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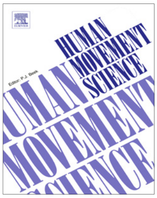

Robotic guidance induces long-lasting changes in the movement pattern of a novel sport-specific motor task

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ABSTRACT

Facilitating the learning or relearning of motor tasks is one of the main goals of coaches, teachers and therapists. One promising way to achieve this goal is guiding the learner through the correct movement trajectory with the help of a robotic device. The aim of this study was to investigate if haptic guidance can induce long-lasting changes in the movement pattern of a complex sport-specific motor task. For this purpose, 31 subjects were assigned to one of three groups: EA (early angle, $n = 10$), LA (late angle, $n = 11$) and CON (control, $n = 10$). EA and LA successfully completed five training sessions, which consisted of 50 robot-guided golf swings and 10 free swings each, whereas CON had no training. The EA group was guided through the movement with the wrist being bent early during backswing, whereas in the LA group it was bent late. The participants of EA and LA were not told about this difference in the movement patterns. To assess if the robot-guided training was successful in shaping the movement pattern, the timing of the wrist bending during the backswing in free swings was measured before (PRE), one day after (POST), and 7 days after (FUP) the five training sessions. The ANOVA (time × group × angle) showed that during POST and FUP, the participants of the EA group bent their wrist significantly earlier during the backswing than the other groups. Post-hoc analyses revealed that this interaction effect was mainly due to the differences in the wrist angle progression during the first 5° of the backswing. The robot-guided training was successful in shaping the movement pattern, and these changes persisted even after 7 days

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without further practice. This might have implications for the learning of complex motor tasks in general, as haptic guidance might quickly provide the beginner with an internal model of the correct movement pattern without having to direct the learner's attention towards the key points of the correct movement pattern.

1. Introduction

When learning a new motor skill, learners often require a lot of time to develop a movement pattern that enables them to achieve the movement goal and that is reproducible and stable after a longer period without practice. This is especially true for more complex motor skills, as learning a complex motor skill requires a high amount of information-processing capacity (Wulf & Shea, 2002), which often prevents beginners from concentrating on all of the important elements of the movement. This can cause large initial errors (Wulf & Shea, 2002), which then can derogate the learning process itself (Sanger, 2004).

A potential solution for this problem is guidance or physical assistance, which might reduce the attentional demands by providing a "perceptual motor-workspace" for the learner (Newell, 1991; Wulf & Shea, 2002; Wulf, Shea, & Whitacre, 1998). Several studies have examined the beneficial effects of haptic guidance in different areas of motor learning (for review see Sigrist, Rauter, Riener, & Wolf, 2013). One experimental paradigm that has been used to investigate the effects of haptic guidance in sensorimotor learning is position control during trajectory learning. A haptic interface guides the learner along predefined multidimensional trajectories in order to provide a correct movement pattern and to prevent errors during the learning process (Reinkensmeyer & Patton, 2009). Furthermore, haptic guidance has the capacity to deliver more movement repetitions than conventional training protocols (Huang & Krakauer, 2009). Hence it has also been applied as a new approach in neurorehabilitation. However, studies with stroke patients yielded controversial results (Kwakkel, Kollen, & Krebs, 2008; Prange, Jannink, Groothuis-Oudshoorn, Hermens, & Ijzerman, 2006). This might be due to the fact that studies in this field are often underpowered; hence one might not distinguish the actual treatment effect in a heterogeneous stroke population (Kwakkel et al., 2008). In addition there was a lack of consensus about appropriate outcome measures in order to quantify motor re-learning without any compensation strategies (for detailed information see Sivan, O'Connor, Makower, Levesley, & Bhakta, 2011). Future studies should consider an intensity- and duration-matched training design to verify improvements that are related to the treatment modalities and not to a higher dose–response under robotic rehabilitation condition (for review see Norouzi-Gheidari, Archambault, & Fung, 2012). To sum up the findings of these meta-analyses, it is not yet clear whether haptic guidance in rehabilitation is superior to conventional rehabilitation treatments or just provides an alternative treatment possibility (Sigrist et al., 2013).

With healthy subjects, there are only few studies focusing on the use of haptic guidance to help position control during motor skill learning (Feygin, Keehner, & Tendick, 2002; Liu, Cramer, & Reinkensmeyer, 2006). In the study by Feygin et al. (2002), the participants learned to track a novel arm movement in three different ways. The first group trained by solely observing the end effector moving along its trajectory. In the second group, the hand of the subject was attached to the end effector while it moved along the trajectory with the line of sight to the apparatus being blocked. The third group experienced the same guidance as the second group but additionally was able to see the movement. The training consisted of 30 movement demonstrations for each group with a recall phase after every second trajectory presentation, during which the subjects had to reproduce the learned movement trajectory. The authors demonstrated that haptic guidance increased position and especially timing accuracy of the learned movement.