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

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1. INTRODUCTION

Mental rehearsal of a physical task (or motor ideation) has been studied since the 1930's [1]. Initial studies looking at the electrical activity in the muscle (EMG) date back to Jacobson [2] who demonstrated that the muscles used in mentally rehearsing a task are the same as those used to perform the task. Since this initial report a range of studies has provided evidence for [3-5] or against [6-8] muscle activation during mental imagery. The nature of the mental rehearsal EMG patterns do not always mirror those produced during physical activity [9] and it has recently been suggested [10] that EMG changes are due to a practice effect and not mental imagery.

The advent of modern imagery techniques have clearly demonstrated that mental imagery of physical activity does activate the brain, however. SPECT [11], PET [12], EEG [13], MEG [14] and fMRI [15] have shown that imagery activates a large fraction of the neural networks that are involved in motor performance. However, although most studies report changes in the motor cortex during motor ideation, as with EMG the detailed nature of the changes can differ between real and imaginary exercise [16, 17]. The physical confines of an MRI or PET study put severe limitations on the kind of psychological experiments that can be performed. In the case of athletes, for example, the imagery process is most successful when the nature and surroundings are closely linked to the physical act of exercise being imagined. In this study we tested whether NIRS could be used to measure motor ideation in the motor cortex, with the ultimate aim of developing a more realistic and more readily reproducible assay for the kind of motor ideation that is used in practice by professional sportspeople.

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2. METHODS

Six subjects (5 male and 1 female, age 40 ± 15 years, 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 three wavelength spectrometer (NIRO200 Hamamatsu, Japan) was used with a 4 cm source:detector separation to measure changes in the oxygenation of hemoglobin in the motor cortex. An optical pathlength of 25 cm was used to convert optical density changes on µM oxyhaemoglobin concentration changes. A 1 Hz acquisition rate was used. Only one of the two NIRS probes in the NIRO200 was used in this study. The probe was positioned over the motor cortex (20% of the distance from the centre of the head to the ear on the opposite side to the dominant hand being exercised in the study). The hair was parted to allow optimum probe contact (as judged by a maximum signal:noise ratio). The subject then performed a preliminary standard "finger tapping" protocol to confirm that changes in the motor cortex could be detected.

The experimental protocol lasted 29 minutes. Two minutes of baseline readings were followed by four minutes of finger tapping (4 x 30s on, 30s off). There was then a five minute baseline prior to four minutes of exercise. During the exercise subjects squeezed and released the bulb of a sphygmomanometer continuously over a repeated five second bout. This bout consisted of a one second isometric contraction (squeeze) followed by release (one second) followed by a three second break. A further five minutes rest was followed by four minutes of "imaginary exercise", where the subjects attempted to visualise the exercise they had just performed. The protocol concluded with five minutes of rest.

3. RESULTS

Figure 1 shows the average oxygenation change for the six subjects during the finger tapping protocol (two minutes to four minutes). The increase in oxygenation during the motor task clearly demonstrates that the spectrometer is measuring oxygenation changes over the motor cortex.