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ARTICLE

Testing the Acceptance of Phantom Limb in Non-Amputees

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The brain is truly a magical organ and it has always fascinated me. My interest in neuroscience has led me to consider complex concepts and issues about the nervous system. The idea for this experiment came from a scenario that I experienced during my volunteering days in a long-term care home. A resident in the home asked me to adjust his shoe on his left foot, as it was hurting him, and he felt the shoe was an ill fit. As I bent down to help him, I was astounded to find that this resident did not have a left foot at all! My research started there. From that point on, I tried to study and understand the neurophysiology behind this phenomenon.

INTRODUCTION

The cerebrum, the largest part of the human brain, contains the cerebral cortex, which also contains nerve cell bodies. The cerebrum is responsible for the integration of complex sensory and motor functions ("Brain," n.d.). The human brain has an assigned area for each part of our body. Every body part is connected to specific neurons in the brain (neurons are the basic units of nervous system, having specialized cells that carry messages between the brain and other parts of body). All sensory information received from each area of our body is conveyed to the brain for interpretation via neuronal connections and are then relayed back to the muscle, tissue or organ for motor action (British Neuroscience Association & European Dana Alliance for the Brain," n.d.). For example: when we detect a stimulus, like a touch (sensation) on our hand, the neurons in our hand send signals to the corresponding neurons in the brain, and when this is interpreted by our brains, we feel the touch. If it is a painful stimulus, we withdraw our hands (motor action) ("Pain and how you sense it," n.d.). If a neuron is inactive for long time, the active regions in the brain take over inactive regions. A reorganization of the brain's neurons happens, because of brain malleability. The area representation for the hand is close to the area for the face in the cerebral cortex. When this hand area in the brain stays inactive for longer duration, the neighboring representing area takes over (Scott, 2011). This is called 'Neuroplasticity'; and it allows the neurons in the brain to compensate for injury and disease. This also enables people to adjust their activities in response to new situations or to changes in their environment. It is a process of re-learning and highlights certain recuperative abilities of the brain.

When a part of our body, such as an arm, is amputated, the limb is no longer physically present, but the area of representation for the arm in the brain's cerebral cortex still exists and slowly gets reorganized. This gives the amputee a realistic sensation that the amputated limb is still there. The experiencing of body parts that are not present on your body is called a 'Phantom Limb'(Cruz, Nunes, Reis, & Pereira, 2003). Often, this can be a painful experience for patients and may require rehabilitation and physiotherapy to overcome the pain.

When your body is in a normal state, all systems remain calm. At a time of stress, our body releases hormones, creating chemical changes that cause increased heart rate, perspiration and low oxygen saturation through shallow increased breath rate ("The Science of Stress, Heart Rate and Breathing," 2013).

Research was done to prove that it is possible to trick the brain and create an illusion to make a person assume a rubber hand as one's own body part in a rubber glove experiment (Ehrsson, Holmes, & Passingham, 2005). Knowing this, I wondered whether it was possible for the brain to accept a phantom limb as part of one's body without the cue of an artificial limb. The experiment was designed based on this query. With the background knowledge, I also thought of numerous novel applications and future implications the experiment could have if successful. The experimental conditions were then decided to involve using human subjects of different age groups and the non-dominant hand chosen to be removed from sight. Cotton ball is selected to provide minimal tactile cuing. A screwdriver was used to create a threat and stress levels were recorded using a pulse oximeter, as it rapidly records the change of the dependent variables: heart rate and oxygen saturation. Other dependent variables were facial expressions and reaction to stimuli. The controlled variables were the environment of experiment and moods of the subjects.

PURPOSE

The purpose of this experiment is to assess if the brain of a non-amputee accepts a simulated phantom limb as part of their body. If there is an increase in subjects' heart rate and decrease in Oxygen Saturation level after the sudden introduction of screwdriver, then it can be concluded that the brain of the non-amputee

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has accepted the simulated phantom limb as part of their body.

MATERIALS

1. Chair
2. Cotton balls
3. Desk
4. Non-transparent screen
5. Pulse oximeter
6. Screwdriver
7. Towel

PROCEDURE

1. The subject and the researcher sit on opposite sides of a desk
2. Record the resting heart rate and oxygen saturation of the subject using a pulse oximeter
3. Have the subject place their dominant hand on a desk and cover their non-dominant hand using a towel
4. Place an opaque screen between the dominant and non-dominant hand
5. Using a cotton ball, simultaneously stroke the subject's dominant hand and do a similar motion in air on the non-dominant side. Instruct to focus on non-dominant side where the air is being stroked. Stroke for about 20-30 seconds
6. After 20-30 seconds, suddenly introduce the blunt screwdriver, performing a rapid stabbing motion aimed towards the empty space 'occupied' by the invisible hand
7. Notice the changes, if any, in subject's reaction and facial expression. Immediately record their heart rate and oxygen saturation using the pulse oximeter. Also note what the subject said with regards to the experiment
8. Compare the results with the prerecorded heart rate and oxygen saturation (step 2)

RESULTS

The experiment was performed with 10 different subjects. After the experiment was performed, 90% of the subjects' heart rates increased and oxygen saturation decreased (Table 1). This is visually represented in Figure 1 and Figure 2. This change in heart rate and oxygen saturation indicates that a stress reaction was created in the subjects with regard to accepting the limb as part of their body and protecting the limb from getting hurt. 9/10 of the subjects felt the presence of an invisible hand as part of their body before the screwdriver was introduced and wanted to guard their hand as the screw driver approached. This demonstrates that the brain accepted the invisible hand as the subjects' own hand. The subjects were startled, and surprised, while some reported of being mildly scared and feeling defensive as the screwdriver approached the invisible limb. Some subjects even stated that they felt as if their own hand was going to be stabbed and that they felt "hypnotized" into believing a hand was present. On the contrary, one of the subjects described that they did not feel an invisible hand, nor did they express a significant change in their facial expression.

DISCUSSION

Some intriguing results were observed during this experiment. This experiment utilizes the phantom sensation to help with proper and faster reorganization of altered sensory and motor maps in the brain, which could enable patients such as stroke patients to regain lost functions. It is possible that if this process is reversed, that we could perform surgery without anesthesia and avoids anesthesia complications! This technique can reduce phantom limb pain by recreating phantom limb sensation and thus encouraging a better sense of motor control and pain control. By creating phantom limb sensation

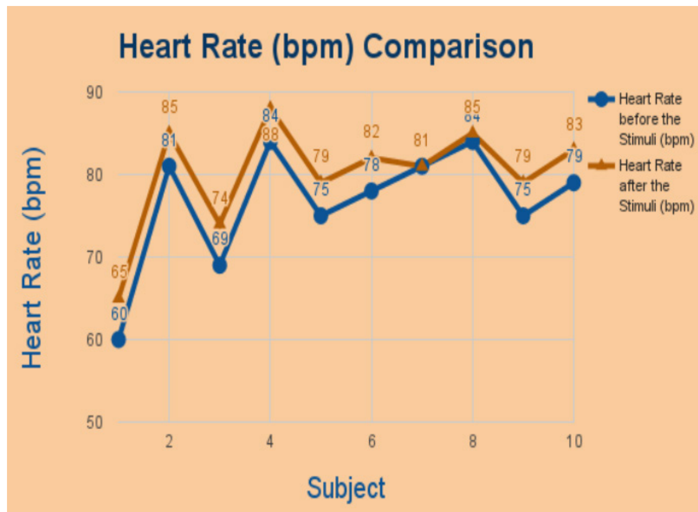

Figure 1. Heart rate (bpm) comparison.

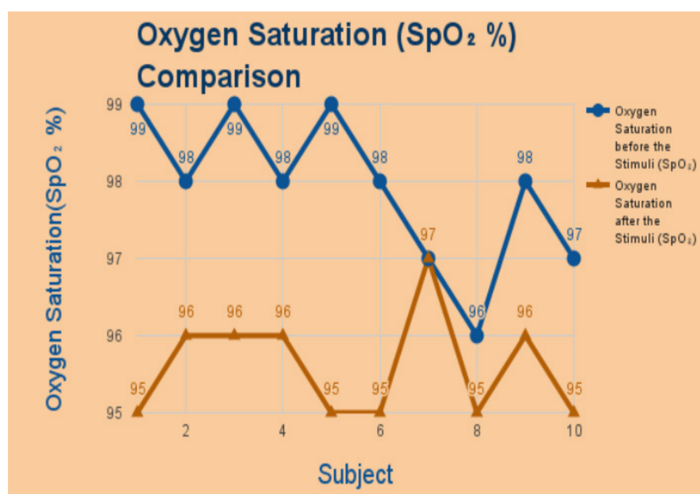

Figure 2. Oxygen saturation (SpO_2%) comparison.

in the area of lost limb, we could train an artificial limb effectively as it would be able to send signals to cerebral cortex and a new mapping would be created which can enhance the functioning of the artificial limb, with more coordination.

CONCLUSION AND FUTURE WORK

By analyzing the results from the experiment, the phantom limb sensation created in a non-amputee could be accepted by the brain as part of their body. The recorded variation in a majority of the subjects' oxygen saturation, heart rate, facial expressions and reactions to the stimuli further proves the theory. I hypothesized that I would be able to see a change in subject's heart rate and oxygen saturation reading after the stabbing of the screwdriver on the phantom limb, and this proved to be true.

In the future, the experiment can be tested with more participants. I also want to analyze the times at which the subject starts to feel the phantom limb and how long it lasts if uninterrupted. Moreover, the dependent variables could be analyzed using more advanced technologies such as fMRI and EKG. In addition, the effect of the experimental environment the subject can be looked into. I would also like to research and find an experimental method that could prospectively create a sensation that a body part is not present, which will aid with one of my applications: perform-

Subject Number	Heart Rate before the stimuli (bpm)	Heart rate right after the stimuli (bpm)	Oxygen saturation before the stimuli (SpO2 %)	Oxygen saturation right after stimuli (SpO2 %)	Facial expressions to the stimuli	Reactions to the stimuli
1	60	65	99	95	Surprised, startled, a little scared, a little worried	"I experienced an invisible hand in a short while. I really felt as if my real hand was being stabbed"
2	81	85	98	96	Surprised, startled	"I slightly felt the presence of an invisible hand and was startled at the screwdriver"
3	69	74	99	96	Surprised, startled	"I felt as if I was hypnotized into thinking there was an illusionary hand present"
4	84	88	98	96	Surprised	"I felt surprised as the screwdriver approached, since I perceived there to be an actual hand"
5	75	79	99	95	Surprised, startled, a little bit of fear	"I felt an invisible hand and thought that the jabbing was performed to my actual hand"
6	78	82	98	95	Astonished	"I was surprised at the motion since I nearly felt like a hand was present there"
7	81	81	97	97	No significant change in facial expression	"I did not feel any changes during the experiment, or to the stimuli"
8	84	85	96	95	Startled	"I slightly felt the presence of an invisible hand. I was a little startled by the stimuli"
9	75	79	98	96	Surprised, startled	"I felt as if the student was going to stab my own hand with the screwdriver"
10	79	83	97	95	Surprised, startled	"I was wanting to move back as the screwdriver approached; sort of like a threat response when something happens to my original hand"

Table 1. Observations summary.

ing a surgery without anesthesia.

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