REEDUCATION OF SENSIBILITY OF THE HAND: DEVELOPMENT OF A SENSORY GLOVE MODEL

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ABSTRACT

Objective: To develop a sensory glove model and test it in subjects with normal sensitivity in the upper limbs, who have been trained to replace hearing with touch. Methods: To make the equipment, a glove, mini-microphones, amplifier and headphones were used. Seven female subjects, with a mean age of 26.28 years (± 1.03) were selected to use the equipment and differentiate textures after training. The training took place over seven days, fifteen minutes a day, with the aim of identifying textures through sound, using the sensory glove. At the end all subjects answered a questionnaire. Results: All the subjects rated the use of the glove as "comfortable". Three subjects (42%) rated the aesthetic appearance of the equipment as "excellent", two subjects (28.57%) as "good", and two subjects (28.57%) as "regular." Six subjects (85.7%) identified the textures by sound alone, and one subject (14.3%) reported that he was aided by touch. Conclusion: It is feasible to manufacture a model of sensory glove using national technology that is readily accessible and relatively low cost, enabling the identification of textures through sound when the equipment is used by individuals trained to replace hearing with touch. Level of Evidence: Level II, prospective comparative study.

Keywords: Peripheral nerves/injuries. Hand. Rehabilitation.

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INTRODUCTION

Alterations in hand sensitivity seriously affect its function, impairing performance in the execution of activities of daily living (ADL) and diminishing the quality of life of the individual.[1,2] Recovery of the hand's sensory function after peripheral nerve lesions proves unsatisfactory in most cases despite advances in surgical techniques and also constitutes a challenge to reconstructive surgery and to rehabilitation.[1,3]
Sensory perception is an experience undergone by the central nervous system in order to create, in the somatosensory cortex, the somatotopic map corresponding to the various regions of the body surface. Innervation density as well as the contribution to sensory perception are the factors that determine the size of the cortical territory occupied by such regions. The cortical region of representation of the hand and of the fingers is located in subarea 3b, inserted in the large primary area SI and has been extensively researched, in humans as well by means of the advent of cerebral imaging exams.[1,4]
For a long time it was believed that the cortical map was totally established in adult age and that it was incapable of reorganization. However, high plastic capacity of the brain has been observed more and more often in recent years, even in adults[1]. Cortical reorganization can occur as a consequence of a series of factors and also after a peripheral nerve lesion, for example. In this kind of lesion, sensory impulses originating from the injured area do not reach the central nervous system[1] and, moreover, the denervated skin area will generate incorporation of areas of cortical representation adjacent to it in the somatosensory cortex, entailing even more sensory alterations for the individual.[1] Such factors associated with age, level and extension of the lesion,[5,6] quantity of scar tissue, atrophy of the terminal organs and occurrence of cross-reinnervation, among others, are determinant of the recovery of sensory function at the affected site.[5,7]
It is in this context that we highlight sensory retraining programs for the hand, defined by Dellon and Jabaley[8] as a set of techniques that help the patient to reinterpret the altered neural impulses that reach the cortex, when the injured hand is stimulated.[6] Nowadays new techniques have been added to those already firmly established, in an attempt to start sensory retraining early on, aiming to maintain the highest pos-

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Study developed by the Post-graduate Program of the Department of Biomechanics, Medicine and Rehabilitation of the Musculoskeletal System of Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo.
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sible level of integrity of the cortical map of the hand. The application and integration of different sensory stimuli soon after nerve repair have proven an effective method in the achievement of this goal.[2,3,9,10]

The senses of hearing and touch are strongly related as they are based on the sensation of vibration, so that vibrational signals produced by touch, such as the sound of friction emitted by touching a certain texture, can be converted into vibroacoustic stimulation, causing the individual to "listen to what the hand feels", as described by Lundborg et al.[1] The way in which the integration of sensory and hearing stimuli occurs in the sensory cortex, as well as the regions where it occurs, are not yet well known,[11,12] but it is known that this is present in many everyday situations.

Accordingly, considering the diverse information about recovery of hand sensitivity and with a basis on the principle of the brain's capacity for integration of the tactile and auditory functions,[13] Lundborg et al.[2] developed an artificial sensitivity system called the "sensory glove"; the model is not yet available on the market, hence the importance of making another model to enable the performance of more studies in the area. This study was aimed at the development of a sensory glove model and its application in individuals with preserved hand sensitivity.

MATERIAL AND METHOD

The project was developed in the Department of Biomechanics, Medicine and Rehabilitation of the Musculoskeletal System of Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo (HCFMRP-USP), by means of a favorable report from the Committee of Ethics in Research of this institution (Process HCRP no.1352/2009). All the guest subjects that agreed to take part in the study signed an informed consent term.

Development of the equipment

The sensory glove was developed on a basis of the model created by Lundborg et al.[2], and consists of: fabric glove; mini-microphones coupled to the nail device; amplifier and headphones.

The materials used to make this glove were: a fabric glove, five electret microphones, five preamplifiers, a signal amplifier with five inlets, headphones, a plastic box for storage, shielded wire for microphone and battery. The glove was built by an electronics technician.

The fabric chosen to make the glove was mesh; the plastic storage box measures nine centimeters in length by six in width and two in thickness and as illustrated in Figure 1 is equipped with: a volume adjustment button, outlet for the headphones and on/off button. Moreover, it has an inlet for five plugs from the microphones and stores the entire amplification circuit, besides a nine-volt alkaline battery.

The circuit does not allow the selective recording of sound from a single microphone if the others are connected; in addition, it transmits the sound homogeneously to the headphones. Thus the microphones are fastened to the glove using Velcro tape, which besides helping to amplify the sound when the texture is passed over it, allows the use of only the desired number of these microphones. The headphones used are from Philips, model SHPI 900.

Application

To test the equipment seven female subjects with mean age of 26.28 years (±1.03) were selected among the employees of HCFMRP-USP and of Hospital Estadual de Ribeirão Preto (HE Ribeirão) that did not have a history of hearing loss or central or peripheral nerve injury involving the upper limbs. For the hearing assessment, all the subjects were submitted to the pure-tone audiometric threshold test in the Speech and Language Pathology sector of HCFMRP-USP and presented hearing thresholds according to standards of normality bilaterally.

The subjects were trained for seven days using the glove with only one microphone coupled to the nail device on the index finger, with the objective of identifying five different textures by sound alone. The training session lasted for 15 minutes a day and was held in the presence of the researcher, in a silent environment. The textures used were fastened to small wooden sticks and consisted of: Velcro, velvet, felt, jute and rough leatherette.

During the training, the subjects were instructed to pay attention to the sound produced by the textures, while they had the digital pulp of the index finger of their right hand (covered by the fabric of the glove and the Velcro tape) stimulated. This protocol was followed: on the first day, only the Velcro and velvet textures were presented at random, and the subjects initially listed to the sound with their eyes open, then with their eyes shut; at the end of the training session, they had to identify the texture with their eyes shut, going by sound alone. On the remaining days, the other textures were

Figure 1. *Components of the sensory glove model: headphones, circuit housing and fabric glove.*

introduced, also at random, following the same sequence of eyes open, eyes shut and identification. At the end of the seven days, the subjects replied to a questionnaire, containing the following questions: “How do you rate comfort during use of the glove?”; “What did you think of the aesthetic aspect of the glove?”; “Were you able to distinguish between the textures by sound alone during the training session?”, where the possible answers were, respectively: comfortable, slightly comfortable and regular; excellent, good, regular, poor; yes and no.

RESULTS

The preparation of the project, the adaptation of the model to the available technology and the making of the system took place in approximately five months. All the subjects concluded the seven-day training and replied to the questionnaire at the end of this period; the results are shown in Table 1. During the training, the individuals did not have any difficulty adapting to the equipment and fully understood the proposal of the study; it was also perceived that they distinguished the textures by sound with relative ease from the second or third days of training.

With regard to comfort during glove use, all the subjects classified the use as “comfortable”. With regard to the aesthetic aspect, three subjects (42%) rated it “excellent”, two subjects (28.57%) as “good”, and two subjects (28.57%) as “regular”. Furthermore, six subjects (85.7%) were able to identify the textures by sound alone and one subject (14.3%) reported that he was aided by “touch”, which might be better described as proprioception.

Table 1. *Answers (%) obtained in each item of the glove evaluation questionnaire.*

	Comfort (Q1)	Aesthetics (Q2)	Function (Q3)
Comfortable	100%		
Regular	0		
Slightly comfortable	0		
Excellent		42%	
Good		28.57%	
Regular		28.57%	
Poor		0	
Yes			85.7%
No			14.3%

Q1: question 1/ Q2: question 2/ Q3: question 3

DISCUSSION

The various sensory systems contribute to the perception of objects and events, in order to confirm or complement each other.[14] Therefore, in the absence or alteration of one of the senses, others can act in an attempt to replace it or to assist it in this task; this is what happens, for example, with blind individuals that use touch for reading.

Likewise, when a particular texture is touched, the sound of friction emitted may go unnoticed, since the tactile afferent impulses promote sufficiently adequate feedback for manipulation of the object; now in a situation of hand sensitivity deprivation, hearing can constitute an alternative means of achieving such feedback.[15] Thus, besides the possibility of distinguishing between different textures by sound, important proprioceptive information can be gleaned from hearing, such as for example when greater pressure is applied while touching an object, a higher sound is perceived, while with a lighter touch, the opposite occurs, and the individual can thus adjust their grip strength.

In this context we emphasize the importance of the sensory glove, which in allowing alternative afferent impulses, that is, auditory impulses, to reach the cerebral cortex coming from the hand with altered sensitivity, enables greater preservation of the cortical map of the hand in an early post-injury phase and therefore better recovery of sensory function.[10]

Some technical difficulties and limitations were encountered during the development of the equipment. The size of the container and of the materials, as well as the shielding of the circuit to enable studies involving magnetic resonance, were the main difficulties found. The final dimensions of the storage box make the equipment a portable model that is easy to transport and install, yet alterations can still be made in order to better couple it to the glove, and to make it lighter and more comfortable, as well as improving its aesthetic aspect. The materials used were easily found and have a relatively low cost.

During the training, even though most of the subjects had declared they were capable of identifying the textures by sound alone, the fact that the proprioceptive stimulus generated by the vibration of the touch of the texture on the finger of the individual with preserved sensitivity constitutes a facilitator in the differentiation of these textures is undeniable.

Thus, new studies should be conducted in order to verify how individuals with hand sensitivity changes respond to the use of the proposed glove model, as well as to investigate the occurrence of cortical sensory integration more thoroughly, by means of functional magnetic resonance imaging, thus contributing to the few studies still existing in the area.

CONCLUSION

This study proved the viability of creating a sensory glove model with national technology of easy access and relatively low cost and that enabled the identification of textures by sound from the use of the equipment by individuals with preserved hand sensitivity, but previously trained to substitute touch with hearing.

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