Cutaneous Sensory perception training using electrical stimulation. Three case studies.

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Abstract

It has been demonstrated that sensory ability can be changed by training and that this can cause neuroplastic changes within the brain. This paper describes a device and its use for the training sensory perception by means of electrical stimulation. Additionally the device can be used orthoticly enabling improved ADL skills. The device consists of force sensitive resisters mounted over a pair of self-adhesive electrodes, which place on the pulps of the index finger and thumb. When an object is grasped, the stimulation is delivered, effectively acting as an amplification of normal sensory input. Three CVA subjects are presented whom, after sensory training showed improved proprioception, two point discrimination and Jebsen-Taylor hand function following training.

Introduction.

In the practice of FES the emphasis is placed upon the production of functional movement controlled by artificial control systems. However accompanying paralysis is often reduced sensor ability which can be a significant handicap in voluntary control of movement. It has been shown that the cortical representation mapping of the hand can be influenced by imposed activities. For example, string players use their left hand to finger the strings and so receive constant varying sensory input, while their right hand, used to hold the bow receives comparatively less sensory stimulation. Using magnetic source imaging, it was shown that the representation on the somatorsensory cortex of the left hand was greater than the right in a group of 9 string players who had played for a mean of 11.7 years[1, 2]. This finding suggests that increased afferent input may lead to neuroplastic adaptation, improving the brains ability to process the information received. Similarly, improvements in stereognosis have been reported in cerebral palsy patients following tendon transfer surgery that has resulted in improved hand function by correcting excessive pronation[3].

Improved sensory ability has also been reported in tetraplegic users of the NeuroControl Freehand system[4]. Measurements of static 2-point discrimination before implantation and after one year's use of the system showed a statistically significant increase in subjects who had some sensory ability measured in the first assessment. This suggests that where some neural pathways remained, the brain was able to improve its use of sensory information when great demands were made. This may also be the mechanism behind the increase in two point discrimination ability seen in stroke subjects who received electrical stimulation exercise to finger, thumb and wrist extensors[5]. In this study exercise were carried out daily for one hour for 3 months. While statistically significant improvements in were also recorded in performance of the Jebsen-Taylor hand function test, it can not be ruled out that direct sensory excitation by the electrical stimulation was also instrumental in the sensory training effect. It therefore might be possible to use electrical stimulation to purposefully influence sensory ability.

Materials and methods

Initial experimentation was made using the University of Surrey Compustim 10B stimulator. Two FSRs (Force Sensitive Resistors) were placed either side of a block of high destiny foam, about 3cm thick. Self-adhesive active electrodes were placed on the pulp of the index finger and thumb while the indifferent were placed more proximately on the hand. The stimulator was set up to give an output when a FSR was pressed. One channel stimulated at 10 Hz while the second stimulated at 40 Hz. The output level was set at comfortable level for the user giving sensation but no muscle contraction. With each FSR labeled as "finger or thumb" The subject was asked to repeatedly grasp and release the foam block. Initial results were encouraging but the equipment could only be used as training device and not for picking up other objects. A more portable system was therefore designed consisting of two Pals Plus 1 1/4 " electrodes that were cut in half, close to the line of the central conductor. The two halves were then placed close together on the pulp to provide the active and indifferent. In order to maintain the separation the assembly had a non-conductive silicon rubber spacer between the electrodes. The FSRs were mounted using double sided adhesive tape on the back of the

electrodes. It was found necessary to curve the FSRs so they followed the contours of the digits. This was achieved by taping them to a 10mm diameter cylindrical former and applying gentle heat.

Assessments

The Jebsen-Taylor test: A standardised hand function test consisting of 6 tasks (card turning, picking up small objects, simulated feeding, stacking draught pieces, picking up empty tins, picking up 500gm full tins). The time to complete each task is recorded.

Rolyon nine hole peg test: Nine pegs were picked up from a dish and inserted into holes in the Rolyon board. The time to insert all nine pegs and then place them back in the dish was recorded. This was performed prior to using electrical stimulation on each occasion.

Proprioception test: Discrimination was tested by moving a single blunt metal pin across the pulp of either the 1st finger or the thumb. With the subject blindfolded, they were asked to identify whether it was the thumb or finger that was touched. If the subject did not respond a score of 0 was recorded. For the correct answer 1 was scored while the wrong answer scored -1. The test was repeated ten times and the scores added for a total score, the maximum score being 10, the minimum score -10. The test was performed prior, with and after stimulation.

Sensation was tested using static two-point discrimination. The hand was divided up into 24 areas, four palm areas and four areas per digit. The subject was blindfolded and asked to say whether they perceived one point or two when the hand was touched with the probe. The hand was scored as follows: 0 = no sensation, 1= sensation but no discrimination or ambiguous answers given, 2 = 10mm, 3 = 6mm, 4 = 4mm and 5 = 2mm discrimination. Each area was tested using the 10mm probes first and the probe separation reduced until no discrimination was possible. The subject was also tested with one point randomly throughout the measurement. The mean two-point discrimination (the sum of the scores divided by 24) was calculated for each hand.

Case study 1

A patient (Male 64 years of age, right side hemiplegic following a CVA 3 years previously) presented at our clinic for electrical stimulation to improve his hand function. In fact his motor function was not greatly impaired, his main disability being in lack of proprioception. If a digit was touched while he was blindfolded, he was unable to correctly identify the area that was touched although he was aware that he had been touched. By experimentation it was found that after repeated stimulation of the thumb and index finger pulps, the subject could better identify the areas when they were tested immediately after training. After initial experimentation using the Compustim 10B system, the second system was used. It was noted after about 1 month of use of the device that the user required a significant reduction in stimulation amplitude from about 60 mA to 15 mA. The lower current amplitude is typical of that found comfortable by individuals with unimpaired sensation. Results are shown in table 1 and 2. There was a 41% reduction in the time required to complete the Rolyon nine-hole peg test. The proprioception test showed that his ability to correctly identify sensation in his finger and thumb was improved. The subject reported that he was much more aware of his hand. He was able to carry a bag and believed his balance to be improved. For example, he was now able to carry a bucket while walking over rough ground with less fear of falling. He felt that use of the system gave him improved awareness for several hours after use.

Table 1. Rolyon nine hole peg test

Week	Hemi hand time in (s)	hemi hand total time (s)	non-hemi total time (s)
-1	372	399	24
0	280	371	25
1	410	429	25
4	223	237	26
6	217	235	25

Table 2. Proprioception test

Week	Hemi pre stim Thumb	index	with stim thumb	index	post stim thumb	index	non - no stim thumb	hemi index
-10	1	0					10	10
-1	1	-1					10	10
0	-2	1	6	3	2	0	10	10
1	4	3	7	7	-1	4	10	10
4	6	4	5	6	8	7	10	10
6	0	8	10	10	6	6	10	10

Table 3 Jebsen – Taylor test subject 3

	First assessments				5 months later			
	non affected	pre	with stim	post	non affected	pre	with stim	post
Cards	6.4	40.6	20.9	18.9	6	13	12.6	7.8
Small objects	16.5	60.9	59.8	26.3	9.3	46.7	23	13.2
Feeding	12.5	43.1	31.6	22.3	12.6	24.3	16.9	13.4
Stacking	5.6	46.7	25.6	17.6	6.9	23.2	10.3	7.7
Light tins	5.8	21.9	12.6	11.2	6	9.4	7.4	6.6
Heavy tins	5.2	12.2	12.9	9.5	5.2	6.8	7.7	5.9
Mean time	8.7	37.6	27.2	17.6	7.7	20.6	13.0	9.1

Case study 2

The second subject (male, 6o years of age, right sided hemiplegia following a CVA 1 year previously due to temporo parietal lobe infarct) like subject 1 also had reasonable motor function but had no sensory ability as measured using 2 point. The sensory training device was used for 1 month and the sensory score was found to increase to 0.42. After a further four months use the score had increased to 0.96 and 1.2 after one month further. In the same period no significant changes were seen in Jebsen-Taylor test score. The subject received greatest benefit when wearing the device while performing functional tasks. However the carryover effect was significant lasting several hours. After 5 months use he felt his improvement had platued and so discontinued using the system.

Case study 3

The third subject (female, 52 years of age, right sided hemiplegia following a CVA due to a migrainous infarct 6 years previously) had practically no sensation on her whole right side of her body. She had used a dropped foot simulator and had reported that it had improved her awareness of her leg. Two point discrimination showed that she had only two areas where she reported sensation in her hand. Despite this she had reasonable hand movements. There was an immediate reduction in Jebsen-Taylor test score of 28% when the sensory training device was used while performing the test (table 3). This reduction was increased to 53% when the test was repeated with the device removed, the system having been used for about 30 minutes. The device was used daily for 3 months for periods of about 15 minutes a day. The tests were then repeated. 16 areas of the hand were now identified as having sensation but no discrimination. Jebsen-Taylor test mean time had fallen 45% prior to stimulation, and was reduced still further when the stimulator was used. A future reduction was seen when the test was repeated without the device resulting in a test time only 18% greater than the non affected hand. The subject reported that she had been able to achieve more with here hand, holding a paintbrush and also using a sculpture tool. However she also said the sensation she experienced was very intense and some times painful. Using the device also had the effect of producing an impression of "crowding" in her head. Use has currently been discontinued pending investigation.

Conclusion

The evidence from these case studies suggests that it is possible to alter sensory and proprioceptive ability and that this may be possible as a therapy. It would appear that sensor input could influence manual dexterity and improve functional tasks. However, further work is required to better understand the mechanisms and consequences of this form of stimulation.

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