Introduction

In fast paced sports settings, anticipation is the key to a successful performance. An athlete's ability to perform under these stressful conditions defines his or her worth to their respective teams. The key in the performance of anticipatory tasks is the ability to focus one's attention to the cues that will enable one to anticipate accurately (Abernethy, 1996). Anticipatory tasks require performers to process these cues under severe time constraints. The ability to anticipate accurately is dependent upon the information-processing capacity of the performer (Nougier, Stein & Bonnel, 1991). The limited attentional capacity available places a limit on the amount of information that can be processed. Thus, the efficiency of these internal processes is dependent on one's ability to focus one's attention to the relevant cues and allocate attentional resources to the relevant cues. Kahneman (1973) proposed that attention capacity fluctuated with arousal. He proposed that the allocation of attention to various stimuli was possible and mediated by factors such as the goal of the performer.

Flexible Allocation Capacity

Contrary to the view that attention capacity was fixed and interference would occur if simultaneous tasks were attempted, Kahneman's model of selective attention proposed attention as a unitary resource with a flexible capacity. The arousal level determines the capacity available for the production of response. Arousal is referred to the physiological and biochemical response to stress that causes an increase in cognitive resources, which were locatable resources. Arousal at optimum levels will maximize the available resources. On the other hand, a performer experiencing arousal beyond the level required for the task would be unable to overcome the negative effects sufficiently to ensure optimal allocation of resources. The inability to optimally allocate resources would cause decrements in performance. Momentary intentions of the performer and the evaluation of demands of the tasks determined the allocation policy. According to this model, when a performer is required to perform two equally difficult tasks, attention capacity for each of the tasks would be equal. However, the ability to time share two tasks not only depends on the difficulty but also the composition of the tasks. Composition here refers to the sensory modalities used to detect the relevant stimuli and the anatomical structure required to perform the task. In response to evidence that showed the ability to concurrently process two tasks was not only dependent on the difficulty of the tasks but also on the composition, Kahneman maintained the unitary resource model by allowing for structural interference in the performance of motor tasks and interference due to similar perceptual modalities used in the performance of tasks. Castiello and Umilta (1988) studied the time course of attention resource demands of athletic performance in volleyball, tennis, 100 metres and 110 metre hurdles. The data from the three experiments led the researchers to conclude that attention resource demands change as a function of the moment they were probed and these changes were related to the difficulty in performance.

The result of the above study underlines the role of attention in producing accurate motor responses. The performing environments in which these motor responses have to be produced are often less than ideal. These less than ideal conditions place additional demands on the performer, which in most cases leads to a decrement in performance.

Stress and Performance

Stress, arousal and activation are energetic concepts, which might affect human motor performance. Stress has been viewed as both an independent and a dependent variable. The independent variable approach, which is stimulus based, treats stress as stimulus characteristics of a disturbing environment (Kerr, 1990). According to this view any task that requires more effort to perform, owing to external or internal stimuli, or both, is characteristic of an increased level of stress even if the task demands are met (Van Gemmert & Van Galen, 1999).

The dependent variable approach, which is response based, views stress as a non-specific response of an individual to a disturbing environment. This view proposes that not all demands are stressful in nature. The individuals' response to this demands caused by stressors are the determinant factor in considering the level of stress experienced by the individual. Stressors, which are classified as physical, emotional and cognitive might not necessarily be detrimental to performance.

Sanders (1983) proposed an interactionist model to describe the relationship between stress and performance. The emphasis given to cognitive functions by the interactionist model proposed by Sanders is very much relevant to the performance of skills in dynamic sports settings. A baseball batter facing a pitched baseball has to identify the characteristics of the baseball that is propelling towards him. Factors such as the velocity and the spin, which would determine the location of the baseball, would have to be identified and processed as efficiently and as quickly as possible. The batter based on this information has to plan and execute his actions to maximize his performance. Based on this model, the accurate perception of the pitched baseball is dependent upon the batter's level of arousal. The selection of the appropriate location of the bat at the time of contact is determined by the effort mechanism. The activation mechanism is involved in the cognitive preparation of the biomechanical parameters (velocity) involved in the swing of the bat. The decision-making process is not crucial, as it may be bypassed in high stimulus-response compatibility or when the skill has been practiced extensively (Jones & Hardy, 1989).

Van Gemmert and Van Galen (1997) proposed an alternative theoretical perspective to explain the relationship between stress and human performance. This theory also proposes that neuromotor noise is related to the hypothesis of resource allocation proposed by Wickens (1984). This relationship is evidence by the propagation of noise on time and space-related basis. Van Gemmert and Van Galen propose that the performance of concurrent task (as in dual task conditions) enhances the level of neuromotor noise when compared to the performance of sequential tasks. The propagation aspect of neuromotor noise is also assumed specific to sensory modalities, with auditory stimuli having longer decay periods compared to visual stimuli. The space related basis of the propagation of neuromotor noise refers to the utilization of common processing capacities that are involved in the condition of stress. Two cognitive tasks (e.g. number writing and number subtraction) that involve the active use of common processing stages, it is expected that the intensity of processing one of the tasks will reduce the signal to noise ratio within the processing stages of the other task. The final element of this theory proposes that noise does not necessarily cause deterioration in performance. It assumes that background noise increases the level of arousal and activation thus heightening the processing capacities of the information processing system although the decrease in signal-to-noise ratio might cause errors. This is caused by the need to find an optimum signal-to-noise ratio in a given situation. To achieve this, humans use two different and optional strategies. The first option affects the chronometric aspects of task performance. This theory assumes that neural activation increases over time but noise levels fluctuate and level off. This they propose will reduce the RT for easy to normal tasks due to the activating effects of neuromotor noise. In difficult tasks, the reduction in signal-to-noise ratio will result in an increase in RT. The second strategy that humans use to overcome the decrement in signal-to-noise ratio is by increasing the biomechanical parameters (e.g. force) in the interaction with the environment. Their study confirmed their assumption that under stressful situations, to compensate for the reduction in signal-to-noise ratio, biomechanical parameters of the motor task were enhanced. This was shown in the increase in axial pen pressure recorded for both the number writing and graphic aiming task.

The assumption that competing processing capacities would prolong reaction time (RT) was proven by the increase in RT for the number writing tasks, but not the RT for the graphic aiming task under cognitive stress. This difference in effects was attributed to the different processing capacities being utilized by the graphic aiming task. This assumption was further emphasized by results on both the tasks not affected by physical stress.

Any sports performer trying to achieve optimum performance has to impose some degree of control over his or her internal state (Jones & Hardy, 1989). Even though studies have shown that stress has both negative and positive effects, these studies have focused on performance as a whole or the speed of decision-making processes involved in the production of motor task. It is necessary that research on the effects of stress on performance focus on the components (e.g. temporal anticipation) of a motor task, so that relevant stress management strategies can be formulated based on insights provided by such fundamental studies.

The purpose of this study was essentially to determine the effects of cognitive stress on the temporal anticipation of a timing motor task. Effects of different levels of difficulty on the temporal anticipation of a timing motor task performed without cognitive stress and the temporal anticipation of a timing motor task performed under cognitive stress was also subjected to further investigation.

Methodology

Research Participants

The research participants of this study (n =36) were undergraduates of the physical education program at a local university between the ages of 20 and 25 years. There were an equivalent number of male and female participants. Participants did not have prior experience with the task and were naive concerning the actual purpose of the study. Participants were volunteers and signed a consent form before their participation in the study. They received course credits for their participation.

Apparatus

The experiment was carried out on a Hewlett Packard Vectra 286 computer with a monochrome monitor (TC1438256CTE10). The experimental task was part of a computer based Motor Learning and Control laboratory activity experiment developed by Goodman and Franks (1990) and written by Nagelkerke and Storlund (1990).

Experimental Tasks

A dual task procedure was used in the study. The procedure required participants to perform a primary temporal anticipation task and a secondary cognitive task. For the primary task, participants joined a vertical moving column and a horizontal moving column by depressing the cursor key (→) of a computer keyboard with a finger of their dominant hand. Upon depressing the cursor key, the vertical column will elongate. An accurate anticipation by the participant will result in the vertical column meeting the horizontal column at the top right hand corner of the screen. An inaccurate anticipation would result in the columns not meeting each other at the top right hand corner i.e. either the horizontal column arriving at the top right hand corner earlier or later than the vertical column which is under the control of the participant. The rate of elongation of the horizontal column varied according to the easy, intermediate and difficult level. The rate of elongation was the slowest for the easy level and increase proportionately for the intermediate and difficult levels. As the trajectory of the horizontal column is constant, the rate of elongation differentiated the difficulty level of the primary task. Augmented visual feedback was provided at the conclusion of each trial.

The secondary task, which induced cognitive stress, required the participants to subtract the number 2 from an initial two-digit number (Van Gemmert and Van Galen, 1997). The subtraction was done repeatedly and continuously, from the outcome of each preceding subtraction, until the primary task was completed.

Participants had to vocalize the outcome of the subtraction. The two-digit number was vocalized by the researcher at the beginning of each trial in the stress conditions Participants performed five blocks of 20 trials each for each task condition. In Conditions A, B and C (Table 1), participants performed the primary task at different levels of difficulty. In Conditions D, E and F (Table 1) participants performed the primary task concurrently with the secondary task.

The assigning of the conditions was on a rotational basis, with the first participant beginning with Condition A, the second participant beginning with Condition B and the assignment of the initial condition will proceed in this fashion. This counterbalancing technique was applied to isolate the practice effect, which might have a bearing on the data. Participants were given an interblock interval of 15 minutes to overcome fatigue.

Data Collection Procedures

The participants' performances were measured using absolute error (AE). This method was chosen as it quantifies the performance of the temporal anticipation task without taking the direction of the error into account. AE, which is the mean error of the trials performed, is an accurate measure of performance when direction of errors is not the criteria used to measure performance of a motor task (Schmidt & Lee, 1999).

Results

Table 2 presents the mean absolute error (AE) of participants in all levels of the experimental task without cognitive stress. The trend observed showed that as task difficulty increased, the mean AE decreased in line with the inverted–U hypothesis of performance under stress (Hanin, 1980). The results showed that the variance in performance under all conditions were large. The large variability of scores can be attributed to differences among the ability of the participants' ability to anticipate and handle cognitive stress effectively.

Table 1: Trial conditions that will be performed by participants

Conditions	Description
Condition A	Participants performed the primary task at the EASY level.
Condition B	Participants performed the task at the INTERMEDIATE level.
Condition C	Participants performed the primary task at the DIFFICULT level.
Condition D	Participants performed the primary task, at the EASY level, and concurrently performed the secondary task.
Condition E	Participants performed the primary task, at the INTERMEDIATE level, and concurrently performed the secondary task.
Condition F	Participants performed the primary task, at the DIFFICULT level, and concurrently performed the secondary task.

Analysis of Main Effect Comparisons

Based on the assumptions of the repeated-measures design; the task, stress and stress by task interaction effects were tested using the multivariate criterion of Wilks' Lambda (Λ). The task main effect was significant ($\Lambda = 0.84$, F (2,70) = 4.43, $p < 0.02$) (Table 3).

Table 2: Means and standard deviation of participants' performance in the experimental task without cognitive stress and the experimental task under cognitive stress.

	Level			
Conditions	**Easy**	**Intermediate**	**Difficult**	**Mean for experimental conditions**
Experimental Task Without Cognitive Stress	2.31 (.99)	2.07 (.76)	2.05 (.97)	2.15 (0.91)
Experimental Task Under Cognitive Stress	3.39 (2.01)	2.81 (1.28)	2.64 (1.16)	2.95 (1.60)
Mean for each level of task difficulty	2.85 (1.74)	2.44 (1.11)	2.35 (1.10)	

The task main effect assessed differences on the performance scores among the three difficulty levels across the two experimental conditions (no cognitive stress and cognitive stress). The significant differences in means showed the participants' performance of the experimental task for the three levels of difficulty were affected under the cognitive stress conditions.

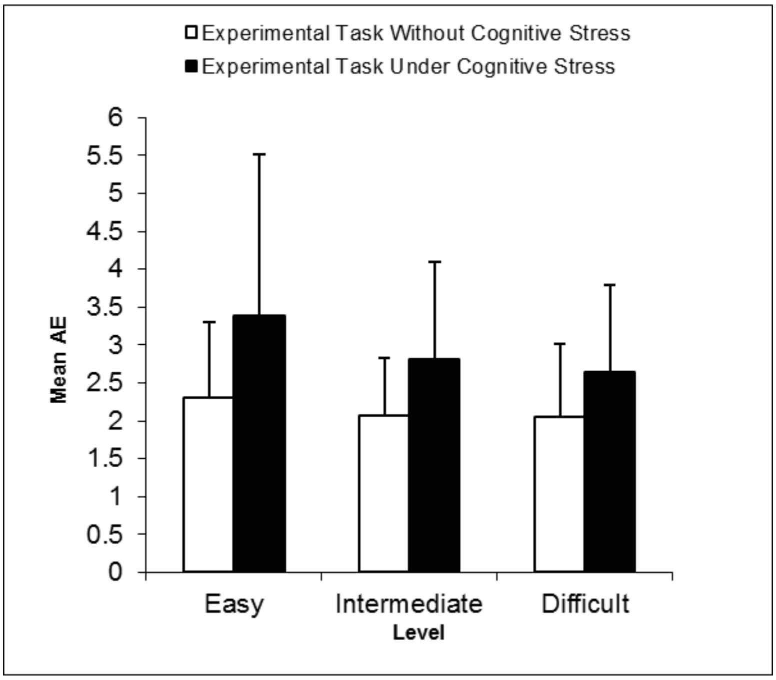

Figure 1: Mean absolute error and standard deviation of participants' performance of the experimental task.

The main effect for stress revealed a significant difference in means,($\Lambda = 0.64$, $F(1.35) = 19.89$, $p = 0.00$) (Table 3). The stress main effect evaluates differences between the two stress conditions averaging across the levels of difficulty. The significant results show that the participants' performance of the experimental task was significantly different under both conditions. The stress by task interaction was not significant. Follow up pairwise comparisons were conducted to identify significant differences in means for the task main effect.

Table 3: Results of the two-way repeated measures analysis of the participants' performance in the experimental task without cognitive stress and the experimental task under cognitive stress.

Source	df	F	*p* *
Task	2	4.43	.02
Error	70		
Stress	1	19.89	.00
Error	35		
Stress x Task	2	.71	.50
Error	70		

** $p < 0.05$*
All values were subjected to Greenhouse-Geisser correction

Task Main Effect

Following a significant task main effect, three pairwise comparisons were conducted. These comparisons identified sources for significant difference in means between the performance of the experimental tasks under cognitive stress and without cognitive stress. A one way analysis of variance was conducted on Condition A and Condition D (easy level), Condition B and Condition E (intermediate level), and Condition C and Condition E (difficult level).

The comparison between the mean AE of the participants' performance of the experimental task at the easy level without cognitive stress and the experimental task at the easy level under cognitive stress yielded a significant difference, ($F(1,70) = 7.50$, $p = 0.01$). The mean AE of the participants' performance of the experimental task without cognitive stress at the easy level was 2.31 (SD = 0.99). The mean AE of the participants' performance of the experimental task under cognitive stress at the easy level was 3.39 (SD = 2.13). The results indicate cognitive stress had a detrimental effect on the performance of the experimental task at the easy level.

The comparison between the mean AE of the participants' performance at the intermediate level produced a significant difference, [$F(1,70) = 9.04$, $p = 0.00$]. The mean AE for the performance of the experimental task without cognitive stress at the intermediate level was 2.07 (SD = 0.76). The mean AE for the performance of the experimental task under cognitive stress at the intermediate level was 2.81 (SD = 1.28). The results demonstrated that the performance of the temporal anticipation task of intermediate difficulty was affected when the participants were under cognitive stress.

In the comparison to test the effect of cognitive stress on the performance of the experimental task, the mean AE of the participants' performance of the experimental task at the difficult level produced a significant difference in means, [$F(1,70) = 5.46$, $p = 0.02$]. The mean AE for the performance of the experimental task without cognitive stress at the difficult level was 2.05 (SD = 0.97). The mean AE for the performance of the experimental task under cognitive stress at the difficult level was 2.64 (SD = 1.16). This showed that the participants were able to temporally anticipate more accurately when the performance of the difficult task was not interfered by cognitive stress.

Discussion

The significant difference for the task main effect showed that the participants' overall performance of the experimental task was affected by cognitive stress. Follow up pairwise comparisons observed significant differences in the performance of the experimental task for all three levels of difficulty. These results concurred with the findings of previous studies [e.g. Smith, Burwitz &

Jakeman, (1988) and Van Gemmert and Van Galen (1999)] with regards to stress and motor performance.

In the case of the current study, the cognitive stress (as induced by the secondary task) caused disruptions in the participants' attentional focus to the pertinent cues relating to the task at hand. Optimal performance of the experimental task required the participants' to focus their attention on the elongation of the horizontal column. Due to the performance of the secondary task, attention was shifted internally (the mental calculation) instead of focussing their attention externally. This internal shifting caused the participants' to miss vital information (e.g. the initiation of the elongation and speed of elongation) regarding the rate of elongation of the horizontal column. Cognitive stress had induced an internal attentional focus, which was just the opposite of the desired attentional focus.

Further examination of the Smith, Burwitz and Jakeman (1988) study revealed an inverted-U relationship between performance of the task and the conditions faced by the participants. This curvilinear pattern of the inverted-U relationship was also observed in this study, where the performance error decreased as the level of difficulty increased. The performance error of the experimental task at the easy level under both conditions was the highest followed by the intermediate level and the lowest performance error was for the performance of the experimental task at the difficult level under both conditions.

The results of the current study are also drew similar findings with that of Van Gemmert and Van Galen, (1999). In the present study, the temporal anticipation task and the number subtraction task demand information computation. The utilization of similar processing capacities for another task within a shared temporal constraint caused the delays in processing of the information needed to accurately anticipate the rate of elongation of the horizontal column. This resulted in a less accurate performance of the temporal anticipation task.

In the case of the present study, both the primary and secondary tasks shared similar processing compositions. Under cognitive stress, the available cognitive resources were insufficient for the concurrent processing of the two tasks that involved similar processing modalities.

Competitive sports comprise of potential stressful events that athletes strive to perform at peak levels under circumstances that are brought about by both internal and external factors. The stress of competition itself can push the athlete to extraordinary levels of performance or reduce the athlete to a failure. The effects of cognitive stress specifically contribute to a competition of limited attention resources that affects the ability of performers to anticipate accurately.

In fast paced sports such as baseball and tennis, where temporal anticipation is a key component, it's of paramount importance that athletes are able to handle the effects of cognitive stress and focus their attention on cues that are relevant to the skill they have to perform. The current study has provided evidence that cognitive stress has both beneficial and detrimental effects on temporal anticipation. It is imperative that efforts are made to understand both the beneficial and detrimental effects of stress on performance in the continuing pursuit of sporting excellence.

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