance on subsidiary tasks? Separate 2 x 2 (Group (fit/unfit x Condition (exercise/nonexercise)) ANOVA's with repeated measures were conducted for each secondary task (memory, probe reaction time). Because fitness has been found to affect memory (Salazar et al., 1991), it was expected that (H1): fit golfers would outperform unfit golfers on the memory task during exercise and nonexercise conditions. Because a difference in reaction time has been found for fit and unfit subjects after exercise (Salazar et al, 1991), it was expected that (H2): all subjects would have faster reaction times in the exercise condition than in the probe reaction time only task.

Question 2: What factors affect golfers' ability to perform the golf putt? A 2 x 2 x 2 (Group (fit/unfit) x Task (memory/reaction time) x Condition (exercise/nonexercise)) ANOVA with repeated measures for cm error was used to answer this question. Several alternative hypotheses were examined. Previous work has shown that fit golfers outperformed unfit golfers immediately after vigorous physical activity. It was thus hypothesized (H3) that: fit golfers would outperform unfit golfers during the exercise conditions. No predictions were made concerning the nonexercise conditions. Also, capacity theory suggests that it is not the type of information being processed that is important, only the amount of information (Kahneman, 1973). Therefore, an alternative hypothesis (H4) was that: fit golfers would outperform unfit golfers during the nonexercise condition with all golfers suffering performance debilitation during the exercise condition. This result was expected because the exercise condition, which increases physiological activation, is thought to provide sufficient information to exceed even fit golfers' capacity to process information during a dual task design. Thus, a significant Group x Condition interaction would have been expected.

Alternatively, multiple resource theory suggests that only those tasks which are processed within the same channel will interfere with one another (Wickens, 1984). Because the reaction time task is thought to be processed in the same channel as other motor movements (Wickens, 1984), whereas numerical information is thought to be processed in another channel, it was hypothesized (H5) that: All golfers would experience performance decrements in the probe reaction time conditions while putting performance was expected to remain constant in the memory conditions. Thus, a task main effect was hypothesized.

Finally, the attention-as-memory view suggests that any task which interferes with memory would cause performance debilitation. Because probe reaction time tasks are not thought to require memory (Kahneman, 1973), a main effect for task was expected. That is (H6), all golfers would experience performance decrements during the memory conditions, but not during the probe reaction time conditions.

CHAPTER IV

RESULTS

The purposes of this investigation included (1) an assessment of the influence of fitness on putting performance during exercise and nonexercise conditions, and (2) a test of three theories of information processing. Preliminary analyses were conducted to determine similarities and differences between fit and unfit groups. Separate one-way ANOVAs for VO_2 $_{max}$, handicap, age, and sex revealed that the groups had significantly different fitness levels, but were similar in handicap, age, and sex. See Table 2 for subject specifics.

Although the handicaps of each group were similar, the two groups performed significantly different during the baseline putting assessment, *F* (1,22) = 5.11, $p < .05$. The unfit group had less error (M = 17.36, SD = 6.64) than the fit group (M = 24.13, SD = 7.95). Both group were similar in their overall golf ability as suggested by their handicaps, the unfit group may have been better putters than the fit golfers. Crews and Landers (in press) also found differences in baseline putting performance between two groups of golfers with similar handicaps. Handicap is a measure of golfers' overall golf ability. The lower the handicap, the better the golfer.

Table 2. Group Characteristics

	Fit	Unfit	$F(1,22)$	p
VO_2 (ml·kg^{-1}·min^{-1})	51.5	35.1	42.03	.000
range	(43.0-68.3)		(29.7-39.4)	
Age (years)	25.8	27.9	.762	.392
range	(18-39)	(21-36)		
Handicap (0-40)	13.3	16.6	1.62	.216
range	(5-24)	(6-24)		
Gender				
Males	9	8	.186	.670
Females	3	4		

Putting is just one element of the game of golf. In addition to putting well, golfers have to drive the ball well, hit good approaches to the green, and chip well when they fail to get the ball on the green in regulation to earn lower handicaps. The golfers in this study had handicaps from 5 to 24, indicating they were average to better than average golfers. Those in the fit group may have been better at some other part of the game (i.e., chipping) then the unfit group which made up for their lesser ability in putting. A second explanation may be that the fit group was underaroused during the baseline condition, whereas the baseline condition represented an optimal arousal level for the unfit group. Too low an arousal level has been associated with poorer performances (Hardy et al., 1991). Fit individuals may not only perform better at higher arousal levels (Piparo et al., 1991), they may require higher arousal levels than unfit individuals to perform their best. In contrast, unfit individuals may perform best at much lower activation states. While this result is without precedence, future research should investigate the possibility that fit and unfit individuals perform differently under baseline conditions.

This result presented a dilemma and possible limitation. Groups could have been labeled relative to putting ability rather than fitness. However, the three theories of attentional interference would predict far different results for groups of differing ability. That is, skills which are more well-learned, require less processing, thus are more automatic and less susceptible to interference from increased task difficulty. Those individuals with less ability should incur more performance decrements, sooner, with increased task demand because greater effort is necessary to process task information. All three theories would have predicted that the less able putters (fit group) would perform poorer during the experimental conditions than the more able putters (unfit group). As you will soon note, the opposite effect occurred with the fit group (less able putters) outperforming the unfit group (more able putters) during all experimental conditions. This provides strong support that the differences were because of fitness and not ability level. Notwithstanding, future research should use groups that are equal in ability. The rest of this chapter will concern the two major questions posed in the introduction.

Pilot Study Results

To test potential chronic effects of fitness as well as examine the three theories of attentional interference, certain procedures needed to be followed. Subjects had to be placed in both exercise and nonexercise conditions, process information from two tasks simultaneously, and have subjects process sufficient information to potentially exceed their limited channel capacity. Further, one of the secondary tasks had to require similar processing as the golf putt while the other required different resources. Finally, one of the subsidiary tasks needed to involve memory while tho other did not. A pilot study was undertaken to ensure that the tasks chosen for this dissertation provided sufficient difficulty to potentially exceed the subjects' limited channel capacity. The pilot study included two fit and 2 unfit subjects who were tested on all protocols to be used in the present investigation.

The results of that pilot study indicated that fit subjects' memory of 7-digits numbers decreased slightly from baseline assessment while unfit subjects averaged three more errors during experimental conditions than they did during baseline assessment. Further, all subjects had slower reaction times during the experimental conditions than during baseline assessment and had slightly slower reactions times in the nonexercise condition than during the exercise condition. Finally, fit subjects had less cm error than unfit subjects during the experimental conditions. These results suggest that the tasks proved difficult enough to exceed the subjects' limited capacity or interfere with their direct, single-step processing of information from memory and that information from the dual tasks were being processed simultaneously. Thus, all requirements were satisfied to test the aforementioned hypotheses and the investigation proceeded as proposed.

Main Investigation

Two questions were asked involving six hypotheses. The first question investigated was: Does fitness affect performance of secondary tasks. Two hypotheses were offered, one for each secondary task. The first hypothesis was that fit golfers would outperform unfit golfers on the memory task in both exercise and nonexercise conditions. This was based on conclusions reached by Salazar et al. (1991) and confirmed in the aforementioned pilot study conducted prior to this investigation. A 2 X 2 (Group x Condition) ANOVA with repeated measures for memory revealed a main effect, F (3, 16) = 8.64, $p < .05$, for fitness which held for both exercise and nonexercise conditions, supporting the expressed hypothesis. As can be seen by Figure 6, the fit group had an overall change of .916 in memory errors for both experimental conditions while the unfit subjects remembered 5 less 7-digit numbers in the experimental conditions than in the baseline assessment. Further, fit subjects had an average memory change of .583 (SD = 1.51) in the exercise condition, whereas the unfit mean change score was 2.75 (SD = 2.96). The larger the change score indicates more error in the experimental condition than in the baseline condition.

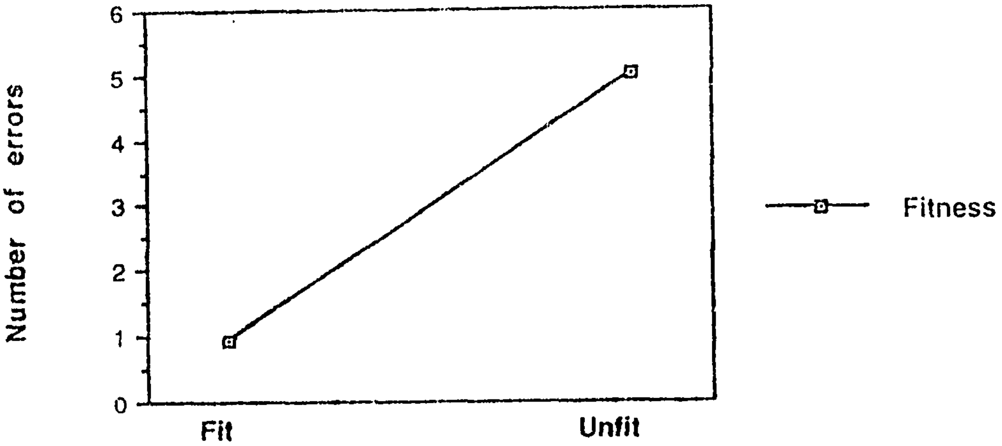

Figure 6: Change in the number of errors from baseline assessment to experimental conditions for fit and unfit subjects.

During the nonexercise condition, the fit group's average change in memory was .33 (SD = 2.54), while the change score for the unfit group was 2.25 (SD = 1.87). No other main effects or interaction effects were significant. Further, there were no significant main effects or interaction effects for order using a 2 x 2 x 2 (Group x Condition x Order) ANOVA.

The second hypothesis was that all subjects would have faster reaction times during the exercise condition than during the nonexercise condition (Salazar et al., 1991). A 2 x 2 (Group x Condition) ANOVA with repeated measures for reaction times was expected to produce a significant main effect for condition. Contrary to expectations, this analysis did not indicate a significant

Condition effect. Further, there was neither a significant Group main effect nor a significant Group x Condition interaction effect. Therefore, there were neither differences in reaction times because of condition, fitness, or the combination of condition with fitness. To determine if there were any order effects, a 2 x 2 x 2 (Group x Order x Condition) ANOVA was conducted. This analysis yielded a significant order effect, *F* (3,16) = 5.69, $p < .01$. As can be seen by Figure 7, those subjects who started in the exercise condition first (M = 39.63, SD = 59.2) had a significantly larger increase in reaction time from baseline measures then the increase they incurred when going to the nonexercise condition (M = 68.70, SD = 51.26). In contrast, those subjects who started in the nonexercise condition (M = 48.56, SD = 35.1) incurred smaller increases in reaction time from baseline measurement when going to the exercise condition (M = 59.23, SD = 50.9). Positive numbers indicate increased times to respond to the audio tones when compared to baseline measures. The average RT for all subjects in the various conditions were as follows: baseline, 443.5 (SD = 57.2); nonexercise condition, 487.60 (SD = 53.9); exercise condition, 507.47 (SD = 60.11). Subjects responded to the audio probe within 2s (2,000 ms) of initiating their putting stroke. The RT's in the present experimental conditions were only slightly higher than the RT's reported for novice (463, SD = 24), subelite (360, SD = 33), and elite (450, SD = 70) pistol shooters at the 0-2,500 ms mark by Rose and Christina (1990). Simple reaction times were used by Rose and Christina (1990), whereas probe RT's were used in the present investigation, .

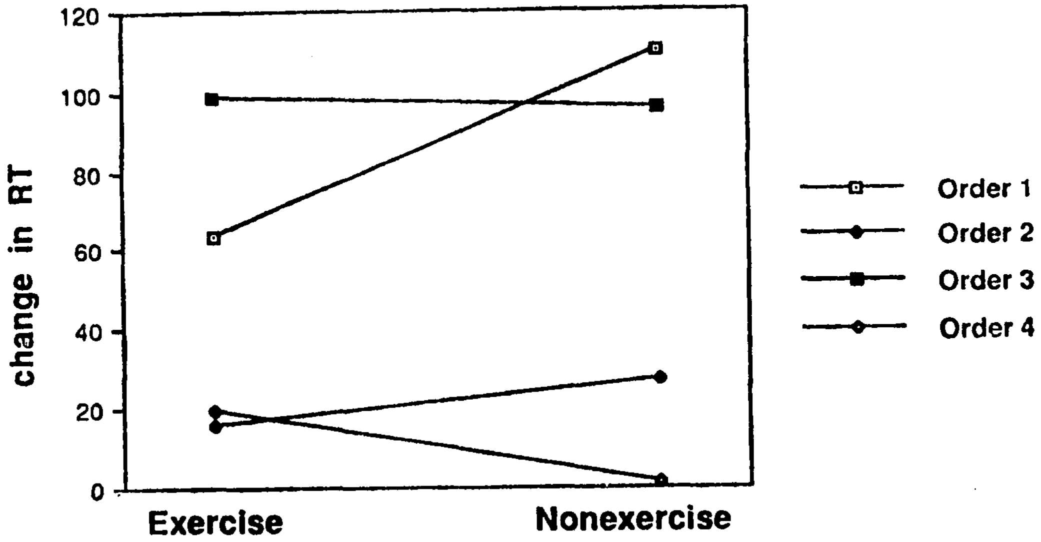

Figure 7: Change in Reaction Time from Baseline Measures to Experimental Conditions.

Note: Order 1 = memory w/exercise, RT w/exercise, RT, memory.

Note: Order 2 = RT w/exercise, memory w/exercise, memory, RT.

Note: Order 3 = memory, RT, RT w/exercise, Memory w/exercise.

Note: Order 4 = RT, memory, memory w/exercise, RT w/exercise

which might have made the task more difficult, accounting for the slight increase in reaction time

The second question investigated in this study concerned factors which influence attentional focus. Previous research, asreported in Tomporowski and Ellis (1986), have found that fit subjects outperform unfit subjects during and immediately after vigorous aerobic activity, but that little, if no differences emerged between fit and unfit subjects during low level or no exercise conditions. Thus, it was hypothesized that fit subjects would outperform unfit subjects during the exercise condition, but that no differences would emerge in the nonexercise condition. A 2 x 2 x 2 (Group x Task x Condition) ANOVA with repeated measures for cm error did not yield a significant Group x Condition effect as was expected. Thus, the hypotheses that fitness in combination with level of exercise was not supported.

In addition to the above hypothesis, three alternative hypotheses were forwarded relative to the three theories of attentional processing now dominant in the literature. The first hypothesis was based on capacity theory (Kahneman, 1973), which states that performance disruption occurs when the individual's capacity to process information has been exceeded and is not dependent on the type of information being processed. Thus, if fit subjects have a greater capacity to process physiological information than unfit subjects (Tomporowski & Ellis, 1986), capacity theory might suggest that fit subjects have a greater capacity to process similar amounts of nonphysiological information than unfit subjects. Relative to capacity theory, it was expected that fit subjects would outperform unfit subjects during nonexercise conditions. However, increasing the difficulty of the task by having subjects exercise immediately prior to performing the dual tasks should have interfered with fit subjects' ability to process primary task information and thus resulted in performance decrements for fit and unfit subjects during the exercise condition. Results from the aforementioned pilot studied confirmed this hypothesis, as all subjects averaged fewer putts made in the exercise condition (4) than they did in the nonexercise condition (5.5). Thus, a significant Group x Condition interaction was expected, with fit subjects outperforming unfit subjects in the nonexercise condition only. The Group x Condition effect was nonsignificant, casting doubt on capacity theory as a viable explanation for the differences between fit and unfit subjects in this study.

A second alternative hypothesis was that all subjects would perform better during the memory conditions than they would during the probe reaction time tasks. This was based on multiple resource theory (Wickens, 1984), which posits that performance disruption occurs only when information from two tasks are processed within the same channel. Numerical information is thought to be processed in a channel separate from movement information and so should not interfere with putting performance (Wickens, 1984). Putting and probe reaction time tasks require movement and should be processed within the same channel (Wickens, 1984), resulting in putting errors if the subjects have no prior experience completing both tasks simultaneously. Because the subjects in this investigation had no previous experience in putting while responding to audiotones, the reaction time task should have interfered with putting performance. This was confirmed in the aforementioned pilot study in which unfit subjects' putting performance decreased from 8 putts made during baseline measures to an average of 4 during reaction time conditions.

Further, multiple resource theory would not predict fitness to have any impact on information processing, unless the information to be processed is physiological in nature. As a result, there should be no differences in performance relative to fitness. The probe reaction time task should interfere equally with both fit and unfit group performance while the memory task should not affect either group and a significant main effect for task would be expected. The task main effect was nonsignificant. Thus multiple resource theory cannot sufficiently explain the results of this study. Finally, a recent, somewhat radical, view of information processing (Logan, 1988a) suggests that automaticity of performance is related to the ease with which information about a task can be recalled. This is the automaticity-as-memory view which suggests that performance becomes automatized when information concerning the task can be retrieved in a single-step, direct-access fashion from memory. Those secondary tasks which require memory should interfere with performance of a primary task unless the individual has sufficient prior practice at completing both tasks simultaneously. Therefore, the automaticity-as-memory view might predict that there would be interference in the memory perturbation conditions. The probe reaction time task is not thought to require memory (Kahneman, 1973). Reacting to the tones should not interfere with putting performance. Because specific practice at the task is of prime importance, one would not expect fitness to influence performance of the memory and putting tasks. Therefore, the final alternative hypothesis was that all subjects would incur performance decrements during the memory tasks while maintaining performance during the probe reaction time tasks. The main effect for task was significant, *F* (3,16) = 5.37, *p* < .05, with all subjects performing better during the reaction time tasks than during the memory conditions (Figure 8). This suggests

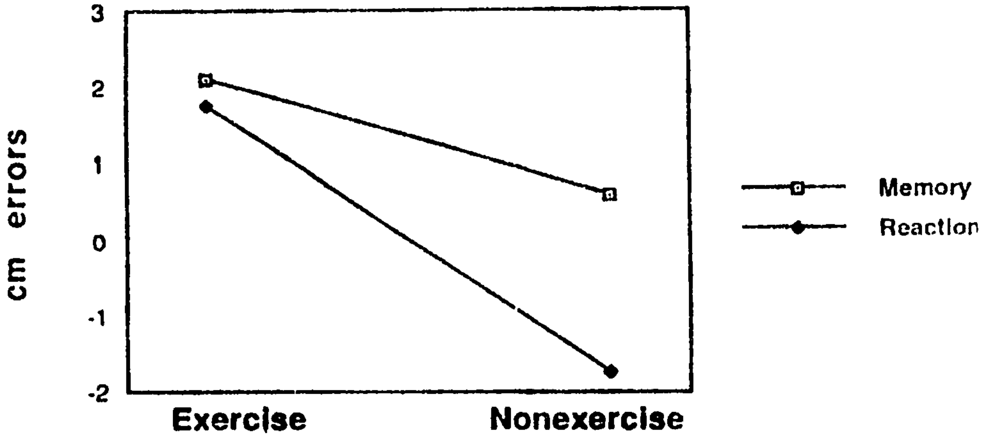

Figure 8: Comparisons of Putting Performance Across Conditions. Note: Negative numbers indicate less cm error and improved performance.

that performance is disrupted when the single-step, direct-access of information from memory is interfered with. In addition to the significant Task main effect, there was also a significant Group main effect, *F* (3,16) = 19.2, *p* < .001. That is fit subjects outperformed unfit subjects throughout all experimental conditions. Fit subjects improved performance from baseline measures during all conditions while unfit subjects experienced performance declines throughout. The results are illustrated in Figure 9. While there

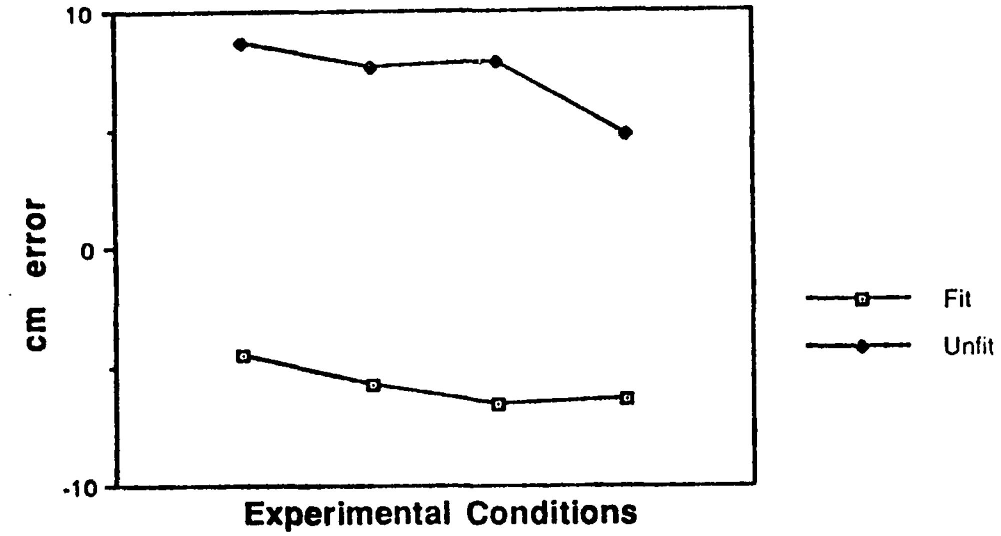

Figure 9: Putting Performance Comparisons Across Tasks and Conditions.

<u>Note</u>: Negative scores indicate a decrease in error or an increase in performance whereas positive scores indicate greater error or performance decrements.

<u>Note</u>: 1 = Memory w/exercise, 2 = RT w/exercise, 3 = memory, 4 = RT.

were significant main effects for Group and Task, the Group x Task interaction was nonsignificant. These results suggest that increased task demands, whether physical or mental, significantly debilitated the unfit group's performance. Finally, a 4 x 2 (Order by Condition) ANOVA yielded a significant interaction effect, $F(3,16) = 4.69$, $p < .05$. Those golfers who were exposed to the exercise conditions followed by the nonexercise condition performed better than those golfers who were firstexposed to the nonexercise conditions (Figure 10).

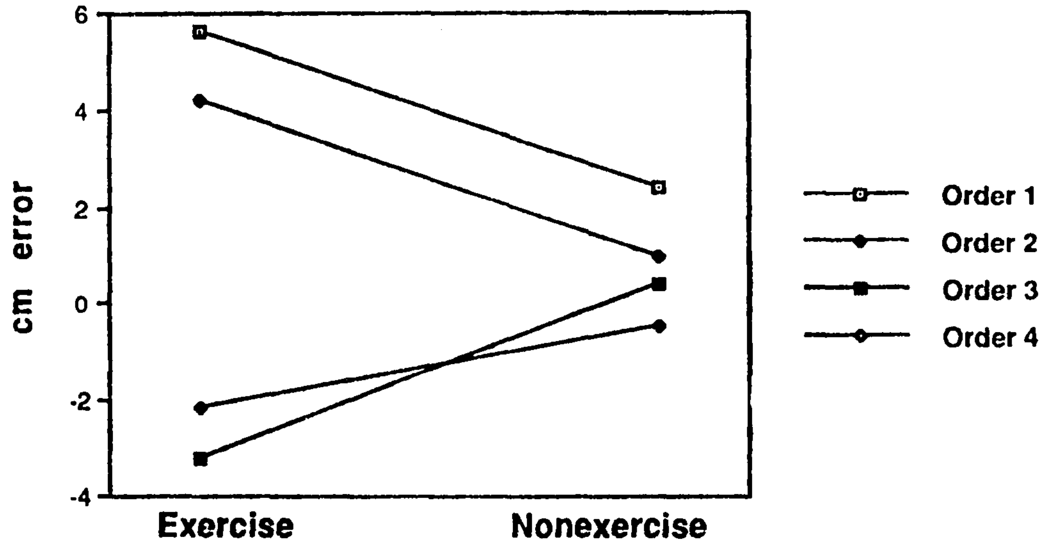

Figure 10: Order x Condition Effects.

<u>Note</u>: Order 1 = memory w/exercise, RT w/exercise, RT, memory.

<u>Note</u>: Order 2 = RT w/exercise, memory w/exercise, memory, RT.

<u>Note</u>: Order 3 = memory, RT, RT w/exercise, memory w/exercise.

<u>Note</u>: Order 4 = RT, memory, memory w/exercise, RT w/exercise.

This result is similar to that of Landers et al. (1985). That study examined the differences between experienced and inexperienced rifle shooters under high-stress and low-stress conditions. Although the present investigation did not examine performance under various levels of stress, it could be argued that this investigation and the Landers et al. (1985) study are similar. The Landers et al. (1985) study assumed that higher levels of stress provide greater amounts of information to be processed than low stress conditions. The assumption made in this study was that having subjects perform an 80% submax treadmill walk just prior to the putting tasks would increase the demand on subjects' ability to process information and so would represent a more difficult task, it also may be representative of high psychological stress.

A subjective measure of task difficulty was included as part of this investigation. Subjects were asked, "On a scale from 1 ('not at all distracting') to 10 ('very, very distracting') how much did the secondary task (RT, memory, memory w/exercise, RT w/exercise) in this condition distract you from putting." A significant interaction effect emerged from a 2 x 2 (Group x Condition) ANOVA, F (3, 16) = 8.64, $p < .05$, revealing that (Table 3) that fit subjects regarded the

Table 3. Distraction Scores

	Condition			
Group	Memory	Ex w/Mem	RT	Ex w/RT
Fit	4.47 (1.3)	4.00 (1.4)	4.33 (1.3)	3.33 (0.8)
Unfit	6.42 (1.8)	7.58 (1.9)	5.25 (2.1)	5.33 (2.2)

<u>Note</u>: Means (SD) of fit and unfit subjects' reported distraction from primary task focus.

two nonexercise tasks as more distracting than the exercise condition. In contrast, the unfit group rated the exercise condition as more distracting than the nonexercise condition. This assessment might indicate that unfit subjects were more distracted from the primary task during the exercise conditions than fit subjects.

To determine if subjects completed a similar aerobically taxing exercise condition, subjects' heart rates were monitored during the exercise condition as well as just prior to initiating their first putt after exiting the treadmill, and again at the completion of the final putt. A one-way ANOVA revealed no differences in heart rates between the two groups just prior to the first putt. Subjects were required to begin putting within two minutes of exiting the treadmill. However, there were significant differences in heart rates, $F\ (1,22) = 4.62$, $p < .05$, at the time the final putt was completed. In addition, there was a significant difference in the change in heart rate from pre-to-post putting, $F\ (1,22) = 15.97$, $p < .001$, between groups. Although fit and unfit subjects were operating under similar heart rates at the beginning of the putting trials, unfit subjects were still having to process a great deal of physiological information at the end of the exercise condition. In contrast, fit subjects had less physiological information to process towards the end of the condition.

CHAPTER V

DISCUSSION

The first question examined in this investigation concerned the effect of fitness on subjects' ability to perform either of two secondary tasks within a dual task paradigm. The two secondary tasks chosen for this study included an audio probe reaction time task and a memory task. In support of Salazar et al. (1991) fit subjects outperformed unfit subjects on the memory task during both the exercise and nonexercise conditions. It appears that exercise which produces cardiovascular fitness also has a significant influence on one's memory.

Contrary to Salazar et al. (1991), reaction times were not significantly faster after exercise than they were for the nonexercise condition. However, major differences exist between those studies reported in Salazar et al. (1991) and the present investigation which could explain the discrepant findings. Subjects in the studies reported by Salazar et al. (1991) did not perform the reaction time task as part of a dual task paradigm whereas the subjects in the present investigation completed the reaction time task as a secondary task within a dual task design. The fact that no differences in reaction times occurred between exercise and nonexercise conditions may suggest that subjects expended greater effort in focusing on the primary task. Focusing on and having to perform a primary task simultaneously with the reaction time task may have masked any decrease in reaction time that might have occurred because of an exercise effect.

The second question examined in this investigation concerned the potential chronic effects of fitness on performance and the mechanisms by which attention influence performance. Previous research on motor performance differences between fit and unfit subjects has been limited to acute effects of exercise. That is, effects have been studied only during and immediately following exercise. As in the McGlynn et al. (1991) study, vigorous aerobic activity of moderate length has been shown to facilitate the motor performance of fit individuals while it debilitates performance of the unfit. This result supports other research which demonstrates the superiority of fit subjects on mental tasks during and immediately following vigorous moderate length cardiovascular exercise (Gutin, 1966; Gutin & DiGennaro, 1968a, 1968b). It has been accepted as virtually axiomatic that the performance differences between fit and unfit subjects during acute bouts of vigorous aerobic activity to be fit individuals' ability to automatically process changes in physiological activation (Tomporowski & Ellis, 1986). McGlynn et al. (1979) suggest that those exercise factors which are responsible for conditioning the body might also be responsible for training the mind. Are fitness effects limited to situations involving exercise or are they transferable to other nonexercise situations as well? In other words, does the effect of becoming fit assist individuals when not physically activated. As previously reported, fitness has been shown to have a chronic effect on intelligence and memory (Salazar et al., 1991). Does fitness, gained through chronic aerobic activity, also influence one's ability to attend to task relevant cues? The present study was undertaken, in part, to determine if fitness exerted a chronic effect on attention.

To answer these questions, subjects were asked to putt during exercise and nonexercise conditions. Both conditions used a dual task paradigm. Subjects performed a golf putting task while simultaneously performing one of two secondary tasks. As previously mentioned, the secondary tasks included an audio probe reaction time task and a memory task. The exercise condition had subjects complete a 20-minute 80% submaximal treadmill walk prior to the completion of the dual tasks. Golfers began putting within 2 minutes of exiting the treadmill and completed putting within 15 minutes to ensure that exercise effects would still be strong at the end of the condition. Fit golfers putted better during each of the experimental conditions than they did during baseline assessment. Performance gains were of similar amplitude across conditions. In contrast, unfit golfers incurred performance decrements during all of the experimental conditions and the decrements were similar throughout.

These findings suggested that the presentation of either physiological or nonphysiological stimuli (i.e., distraction) not only do not interfere with fit individuals' processing of task information but assist their ability to attend to and perform the golf putt. On the other hand, presentation of either physiological or nonphysiological stimuli distracted unfit golfers attention to the golf putt resulting in performance deterioration. The similar decrements in unfit golfers' performance and similar improvements in fit golfers' performance during both exercise and nonexercise protocols further supports the notion that the activation/performance relationship is not a direct relationship but is mediated through attentional processes. These findings also suggest that fitness, gained through continuous aerobic activity, exerts a powerful chronic influence on motor performance by improving one's ability to process information.

Although it appears that the arousal/performance relationship is mediated through the ability to attend to primary task information, it is interesting to note that fit subjects found it easier to concentrate during the exercise condition while the unfit group found the exercise condition more distracting than the nonexercise condition. It was thought that the exercise condition would be more difficult for all golfers because it added a third stimulus to be processed (changes due to physiological activation) with primary and secondary task information. Several possibilities exist for this finding.

One explanation for the discrepancies in the ratings of task difficulty may be related to motivational variables. Numerous studies report that avid exercisers view exercise quite differently then nonexercisers (Joseph & Robbins, 1981; Sachs, 1981).

Individuals who adhere to a regimen of vigorous aerobic activity perceive exercise as pleasant and expect exercise to benefit mood and performance (Tomporowski & Ellis, 1986). Fit subjects, who reported engaging regularly in vigorous physical exercise for the past six months, may have reported that performing in the exercise condition was not that difficult because they expected exercise to be of some benefit. In contrast, unfit subjects, who reported not engaging in any program of physical activity for the past six months, perceive exercise as physically and psychologically stressing (Tomporowski & Ellis, 1986) and may have expected the exercise condition to be more difficult. Individuals who exercise may be more motivated at all tasks. Thus, motivational variables may play an important role in studies assessing the effects of exercise on mental and motor performance. Motivational variables were not assessed as part of this investigation but should be assessed in future investigations.

A second explanation may be related to when the task difficulty ratings were measured. Subjects were asked to rate how distracting they perceived the secondary tasks to be at the conclusion of the condition. Although fit and unfit groups had similar heart rates when putting at the outset of the exercise condition, fit subjects had considerably lower heart rates at the end of the condition than did unfit subjects. Thus, task difficulty ratings may have been related to the fact that at the time task difficulty ratings were assessed, unfit subjects still had elevated heart rates. Heart rate was not monitored during the nonexercise condition and so no comparisons can be drawn between the two conditions. Future investigations should monitor heart rates in exercise and nonexercise conditions.

Also investigated as part of this study were the possible mechanisms by which attention affect performance. Three theories or views of information processing (attention) were tested to determine which, if any, might explain performance differences. That is, how do fit and unfit individuals process different types of information?

Capacity theory suggests performance deterioration occurs when processing demands exceed total resources. Breakdown occurs because of a system overload. When too much information is processed, the individual no longer maintains the ability to process that information in parallel, but must instead process it sequentially with the least demanding information processed first (Kahneman, 1973). In the present investigation it was hypothesized that fit subjects would outperform unfit subjects in the nonexercise condition but that there would be no differences in the exercise condition. This hypothesis was not supported in the present investigation.

The second hypothesis was based on multiple resource theory, which states that performance interference occurs when tasks are simultaneously being processed within the same channel. Because the probe reaction time task is thought to be processed in the same channel as the putting task, it was hypothesized that a significant task main effect would emerge, with all golfers incurring performance decrements in the reaction time task only. However, this hypothesis was not supported because the significant task main effect was not in the correct direction. That is, subjects did not putt better in the memory task than in the reaction time task.

The final hypothesis was that a significant task main effect would occur, with all golfers putting better in the reaction time condition than in the memory condition. This hypothesis was supported. Thus, it appears that the somewhat radical, automaticity-as-memory view is the most acceptable explanation for the findings of the present investigation. That is, performance declines when extraneous information interferes with the single-step, direct-access retrieval of primary task information.

Consistency is important in the automaticity-as-memory view (Logan, 1988a). It assumes that individuals learn specific responses to specific stimuli and that transfer to new stimuli is poor. For this reason, a significant group by task effect was not expected to occur. While a significant interaction effect did not emerge, a significant group effect did, with fit golfers outperforming unfit golfers throughout. This might suggest that memory theory may need to be modified to consider such things as fitness effects. This would appear warranted as recent findings (Salazar et al., 1991) lead to the conclusion that prolonged exercise produces a facilitative effect on several cognitive functions, including memory.

Although memory theory was supported in the present investigation, one may not completely eliminate resource theory. As suggested by Logan (1988a), a new theory may need to be developed which incorporates both resource theory and memory theory. There appears to be no basic incompatibility between resource theory and memory theory. While few points of contact have been made in the literature, there is no reason, in principle, why performance could not be described both in terms of resources and memory (Logan, 1988a).

If a new theory is developed, incorporating tenets of resource theory and memory theory, reduction of resources might be considered as a cause or as a consequence of automaticity (Logan, 1988b). Crossman (1959) argued for a kind of "natural selection" process in which solutions to problems were selected randomly. If the solutions were faster than average, the probability of those solutions being selected again would be increased. With practice, the fastest method would dominate. The same sort of process might work with resource demands rather than speed as the criterion (Logan, 1988a). Methods could be selected randomly; if they demanded less resources than average, their selection probability would increase. Eventually, the least demanding method would dominate, automatizing performance.

Alternatively, in Logan's (1988b) memory theory, resource reduction could be seen as a consequence of automaticity rather than a cause. The single-step, direct-access retrieval of a solution from memory characterized as automatic could require fewer resources compared with the demands of multi-step processes that govern less automatic performance. Automatic or well-learned performance is simpler than unlearned or novice performance and so would demand fewer resources. Logan (1988b) points out that automaticity is a consequence of experience, not a consequence of a need to reduce resource demands. Logan assumes that encoding into and retrieval from memory are obligatory consequences of attention. Attending to an object causes it to become encoded into memory and at the same time makes available whatever was associated with that object in the past. Practice forces a person to attend to aspects of the task, which are encoded into memory. Repeated exposure adds more to memory, and the more memory the faster and more reliable the retrieval. Performance becomes fast and effortless. Resource demands would diminish as single-step retrieval dominates. Support for Logan's call for new theory may come from research on neural memory systems.

Neuromodulatory Research

Research examining cognitive development in humans utilizes variations in the physical and social experiences of animals. The typical protocol for examining neural memory systems involves assigning animals to one of three conditions: (1) environmental complexity (EC), (2) social condition (SC), and (3) individuals condition (IC). Ten to twelve EC animals are housed in large cages filled with various objects that the animals are free to explore. Often the animals are given additional daily experiences on mazes or toy-filled areas. Social condition animals are kept in standard sized cages in pairs or small groups without objects beyond food and water containers, while IC animals are housed alone in standard sized lab cages.

Early research found that EC rats had heavier cerebral cortices than either SC or IC littermates (Bennet, Diamond, Krech, & Rosenzweig, 1964), in part because the cerebral cortex was thicker (Diamond, Law, Rhodes, Lindner, Rosezweig, Krech, & Bennet, 1966). Further anatomical examination demonstrated that several types of neurons in those regions of the brain involved in the experience had more dendrite branching (Greenough & Volkmar, 1973). The additional connections provide room for new synaptic connections among neurons which is believed to be the way the brain stores information (memory) about experience (Black, Greenough, Anderson, & Isaacs, 1987).

Turner and Greenough (1985) found that EC rats have more synapses per neuron than IC or SC littermates. Similar effects have been found in other areas of the brain (e.g., cerebellum: Floeter & Greenough, 1979; Pysh & Weiss, 1979; hippocampus: Juraska, Fitch, Henderson, & Rivers, 1985), and with other types of experiences (e.g., maze training: Greenough, Juraska, & Volkmar, 1979; handedness preference reversal: Greenough, Larson, & Withers, 1985). The extra stimulation in the EC cages appear likely to increase neural activity levels in brain regions processing that information (Black et al, 1987). One theory for the production of new synapses in later development and adulthood is suggested to be dependent on experience-associated neural activity. That is, synapses are formed as a result of the activity of neurons involved in the information processing and/or neuromodulatory systems. The synapses might be generated nonsystematically or in excess at the outset with some aspect of patterned neuronal activity determining the survival of a subset (Greenough, 1984). The synapses formed are localized to regions involved in the information-processing activity that caused their formation.

Theoretical Implications

The findings and theories of neuromodulatory systems might suggest that new experiences which produce synapses increase the capacity of the brain to store information (memory) about the experience. Further, structural changes are restricted to those areas of the brain involved in the processing of information about the experience (multiple resources). Finally, performance becomes automatized with the selective survival of those synapses actually involved in the process of the information as a result of a number of similar experiences. That is, continued similar experiences (practice) results in selective survival of only those synapses actually involved in processing the information about the experience which would suggest direct, single-step access to memory and automatized performance. Support for this is demonstrated by the fact that EC rats perform better and faster on maze learning than IC or SC littermates (Black et al., 1987).

These facts and theories are compatible with Logan's (1988a) notion for a new theory combining resource theory and memory theory. Although neural memory theories are compatible with the unison of resource theory and memory theory, the effects of exercise have yet to be explained.

Much of the work on brain morphology was conducted to determine the effects of learning throughout the lifespan. Does the brain retain the capacity to change, referred to as "plasticity", with new experiences even into old age? Although there is agreement that the brain retains plasticity, even into old age, extrinsic factors like physical exercise, nutrition, and chronic stress have been found to influence cognitive development in older animals and humans (see Black et al, 1987). One must ask whether such extrinsic factors also influence cognitive development in younger adults and children.

Exercise Effects on Neural Processing

Dustman, Ruhling, Russell, Shearer, Bonkat, Shigeoka, Wood, and Bradford (1984) conducted a physical exercise training program with sedentary adults, ages 55-70 years, being assigned to an aerobic conditioning protocol, an exercise control group or a nonexercise control group. The experimental exercise group either walked fast or did a slow jog, increasing their heart rate to 70-80% of their heart rate reserve and maintaining this rate for longer periods of time as their conditioning improved. They did this in one-hour sessions, three times per week for four months while the exercise control group engaged in strength and flexibility training. The nonexercise control group was not to exercise during the four-month period.

The aerobic conditioning subjects increased their VO_2 max by 27% while the exercise control group realized a 9% increase in VO_2 max. There was no increase in VO_2 max for the nonexercise control group. Further, on average, both exercise groups improved on neuropsychological tests, which included response time, visual organization, memory, and mental flexibility, while the nonexercise control group did not. Moreover, the type of exercise was strongly related to the magnitude of VO_2 max improvement. Individuals participating in aerobic activities, fast walking or slow jogging, improved significantly more than the individuals engaging in strength and flexibility training.

The authors suggested that the improved transport and utilization of oxygen was realized in brain as well as other body tissue. An increase in cerebral oxygen might result in improved neuropsychological function because of increased turnover of neurotransmitters which are dependent on oxygen for metabolism (Dustman, LaMarche, Cohn, Shearer, & Talone, 1985). Oxygen in the brain is an important substrate for turnover of neurotransmitters that are essential for cognitive and motor activities (Bartus, Dean, Beer & Lippa, 1982; Gibson & Peterson, 1982; Simon, Scatton, & Le Moal, 1980). Neuropsychological test performance has proven to be sensitive to reduced levels of oxygen, as demonstrated by impaired performance of young adults at altitude (McFarland, 1969), while adverse altitude effects have been shown for some of the tasks used in the Dustman et al. (1984) study: critical flicker fusion threshold (Sen Gupta, Mathew, & Gopenath, 1979), digit symbol (Evans, Carson, & Shields, 1969), memory (McFarland, 1969), and response time (Cahoon, 1972; Kobrick, 1972; Ledwith, 1970). The administration of oxygen to elderly subjects and to patients with chronic obstructive pulmonary disease has resulted in improved cognitive performance (Block, Castle, & Keitt, 1974; Jacobs, Winter, Alvis, & Small,1969; Krop, Block, & Cohen, 1973; Krop, Block, Cohen, Croucher, & Shuster, 1977), in the absence of recent memory loss (Raskin, Gershon, Crook, Sathanathan, & Ferris, 1978) or other evidence of a dementing process (Ben-Yishay, Diller, & Reich, 1979; Levin & Peters, 1977; Thompson, 1975). Further, hypoxia (reduced oxygen intake) has been shown to cause a decline in acetycholine metabolism (Gibson & Peterson, 1982), and oxygen is utilized directly for the synthesis and degradation of dopamine, norepinephrine (NE), and serotonin (5-HT) (Gibson & Peterson, 1982; Gibson, Pulsinelli, Blass, & Duffy, 1981). Each of these neurotransmitters has been implicated in human behavior (Beck, 1978). Oxygen transport of neurotransmitters may increase as a result of chronic exercise/fitness, thus increasing fit individuals' ability to process information more efficiently than less fit individuals.

Spirduso (1983) reported that the ability of rats to initiate fast movements was clearly related to nigrostriatal dopaminergic efficiency, suggesting that chronic exercise can influence neurotransmitter systems. Direct evidence of this was provided by Brown and colleagues (Brown, Payne, Kim, Moore, Krebs, & Martin, 1979; Brown & Van Huss, 1973). They found an increase in whole brain levels of NE and 5-HT for rats which had participated in a running program designed to simulate middle distance running in humans. Elderly rats, who were housed in environments which provided for increased sensory and motor stimulation, had larger and more complex neuronal structures, with larger and heavier forebrains, with an enhancement of cholinergenic activity (Connor, & Diamond, 1982; Connor, Wang, & Diamond, 1982; Cummins, Walsh, Budtz-Olsen, Kostantinos, & Horsfall, 1973; Riege, 1971; Uylings, Kuypers, Diamond, & Veltman, 1978). These changes may have occurred because of increased perfusion and oxygenation of brain tissue. There is substantial evidence that movement, sensory stimulation, and even ideation result in an immediate increase of cerebral blood flow in activated cortical areas (Engel, Kuhl, & Phelps, 1982; Gross, Marcus, & Heistad, 1980; Larsen, Skinhoj, & Lassen (1981); Mazziotta, Phelps, Carson, & Kuhl, 1982; Phelps. Kuhl, & Mazziotta, 1981), with a concomitant flow increase in frontal association areas (Ingvar, 1980). The physical activities associated with the Dustman et al. (1983) study, in addition to improving aerobic efficiency, may have provided sufficient cortical stimulation to promote structural and functional change.

The fact that aerobic conditioning resulted in improvements for a variety of neuropsychological tests in the Dustman et al. (1984) study may indicate that this type of exercise affects processes underlying attention and concentration, which in turn determine performance. Attention wanes during periods of hypoxia (Petajan, 1973), perhaps due to a release of cortical inhibitory influence on the ascending reticular activating system (Dell, Hugelin, & Bonvallet, 1961; Petajan, 1973). Evidence has been reported that demonstrates reduced inhibitory control in healthy elderly people that is believed to be related to reductions in certain populations of cortical cells and to less efficient neurotransmitter systems (Dustman & Snyder, 1981; Dustman, Snyder, & Schlehuber, 1981; Podlesny & Dustman, 1982). Thus, adults who engage in chronic aerobic activity may have an increase in the supply of oxygen, increasing neurotransmitter efficiency to those parts of the brain engaged in cognitive and motor activity. Increasing the supply of neurotransmitters may increase the speed at which information is processed. Therefore, attention is improved as well as the resultant cognitive and motor performance for individuals who engage in regular aerobic activity.

Summary

In summary, subjects in the present examination putted better during the reaction time tasks than they did during the memory tasks. Further, fit individuals outperformed unfit individuals throughout all experimental conditions. These findings suggest that performance is debilitated when single-step, direct-access retrieval of information from memory is interrupted and that chronic exercise/fitness influences one's ability to process task relevant information. These findings also indicate that although memory theory provides a better explanation for performance than either capacity theory or multiple resource theory, memory theory may need to be modified to account for fitness effects. Previous neuromolecular research supports Logan's (1988a) call for a unified resource-memory theory.

Resource/Memory Model

Figure 11 illustrates how performance could be described simultaneously in terms of resources and memory at various stages of learning. According to Logan (1988a), initial performance is poor because attention is not selective, processing is slow and consciously controlled. Kahneman (1973) would argue that performance is low because demands exceeds resources. Practice would increase capacity to process information (Kahneman, 1973) while developing a more efficient retrieval process of stored information about what is being learned (Logan, 1988a). Thus, performance improve. Stage I as depicted in Figure 11 illustrates this progression. Stage I can be compare to Fitts and Posner's (1967) first two stages of learning (analytical and sensory) in their learning theory model.

Optimal performance is achieved when processing of task information becomes automatic (Fitts & Posner, 1967) or subcortically controlled (Shiffrin & Schneider, 1979). This occurs because attention, with practice becomes selective to the most relevant cues. Processing becomes efficient as a direct, single-step access to retrieval of task information dominates. Kahneman (1973) would argue that performance is optimized because resources exceed capacity. Logan (1988a) suggests that direct, single-step processing can be conceptualized as a reduction of resources. Thus, capacity of resources increases while demand on those resources decreases (Stage II). Very little of available resources is necessary to process task-relevant cues. The question is, what is done with the remaining available resources. Logan

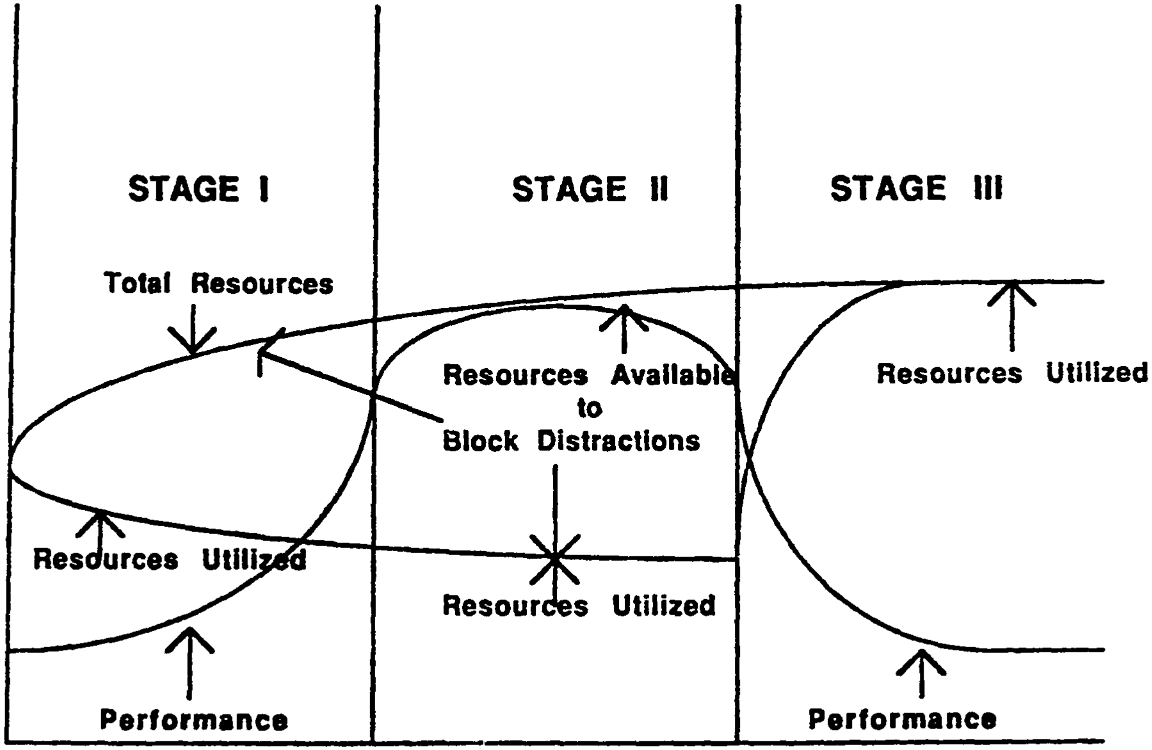

Figure 11: Proposed Attentional Interference Model. This model depicts the relationship between task-focused attention, distraction-blocking resources, and performance at various stages of learning.

(1988a) suggests that with better concentration not only are task cue-response associations strengthened but the ability to block out irrelevant cues also emerges. Thus, performance is improved because individuals have developed an efficient, effortless, automatically controlled processing of task cues as well as increasing one's resources to block out potential distractors. Performance remains optimized as long as one maintains the ability to process task information efficiently by blocking out potential distraction. Capacity theory suggests that transfer to new situation would be complete since its not the type of information to be processed that is of importance, only the total amount of information. Logan (1988a) would argue that transfer to new situations is poor because no mechanisms or strategies have been developed to block out new distractions associated with the new situation.

Performance falters (Stage III) when demands exceed resources to block out distraction (Kahneman, 1973), when processing of distraction requires the same resources as the primary task (Wickens, 1984), or when distractions are no longer able to be blocked out (Logan, 1988a). The performer's attention is divided between attempts at blocking out the distraction while alternatively attempting to control performance. In other words, processing reverts to a novice-like stage. Processing again becomes, slow, with nonselective attention, which is consciously controlled.

The sport millieu is replete with both external (e.g., visual, auditory) and internal (e.g., self-doubt, self-examination, anxiety, fatigue, pain) distractions. Ultimate success in sport is dependant upon one's ability to block out the effects of these potential distractions so that performance can remain automatic.

A dearth of research exists concerning the influence of audio-visual distractions in sport. The evidence which does exist is conflicting at best. For example, the presence of noise debilitated performance in a cognitive vigilance task in which digit sequences had to be identified (Jones, Smith, & Broadbent, 1979) and in an incidental learning task (Hockey & Hamilton, 1970). Increased response errors and extended reaction times were found for self-paced tasks, especially if the audio distractions were at least 95 dB (Smith, 1990). Singer, Caraugh, Murphy, Chen, and Lidor (1991) found that 90 dB of white noise did not impair accuracy for a nondominant handball throwing task when subjects were provided with additional training. In addition, Hockey (1970) and Gowron (1982) reported that tracking performance was enhanced in the presence of noise.

Singer et al. (1991) concluded that these studies suggest that noise effects are variable at best and that the individual's perception of the setting is an important determinant in observations of performance facilitative or degradation. Further, Smith (1990) argued that the demands of the task and commensurate changes in attentional selectivity appear to be responsible for performance changes. These arguments are consistent with Hockey's (1970) interpretation that specific tasks may require more attentional processing to complete the appropriate goal-directed responses, and with Kahneman's (1973) contention that particular tasks may demand different amounts of effort. Unanimous agreement on a systematic relationship between noise effects and task demands remains to be resolved (Keele & Neill, 1978; Smith, 1990). Nataanen, Alho, and Sams (1985) reviewed event-related brain potential studies and concluded that task difficulty contributed minimally to selective attention effects during the presentation of auditory noise.

In contrast, findings are generally in agreement concerning visual distractors on performance. In a typical visual distracter task, Eriksen and Eriksen (1974) examined probe reaction time to target letters which were adjacent to similar, different, or no letters. They found reaction times slowed when adjacent letters were interpreted as an instance of automatic letter name processing for the flanked letters (Eriksen & Eriksen, 1974; Schneider, Dumais, & Shiffrin, 1984). A similar finding was reported by Schafer and LaBarge (1979) for the processing of unattended words. Presenting target words and nontarget words in close proximity interfered with the appropriate goal-directed response, with primary task performance suffering.

Stroop interference effects could be similarly interpreted. Irrelevant stimuli near the focus of attention are automatically processed and task performance is debilitated (Broadbent, 1982; Kahneman & Triesman, 1984). Stroop effect studies clearly indicate that the ability to suppress irrelevant stimuli decreases as the proximity of irrelevant stimuli to target stimuli decreases. Allport

(1989) provides a cogent argument for these findings. When non-target cues (distractions) provide a compatible source of information for encoding into the required representational domain, interference with target cues is likely to occur (Allport, 1989).

For visual distractors, spatial location of cues also seems to contribute to task interference. Event-related potential studies on visual stimuli indicate that spatial focusing of attention functions differently for stimuli presented to the fovea and peripheral retina (Hillyard, Munte, & Neville, 1985). When both the distractor and target cues are in the fovea, task interference occurs. In contrast, when irrelevant cues are presented peripherally, task interference is minimal (Singer et al., 1991).

Finally, the predictability of visual distractors is important for task performance. Predictable distractors are more easily blocked out than unexpected visual distractions (Singer et al., 1991). The predictive nature of audio or visual distractors permits selective monitoring of the environment and preparation for an upcoming sensory-motor response (Singer et al., 1991). By preparing for a specific distraction that occurs as expected, the probability of inhibiting a competing orienting response is increased with task performance likely to be uninterrupted (Allport, 1989). These findings may suggest that similar source cues may provide a more potent distractor, but that under certain conditions cues processed within other resources may also interfere with performance.

One could thus argue that automaticity of performance is destroyed when the presentation of irrelevant stimuli is unpredictable, within the fovea, in close proximity to target stimuli, or too intense to be blocked out. This suggests that the total amount of resources as well as the area of processing (multiple resources) may come into play when attempting to process task information in a direct, single-step fashion. One could then conclude that the overriding factor is not the amount of resources, the pool of resources, nor the ability to process task-information in a direct, single-step process, but the ability to block out potential distraction. From this, one may predict that when the ability to block out irrelevant cues is surpassed, automatic processing of task relevant information ceases, resulting in performance hysteresis. This may be most evident in the recent work on the arousal/performance relationship of Hardy et al. (1992).

Effects of Exercise on the Model

The previous discussion concerns the relationship between level of learning, the ability to block out potential distractions, and performance. Physiological activation and fitness level also may affect the relationship. Based on the findings of the present investigation as well as previous work (Gutin, 1966; Gutin & DiGennaro, 1968a, 1968b, Piparo et al., 1991) physiological activation may increase demand by adding more nontask information to be processed. Because unfit subjects have no practice blocking out this type of information, Logan (1988a) might suggest that they would lose their ability to process task information automatically, resulting in performance decrements as was demonstrated in the studies cited above.

The same may not occur in fit individuals for two reasons. First fitness increases oxygen to the brain which provides for greater efficiency in neurotransmitter turnover (Black et al., 1987). This provides for faster and more efficient transport of information from memory. Second, fit individuals, through exercise, may develop abilities to inhibit physiological information from reaching consciousness. Thus, fit individuals may improve the "hardware" to effectively deal with distraction as well as develop strategies to block out certain kinds of phsiological and cognitive distractions.

Implications of Arousal/Performance Research

Surprisingly, unfit subjects significantly outperformed fit subjects during the baseline putting assessment. Although this finding is apparently without precedence, Piparo et al. (1991) found that unfit subjects outperformed fit subjects during baseline putting assessment, but that this difference was not significant. One explanation for the differences between the two studies may have been the relative "fitness" of the fit and unfit groups. In the present investigation, the fit group had a mean VO_2 max of 53.8 $ml \cdot kg^{-1} \cdot min^{-1}$ whereas the fit group in Piparo et al. (1991) had a mean VO_2 max of only 45.8 $ml \cdot kg^{-1} \cdot min^{-1}$. The unfit groups in each study had similar VO_2 max levels, 33.8 $ml \cdot kg^{-1} \cdot min^{-1}$ in the Piparo et al. study and 35.9 $ml \cdot kg^{-1} \cdot min^{-1}$ in the present study. Thus, the fit group in the present investigation was "more fit" than in the previous investigation. The unidimensional inverted-U hypothesis (Yerkes & Dodson, 1908) and the more recent, multidimensional catastrophe theory (Hardy, Jones, & Parfit, 1991) state that performance is substandard when arousal is too low. Subjects with increasing levels of fitness may find conditions of low activation too low for optimal performance whereas subjects with lower levels of fitness may find low activation states to be best for optimal performance.

The present study, while not intended to examine arousal theory, presents considerations for future arousal/performance research. Present findings suggest that the arousal/performance relationship is mediated through attentional processes. Specifically, performance declines when an increase in task difficulty (either through increases in physiological or cognitive demand) interferes with the direct, single-step retrieval of task information from memory. As can be seen by Figure 12, the arousal/performance pattern of fit and unfit individuals followed markedly different patterns. That is, unfit subjects' performance declined when cognitive demand increased but physiological demand remained stable. Catastrophe theory (Fazey & Hardy, 1988) predicts performance decrements with high physiological arousal and high cognitive anxiety. If one considers high cognitive anxiety, the preoccupation with one's own internal states (Wine, 1971) a type of internal distractor (Singer et al., 1991), then a condition of high cognitive demand or high cognitive anxiety must be accompanied by higher physiological activation beforeperformance would be predicted to decline. This was not the case for unfit subjects. Future arousal/performance research may need to control or account for subjects' fitness differences.

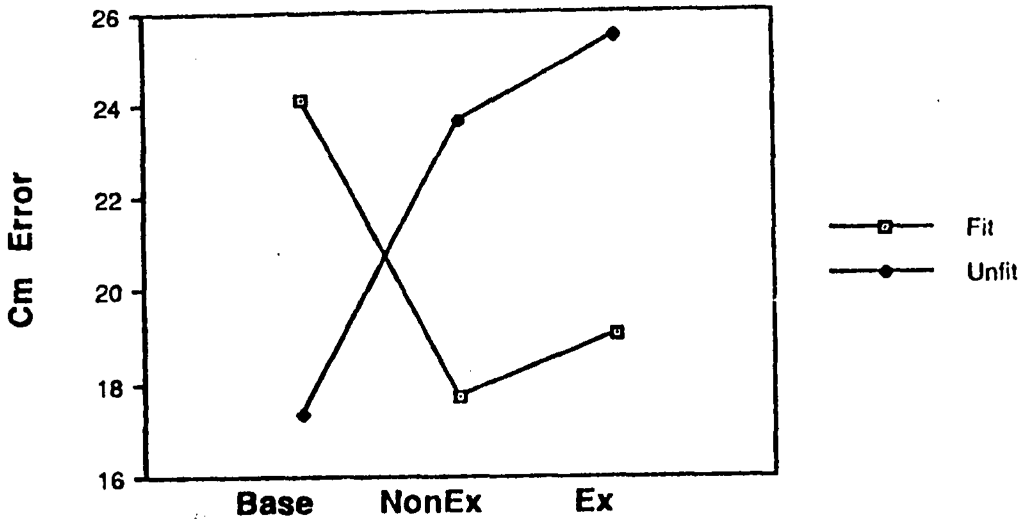

Figure 12: Group by Condition Comparisons.

Note: Negative score indicate less cm error and improved performance.

Even more compelling than an examination of arousal/performance patterns of fit and unfit individuals, is the need to understand the mechanisms which result in the arousal/performance relationship. It appears as though the arousal/performance relationship is mediated through attentional process. However, if fit and unfit subjects display different performance/arousal patterns, one must ask if fit and unfit individuals process information differently. Or, if they process information similarly, what information is processed, how is that information processed, and how does fitness influence that process?

Implications for Sport

For those athletes engaging in highly vigorous aerobic activities, cardiovascular fitness is a must, not only to withstand physical fatigue, but to remain mentally alert. The same may be true for athletes involved in less aerobically-demanding sports (i.e., golf, archery, rifle shooting). Aerobic training may provide less fit athletes with greater capacity to withstand excessive mental demand associated with their sport. Sport psychology consultants may need to assess the fitness level of their client if performance appears to decline late in competition or the athlete makes mistakes in judgments or makes poor decisions. These errors may be the result of "mental fatigue" which may be abated by cardiovascular conditioning.

CHAPTER VI

CONCLUSIONS AND FUTURE DIRECTIONS

Early theories of information processing associated attention with the amount of available resources. Initially, resources were construed as a sort of general undifferentiated entity. Tasks were thought to interfere to the extent that they depended on resources from the general pool. Norman and Bobrow (1975) then argued that there may be various types of resources corresponding to various factors that may be put into production. Kahneman (1973) made a distinction between two types of attention models, structural models and capacity models, "which respectively emphasize the structural limitations of the mental system and its capacity limitations" (p. 11). Structural limitations, according to Kahneman, included those factors claimed to produce extra cost for concurrence as well as the inability of some processing apparatuses to serve both tasks simultaneously, although they are needed by both. Neither type of model in itself was able to account for all known phenomena of interference (Navon & Gopher, 1979).

Navon and Gopher (1979) argued that the central capacity notion could not withstand the finding that when the performance of a certain task is disrupted more than the performance of another one by pairing either of them with a third, it is disrupted less by a fourth task. For example, Brooks (1968) demonstrated that the same task was performed slower when the processing and response of both tasks called for the same processing system than when they used different systems (i.e., vocal responses were found to interfere more than spatial responses than with recall of a line diagram). Baddeley, Grant, Wight, and Thompson (1975) showed that performance of a pursuit rotor task deteriorated when paired with Brook's visual recall task. A similar finding is the result that auditorial presentation of a word to be remembered impairs shadowing of a message played to the other ear more than visual presentation of a word does (Mowbray, 1964). Allport, Antonis, and Reynolds (1972) replicated this finding and extended it by showing that interference with shadowing could be almost eliminated by using nonverbal concurrent tasks such as picture encoding or playing piano music. Triesman and Davies (1973) provided more convincing evidence that monitoring tasks interfered with each other when stimuli presented in the same sense modality, visual or auditory, than when they were presented in different modalities.

Hence, there seemed to exist various components that different processes share to variable degrees. These findings appeared to warrant the idea that a major source of conflict between tasks is structural (see Allport et al., 1972). However, a strict structural model seemed inadequate once it was realized that processes that use the same mechanism sometimes interfered with each other but seldom block each other out completely (Navon & Gopher, 1979).

Examples of these included Brook's (1968) experiment when input and response are in the same modality, and Triesman and Davies (1973) study in which stimuli to be monitored were presented concurrently to the same modality. This led to the rejection of multiple channels or mechanisms in favor of multiple resources (Navon & Gopher (1979). Not only could the processing system be conceived as a whole involved in processing several activities in variable proportions, but a specific mechanism or modality was thought to accommodate more than one process at the expense of quality or speed of performance rather than be dominated by one process exclusively. In other words, resources were thought not to be homogeneous because the human system may not be a single-channel mechanism but a rather complicated system with many channels, reservoirs, or facilities. Each may have its own capacity which could limit the amount of information that could be stored, transmitted, or processed by the channel at a unit of time. Each specific capacity could be shared by several concurrent processes; different tasks may require different types of resources in various compositions (Navon & Gopher, 1979).

Logan (1988a, 1988b), among others, then argued that it's not the processing of information that is key, but the ability to store and retrieve information from memory that caused task interference. The present investigation supports Logan's (1988a) view. That is, performance of a primary task was disrupted when one had to recall a 7-digit number, but not when the secondary task did not require memory (reaction time task). This was true even though both tasks were presented auditorially. (Remember, movement information is thought to be processed with resources different than those required for processing numerical information.) However, the two tasks differed on one important feature. Completion of the reaction time task occurred while the golfers were preparing to putt whereas the memory task required golfers to retain the 7-digit number throughout the preparation for and execution of the putt. Thus, it may be concluded that execution of the putt, but not the preparation for the putt was disrupted. Even though subjects were required to begin their putting stroke immediately after responding to the last tone (within 1 second), this may have been sufficient time to prepare (recall information about speed, distance, and direction). Recall of task information was made more tenuous by having to recall task information as well as the 7-digit number. Although the present study demonstrates the superiority of memory theory over resource theories, previous evidence suggests that the human processing system may contain multiple resources, each of which has capacity limitations. It may not be the processing of information from those resources, but the retrieval of information from memory from various resources and the inability to block out potential distractions which cause performance disruption. It may also be, as Logan (1988a) suggests, that an executive or overriding mechanism exists which affects all resources. The executive mechanism may be involved in the blocking out of potential distraction, allowing for direct, single-step access of task information from memory and automatized performance.

Methodological advancements may help clear up the present debate. Development of protocols which use the same processing system but require different receptors or modes of response may be imperative. For example, the present audio probe reaction time task could be adapted to use visual cues instead. One could then compare the effects of visual and audiatorially presented cues on the performance of a primary task. One also could change the reaction time task to include memory. Subjects could receive the tones prior to the putt, but not respond to them until after completion of the putt, and then as quickly as possible. This could then be compared to results of some other memory task like that used in the present investigation. This would utilize the same receptive vehicle and memory, but different response modes. These are just a couple of suggestions. Much more work on information processing needs to be conducted.

Future research should more closely examine the similarities and differences between resource theory and memory theory. Further, researchers need to consider structural changes occurring in the brain due to learning. Continued work on psychophysiological measures also may better describe what is occurring during attentional processing. Hatfield, Landers, and Ray (1984, 1987), Landers, Pettruzello, Salazar, Crews, Kubitz, Gannon, and Han (1992), Salazar, Landers, Petruzello, Crews, and Kubitz (1988), and Salazar, Landers, Petruzello, Crews, Kubitz, and Han

(1990) have attempted to observe physiological changes in heart rate, blood pressure, and electroencephalographic readings that are elicited by attentional demands involved in various sport skills. Finally, the influence of such factors as cardiovascular fitness, nutrition and chronic stress need to be considered in any new model of attention. Questions yet to be answered include: Does capacity refer to the ability to process or store and retrieve information? Does interference occur because information from separate tasks require similar resources or is there some executive center through which all information ultimately passes before responses are made at which time interference could occur? How does cardiovascular fitness improve attention? Answering these questions may also have important implications for sport.

Implications for Sport

Successful sport performance requires selective attention, directed to the most salient aspects of a task while disregarding ancillary sources of information (Singer et al., 1991). Distractions in sport are many and are associated with external events or internal states. External events include sudden auditory or visual occurrences (i.e., the roar of the crowd). Internal states might include too much self-awareness, fear of failure, self-doubt (loosely defined as cognitive anxiety). It appears that fitness mediates one's ability to focus on the most salient task cues necessary for optimal performance. Continued examination of the performance/arousal pattern as it relates to fitness levels is thus warranted.

In the present investigation, fit and unfit golfers displayed different patterns of performance with increased cognitive and physiological demand. At baseline levels, unfit golfers outperformed fit golfers. However, a reversal of performance efficiency was realized under experimental conditions. That is, fit golfers improved performance while unfit golfers incurred performance decrements. This pattern appears to hold true whether the increase in demand is cognitive or physiological in nature. However, the Piparo et al. (1991) study and the present investigation employed only vigorous aerobic activity (80% of VO_2 max or better) and the present investigation only used one level of each of the secondary tasks. Future researchers may vary the level of exercise (20, 40, 60, 90% of VO_2 max) or the cognitive task (simple reaction time task instead of choice RT or retention of less than and more than 7-digit numbers) to determine if unfit subjects would still have performed poorer than at baseline levels and if fit subjects' performance would deteriorate prior to physical exhaustion and under what circumstances? In other words, would the resultant arousal/performance curve still have produced a negative linear relationship or would the curve be similar to the front half of the inverted-U or catastrophe pattern.? In addition, future research should directly asses the effects of fitness on the arousal/performance relationship as well as study the entire catastrophe curve for fit and unfit subjects to determine at which point hysteresis may occur for fit and unfit individuals and under what types of demands does the relationship change. The present investigation suggests that fitness may confound arousal/performance research. Thus, fitness may need to be controlled or measured in any arousal/performance research.

Other questions of concern would include: Is there some minimal fitness level necessary for optimal performance at increased demands? Do higher levels of fitness allow for optimal performance under even greater physiological and cognitive demand? Do increasing fitness levels require higher levels of activation before optimal performance can occur? Finally, in the present investigation, fit subjects engaged in regular programs of aerobic exercise while unfit subjects did not. Does altering one's fitness level alter one's arousal/performance pattern? In other words, if unfit subjects trained aerobically, would their arousal/ performance pattern simulate the fit pattern?

Further, the present investigation was not able to determine whether the fitness effects where because of "hardware" improvements or in the development of strategies to block out distraction. Training studies, in which unfit subjects engage in a systematic program of aerobic exercise, may help determine whether the effects are physiological, cognitive or a combination of both.

Answering these questions may have tremendous implications for those involved in sports and physical activity. The present research suggests that fit individuals require some sort of activation for optimal performance. The higher the fitness level the more activation necessary for optimal performance. In aerobically demanding activities, the physiological activation may be sufficient. In such nonphysically demanding activities as golf, archery, rifle and pistol shooting, major competitive events may increase cognitive anxiety (demand) sufficiently to activate the system for optimal performance. However, in practice or less demanding competitive events, fit individuals may first need to engage in some aerobic activity or increased cognitive demand (i.e., goal setting) to achieve optimal performances. In contrast, unfit individuals may not perform optimally in physically or cognitively demanding arenas. Becoming fit may be necessary to perform up to one's ability in more demanding arenas.

In conclusion, much work yet needs to be conducted to determine how humans process information and how the processing and storage of information affects performance. The work must continue in a variety of arenas including the "software" or processing of the information and the structural "hardware" changes accompanying learning. Examination of the impact of such extrinsic factors as cardiovascular fitness, nutrition, and chronic stress must be undertaken. However, one thing appears clear. That is, regardless of how information is processed, fitness has a positive effect on performance, whether that performance is aerobically or cognitively demanding.

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APPENDIX A

THE UNIVERSITY OF NORTH CAROLINA AT GREENSBORO
SCHOOL OF HEALTH AND HUMAN PERFORMANCE
SCHOOL REVIEW COMMITTEE
INFORMED CONSENT FORM

I understand that during the study I will report to the Human Performance Laboratory (HHP 240) for four visits. During the first visit I will putt 20 golf balls. This will be followed by a continuous variable speed walking graded protocol on the treadmill. I understand that this protocol will entail that I begin walking at 3 miles per hour at 0% grade and that speed will be increased .2 mph every 10 seconds while maintaining the 0% grade until I begin running. At that time the speed will be decreased .7 mph and the grade increased 2% every two minutes until I reach volitional exhasution (when I decide that I can no longer continue walking). I realize that 3 out of 10,000 persons experience a cardiac event during max stress testing and 1 out of every 10,00 die. However, I desire to participate in this study because I will be continuously supervised by the researchers who will ensure proper treadmill safety techniques and the American College of Science Medicine guidelines are followed throughout the testing. This is an additional control which will help me make judgements about the safety of this study.

I understand that I will return to the lab two more times within two weeks of the max test. At this time, I understand that I will be asked to engage in a submax protocol in which I will walk on the treadmill for 20 minutes at 80% of my max VO_2 at the speed and percent grade extrapolated from the max test. I understand that the performance of the exercise during the session may result in some physical discomfort and may provide some muscular soreness for a few days following the session. I understand that I will be continuously supervised by the researchers to ensure that proper treadmill safety techniques and the American College of Science Medicine guidelines are followed throughout the testing.

I also understand that I will be asked to putt 40 golf balls during these two visits immediately after the exercise condition. Further, I understand that I will be asked to report to the lab one more time within the two week period to putt 40 golf balls without exercising.

I confirm that I participate in this study completely voluntarily and that no coercion of any kind has been used to obtain my cooperation. I understand that I can withdraw my consent and terminate my participation in this study at any time. I understand that all information obtained in this study will remain confidential and anonymous. I understand a summary of the results of the study will be made available to me, per my request, after completion of the study.

I confirm that I have been informed of the procedures that will be used in this study. I understand what is required of me as a subject. I confirm that any questions I may have regarding the study and the procedures have been answered to my satisfaction, and I wish to give my voluntary cooperation as a participant.

I understand that this project and this consent form have been approved by the University Institutional Review Board which ensures that research projects involving human subjects follow federal regulations. If I have any questions about this, I will call the Office of Research Services at (919) 334-5878.

Any new information that might develop during the project will be provided to me if that information might affect my willingness to participate in this project.

______________________	______________________
Signature	Phone Number
______________________	______________________
Address	Date
______________________	______________________
Spouse Signature (if married)	Date

USGA Handicap of average 18 hole golf score______________________

Do you presently exercise? Yes_____ No________. If yes, how many days per week?______________ Type of exercise?________________

____

____

If you answered no, have you engaged in a regular exercise program at any time during the last 6 months? _____ If yes, please explain.______

____

____

____

____.

APPENDIX B.

SUBJECT MEDICAL HISTORY QUESTIONNARIE

Name____________________________Date__________________

1. Has your doctor ever said you have any kind of heart trouble?

   Yes__________No___

2. Do you frequently have pains in your heart and/or chest or have abnormal heart beats? Yes_________No_________

3. Do you often feel faint or have spells of severe dizziness?

   Yes____No____

4. Has a doctor ever said that your blood pressure was too high?

   Yes____No____

5. Has a doctor ever said that your blood pressure was too low?

   Yes____No____

6. Has a doctor ever said that you have a joint or bone problem (e.g., arthritis) that has been caused or made worse by exercise or that might be made worse with exercise? Yes_____No_____

7. Are you over 65 and not accustomed to vigorous exercise?

   Yes_____No____

8. Do you smoke cigarettes? Yes____No_____

9. Has your father, mother, sister, or brother had any heart trouble or strokes before age 50? Yes_____No____

10. Do you have diabetes? Yes________No________

11. Has your doctor ever said your cholesterol was/is high? Yes_____No___

12. Have you ever had back pain/problems which lasted more than one week? Yes_____No___

13. Do you take medicine for anything? Yes_______No____
If yes, please explain.____
____

14. Has your mother, father, sister, or brother ever had high cholesterol, died suddenly or died prematurely? Yes____No_____