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Visual Augmentation of Spatiotemporal Errors in a Rowing Task

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Introduction
Making errors during exploration of a new motor skill improves learning. To explore how error-driven processes help learning, error augmentation (EA) has been proposed (Parmar & Patton, 2015). For EA to be effective, amplified error gains and instructions have to be well defined. More than optimal gains may impair learning if the learner over-compensates them (Patton, Wei, Bajaj & Scheidt, 2013); and unclear instructions can raise the cognitive workload. Studies have shown an advantage of haptic EA over unamplified gains for learning (Milot, Marchal-Crespo, Green, Cramer & Reinkensmeyer, 2010). Visual EA is also promising for skill acquisition. Studies on simple tasks have found advantages of visual EA and suggested that there was a practical limit on the EA gains to assist learning (Wei, Patton, Bajaj, & Scheidt, 2005). But, visual EA gain limits for learning complex skills have not been studied yet. Here we study the effect of gradually increasing the visual EA gain on the performance of a complex rowing task. Subjects were not informed about the presence of EA and the gain change. Thus, we observed how they coped with the amplified errors.

Methods
Haptic and auditory rendering, visuals and EA were done by our simulator (Sigrist, Rauter, Marchal-Crespo, Rienr & Wolf, 2015). The task was the trunk-arm sweep rowing. A cycle was formed by two phases that needed distinct velocity profiles. Five students from our lab, who took part in previous studies with the same protocol as in Sigrist et al. (2015), participated at this pilot study. They were not naïve to the task and simulator.

A virtual blue oar was shown for the visual feedback. It displayed the reference trajectory of the oar on the right-hand sided screen. The error which was visually augmented was the angular deviation of the subject's oar from the reference trajectory. The deviation was calculated based on the combination of vertical and horizontal deviation. For visual EA, green to red traces were drawn proportional to the magnitude of the deviation. To assess the spatial and temporal performances, the mean spatial and velocity errors were used as the performance variables. Spatiotemporal analysis was used to calculate them.

Reference oar and error traces were explained to the participants, but they were not aware that their error would be visually augmented. The protocol consisted of a demonstration, 3-minute baseline test (BL), training and a short-term retention test (RE). The training phase comprised five sessions of 3-minute training with visual EA (T) and 1-minute non-feedback catch trial (CT) where visual feedback was removed. In the first training session, the actual error was displayed to the subjects, i.e. the gain was 1.0. The gain was increased by multiples of 20% in the following sessions until it was set to 1.8 in the last training session.

Results
Subjects could keep up with an EA gain up to 1.4 but got confused when it was higher than 1.6. After training with gain 1.6, four out of five subjects performed worse in the non-feedback session compared to the previous one (CT4 vs CT3 in Fig.1). Gain 1.8 was especially challenging for the subjects to handle the task. Subjects were also asked about their feelings on their performances. They reported that they were better in the initial training sessions. Subjects thought that the effort to keep up with the task was too high for the gain 1.8. In general, subjects found the task to be frustrating with gains higher than 1.6.

**Fig. 1.** Mean velocity error for each subject and condition.

**Discussion**

Effect of visual EA gains for a complex task was studied. The gains up to which the subjects could manage the task were lower than what was reported in (Patton et al., 2013). In fact, Patton et al. (2013) found that learning of a simple reaching task with visual EA gain of 2 was twice as fast as non-EA condition. This is not surprising since our task was more complex and required a larger range of motion with upper body. Thus, for complex tasks lower visual EA gains can be more suitable than what has been earlier suggested. In the next study, a visual gain 1.6 will be tested by informing subjects.

**References**


