Evaluation of multimodal feedback effects on improving rowing competencies

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Abstract
This study focused on the selection and preliminary evaluation of different types of modal and information feedback in virtual environment to facilitate acquisition and transfer of a complex motor-cognitive skill of rowing. Specifically, we addressed the effectiveness of immediate information feedback provided visually as compared to sensory haptic feedback on the improvement in hands kinematics and changes in cognitive load during the course of learning the basic rowing technique. Several pilot experiments described in this report lead to the evaluation and optimization of the training protocol, to enhance facilitatory effects of adding visual and haptic feedback during training.

1. Introduction
Skills are gradually acquired with experience and practice time [2, 7]. Motor skills, such as rowing, require coordinating motion efforts, motor-cognitive skills, body strength, extensive practice, close guidance and coaching to achieve high competency. Novices are characterized by poor and slow skill performance, effortful and under a close conscious supervision. Relevant information is missed or misinterpreted; redundancies and higher level structures are not recognized and not used, elements of procedures are skipped or not performed in order. These problems are reduced or completely disappear in expert performance where procedures are performed rapidly, smoothly, as a unified response unit, requiring little conscious supervision with limited conscious supervision (automatic), and making use of higher level structures and redundancies [4]. A multimodal virtual reality (VR) environment offers many degrees of freedom which enrich the traditional supervision and guidance of the coach enabling performance to become more objectively evaluated and communicative to the trainee. The on-line information can be given as a multimodal feedback that spans the senses and includes visual, auditory, and haptic/kinematic interactions [12]. It has been found [8] that augmented feedbacks greatly improve training of highly complex patterns of bimanual coordination and postural control as can be found in rowing. These feedbacks assist the coach in generalizing the global organization of interacting local (e.g., muscular, articular, perceptual) components [1]. Augmented feedbacks play a dual role in the learning process: first, by providing the learner with performance information about the success of the movement in progress or what must be done on a succeeding performance attempt; second, by motivating the learner to continue striving toward a goal [10]. Augmented feedbacks can be given in different forms: knowledge of result (KR) informs the performer on the match between his action and the designated target or goal; knowledge of performance (KP) gives indication about movement characteristics e.g. the left arm was held in perfect height or the hand was not stable; augmented sensory feedback means that an external device is used to enhance sensory feedback. Multiple-resource-theory of attention states that a task that engaged different forms of input modalities will be performed better than tasks completed within the same modality [10]. The use of more than one modality can improve perception and enhance performance and as well affect the cognitive load. Kahneman [6] has shown that pupil size can serve as an index of processing load: pupil’s dilation correlates with increasing cognitive workload. In a system with complex multiple stimulations the attention load may exceed processing capacity and one task element or another must suffer. Since attention management under high load can be improved with training [5], we assume that during practice, the participant acquires distribution strategy to all the tasks. We expect that training will induce quantitative and qualitative...
changes in kinematics, coordination (timing) and cognitive load: 1) accuracy of hands movement geometry will increase as practice continues; 2) co-articulation will develop inducing smoother trajectory with higher velocities at reference points as ABC in later discussion; 3) timing of rowing cycle will improve; 4) cognitive load will decrease.

2. Method

Rowing is a complex task involving physical and cognitive skills, coordination between body organs, respiratory system and pace. We adopt a simplified rowing task that requires production of smooth and cyclic hands movement between 3 points A, B and C in 2D plane, representing the three critical phases of hand’s movement during the stroke: catch, finish and start of recovery, respectively. The time sequence of the points is shown in Fig. 1.

![Fig. 1 Geometrical representation of hands trajectory during rowing cycle comprised of coordinated movement between the 3 points A, B and C.](image)

In the preliminary phase of this experiment we tested two subjects: one trained in Visual feedback condition and another trained in Haptic feedback condition. Figure 2 depicts the evolution of their hand
trajectories. In Visual condition, on day one pre-test, the three targets were consistently missed. Moreover, the overall shape of the trajectory, that should resemble a rain drop shape when the task is skilled, is jerky. On day five retention session the trajectory shape has been significantly changed: it got a clear drop shape on all strokes while the accuracy of going through the A, B and C points was significantly increased. Trajectory changes were accompanied by an increase in mean speed at the three target points. These observations are in line the predictions of the minimum jerk model [3].

In particular the minimum jerk model assumes that given a starting point, an end-point and one or more via-points, that are identified as the position in the path where a local minimum speed is attained, corresponding to the point of local maximum curvature, the motor system preplans an entire hand trajectory that passes through all these points with the smoothest possible (i.e. minimum jerk) trajectory, implying increase in the angular velocity at via points.

On the meanwhile, the subject that was trained in haptic condition shows a different pattern of results. On day one pre-test, he performed relatively well with regard to the accuracy of passing through the points A, B and C. However, in terms of movements’ geometry, his performance was very poor, jerky and composed of discrete segmented movements. Training induced significant improvement in the overall shape of the path and there was an increase in the angular movement velocities at target points. However, the accuracy of passing through the points was decreased. This suggests that speed-accuracy trade-off characterized the course of training, as opposed to the results of the first subject.

Regarding attention along the course of training, pupil diameter decreased (data for one subject is shown in Fig. 3), suggesting that changes in attentional load are correlated with the acquisition of the rowing skill.

4. Conclusions

The experimental protocol, although in the preliminary stage of subject testing, has already presented interesting possibilities in training co-articulation in complex motor schemes. While the overall scheme seems promising at this stage no conclusions can be made when comparing the effect of different feedback types.

Acknowledgments

This work was supported by the SKILLS Integrated Project (IST-FP6 #035005, http://www.skills-ip.eu) funded by the European Commission.

References

[6] Kahneman,D. J. Beatty, 1966: Change in cognitive load affects pupil diameter (PD), fixation duration and number of blinking


<table>
<thead>
<tr>
<th>Feedback</th>
<th>Description</th>
<th>Layout</th>
</tr>
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<tbody>
<tr>
<td>None (control)</td>
<td>Static black screen and static yellow bars. No haptic feedback is provided.</td>
<td></td>
</tr>
<tr>
<td>Haptic</td>
<td>Dynamic rowing scenario and static yellow bars. Haptic feedback is provided for A and C locations.</td>
<td>![Haptic Feedback Image]</td>
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<tr>
<td>Visual</td>
<td>Dynamic rowing scenario with dynamic bars on recovery phase. The bars represent on screen the same spatial organization of the phases in stroke (catch, finish, start of recovery). At the end of each stroke bars’ colors are updated to indicate overall accuracy of movement in the ABC part. Direction of error is also shown.</td>
<td>![Visual Feedback Image]</td>
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Table 1. Experimental groups and the corresponding layout of the training environment.