Vibrotactile feedback elicits embodiment of robotic hand in active motor task*

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Abstract—We evaluated the possibility to induce embodiment of a prosthesis in preliminary experiments with healthy subjects during active contact task conveying contact information by vibrotactile stimulation.

I. INTRODUCTION

The Rubber Hand Illusion (RHI) is a perceptual illusion which elicits a feeling of ownership of an alien rubber hand; it can be induced in an individual when a visible fake hand is stroked while synchronously stroking the person’s own hand, hidden from view [1]. Recent findings demonstrated the possibility to elicit, both in healthy subject and in amputees, self- attribution of an alien hand during RHI experiments using mismatched visuo-tactile stimulation (touch on the alien hand and vibration on the real one) [2], [3]. These studies suggested that similar effects can be achieved by replacing the rubber hand with a prosthesis equipped with artificial sensors providing synchronous tactile feedback through an array of vibrotactile stimulators on the stump. Such a prosthesis holds the potential to be easily incorporated within one’s body scheme and to be more accepted by the users. However, RHI experimental conditions tested in previous studies (passive, brushstrok stimulation) differ with respect to daily life tasks, in particular: during the grasping of objects, the hand is in movement and no passively received the stimulation as in case of RHI experiments, in addition, touch stimulation is different with respect to brushstroke one. For such reason, in the present work we investigated in healthy subjects whether embodiment illusion could be induced by using multi-DoF robotic hand with finger movements and mismatched visuo- tactile stimulation.

II. METHODS

Ten naïve volunteers (five female, age 28±2) participated in the study. Each participant sat comfortably on a chair in front of a table, with his/her left arm lying in a supine position behind a screen throughout the entire experiment (Fig. 1). A robotic left-handed hand was placed palm up in front of the participant. Participants wore a data glove (DG5-Vhand Data glove) that allows to record the movement of fingers of the hand of participant and translate these movements to the fingers of robotic hand [4]. They were instructed to fix his/her sight on the alien hand and to raise and lower their fingers while keeping the other fingers still, until the robotic hand touches a transparent plexiglas bar placed above. When the digits of the robotic hand touched the object the vibrotactile stimulators [2], [3] placed on the digits on the data glove were activated. We investigated the experimental condition both with synchronous (the stimulations and movements of the alien hand and of the real hand performed synchronously) and asynchronous (a small temporal delay [~ 0.4 s] between stimulations and/or movements) stimulation timing in order to compare the outcomes. For each condition, we asked to participants to rate the vividness and prevalence of the perceived illusion. The vividness of illusion was defined as how life-like and realistic the illusion was when it was experienced and it was rated from 1 to 9. The prevalence rating (from 0% to 100%) reflected the percentage of time that the illusion was experienced (equivalent to the continuance of the illusion).

Figure 1 Experimental set-up

III. RESULTS AND DISCUSSION

The mean vividness and prevalence response were greater in the synchronous case than in asynchronous one (no illusion condition). Paired t-tests demonstrated statistical differences between synchronous and asynchronous stimulations for both vividness and prevalence rates (p<0.01 for both vividness and prevalence). This demonstrated that vibrotactile sensory substitution can be used to induce self-attribute of an artificial hand during the active contact of objects. Further experiments should be made to demonstrate it in amputees.

REFERENCES

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