Evaluation of user-interfaces for FES systems by means of a dual-task experiment

Vanoncini M 1, Andrews BJ 2

1 University of Reading, Department of Cybernetics, Whiteknights, Reading RG6 6AY, UK
2 Brunell University, Osterley Campus, Borough Road, Isleworth, Middlesex TW7 5DU, UK

Email: m.vanoncini@reading.ac.uk

Abstract
A pilot study using a dual-task experiment was performed to compare the cognitive loading of two user interfaces for a FES assisted rowing for paraplegics. The subject was required to row while performing a concomitant secondary cognitive task.

The dual-task was found to be simple to implement, yet effective in the evaluation of the cognitive load. However, this study also showed that the practical implementation requires particular attention and experience in the choice of the secondary task.

1 Introduction
Systems for FES assisted activities such as standing or walking are traditionally evaluated through indexes based on the measurement of the actual performance achieved (e.g. duration of the walking session, distance covered, walking velocity, average stride length).

However, the final success of such systems heavily depends on their ease of use: a proper evaluation, therefore, should take into consideration cognitive load imposed by the user interface.

The study focused on the comparison of two user interfaces for the control of the FES assisted rowing [1]. This activity requires the user to control the timing of the two main phases of the rowing cycle: the drive (in which the quadriceps are stimulated to achieve knee extension) and the recovery (in which the hamstrings are stimulated to achieve knee flexion).

The first user interface was a simple momentary action switch positioned on the Concept II handlebar. When pressed, the FES controller switches state from “drive” to “recovery” and back again to “drive” when released.

The second interface is based on a force sensor located in-line with the handlebar. This force signal has a characteristic increase during the first part of the drive and then decreases to reach a minimum value, which is maintained throughout the recovery phase. A pull on the handle initiates the drive phase, which ends when the force crosses a lower preset threshold (see figure 1).

Figure 1: Force exerted on the oar (in N) and stimulation states over time (in s) in 2 rowing cycles. State A= stimulation of the quadriceps State B= stimulation of the hamstrings

2 Methods
2.1 The Dual task paradigm
Dual task experiments are used to measure the level of attention that a certain activity requires.

They are based on the comparison of the performance achieved in two different situations:
A. only the activity under study is performed.
B. the activity is performed at the same time as a secondary task.

As cognitive resources are limited, B will induce a decrease in the level of attention that a
subject is able to dedicate to the main task: as a result, the performance on the latter will decrease. Although the method is well established in the field of psychology (see [2], [3], [4], [5]), a clear standardization of the test is almost impossible. The procedure must take into consideration the primary task under study. This implies finding a suitable measure of the performance as well as an “appropriate” secondary task. In order to be “appropriate” a secondary task must use the same kind of cognitive abilities required by the main task.

2.2 Use of dual task testing technique in the present study

Rowing was the primary task, while the secondary task consisted in the memorization and oral repetition of randomly generated strings number. The strings were delivered at a fixed pace through the speakers of a personal computer. The length of the strings was determined before the start of the trials, as the maximal length that the subject could remember. In this way, the level of difficulty of the secondary task was set on the particular subject.

The physical performance was quantitatively assessed by a set of variables, measured during each rowing cycle:

Time to complete the rowing cycle.
Time to complete the drive phase.
Time to complete the recovery phase.
Ratio drive: recovery time.
Peak “recovery” handlebar velocity.

A paraplegic subject was asked to row at his preferred pace in four different situations:

1) rowing only, using the “push button” interface.
2) rowing while performing the secondary task, using the “push button” interface.
3) rowing only, using the “force sensor” interface.
4) rowing while performing the secondary task, using the “force sensor” interface.

A multifactorial MANOVA (two factors, two levels each) was performed on the data collected in the four situations. Each variable was considered independently and a factorial MANOVA was performed to determine whether any of the five variables was more appropriate to mark the difference between the four situations.

Finally, a t-test was carried out on the data collected during the “single task” rowing sessions. These would be the only data available if a “traditional” evaluation method (i.e. without a dual-task test) was to be used for the comparison of the two user interfaces.

3 Results

The results of the multifactor MANOVA performed on the whole group of variables showed that the rowing performance was not dependent on the type of user interface used (significance level 5%). On the contrary, the performance was influenced by the presence of a secondary task, as well as by the interaction between the two factor (controller type and single/dual task) i.e. the difference between the performance in the situation “controller1, single task” and the situation “controller2, dual task” is not only caused by the fact that a secondary task was added.

The factorial MANOVAs carried out on each of the five variables exhibited the same pattern in 3 out of 5 cases.

The results of the t-test conducted on the data collected in “single task” rowing session, on the contrary, showed rowing performance to be influenced by the type of controller used (level of significance 5%). In particular, the subject appeared to row at a lower pace when the subject was using the controller based on the force sensor.

4 Discussion and Conclusions

This pilot study was limited with only one subject and a relatively small number of trials. Furthermore, it was assumed rowing speed to be a good index of performance and influenced only by two factors - the type of user interface and the presence of a concomitant task.

Given these limitations, the results indicate the potential of dual-task methods in the evaluation of FES user interfaces. The technique proved to be simple to implement, yet able to rank different user interfaces according to the relative demand on cognitive resources. This type of information, often neglected, could be very important in the estimate of the success of
FES systems outside the controlled environment of a research or clinical laboratory.

In order to apply this technique, however, particular attention must be taken in the choice of the secondary task. This should be chosen to maximally challenge the subject’s cognitive capacity and should be subject and primary task dependent. The secondary task should require a similar level of cognitive demand as the main task. As a result, no particular advice can be taken from the literature on selection of a dual-task paradigm. Every study has its own specificity and very few experiments have been explicitly designed for the evaluation of user interfaces.

In our study, the secondary task seemed to be set at an appropriately level, as it was able to influence the rowing performance. However, the change in the rower’s performance due to the addition of the secondary task could have been the result of an entrainment effect. The secondary task used in this study had a fixed pace that is synchronized with the primary task.

Thus the rower could have paced himself to the secondary task. This is a limitation to be addressed in further research.

References

Acknowledgements
The authors would like to thank Prof. C.Frigo and Dott.Ing. M.Ferrarin from the Politecnico di Milano for their contribution to the present study.