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Effects of Preliminary Muscular Tension on Reaction Time and Movement Accuracy

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The purpose of the study was to examine how preliminary muscular tension affected reaction time and movement accuracy. The main dependent variables were reaction time and movement accuracy. Movement accuracy was measured by absolute movement error. Also simple and choice conditions were employed to identify the effect on task complexity at a performance level with preload being varied between 0kg-16kg.

The results showed that the shortest reaction time was the medial range of muscular tension. The movement accuracy gradually decreased as the tension level increased. Choice conditions demonstrated longer reaction time and more variability than those of simple conditions.

INTRODUCTION

It is generally understood that "excessive tension inhibits performance." It is also recognized by researchers that "moderate tension facilitates performance as suggested in the inverted U hypothesis." These statements, however, are apt to cause confusion because they are too broad and general.

Characteristically, there is no clear distinction between a type of tension caused by emotional confusion and another type by physical readiness and effort; and no accounting for how these different types of tension affect performance. Bills(1927) called attention earlier to two types of tension and pointed out one type is due to emotional upset and is inhibitive of performance, while the other is due to effort and is facilitative.

The same trend was found in Cox's study(1986) on the relationship between competitive state anxiety associated with emotional tension such as worries and cares which were found to be inhibitive of performance regardless of the degree; the less cognitive anxiety, the more facilitative of performance. As suggested in the inverted U hypothesis, performance gradually improved to a point as somatic state anxiety related to muscular tension and heart rate increased and it was inclined to deteriorate as somatic state anxiety increased over the optimal point(Cox, 1990). This result indicates that emotional and physical tensions have different effects on peformance.

How physical tension affects performance and what is the optimum when the tension has a positive effect on the performance are of a great concern in sports and physical education. In order to answer these questions, first, some accurate experiments should be performed on the related variables in a strictly controlled laboratory situation and, second, the results should be assessed in actual situations. To determine the relationship between physical tension and performance, it is essential to examine the changes in performance affected by physiological factors such as muscle tension, skin resistance, heart rate, breathing, and blood pressure. Until 1970 very little research was done on changes in performance brought about by muscle tension. The scope of the research was not extensive enough and contradictory results were reported. The earlier researchers were mostly concerned about task performances such as pursuit learning(Courts, 1942), reaction time(Henry, 1951), tapping(Boder, 1935), Knee-jerk, etc. and reported that the tasks such as ball throwing(Rushell, 1932) and maintaining position (Seashore, 1938) were inhibitive of performance.

From 1920 through 1960, most of the research on muscle tension and performance was mainly concerned about the changes in reaction time in prime movers and muscles unrelated to performance when they were stimulated and responded. Angell and et al.(1919) made three subjects respond to the signal given by a stronger contraction of muscles 0.5 sec after a preliminary light contraction of muscles. As a result, the reaction time was 20% slower than in an ordinary situation. In this study, however, the level of muscle tension was not measured ; a foreperiod was not provided randomly ; and the data were not statistically treated, thus leaving the problems unsolved.

Knott(1939) made the subject support various weights by hand and measured reaction time. When 5, 10 and 20 Ib. Weights were used, the gain in reaction time ranged 7-15%, all of which were statistically significant. When 5 Ib. was held, reduction in mean reaction time of approximately 12% occurred. This was also statistically significant. At 10% of the weight the maximum effect was reached and, beyond that, there was some deterioration of effectiveness. Henderson(1952), Davis(1956), Court(1942), Freeman(1951), Freeman and Kendall(1940), and Henry(1951) also reported that preliminary muscle tension brings a gain in reaction time. Fink(1956) and Patton(1957) found correlations(−.97, −.81, −.93) between the level of tension and reaction time ; that is, they were in inverse proportion. Bills(1929) found that tension stimulated for experimental purposes was facilitative in various tasks.

Freeman(1933) said that the greater the tension, the longer the reaction time, and the same was true with tension of those muscles unrelated to performance. Pinneo(1957) also found performance kept deteriorating in the pursuit learining tasks carried out by using a dynamometer. Besides King & Schlosberg(1959) and Teichner(1957) found in their studies that preliminary muscle tension had a negative effect on reaction time. Davis(1956) made the subject hold 500g in the left hand to cause tension in the muscles unrelated to performance while performing reaction time with the right hand. It was reported that no significant difference was found.

More recently Clarke(1968) measured reaction time by stimulating 6 tensions and utilizing a hand gripping device. During preperiod the subjects were ready for one of 6 tensions and reacted to an auditory stimulus by increasing the force of reaction as fast as possible. It was found that the reaction times measured from the stimulus until the first change in grip grew faster 0.17 sec to 0.11 sec reaching a maximum at 15kg. Marteniuk's study (1968), in which a ball catching task was performed with pretensions of 0, 5, 10, 15 and 20 Ibs. stimulated for experimental purpose, also showed that reaction time grew faster as tension increased, reaching the maximem at 15 Ib. pretension. This supports the inverted U hypothesis. On the other hand, it was found that, as pretension increased, reaction time decreased linearly. Schmidt and Stull(1970) conducted a similar study to Clarke's(1968) to determine whether the increasing reaction times are of central or peripheral variables. The results showed the total reaction time was not affected by pre-muscle tension. Depending on pretension, premotor reaction time became faster and motor reaction time slower, which partly supports the partial programming hypothesis.

The above mentioned studies, however, were all concerned with the effect of muscle tension on reaction time, but not with movement accuracy. Kim, Carlton, and Newell(1990) clarified that preload was an important variable which accounted for force variability. They showed that force variability gradually increased as preload increased from ON to 105N. In view of Quinn's(1979) impulse variability modal and Schmidt, Zelaznik, Hawkins, and Frank's argument that movement accuracy is an proportion to force variabiltity, it could be hypothesized that muscle tension is an important variable that accounts for movement accuracy.

The current study was primarily planned to clear the disagreement among the results of the previous studies. Those studies used reaction and movement times as subordinate variables, but they did not record the degrees of movement accuracy, which are the results of movement. The muscle tension stimulated for an experiment usually worked in the same direction as in the task(for example, in a hand gripping device) and had a probable effect on reaction time, but the samples in different directions were not studied. Therefore the present study was planned to investigate reaction time and movement accuracy in both simple and choice situations using the tasks unrelated to the direction of muscle tension while changing pre-muscle-tension systematically by using a hand gripping device.

METHODS

1. Subjects

Twelve right-handed adult male volunteers were used who had no experience in the task used in this study. They were paid after the experiment.

2. Task and Apparatus

The task was to hit the target moving to the left or right of the reaction switch. The apparatus involved the multipurpose reaction time developed by Kang-Hun Lee(1991), a performance task, a hand gripping device with steel pens to stimulate muscle tension, and a target sheet(paper). The size of the target sheet was 13.5×9.5cm and the sheet had a cross(+) in the middle, and the diameter of the core of the cross 1mm.

Reaction time was automatically measured by computer, while the foreperiod and the number of choice conditions were controlled by a program. A piece of wooden board(80cm×35cm×4.5cm) covered with a metal sheet; a micro switch of 2mm tolerance installed in the middle; two targets at 30cm on both sides of the switch; a hand gripping device with sharp steel pens which were to hit the metal sheet through the target sheet (paper). The arrangement of the test apparatus is shown in Figure 1.

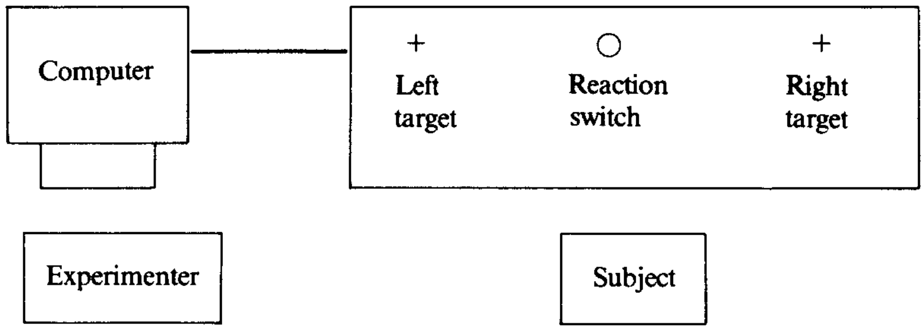

Figure 1. Arrangement of test apparatus

3. Experimental Design

The experiment was performed with a 2×4 2-factor within the subject design ; the first involved task complexity consisting of simple and choice conditions and the second was levels of muscle tension, 0kg, 8kg, 12kg and 16kg. Reaction time and movement accuracy were subordinate variables.

4. Procedure

The experiment was performed on one subject at a time in a sound-proofed laboratory. The experimenter explained the procedure to the subject and the subject was directed to maintain a required muscle tension by pulling the hand dynamometer during the foreperiod and to perform as fast and accurately as possible. The test started when the subject in a relaxed sitting position gripped the dynamometer and pressed the home key. The test proceeded according to the experimenter's manipulation. First a warning signal was given ; after a foreperiod of 1-3 sec provided randomly, the subject aimed at and hit the target reacting to an auditory response signal. After 3 preliminary exercises, 15 tests were performed by conditions with 20 sec rest after 5 tests. When each condition was completed, the subject took 2 minutes' rest. The target sheet was replaced after every 5 tests and absolute errors missing the target were measured to the mm.

5. Treatment of the Results

The data from the individual subject were treated to obtain the reaction times and the mean values for movement accuracy. Based on the results, mean values and standard deviation were calculated by test conditions, and two-way ANOVA was performed, and also posttest was performed if necessary.

RESULTS

1. Reaction Time

The mean values and standard deviation for reaction time by test condition are shown in Table 1. The reaction times by task complexity were respectively 215.9 msec for simple conditions and 352.6 msec for choice conditions with a 136.7 msec difference, which was statistically significant $F(1.11)=293.95$, $P<0.0001$. The result is assumed to be a general phenomenon, that is, a reaction time delay caused by the increase of alternatives.

The reaction times by tension level showed 216.9 msec, 215.2 msec, 210.5 msec, and 215.9 msec respectively on tension levels by simple reaction condition, 0, 8, 12, 16kg with the fastest reaction at 12kg and the slowest at 16kg. However, the reaction time differences by tension level were not significant statistically. The reaction times by tension level caused by task complexity showed similar results.

The analysis of covariance showed no significant differences in reaction times by muscle tension level, but indicated the trend of the inverted U hypothesis as predicted by the activation theory and confirmed that the point of peak performance was changed by task complexity. As shown in Table 1, reaction time became faster until muscle tension reached the optimum beyond which reaction time deteriorated. Reaction time in simple tasks was the fastest on muscle tension level 8kg(M=210, 48msec) the fastest reaction time in choice task was on muscle tension 12kg(M=210, 48msec). This is in agreement with the previous study result that the degree of activation varies by task complexity.

Table 1. Reaction times by test condition and mean movement errors and standard deviation

Division	Task Complexity									
	Simple					Complex				
	Tension level					Tension level				
	0kg	8kg	12kg	16kg	Total	0kg	8kg	12kg	16kg	Total
RT	216.9	215.2	210.5	221.0	215.9	352.5	345.7	352.3	359.7	352.6
	32.0	27.2	25.9	31.8	29.3	34.6	27.8	38.3	38.4	34.8
ERR	6.7	7.4	7.0	7.6	7.2	6.9	8.4	8.8	8.3	8.1
	2.9	3.8	3.3	3.7	3.5	2.4	3.5	4.3	2.9	3.3

2. Movement Accuracy

The mean movement errors by test condition and the standard deviation are shown in Table 1. The movement errors caused by task complexity were 7.2mm at simple test condition and 8,1mm at choice test condition with a 0.90mm difference, which was not significant statistically F(1.11)+2.61, p 0.13. This shows the number of alternatives has no effect on the accuracy of movement execution. The movement errors for tension level showed 6.7, 7.4, 7.0, and 7.6mm respectively at simple reaction conditions, 0, 8, 12, 16kg with the least error at 0kg. The errors for tension level showed 6.9, 8.4, 8.8, 8.3mm respectively at choice reaction conditions, 0, 8, 12, 16kg with the least error at 0kg and the most at 12kg. The movement errors by tension were found to have a statistically significant difference F(3.33)=3.90, P<0.01. To investigate the source of the effect by muscle tension condition, a contrast test was performed to find significant difference F(1.11)=10.92, P<0.007 between 0kg and 8kg, F(1.11)=6.16, P<0.03 between 0kg and 16kg, and no significant difference among other condition. The result shows movement accuracy becomes higher as muscle tension increases and the correlatives of task complexity and tension condition were not significant statistically.

DISCUSSION

The aim of this experiment was to retest the results obtained by Clarke (1968), Schmidt and Stull(1970). The test was performed by measuring reaction time at different levels of tension produced systematically and in a task unrelated to the direction of muscle tension. In order to determine how the movement accuracy variable was affected by activation level, this experiment involved the variable which was the result of motor performance and has been overlooked by previous researchers. The experiment showed that reaction time did not have any significant difference by tension level regardless of task complication time became shorter as muscle tension increased nor Marteniuk's (1968) result. Clarke's (1968) test situation was very similar to that of the present experiment on muscle tension levels, auditory signal, the ages of subjects, and reaction time measures. While Clarke performed one test for each condition, the current study performed is tests repeatedly for each condition. The agreement of the results of the two different experiments seems to be coincidental. In Clarke's experiment muscle tension followed the direction of task performance and probably reaction time became shorter owing to preliminary readiness. The same was true with Schmidt and Stull's (1970) study which did not agree with Clarke's result in the similar test.

In this experiment the result of reaction time did not show a statistically significant difference between muscle tension conditions, that is, simple and choice situations, but ther was a genral trend to follow, in both simple and choice tasks, what the activation theory predicted. In the simple task, the fastest reaction time was attained at 12kg and in the choice task it was attained at 8kg. The variability by subject decreased as tension increased and in the simple reaction task the lowest value occurred at 12kg and in the choice reaction task the lowest value was at 8kg. As muscle tension increased in the subject, reaction time became consistent, and consistency was the highest at the medial point. The result showed that, as the activation level heightened, performance ability improved until reaching the optimum, beyond which it tended to deteriorate. This is congruent with the inverted U hypothesis(Cox, 1986). This is also in agreement with Martens(1974) and Schmidt's (1982) result that the optimal activation level can vary by task complexity and this may suggest that the optimal activation level can vary for reaction time by tension level and the amount of information to process. As Broadbent(1959) pointed out, a lot of research had been performed on reaction time, but little had been done to investiagte the variability of optimal level by task complexity and muscle tension. Further experiments designe more accurately could determine the optimal activation level by choice situation.

An analysis of movement accuracy which was the result of movement execution showed that there was no singnificant difference in the size of movement error by task complexity, but a significant difference was found by muscle tension level. Another analysis demonstrated that there was significant difference between the conditions, 0kg, 8kg, 12kg, 22kg; at the tension condition 0kg movement error was the least. In general, movement accuracy decreased as muscle tension increased. The cause can be explanined to be of an attention deviation effect(Martens, 1974; Marteniuk, 1968; Landers, 1980), that is, the subject was probably distracted from the task by the increse of tension. It is very likely that the subject's attention which had been fully given to task performance gradually shifted toward the maintaining of muscle tension. The shift of attention was probably inevitable particualrly while the subject was trying to keep a required level of tension when the tension increased. Therefore the result occurred when attention was given to movement accuracy and the maintaining of the tension level imposed by the dynamometer. The experiment showed that movement accuracy decrased as muscle tension increased. The results of this study, which are on an anisometric task, have turned out to be similar to that of kim et al.'s (1990) isometric task.

Whether it was peripheral or central that muscle tension affected reaction time was not tested in this study, but the variability of reaction time by muscle tension was accounted for based on the activation and motor program theory. In this experiment Clarke(1968) attempted to investigate, using the isometric contraction task, the prediction that reaction delay by muscle tension would be caused by a peripheral element. He argued that muscle reaction time shortened because preliminary muscle tension tightened the muscle which performed important functions in reactions and were relaxed as elastin extended. However, the current study is focussed on the interpretation that the reaction time change by muscle tension was caused by central activation as the activation as the activeation theory predicted. The studies on activation support the idea that the subject's alertness is a determining factor for reaction time in an alert situation (Adams & Boulter, 1962) and other execution situations. And Pinneo(1961) discovered that various stimuli including sounds and shocks beginning with the peripheral were strong enough to heighten the activation level and gripping the dynamometer helped to increase alertness. It was possible in Clarke's experiment that the subject had alertness increased by proprioceptive feedback from tensive muscle and increased alertness contributed the inducement of a fast reaction. Therefore the reaction time change in Clarke's study was probably derived from the central mechanism.

That no significant change in reaction time was found in this study probably indicates the induced tension condition was not great enough to change the subject's activation level. Activation theory is supported or attacked depending on the pattern and complication of the task, the method to reduce the activation condition and the effect of interaction of subordinate and independent variables in the experiment. Therfore further studies should be undertaken for the solution of these problems employing a more accurate experimental design.

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