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ACUTE EFFECT OF VARIOUS EXERCISE INTENSITIES ON COGNITIVE PERFORMANCE

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Abstract:
The aim of this study was to examine the acute effect of various exercise intensities on coincidence anticipation timing at different stimulus speeds. Fifteen male students who attend to Faculty of Sport Sciences at Mugla Sitki Kocman University, have been dealing with individual or team sports and having licenses for 5 or more years with no health problem or disability, participated in this study voluntarily. Athletes were subject to incremental running protocol on treadmill at 70 percent and 90 percent exercise intensity. Coincidence anticipation timing performances of athletes at each stimulus speeds (6 mph, 9mph and 12 mph) were measured in rest and steady state at each exercise intensity (70 percent and 90 percent). Bassin Anticipation Timer device was used for determining coinciding anticipation timing performance. The data were recorded in SPSS program. Repeated Measures ANOVA, Bonferroni Correction were used. According to, a Repeated Measures ANOVA statistically significant difference was found in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises ($F(2, 28)=9.446$), $p=.001$, multivariate partial eta squared=.40). Post hoc tests using the Bonferroni correction revealed that coincidence anticipation timing mean absolute error scores (6 mph) were statistically significantly higher at 70 percent and 90 percent intensity exercises than mean absolute scores measured at rest. For 9 mph, statistically significant difference was found in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises ($F(2, 28)=6.124$), $p=.006$, multivariate partial eta squared=.30). Bonferroni correction explained that mean absolute error scores (9 mph) measured at 70 percent and 90 percent intensity exercises were statistically significantly higher than mean absolute scores measured at rest. For

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12mph, no statistically significant difference was found in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises ($F(2, 28)=1.873$), $p=.172$, multivariate partial eta squared=.11). Mean absolute error scores (12 mph) measured at 90 percent intensity exercises were higher than mean absolute scores measured at rest and 70 percent intensity. In conclusion, it has been seen that high and moderate intensity exercises influence coincidence anticipation timing negatively at low, moderate stimulus speeds. Thus, in the planning of the training programs, it is important to enhance sensory-motor function stamina of athletes for high intensity activities and it is suggested that the athletes could be involved in exercises that improve their response to different stimuli.

Keywords: athlete, coincidence anticipation timing, exercise intensity, stimulus speed

1. Introduction

Coincidence anticipation timing is the ability of an athlete to program the applications to be followed for an aim based on anticipation of possibilities in due time and precision related to the anticipation of consequences at a given time and frequency. (Weineck, 2011). According to Poulton (1957), random anticipation timing consists of the combination of two different forms which are effector and receptor timing. Effector anticipation is the ability of the individual to move his extremities before an activity. Receptor anticipation is the ability to guess in how much time an external event will take place. According to Information processing theorists, when we perform an interceptive activity (such as hitting a football, hitting a tennis ball or catching a ball), we first evaluate the velocity and path of motion. Afterwards, we calculate how much time is required to intercept and reach the object and how much time is required for our extremities to get into interceptive position (Mc Morris, 2004). In most sports, accurate and precise anticipation ability plays a vital role for a perfect performance (Williams et al., 2011; Omar et al., 2017). An athlete with a good anticipation capacity can guess a fast and dynamic target in right time and react at the right time (Omar et al., 2017).

Coincidence anticipation timing is one of the important perceptual-cognitive characteristics that affect cognitive performance in most sports, is influenced by fatigue and high intensity exercises and therefore changes in the performance of athletes are observed. Though there are studies analyzing the relationship between exercise intensity and cognitive performance, there is no definite conclusion (Lambourne and Tomporowski, 2010). Some studies indicate that moderate exercise enhances cognitive performance (Davranche and Audiffren, 2004), some studies indicate that high intensity exercise influences cognitive performance negatively (Smith, 2016; Duncan et al., 2013), still other studies indicate that there is no relationship between exercise intensity and cognitive performance (Lyons et al., 2008).

Stimulation is defined as being ready to get into action both physiologically and cognitively (Mc Morris, 2004). Duncan et al. (2017), as a result of a literature review, have suggested that exercise intensity, which causes inverted U relationship between exercise intensity and performance, behaves like physiological, cognitive, and psychomotor stressor. In another study exercise related stimulation is viewed as a factor which influences performance temporarily (Lambourne and Tomporowski, 2010). In the literature, there are various theories including Drive Hypothesis, Inverted U Hypothesis and Cue Utilization Theory in order to explain the relationship between performance and stimulation. Drive theory suggests that performance is influenced by three factors; complexity of the task, stimulation and learned habits and it also suggests that the higher stimulation level the better the performance (Jarvis, 2006). On the contrary, the primary traditional Inverted U hypothesis used by sport psychologists (Sabzi et al., 2014) indicates that performance at optimal level stimulation reaches a peak but stimulation above or below optimal level, causes deteriorated performance. According to Inverted U hypothesis high or low intensity exercise causes deteriorated cognitive performance however moderate intensity exercise causes optimal performance (Yerkes and Dodson, 1908). Although Yerkes and Dodson's theory was highly influential, it was criticized for being insufficient to explain why stimulation influences performances. So Easterbrook developed Cue Utilization Theory. According to this theory at low stimulation level people pay attention to both relevant and irrelevant clues. However, as stimulation level increases attention reaches the optimal level and people focus on relevant clues only. This refers to the apex of the curve of Yerkes and Dodson Theory. However, if stimulation level increases further the attention level, focus on relevant clues decrease. Thus, performance decreases with high stimulation (Mc Morris, 2004).

In recent years, studies have mainly been focused on the relationship between performance and anxiety (Jarvis, 2006). One of the theories studying the relationship between performance and anxiety and indicating how exercise can influence performance is Catastrophe model (Jarvis, 2006; Hardy and Parfitt, 1991).

According to Hardy and Parfitt (1991) when cognitive anxiety is low, the relationship between physiological stimulation and performance is an inverted U. Yet if physiological stimulation is high (depending on exercise intensity), cognitive need also increases (during increased stimulations peed) and the relationship between physiological stimulation and cognitive performance is negative, which causes a deterioration in performance (Duncan et al., 2013). In cases when physiological stimulation is high (90 percent of heart rate reserve) and stimulation speed is cognitively the hardest, cognitive performance namely coincidence anticipation timing is influenced negatively. These results are based on Catastrophe Model (Duncan et al., 2013; Duncan et al., 2016). High intensity exercises create a negative impact upon the homeostatic balance of organism and cause fatigue signs (Aslan et al., 2011). It is indicated in a study that (Royal et al., 2006) as exercise intensity increases so does stimulation level. In literature, the increase in stimulation level caused by exercise intensity is related to increase in perceived difficulty level and increase in heart rate (Brisswalter and others, 2002). The reason for it is defined as increase in stimulation level of physiological changes stemming from exercise. On the other hand the relationship between stimulation and exercise has not been fully understood (Lyons, 2011).

The findings of studies performed to analyze the influence of exercise or fatigue on gross motor or sport specific and cognitive tasks can be explained with one of the stimulation theories mentioned above which explains the relationship between stimulation and performance. These models have been discussed but the relationship has not been able to be explained definitely up to now. They need to be further supported by scientific studies in order to be explained better (Zaichkowsky and Baltzell, 2001). In literature, there are different results obtained at different studies analyzing the acute effect of exercise intensity on coincidence anticipation timing, which requires further study of the issue. So in this study coincidence anticipation timing, which is an important element for cognitive performance, was analyzed at various fatigue conditions (70 percent and 90 percent intensity exercises). The results of this study will provide trainers and athletes with information about current cognitive performance of athletes. It will also make a contribution to the literature for planning training programs for accomplishing high level perceptive-cognitive performance in training and competitions.

2. Material and Methods

2.1 Participants

Fifteen male students who attend to Faculty of Sport Sciences at Mugla Sitki Kocman University, have been dealing with individual or team sports and having licenses for 5 or more years with no health problem or disability, volunteered for the study (mean age: 21.06±1.16 years, mean height: 179.80±4.47 cm, mean body mass: 77.80±9.83 kg).

2.2 Experimental Process

In previous studies about coincidence anticipation timing, exercise intensity of 70 percent of heart rate reserve was considered as “moderate” intensity and exercise intensity of 90 percent of heart rate reserve was considered as “high” intensity exercise (Duncan et al., 2013; Lyons et al., 2008; Duncan et al., 2016). Athletes were informed about the nature and possible risks of the study before giving Informed Consent Form. They were warned not to take alcohol, caffeine or stimulants during 24 hours prior to incremental running protocol on treadmill at visit to laboratory. After all athletes signed Informed Consent Form, fifteen participants were divided into groups of 7 (first group) and 8 (second group) people. The measurements of this study were conducted in 3 sessions on different days. Participants attended 2 sessions within a 5-day period a testing laboratory (Table 2).

The first session to laboratory was familiarization session which anthropometric data of all athletes (body mass and height were measured with a scale of 0.01 kg sensitivity level and a digital height measurement device, respectively) were collected and each participant was familiarised with the Bassin Anticipation Time. The second session, athletes in the first group were subjected to incremental running protocol (70 percent and 90 percent intensity) (Table 2). In steady state at each exercise intensity, coinciding anticipation timing at different stimulus speed (6mph, 9mph, 12 mph) were measured in random order (Table 1). The third session, athletes in the second group were subjected to incremental running protocol (90 percent and 70 percent intensity). In steady state for each exercises intensity, coinciding anticipation timing at different stimulus speed (6mph, 9mph, 12 mph) were measured in random order (Rodrigues et al., 2011). There was one day between second and third session (Table 2)

2.3 The following experimental procedure was applied to athletes in first and second groups during the second and third session on laboratory (Table 2);

In this study, repeated measures design was used. Coinciding anticipation timing measurements at different stimulus speeds (6mph, 9mph, 12 mph) were taken from athletes in rest and steady state for two exercise intensity (70 percent and 90 percent intensity). If a learning, or order, effect is possible, an experimental design may attempt to counterbalance the effects and distribute them across both conditions (Armour and MacDonald, 2012). Counterbalanced design was applied for exercise intensities (70 percent and 90 percent intensity) (Table 2). Athletes in both first and second group were not made conscious of which condition they had been assigned and stimulus speeds to until completion of all experimental trials. Any information was not provided to participants about their heart rate during the tests (Duncan et al., 2013).

Athletes in both first and second group came to laboratory at 8.00-11.00 am in a well-rested and well-hydrated state on different days. They were applied the same experimental design to both groups (Table 2). Firstly, RS400 brand polar watch were attached to athletes in order to determine the rest heart rate and to measure the changes of heart rate of athletes during exercise. And then, the target heart rate of each athlete for each exercise' intensity (70 percent and 90 percent) was calculated with Karvonen method (Karvonen et al., 1957). Later, Coinciding anticipation timing of athletes was measured at different stimulus speeds in rest condition. For this, five measurements were taken at each stimulus speed (6mph, 9mph, 12mph) in random order (Table 1). After measuring rest anticipation timing, athletes were given 15 minutes to warm up. Then, Athletes underwent increasing intensity running protocol on treadmill. They started with 5 km h^{-1} and slope was raised by 1 km h^{-1} every 30th and 60th seconds. By means of coincidence anticipation, timing device attached to the side of treadmill. When athletes reached steady state for 70 percent intensity or 90 percent intensity, their coinciding anticipation timing was measured at different stimulus speed (6mph, 9mph, 12mph) in random order (Table 1).

After measuring coinciding anticipation timing performance, they continued to exercise until they reached steady state for 90 percent or 70 percent intensity. When they reached steady state for 90 percent intensity or 70 percent intensity, their coinciding anticipation timing was measured at different stimulus speed again (Duncan et al., 2013) (Table 2). Reaches to steady-state of athletes (70 percent; average 5 minutes, 90 percent: average 8 minutes) lasted with an average duration of 5 to 8 minutes although it varies according to exercise intensity and fitness level. In steady state for two exercise intensity, the signal was sent by the person performing the study. Then, five measurements were taken at each stimulus speed (6mph, 9mph, 12mph) in random order (Table 1). Athletes completed the coinciding anticipation timing performance at an average of 35 seconds at each exercise intensity's target heart rate. After measuring it, athletes stop running slowly. The results were recorded in milliseconds based on being early (negative) or late (positive) at rest and each exercise intensity.

2.3 Data Collection Tool

2.3.1 Bassin Anticipation Timer Device (Lafayette Instrument Company, Model 35575)

Bassin Anticipation Timer Device was used for measuring the coincidence anticipation timing at different stimulus speeds (6mph, 9mph, 12mph) of athletes at rest condition and each exercise intensities' target heart rate (70 percent and 90 percent) in random order (Table 1). The device consists of 3 parts which are control panel, response key and a runway through which LED lights move as a linear serial. All LED lights are designed in a moving line in order to warn participants that dynamic stimulation is coming (Alaei, 2015). In this study, start and finish speeds were fixed as 6, 9 and 12 mph for different stimulus speeds and the target light was set as the 12th light of the 3rd set. In order to reduce the possibility of athletes' guessing the time of test the warning light was set with a random delay of 1 to 2 seconds (Duncan et al., 2013). For maximum efficiency while measuring coincidence anticipation, timing only one athlete was taken into the laboratory so that other participants did not learn the process.

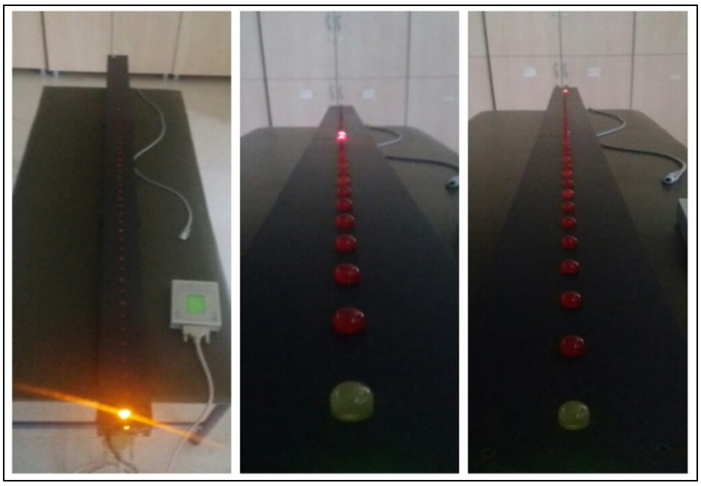

Figure 1: Bassin Anticipation Timer Device

2.4 Data Analysis

In literature, absolute error is the frequently used timing standard utilized for coincidence anticipation timing. It indicates the absolute value for each raw data score regardless of the response's being early or late (Sanders, 2011). The raw data of coincidence anticipation timing of each athlete for each stimulus speed (6mph, 9mph, 12mph) at rest, 70 percent and 90 percent exercise intensity were converted into absolute error score. Later, they were statistically analyzed. Statistical calculation was performed on SPSS (version 18.0). It was examined that absolute error at three different stimulus speed (6mph, 9mph, 12mph) measured rest, steady state in each exercise intensity (70 percent and 90 percent intensity) whether show a normal distribution or not. The data showed a normal distribution by taking into account Shapiro Wilk test result. Repeated Measures ANOVA was used in order to find out whether a statistically significant difference exists among scores of coincidence anticipation timing absolute error scores at rest, 70 percent and 90 percent exercise intensities. Sphericity was analyzed by Mauchly's test. If any differences were determined, pairwise comparisons with Bonferroni correction were used. Significance level was accepted as $p<0.05$.

Table 1: Coinciding anticipation timing performance at different stimulus speeds (6mph, 9mph, 12mph) of each athletes in rest, steady state for 70 percent and 90 percent exercise intensity in random order

<table>
<tr><td></td><td></td><td>Coinciding Anticipation Timing</td><td>Rest</td><td>70 percent intensity</td><td>90 percent intensity</td></tr>
<tr><td rowspan="7">First Group</td><td>Athletes</td><td></td><td>Stimulus Speed</td><td>Stimulus Speed</td><td>Stimulus Speed</td></tr>
<tr><td rowspan="6">1
2
3
4
5
6
7</td><td>1.Measurement</td><td>6, 9, 12</td><td>6, 9, 12</td><td>6, 9, 12</td></tr>
<tr><td>2.Measurement</td><td>12, 9, 6</td><td>12, 9, 6</td><td>12, 9, 6</td></tr>
<tr><td>3.Measurement</td><td>9,6,12</td><td>9,6,12</td><td>9,6,12</td></tr>
<tr><td>4.Measurement</td><td>6, 9, 12</td><td>6, 9, 12</td><td>6, 9, 12</td></tr>
<tr><td>5.Measurement</td><td>12, 9, 6</td><td>12, 9, 6</td><td>12, 9, 6</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="7">Second Group</td><td>Athletes</td><td>Coinciding Anticipation Timing</td><td>Rest</td><td>90 percent intensity</td><td>70 percent intensity</td></tr>
<tr><td rowspan="6">8
9
10
11
12
13
14
15</td><td>1.Measurement</td><td>12, 9,6</td><td>12, 9,6</td><td>12, 9,6</td></tr>
<tr><td>2.Measurement</td><td>6,9,12</td><td>6,9,12</td><td>6,9,12</td></tr>
<tr><td>3.Measurement</td><td>9,6,12</td><td>9,6,12</td><td>9,6,12</td></tr>
<tr><td>4.Measurement</td><td>12,9,6</td><td>12,9,6</td><td>12,9,6</td></tr>
<tr><td>5.Measurement</td><td>6,9,12</td><td>6,9,12</td><td>6,9,12</td></tr>
<tr><td colspan="4"></td></tr>
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Table 2: Visual Plan of the Study in Laboratory

First session		**The second session**		**The third session**
		First group; Athletes (1,2,3,4,5,6,7)		**Second Group;** Athletes (8,9,10,11,12,13,14,15)
Anthropometric Measurements Familiarization with Bassin Anticipation Timer	After 2 days	Measuring Rest Heart Rate ⇩ Wearing Polar Watch ⇩ Resting CAT (6mph, 9mph, 12mph) ⇨ ⇩ 15 minutes Warm-up ⇩ Incremental Running Protocol on Treadmill ⇩ Until steadv state	5 measurements for each stimulus speed	Measuring Rest Heart Rate ⇩ Wearing Polar Watch ⇩ ⇦ Resting CAT (12mph, 9mph, 6mph) ⇩ 15 minutes Warm-up ⇩ Incremental Running Protocol on Treadmill ⇩ Until steady state
		Reach steady state for targeted heart rate for 70 % exercise intensity (CAT: 6mph, 9mph, 12mph) ⇨ ⇩	5 measurements for each stimulus speed	⇦ Reach steady state for targeted heart rate for 90 % exercise intensity (CAT: 12mph, 9mph, 6mph) ⇩
		Reach steady state for targeted heart rate for 90 % exercise intensity (CAT: 6mph, 9mph, 12mph) ⇨	5 measurements for each stimulus speed	⇦ Reach steady state for targeted heart rate for 70 % exercise intensity (CAT: 12mph, 9mph, 6mph)

3. Results

Table 3: Comparison of (6mph) mean absolute error score (millisecond) measured at rest and 70 percent, 90 percent intensity exercises

Measurement		M	S.D.
1	Rest	12.50	2.36
2	70 % exercise	16.44	4.70
3	90 % exercise	19.42	5.35

The means and standard deviations were presented in Table 3. Mauchly's test indicated that the assumption of sphericity was satisfied $X^2(2)=.972$, p=.615. A repeated measures ANOVA with a Sphericity Assumed determined that statistically significant difference was found in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises (F(2, 28)=9.446), p=.001, multivariate partial eta squared=.40). Post hoc tests using the Bonferroni correction revealed that mean absolute error scores (6 mph) measured at 70 percent and 90 percent intensity exercises were statistically significantly higher than mean absolute error scores measured at rest.

Table 4: Comparison of (9mph) mean absolute error score (millisecond) measured at rest and 70 percent, 90 percent intensity exercises

Measurement		M	S.D.
1	Rest	11.98	3.51
2	70 % exercise	17.98	5.86
3	90 % exercise	18.68	8.15

The means and standard deviations were presented in Table 4. Mauchly's test indicated that the assumption of sphericity was satisfied $X^2(2)=.659$, p=.719. A repeated measures ANOVA with a Sphericity Assumed determined that statistically significant difference was found in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises (F(2, 28)=6.124), p=.006, multivariate partial eta squared=.30). Post hoc tests using the Bonferroni correction revealed that mean absolute error scores (9 mph) measured at 70 percent and 90 percent intensity exercises were statistically significantly higher than mean absolute scores measured at rest.

Table 5: Comparison of (12mph) mean absolute error score (millisecond) measured at rest and 70 percent, 90 percent intensity exercises

Measurement		M	S.D.
1	Rest	14.49	4.81
2	70 % exercise	17.26	8.50
3	90 % exercise	19.16	9.66

The means and standard deviations were presented in Table 5. Mauchly's test indicated that the assumption of sphericity was satisfied $X^2(2)=2.21$, p=.331. A repeated measures ANOVA with a Sphericity Assumed determined that no statistically significant difference was found in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises (F(2, 28)=1.873), p=.172, multivariate partial eta squared=.11). Mean absolute error scores (12 mph) measured at 90 percent intensity exercises were higher than mean absolute scores measured at both rest and 70 percent intensity exercise

5. Discussion

Fatigue is an element which restricts performance (Thomson et al., 2009) by affecting motor processes as well as perceptual processes in learning and performance skills (Anshel and Novak, 1989). Exercise intensity is a frequently mentioned moderator in acute exercise studies. The importance attached to exercise intensity stems from the interest in understanding influence mechanisms. Inverted U hypothesis and Drive theories suggest that exercise intensity influences the extent of impact. Especially inverted U Hypothesis suggests that moderate intensity exercise will be quite useful while Drive Theory suggests that the impact is greatest with high intensity exercises. When considering mechanisms such as heart rate, catecholamine, and brain derived neurotropic factor, exercise intensity is important for determining the amount of change in these physiological mechanisms (Chang et al., 2012). In most sport competitions, visual-cognitive and motor performances take place in a high physiological stimulation and cognitive anxiety condition, both acts at the same time when performance is required (Duncan et al., 2017). Thus, it is essential for athletes for a good performance that high stimulus and anxiety levels are optimal.

The aim of this study was to examine the acute effect of various exercise intensities (70 percent and 90 percent) on coincidence anticipation time at different stimulus speeds (6mph, 9mph, 12mph). A repeated measures ANOVA determined that statistically significant difference was found in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises (F(2, 28)=9.446), p=.001, multivariate partial eta squared=.40). Post hoc tests using the Bonferroni correction revealed that mean absolute error scores (6 mph) measured at 70 percent and 90 percent intensity exercises were statistically significantly higher than mean absolute error scores scores measured at rest (Table 3). Statistically significant difference was found in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises (F(2, 28)=6.124), p=.006, multivariate partial eta squared=.30). Post hoc tests using the Bonferroni correction revealed that coincidence anticipation timing mean absolute error scores (9 mph) measured at 70 percent and 90 percent intensity exercises were statistically significantly higher than mean absolute error scores measured at rest (Table 4). No statistically significant difference was determined in mean absolute error scores measured at rest, 70 percent and 90 percent intensity exercises (F(2, 28)=1.873), p=.172, multivariate partial eta squared=.11). Mean absolute error scores (12 mph) measured at 90 percent intensity exercises were higher than mean absolute error scores measured at rest and 70 percent intensity exercise (Table 5)

There are studies in literature which suggest that different exercise intensities do not influence decision making precision and 70 percent intensity exercise (moderate intensity) and 100 percent intensity exercise (high intensity) enhance decision making speed (McMorris and Graydon, 1996), significant improvements in performances of martial athletes and team sports under highly challenging conditions, performances of athletes who are not experts at any sport deteriorate (Deligneres et al., 1994), exercise at maximal intensity influence visual response time negatively (Senel et al., 2010), during physical exercise at lactate threshold selective reaction time improves (Kashihara, 2005). Fontana and others (2009) studied decision making performances of experienced and inexperienced football players at four different exercise intensities (rest, 40 percent, 60 percent and 80 percent of maximal aerobic power). Sixteen experienced and sixteen inexperienced football players were asked to answer seven decision making questions as fast and correctly as possible at each exercise intensity. Consequently, exercise did not influence decision making precision; however, decision making speed of both experienced and inexperienced football players enhanced in parallel with exercise intensity. These results indicate that physiological stimulation influences only decision making speed.

The result of the study was conducted by Browne et al., (2017) indicated that the effect of acute high-intensity exercise on cognitive performance in trained individuals was based on the specific cognitive domain being assessed. Generally, simple tasks were not influenced, while the results on complex tasks remain ambiguous. They suggested that multiple factors effects the acute exercise–cognition relationship so, future research should control for potential moderators and thus be highly specific when determining and defining exercise intensities, participant fitness, and cognitive domains. Different studies analyzing the influence of various exercise intensities on coincidence anticipation timing present different results (Lyons et al., 2008; Duncan et al., 2015; Duncan et al., 2016). The difference stems mainly from methodical differences such as differences in exercise type and criterion, coincidence anticipation timing tasks, stimulus speeds and participants' characteristics (Duncan et al., 2013). Duncan et al., (2013) studied the impact of exercise intensity on coincidence anticipation timing at various stimulus speeds. Eleven males and three females participated in the study. In conclusion, high intensity exercises were related to weak coincidence anticipation timing performance. However, it was also reported that stimulus speed played a key role in this relationship and it was observed that as exercise intensity increased athletes made more mistakes at faster stimuli. Omar et al., (2017) concluded in their study that as stimulus speed increased so did error size and stimulus speed had an effect on coincidence anticipation timing. In another study Lyons et al., (2008) analyzed the effect of moderate and high intensity exercise (70 percent and 90 percent of heart rate target) on coincidence anticipation timing of expert and novice Gaelic players. They concluded that exercise intensity had no impact on coincidence anticipation timing and improved coincidence anticipation timing performance was observed only moderate intensity exercise. Wu et al., (2013) attributed the reason of the better coincidence anticipation timing of athletes in motion to the high activity of their inferior parietal and inferior frontal gyrus. Isaacs and Pohlman (1991) analyzed the impact of different metabolic loads (pedalling without load, 25%, 40%, 75% and VO_2 peak) on anticipation performance measured during exercise. Anticipation timing performances of 6 female and 4 male subjects were measured at bicycle ergonometry at steady state at fast (7mph) and slow (3mph) stimulus speeds. Consequently, coincidence anticipation timing measured during cycling at VO_2 peak deteriorated statistically. No statistically difference was observed for other exercise intensities. Bard and Fleury (1978) concluded that exercise performed at bicycle ergonometry to fatigue did not affect vision space which is a visual capacity component and anticipation timing.

Duncan et al., (2016) 8 male and 10 female investigated whether effect of the change in physiological stimuli can be estimated correctly with Catastrophe model. Consequently, they reported that in cases of high anxiety and high physiological stimulus absolute error scores were higher and coincidence anticipation timing was influenced negatively. Cognitive anxiety was found to be higher in exercises performed at 90 percent intensity of heart rate reserve than exercises performed at 30 percent, 50 percent and 70 percent intensity exercises of heart rate reserve. The results of the study are partially consistent with catastrophe model. The results of this study are also in parallel with other studies and supported by Catastrophe model. The study of Duncan et al., (2017), which analyzed the effect of changes in physiological and psychological stimuli on short service performances in competition and training environments. They observed that increased physiological stimulation and accompanying increased cognitive anxiety affected short service performance negatively in competitions. Smith et al., (2016) suggested in their study that 90 percent intensity exercise affected cognitive performance negatively when compared with 70 percent intensity exercise and rest condition. In another study Mekari et al., (2015) concluded that when compared with moderate and low level exercises, cognitive functions deteriorated during high intensity exercises (performed with 85 percent of power output) and thus the precision of answers to responses diminished. They attributed the situation to decrease in oxygenation of prefrontal cortex during high intensity exercises. McMorris et al., (2011) report that the increase in exercise related stimulation level caused an increase in brain concentration of neurotransmitters like norepinephrine and dopamine. They observed that while this event enhanced processing speed it also caused neural noise and had a negative impact on performance precision.

5. Conclusion and Recommendations

In conclusion, it has been seen that high and moderate intensity exercises influence coincidence anticipation timing negatively at low, moderate stimulus speeds. High and moderate intensity exercises affected also high stimulus speed but the result was not significant. It is thought that improving endurance of perceptual-motor functions to high-intensity activities while planning training programs will contribute to optimizing the physical and cognitive performance of athletes. It is suggested that the athletes could be involved in exercises that improve their response to different stimuli so training athletes in a multiple stimulus environment plays an important role in the enhancement of coincidence anticipation timing performance in training. It is recommended that different studies which examine the effects of different exercise intensity on cognitive or visual performance such as coinciding anticipation timing, reaction time, visual capacity, visual perception, should be done in elite athletes in different environments, different age groups and different sport branches.

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