Assessment of a bilateral percutaneous hand grasp neuroprosthesis for spinal cord injured persons with tetraplegia

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I. Abstract
Stimulation was applied simultaneously to right and left hands to investigate functional improvements resulting from bimanual stimulation compared with unilateral stimulation with the unstimulated hand assisting, or two unstimulated hands. Percutaneous electrodes were placed in the hand musculature of two persons with tetraplegia. Electrical stimulation was applied to the electrodes to provide hand grasp and release in the right and left hands. Three tasks were designed to assess bimanual hand activity: twist open a container; cut up a standardised food object using a knife and fork simultaneously, and; distraction of two cylinders linked by a device to measure tension. In these tasks, quantitative measurements indicated that bilateral stimulated hand grasps either enabled the subjects to complete a task or give an improved result when compared with unilateral or no stimulation.

II. Introduction
The application of electrical stimulation, for the purpose of restoring hand grasp and release to persons with tetraplegia, has been developed to an advanced degree (see [2] for review). In this study, application of such stimulation is made to both right and left hands simultaneously. Assessment is made of the functional usefulness of this by choosing three tasks and measuring the performance of the individual in completing those tasks. The benefits resulting from the provision of bilateral stimulated hand grasps is measured by the subjects' performance in the tasks. This performance was compared with that for the same tasks whilst using one stimulated hand grasp with the non-stimulated hand providing assistance and also, in a separate set of trials, two unstimulated hands.

III. Method.
Intramuscular percutaneous electrodes (Neurocontrol Corp., Cleveland, OH) were placed in both the right and left hand in muscles identified to produce lateral and palmar prehension [1]. The recipients of the electrodes were two men with spinal cord injuries at the C5 level. The method of electrode placement was most similar to that described by Smith and colleagues [3]. Subjects were issued with a percutaneous stimulator (Neurocontrol Corp.) and exercised daily to condition muscles for functional use. The arms were splinted during stimulation to augment wrist extension where active wrist extension was insufficient to maintain a functional position for the wrist.

The three tasks chosen for the functional assessment were most suited to completion using two hands. The first task required the subject to twist open a screw-top container. The object was acquired before the measurement began. One hand gripped the base of the container and the other gripped the screw-top. The container was held in the hands away from the body without resting on any other surface. After the subject affirmed their grasp stability, the time required to open the top was measured. The second task involved cutting up a standardised food object with a knife and fork used simultaneously. The fork was used to stabilise the object while the knife cut a portion of it. The knife and fork were acquired prior to the commencement of measurement. The knife and fork were placed in the right and left hands as preferred by the subject for the best outcome. The object was placed on a plate situated in front of the chest at a subject-preferred distance away from the body. The object consisted of a commercially available chocolate-coated turkish delight bar at room temperature. Performance was assessed by measuring the time required to separate an 8 mm transverse slice from the main block. It should be noted that subjects were unable to perform the task using a knife only, as the object slid around the plate. The third task involved measuring the force of distraction that the hand grasps could sustain. Two aluminium cylinders were joined to each other by tracer wire, in the middle of which was a proving ring to provide a measurement of tension in the tracer wire. One cylinder was held in each hand and the cylinders were acquired before the test commenced. The cylinders were held away from the body without contact to the table top. Whilst the hands were drawn away from each other, the tension signal in the tracer wire was amplified (gain 1000) and sampled (250 Hz) to computer storage. The maximum tension produced
before grasp failure was measured.

Tests were considered unsuccessful when the candidates were: unable to begin the task; unable to hold the object for the complete trial, or; used self-assistance (see [4] for definition).

IV. Results
In endeavouring to open the container, subjects A and B were unsuccessful in 5 attempts without stimulation, were successful in 1/5 attempts with unilateral stimulation (57s and 22s completion time respectively) and successful in 5/5 and 4/5 attempts respectively (5.2"0.8s; 13.5"0.7s) with bilateral stimulation. In cutting up food: without stimulation, A was successful in 4/4 attempts (25.3"4.2s) whereas B was unsuccessful in 3/3; with unilateral stimulation A was successful in 3/4 attempts and B in 2/5 (10.0"2.8s; 8.5"1.0s), and; with bilateral stimulation A and B were successful in 4/4 and 5/5 attempts (6.8"1.8s; 14.4"1.2s). In the distraction task, the maximum force produced by A without stimulation was (0.31"0.02kg: n=3) and with bilateral stimulation this increased to (0.51"0.02kg: n=4).

V. Discussion
The results demonstrated that in undertaking the three tasks using bilateral stimulated hand grasps, one stimulated hand aided by a non-stimulated hand or two non-stimulated hands, the two subjects showed their best performance using bilaterally stimulated hands. In opening the container, both subjects showed an increase in the number of completions and rate of completion with bilateral stimulation over unilateral or no stimulation. For the cutting up of the food object, bilateral stimulation provided the most reliable result although, in the case of subject B, not always the fastest result. The distraction experiments indicated that a greater than 60% increase in the distraction force resulted by the application of bilateral stimulation

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VII. References