Human Movement Science 43 (2015) 216–228

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

The effect of real-time auditory feedback on learning new characters

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ARTICLE INFO

Article history:
Available online 18 December 2014

PsycINFO classification:
2300
2320
2326
2330
2343

Keywords:
Handwriting
Movement
Sonification
Motor learning

ABSTRACT

The present study investigated the effect of handwriting sonification on graphomotor learning. Thirty-two adults, distributed in two groups, learned four new characters with their non-dominant hand. The experimental design included a pre-test, a training session, and two post-tests, one just after the training sessions and another 24 h later. Two characters were learned with and two without real-time auditory feedback (FB). The first group first learned the two non-sonified characters and then the two sonified characters whereas the reverse order was adopted for the second group. Results revealed that auditory FB improved the speed and fluency of handwriting movements but reduced, in the short-term only, the spatial accuracy of the trace. Transforming kinematic variables into sounds allows the writer to perceive his/her movement in addition to the written trace and this might facilitate handwriting learning. However, there were no differential effects of auditory FB, neither long-term nor short-term for the subjects who first learned the characters with auditory FB. We hypothesize that the positive effect on the handwriting kinematics was transferred to characters learned without FB. This transfer effect of the auditory FB is discussed in light of the Theory of Event Coding.

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http://dx.doi.org/10.1016/j.humov.2014.12.002
0167-9457/

1. Introduction

Sounds can naturally reveal phenomena that are external to our field of vision or that contain dynamic cues to which the eye is less sensitive (Fitch & Kramer, 1994; McCabe & Rangwalla, 1994). Consequently, they might form a powerful feedback (FB) medium for enriched motor training. Human movement sonification enables the exploration of new training methods in sports and motor learning, as well as the study of new therapeutic approaches in rehabilitation (Effenberg & Mechling, 2005; Höner et al., 2011; Konttinen, Mononen, Viitasalo, & Mets, 2004; Vogt, Pirrò, Kobenz, Höldrich, & Eckel, 2009). The purpose of sonification is to enrich movement perception by transforming selected kinematic or dynamic movement parameters into congruent synthetic sounds. Sonification of movements seems to improve both their perception and reenactment (Effenberg, 2005; Young, Rodger, & Craig, 2013). The relatively close neural connections between auditory and motor areas may explain these audio-motor interactions (Bengtsson et al., 2009; Haueisen & Knöshe, 2001; Schmitz et al., 2013). Furthermore, a growing number of studies report that the audiovisual perception of sonified movement modulates the activity of the multisensory brain areas which then might lead to a more accurate representation of the movement (Bangert et al., 2006; Butler, James, & James, 2011; Le Bel, Pineda, & Sharma, 2009; Scheef et al., 2009; Schmitz et al., 2013). Finally, in addition to their informative characteristics, sounds can be playful and motivate learners (Schaffert, Barrass, & Effenberg, 2009). Since handwriting learning requires daily training over several months, learner's motivation is an important component to take into account.

Yet, audition is not the sensory modality that is primarily associated with handwriting, which is a silent activity. A priori, proprioception would be more adapted to help writers to perceive the correct movement: Indeed, teachers do just this when they hold a child's hand and guide his/her movement (e.g. Bluteau, Coquillard, Payan, & Gentaz, 2008; Teo, Burdet, & Lim, 2002). However, there are limits to the use of supplementary proprioceptive guidance. First, its effectiveness has been addressed mostly on simple motor tasks (for a review, see Sigrist, Rauter, Riener, & Wolf, 2013), but not on more complex tasks as handwriting. Secondly, proprioceptive guidance with force-feedback devices requires costly tools and complex implementation. In particular, this would first require recording an ideal trajectory that the writer would then have to reproduce and from which corrections could be made. Lastly, guiding the pen to the correct trajectory affects the action of the writer, tending her/him to some passiveness. Applying real-time auditory FB in handwriting is a more original approach, although first attempts were carried out a few decades ago in handwriting rehabilitation. For example, auditory FB was applied for the treatment of writer's cramp (Bindman & Tibbetts, 1977; Reavley, 1975). The method consisted in transforming electromyography (EMG) recording into auditory biofeedback during relaxation and handwriting tasks. Although the method seemed attractive, Ince, Leon, and Christidis (1986) raised criticisms about these studies and reported some methodological difficulties. Notably, handwriting involves numerous small muscles which are not easily reachable with surface EMG. More recently, rather than applying auditory FB linked to the muscle activity, Baur, Fürholzer, Marquart, and Hermsdörfer (2009) applied auditory FB to the fingers' grip force on the pen for the treatment of writer's cramp. The auditory FB consisted in a continuous low-frequency tone when average grip force exceeded 5 N during handwriting. The tone frequency increased in four steps according to the grip force level and patients were instructed to perform the writing exercises in such a way that they heard a pleasant, low-frequency, tone. After seven hours of training, the grip force and the pressure applied by the pen on the paper decreased but the velocity and the fluency of their handwriting did not change significantly. These results were therefore encouraging for the rehabilitation of writer's cramp but not for handwriting movement improvement *per se*.

Plimmer, Reid, Blagojevic, Crossan, and Brewster (2011) tested a multimodal system based on auditory FB and haptic guidance for signature learning in blind children. The auditory FB consisted in sounds varying in stereo pan and pitch according to the x and y movement of the stylus, respectively. The haptic guidance was provided to the writer through a force-feedback haptic pen that reproduced the movement of the teacher's pen. While the authors concluded that the multisensory FB was efficient in helping the blind children write their signatures, this conclusion was not supported by a kinematic analysis.