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EFFECTS OF SHORT-TERM TRAINING ON BEHAVIORAL LEARNING AND SKILL ACQUISITION DURING INTRAORAL FINE MOTOR TASK

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Abstract—Sensory information from the orofacial mechanoreceptors are used by the nervous system to optimize the positioning of food, determine the force levels, and force vectors involved in biting of food morsels. Moreover, practice resulting from repetition could be a key to learning and acquiring a motor skill. Hence, the aim of the experiment was to test the hypothesis that repeated splitting of a food morsel during a short-term training with an oral fine motor task would result in increased performance and optimization of jaw movements, in terms of reduction in duration of various phases of the jaw movements. Thirty healthy volunteers were asked to intraorally manipulate and split a chocolate candy, into two equal halves. The participants performed three series (with 10 trials) of the task before and after a short-term (approximately 30 min) training. The accuracy of the split and vertical jaw movement during the task were recorded. The precision of task performance improved significantly after training (22% mean deviation from ideal split after vs. 31% before; $P < 0.001$). There was a significant decrease in the total duration of jaw movements during the task after the training (1.21 s total duration after vs. 1.56 s before; $P < 0.001$). Further, when the jaw movements were divided into different phases, the jaw- phase and contact phase were significantly shorter after training than before training ($P = 0.001$, $P = 0.002$). The results indicate that short-term training of an oral fine motor task induces behavior learning, skill acquisition and optimization of jaw movements in terms of better performance and reduction in the duration of jaw movements, during the task. The finding of the present study provides insights into how humans learn oral motor behaviors or the kind of adaptation that takes place after a successful prosthetic rehabilitation.

Key words: jaw movements, periodontal mechanoreceptors, manipulation task.

INTRODUCTION

Mastication is a complex intermittent rhythmic act in which the tongue, facial and jaw muscles act in coordination with each other, to position the food morsel appropriately in between the teeth, break it down into smaller pieces and prepare it for swallowing (for reviews see Lund, 1991, 2011). The fine-tuned coordination of tongue, facial and jaw muscles is achieved by the ability of the central nervous system to receive and integrate sensory information from various types of oro-facial mechanoreceptors, including the periodontal mechanoreceptors (PMRs) (Lund, 1991, 2011; Trulsson and Johansson, 2002; Lund and Kolta, 2006). The sensory information is used by the central nervous system to adjust the motor output through changes in the jaw muscle activity and alter the chewing forces and jaw kinematics (Trulsson and Johansson, 2002). The basic rhythm of jaw movements during mastication is set by a pool of neurons in the medial bulbar reticular formation in the brain stem called the central pattern generator (CPG) (Dellow and Lund, 1971; Lund, 1991, 2011). The CPG is activated by adequate inputs from higher centers (motor cortex) of the brain and can be modulated by the sensory inputs from the orofacial mechanoreceptors (Dellow and Lund, 1971; Lund, 1991). Hence, it was suggested that face primary motor cortex and somatosensory cortex are important for initiation and fine regulation of the self-perpetuating cycle of mastication (for reviews see Lund, 1991, 2011; Sessle et al., 2005, 2007, 2013).

The primary motor cortex, in general not only contributes to the initiation, control and execution of the jaw motor functions (for example jaw movements during mastication), but also to the learning of new motor skills (Sessle et al., 2007). Efficient learning and performance of a skilled motor task would require efficient gathering and processing of sensory information relevant to an action (for a review see Wolpert et al., 2011). Previously, studies have suggested that PMRs efficiently encode vital information about the intensity, temporal, and spatial aspects of forces acting on the teeth and signal to the CPG and sensorimotor cortex (i.e., motor cortex and somatosensory cortex) and inform about the tooth food contact (Trulsson et al., 1992; Trulsson and Johansson, 1996). A loss in somatosensation from the periodontal

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Abbreviations: ANOVA, analysis of variance; CPG, central pattern generator; EMG, electromyographic; PMR, periodontal mechanoreceptor; SEM, standard error of mean.

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ligament associated with tooth extraction, for example, may affect the coordination of orofacial motor and sensory functions (for reviews see Sessle et al., 2005; Avivi-Arber et al., 2011).

It was suggested that intraoral manipulation and splitting of a food morsel is a demanding task which requires a high degree of oral sensorimotor skills (Svensson et al., 2013). It could inarguably be accepted that practice resulting from repetition could be a key to learning and acquiring a motor skill (Lee et al., 1991). Further, skilled motor training involves optimizing the linking of action phases (Safstrom et al., 2013) and also results in cortical reorganization and adaptation of the behavior of motor units (Muellbacher et al., 2001; Duchateau et al., 2006). Acquisition of skilled movement refers to processes by which movements, produced either alone or in sequence come to be performed effortlessly through repeated practice and may also be associated with significant reorganization of the motor cortex (Pascual-Leone et al., 1994). However, neuroplasticity resulting from the training of skilled motor tasks may depend on the specifics of the task and the muscle group being trained (Duchateau et al., 2006). It has been suggested that short-term periods of movement training not only changes motor function but also brings out persistent changes in the somatosensory function (Ostry et al., 2010; Arce-McShane et al., 2014). However, most of these documentations have been made in reference to the limb sensorimotor cortex and relatively little emphasis has been given to face sensorimotor cortex (Sessle et al., 2005). We also think that results from the spinal system may not always be extrapolated to the trigeminal system. Hence, the aim of the present study was to test the hypothesis that repeated precision splitting of a food morsel during a short-term training with an oral fine motor task would result in increased performance and also lead to optimization of jaw movements, in terms of reduction in duration of various phases of jaw movements, during the task.

EXPERIMENTAL PROCEDURES

Study participants

Thirty healthy volunteers (14 males and 16 females) in the age range of 19–40 years and mean age of 27 ± 0.6 (mean ± Standard error of mean (SEM)) were recruited from the staff and students at Department of Dental Medicine, Karolinska Institutet, Huddinge, Sweden. The participants in the study were in good oral and general health and did not report any functional or neurological problems regarding biting or chewing, during mastication. At the time of the experiment, all participants were free from any ongoing or previous prosthetic or endodontic treatment and gross malocclusion, overjet/overbite of the anterior teeth. The study was conducted in accordance with the Declaration of Helsinki II and approved by the regional ethical review board, Stockholm, Sweden (Dnr 2012/1562-31/1). Informed consent was obtained from all the participants, prior to the start of the experiment.

Assessment of jaw motor function

The jaw motor function was assessed by recording the mandibular movements using a custom-built 3D jaw movement-tracking device (Physiology Section, IMB, Umeå University, Umeå, Sweden). A small magnet ($10 \times 5 \times 5$ mm) was attached to the lower central incisor and the jaw tracker employed could measure the vertical movement of the lower jaw with reference to the upper jaw. The position of the magnet in all three dimensions (accuracy: 0.1 mm; bandwidth: DC – 100 Hz) was tracked with an array of magnetic sensors attached to the head with a light weight wooden frame resting on the bridge of the nose and strapped around the head with spectacle like frames. The tracking device was light weighted (220 g), allowed free movement of the head, and interfered minimally with the oral function. For detailed description of the equipment see (Grigoriadis et al., 2011).

A pair of bipolar surface electrodes (2 mm in diameter, separated by 12 mm) was also attached, with double-sided adhesive tape, to the central part of the right and left masseter muscle, midway between the superior and inferior borders and anterior and posterior borders and were positioned perpendicular to the direction of muscle fibers. The position of the electrode was determined by palpation of the masseter muscle and asking the participant to clench the teeth. The electrodes were integrated with shielded differential pre-amplifiers (bandwidth 6 Hz to 2.5 kHz). Prior to the application of the electrodes; the skin over the recording surface was thoroughly cleaned with sterile alcoholic wipes and the electrodes coated with electrode gel to reduce impedance. In addition, a pair of customized microphones mounted inside the earplugs of a headset (Physiology Section, IMB, Umeå University, Umeå, Sweden) was employed to record the sound of the cracking food. The microphones were positioned in the external auditory canal and calibrated for each participant prior to start of the experiment (Svensson et al., 2013).

Behavioral task

The participants were comfortably seated on an office chair in an upright position and were asked to keep a commercially available, spherical shaped food morsel (sugar coated chocolate candy, diameter of 10 mm with an approximate weight of 0.84 ± 0.01 g, measured by weighting 10 randomly selected Marianne chokladdragéer; Fazer, Finland, candies from the same batch) between the tongue and the mid-section of the hard palate with their teeth in maximum intercuspation, before the start of the recordings (Svensson et al., 2013). The participants were then asked to move the candy with the tongue to position it in between the anterior teeth (upper and lower central incisors) and to subsequently split it into precisely two equal halves. The participants then spat out the split candy pieces in a plastic cup, held by the examiner. No instructions were given on how rapidly the task was to be performed however; the examiner gave verbal instructions about the start of the task.