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The role of direct haptic feedback in a compensatory tracking task

Evangelia-Regkina Symeonidou, Mario Olivari, Heinrich H. Bülthoff, Lewis L. Chuang
Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Haptic feedback systems can be designed to assist vehicular steering by sharing manual control with the human operator. For example, direct haptic feedback (DHF) forces, that are applied over the control device, can guide the operator towards an optimized trajectory, which he can either augment, comply with or resist according to his preferences. DHF has been shown to improve performance (Olivari et al. submitted) and increase safety (Tsoi et al. 2010). Nonetheless, the human operator may not always benefit from the haptic support system. Depending on the amount of the haptic feedback, the operator might demonstrate an over- reliance or an opposition to this haptic assistance (Forsyth and MacLean 2006). Thus, it is worthwhile to investigate how different levels of haptic assistance influence shared control performance.

The current study investigates how different gain levels of DHF influence performance in a compensatory tracking task. For this purpose, 6 participants were evenly divided into two groups according to their previous tracking experience. During the task, they had to compensate for externally induced disturbances that were visualized as the difference between a moving line and a horizontal reference standard. Briefly, participants observed how an unstable air- craft symbol, located in the middle of the screen, deviated in the roll axis from a stable artificial horizon. In order to compensate for the roll angle, participants were instructed to use the control joystick. Meanwhile, different DHF forces were presented over the control joystick for gain levels of 0, 12.5, 25, 50 and 100 %. The maximal DHF level was chosen according to the procedure described in (Olivari et al. 2014) and represents the best stable performance of skilled human operators. The participants' performance was defined as the reciprocal of the median of the root mean square error (RMSE) in each condition.

Figure 1a shows that performance improved with in- creasing DHF gain, regardless of experience levels. To evaluate the operator's contribution, relative to the DHF contribution, we calculated the ratio of overall performance to estimated DHF performance without human input. Figure 1b shows that the subject's contribution in both groups de- creased with increasing DHF up to the 50 % condition. The contribution of experienced subjects plateaued between the 50 and 100 % DHF levels. Thus, the increase in performance for the 100 % condition can mainly be attributed to the higher DHF forces alone. In contrast, the inexperienced subjects seemed to completely rely on the DHF during the 50 % condition, since the operator's contribution approximated 1. However, this changed for the 100 % DHF level. Here, the participants started to actively contribute to the task (operator's contribution >1). This change in behavior resulted in performance values similar to those of the experienced group Our findings suggest that the increase of haptic support with our DHF system does not necessarily result in over-reliance and can improve performance for both experienced and inexperienced subjects.

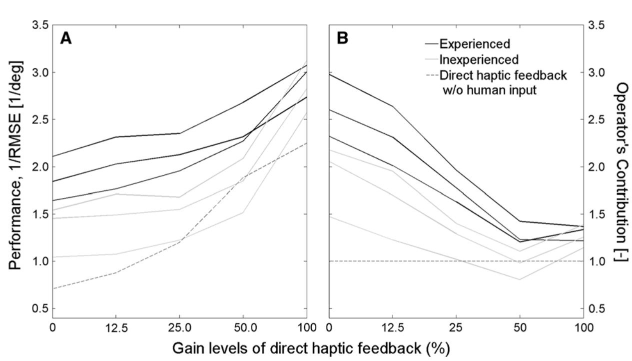

Fig. 1 **a** Performance of the experienced and in experienced participants as well as the baseline of direct haptic feedback (DHF) assistance without human input for increasing haptic gain. **b** The ratio of overall system performance to DHF performance without human input for increasing haptic gain

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Comprehending negated action(s): embodiment perspective

Nemanja Vaci[1], Jelena Radanović[2], Fernando Marmolejo-Ramos[3], Petar Milin[2,4]
[1] Alpen-Adria University Klagenfurt, Austria; [2] University of Novi Sad, Serbia; [3] University of Adelaide, Australia; [4] Eberhard Karls Universität Tübingen, Germany

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According to the embodied cognition framework, comprehension of language involves activation of the same sensorimotor areas of the brain that are activated when entities and events described by language structures (e.g., words, sentences) are actually experienced (Barsalou 1999). Previous work on the comprehension of sentences showed support for this proposal. For example, Glenberg and Kaschak (2002) observed that judgment about sensibility of a sentence was facilitated when there was congruence between the direction of an action implied by the sentence and the direction of a movement required for making a response, while incongruence led to slower responses. It was also shown that linguistic markers (e.g., negation) could modulate mental simulation of concepts (Kaup 2001). This finding was explained by the two-step negation processing: (1) a reader simulates a sentence as if there is no negation; (2) she negates the simulated content to reach full meaning. However, when a negated action was announced in preceding text, negated clause was processed as fast as the affirmative one (Lüdtke and Kaup 2006). The mentioned results suggest the mechanism of negation processing can be altered contextually.

In this study, we aimed at further investigating the effects of linguistic markers, following the assumptions of embodied