INTRODUCTION
Researchers have investigated the effects of exercise on different visual functions, such as visual acuity, contrast sensitivity (CS), kinetic visual acuity (KVA), and dynamic visual acuity (DVA). This study extended this line of research on the effects of exercise to include coincidence anticipation timing (CAT).

Purpose: Investigate the effects of varying levels of exercise intensity on CAT.

CAT refers to a subject’s ability to anticipate the arrival of a stimulus to a defined point and elicit a response coincident with the moment of arrival (Schmidt, 1968). A highly accurate and consistent coincidence anticipation performance depends upon the ability to predict the movement characteristics of the object and to execute the coincident response (Fleury, 1998).

There are very few studies that have investigated the effects of varying exercise intensities on visual abilities. Whiting and Sanderson (1972) investigated the changes in static visual acuity (SVA). This study found that after playing table tennis, the subjects’ SVA was significantly better than before play. However, CS has been a more popular area of study. CS studies have shown that exercise was followed by significant improvement in resolution acuity across different magnitudes of exercise workloads (Vlahov, 1972; Vlahov, 1980; Woods & Thomson, 1995). Also, Millslagle, DeLaRosby, and VonBank (2005) investigated DVA while cycling at different exercise loads. This study found that accuracy of DVA improved during incremental exercise.

Hypothesis: CAT will progressively decrease, or improve, as exercise loads are incrementally increased.

METHODS

Subjects: 16 female college-aged students were selected from the University of Minnesota Duluth.

Equipment. Each subject’s SVA and CS were assessed using an Optec 2000 Vision Tester. These visual criteria along with the subject’s history and present involvement in ballistic sports were used to screen each volunteer. A DVA apparatus as described by Millsagile (2004) was used to determine the threshold of tracking capability for each subject. Birikholz and Jones’ guidelines (1991) were used to determine each subject’s seat height for the electronic Collins Pedal Mate ergometer (model number 2149). Each subject wore a Polar T31 heart-rate belt that transmitted heart rate to an Accurex IIa

Figure 1: Variable Exercise Intensities and Error Score Means

Procedure. In the first phase of the study a variety of preliminary tests were conducted. First, the subject’s SVA and CS were assessed using the Optec 2000 Vision Tester. A minimum criteria of 20/20 vision and normal CS were required. Next, the subject’s threshold tracking speed was determined using a DVA apparatus (Figure 1). Then, the subject was positioned on the cycle ergometer wearing the heart-rate belt and monitor and performed the ACSM (2005) maximal cycle ergometer test. The subject’s maximum workload in watts and heart rate were recorded, which was then used to determine the 30%, 60%, and 90% intensity workloads.

In the second phase of the study, the subject returned for CAT testing (Picture 2). The CAT apparatus was programmed at the subject’s threshold speed. Then, the subject’s resting CAT data was obtained and recorded. Next, the subject exercised at 60 revolutions per minute for 5 minute bouts at 30%, 60%, and 90% of predetermined maximum workload. The exercise conditions were randomized to minimize the learning effect. Fifteen CAT trials were conducted for each exercise intensity condition. The subject was given a rest period between each condition.

Data Analysis. Subject’s CAT scores for each condition were converted to absolute error (AE), constant error (CE), and variable error (VE). A one-way analysis of variance (ANOVA) was conducted for each error score to examine the relationship between CAT and the different exercise intensity conditions. Then, multiple independent t-tests were conducted to examine the relationship between rest and the 90% intensity condition.

RESULTS & DISCUSSION

Overall Effects. There were no significant main effects found for AE (F3,60=1.55, p=0.21), CE (F3,60=0.37, p=0.77), and VE (F3,60=2.39, p=0.08). However, a clear trend in the mean error scores was found, see Figure 1. Magnitude (AE) and bias (CE) improved as exercise intensity increased and the subject’s consistency (VE) increased as exercise intensity increased.

Rest condition versus 90% condition. Further examination of the differences between rest and the 90% exercise condition was performed, see Table 1. Significant effects for AE and VE were found.

One possible explanation for these results is that exercise stimulates the reticular activating system which subsequently improves the accuracy of the visual system (Andreassi, 1965). As exercise intensity increases, the subject demands more visual effort, which increases the stimulation of the reticular activating system. Alertness improves with increasing exercise intensity and makes subjects more prepared to process visual information (Watanbe, 1983). Thus, the accuracy of the visual system is thought to improve with increasing exercise intensity.

In summary, the visual abilities and CAT improved as exercise intensity increased. This supports the hypothesis as well as previous research (Whiting and Sanderson, 1972; Vlahov, 1972; Vlahov, 1980; Woods & Thomson, 1995; Millslagle, DeLaRosby, and VonBank, 2005).

Table 1: Results of Independent t-tests

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<thead>
<tr>
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<th>M</th>
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<th>SD</th>
<th>t</th>
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<tbody>
<tr>
<td>AE</td>
<td>67.45</td>
<td>33.88</td>
<td>48.57</td>
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<td>CE</td>
<td>42.95</td>
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<tr>
<td>VE</td>
<td>86.86</td>
<td>39.16</td>
<td>56.94</td>
<td>20.71</td>
<td>2.7</td>
<td>0.01</td>
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</table>

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