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NIRS-DETECTED CHANGES IN THE ARM DURING MENTAL REHEARSAL OF PHYSICAL ACTIVITY (IMAGINARY EXERCISE)

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1. INTRODUCTION

Using imagery to perform a conscious mental rehearsal of a physical task, designed to aid performance [1], has proved beneficial in a variety of tasks, ranging from physical therapy to flight training to sporting performance [2]. Yet the physical/psychological basis underpinning the success of mental rehearsal is still unclear [3]. A number of theories have been proposed. One, psychoneuromuscular theory, suggests that imagery results in a neuromuscular pattern that is identical to the patterns used in actual movements [4]. Mental rehearsal is therefore likened to exercise with the gain turned down. Consistent with this theory functional magnetic resonance studies have shown that imagery activates a large fraction of the neural networks that are involved in motor performance [5-7]. However, there is conflicting evidence as to whether this effect extends to the activation of the site of physical activity itself [8, 9].

Previous studies testing the psychoneuromuscular theory of mental rehearsal have looked at changes in muscle EMG with conflicting findings supporting [8] or disputing [9] effects at the muscle. Blood volume and blood flow increase in response to exercise, to increase the flow of oxygen to the working muscles [10]. There have been no previous studies comparing the effect of these hemodynamic parameters on mental imagery of a physical activity. Near infrared spectroscopy (NIRS) is an easy and non-invasive way of measuring continuous blood volume changes during exercise. It has the advantage for studies of imagery that, once placed on the muscle, the probes and measuring device are light and non-intrusive. There is therefore minimal psychological distraction to the subject in performing the imagery test as opposed to more invasive or "bulky" measuring devices.

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2. METHODS

Fifteen subjects (13 male and 2 females, age 25.1 ± 6.0, mean ± SD) participated in the study. Subjects consented to the study, which complied with University of Essex ethics committee regulations. Subjects were seated with their dominant arm resting on a desk top throughout the study. A dual wavelength spectrometer (Micro RunMan, NirSales Inc. Philadelphia, PA, USA) was used with a 3 cm source:detector separation to measure changes in the concentration of hemoglobin in the muscles above the dominant forearm [11]. As originally designed the algorithm used by the RunMan measured arbitrary changes in hemoglobin concentration and (hemoglobin + myoglobin) oxygenation calculated from changes in light attenuation at 780 and 850 nm (using 20 nm bandwidth filters). We have adapted this algorithm to measure quantified relative changes in these parameters (in μM chromophore using *in vitro* optical extinction coefficients [12] and a modified version of the Beer-Lambert Law, allowing for the spectral distortions [13] and additional pathlength [14] due to the multiple scattering of light by tissue). This is essentially the same algorithm as used in the Hamamatsu NIRO range of NIR spectrometers (although the reduced number of wavelengths and the much broader spectral bandwidth could lead to some differences in the absolute values). The probe was securely strapped to the arm to maintain its stability and position throughout the test (note that the exercise protocol was such that there was minimal movement of the arm during the protocol). A 1 Hz acquisition rate was used. The light source was positioned along the longitudinal axis of the anterior forearm, approximately 2 – 4 cm from the antecubital fossa. Subjects performed two protocols and they were always in the same order. Immediately following probe placement and calibration there was a two minute baseline period, followed by a four minute exercise period and then a four minute recovery period. During the four minutes of exercise subjects squeezed and released the bulb of a sphygmomanometer continuously over a repeated five second bout. This bout consisted of a 1 second isometric contraction (squeeze) followed by release (one second) followed by a 3 second break. This rhythm was repeated for the 4 minute exercise. During the baseline and recovery period the subject was asked to sit in a quiescent state.

The probe was then removed and the subject left to their own devices as long as they did not engage in exercise (other than walking). Following a minimum of one hour's rest, the probe was replaced in the same position as before. In the second protocol the same procedure was followed (calibration, two minute baseline, four minute activity, four minute recovery) only this time the subjects were asked to mentally rehearse the exercise following the same rhythm as before.

All subjects completed a standard Vividness of Movement Imagery Questionnaire VMIQ to assess the impact of their ability to image the physiological response [15]. The VMIQ is a 48 item questionnaire which measures imagery on five-point Likert scales in both internal ("feeling" oneself perform) and external ("seeing" oneself perform) modalities (24 questions for each). It is designed to measure the vividness of a subjects' movement imagery and has a test-retest reliability coefficient of .76 [15]. The lowest and therefore "best" possible score is 48 (24 in each modality) whereas the highest and "worse" score is 240 (120 in each modality). The VMIQ has been used in various studies assessing the impact of vividness of imagery on sporting performance [16, 17].