

Surrogate tactile feedback integration seems to be mediated by tactile sensibility

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Introduction

Potential users of sensorimotor assistance systems typically do not only suffer from motor deficits, but from sensory deficits as well. In the motor system of healthy people, multiple sources of sensory information, such as tactile and kinesthetic information, are merged to make movements more precise and efficient. Therefore, it appears appropriate to integrate surrogate tactile feedback into sensorimotor assistance systems to compensate, at least partially, the missing natural sensory feedback. A considerable issue of surrogate tactile feedback may be the delay between onset of a tactile signal, e.g. at the finger of an artificial hand, and the presentation of the surrogate feedback. In our study we therefore focus on the question, which delay such surrogate feedback may have until it exerts a disturbing effect.

Method

To evaluate the concept of surrogate tactile feedback, healthy participants were instructed to perform tapping movements in the context of a synchronization-continuation paradigm. Participants tapped with the right index finger against a surface in two isochronous rhythms (2 and 4 Hz) with the goal of reproducing each rhythm as precisely as possible. Surrogate Feedback was given with an electromechanical plunger, at the hallux of the left foot. Prior to the experiment, the task was explained and the feedback mounting was adjusted to fit the foot. Participants were instructed to keep their foot in the correct position during the experiment. The feedback signal was triggered by a lighting barrier, which also indicated the time of contact between finger and surface. Depending on the experimental condition, the surrogate feedback was delayed for 0, 12, 24 or 48 ms. A control condition entirely without surrogate feedback was also present. Previous to the experiment, skin sensitivity (touch-pressure threshold) of the participants was tested at the same site where the surrogate feedback was applied, using the Semmes-Weinstein Monofilament test.

Results

The variability of the inter-tap-intervals was used as an indicator of temporal precision of the tapping movements. When the surrogate feedback was not delayed, the variability was comparable to the control condition, hence the feedback did not have a significant influence on the timing precision. The delayed conditions instead elicited a significantly higher variability. To take the inter-individual skin sensitivity into account, the participants were grouped using a median split into two sensitivity categories. While the low sensitivity group did not yield any differences, the high sensitivity group showed a significantly higher variability, when the extended feedback was delayed for 48 ms.

Conclusion

Generally, extended feedback seems to perturb motor coordination when delayed, but not when it is properly aligned with the natural, proprioceptive feedback. The results of the split two sensitivity groups suggests that a certain level of skin sensitivity is necessary for the application of surrogate feedback. At lower levels of skin sensitivity, the feedback seems to be ignored by the motor system.