

Preliminary evaluation of timing training accelerator for the SPRINT rowing system

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Abstract

This paper shows the selection and preliminary evaluation of rowing gesture timing training on the SPRINT platform. After the analysis of experts' gestures and a literature review of rowing technique features, the selection of proper feedbacks and the development of the training protocol are investigated. The general problem discussed here is the learning of timing of complex motor pattern under the effect of load. Eight novice adults participated the experiment, half of them receiving vibrotactile feedback (VIB), both receiving knowledge of results (KR) after training blocks. Preliminary results show the difficulty people had to accomplish the task and to exploit feedback. There is in fact no evidence of feedback effectiveness when comparing VIB-KR and KR group. Some causes were hypothesized and a side effect of load condition arisen from data. Therefore timing training will be further investigated exploiting information gathered.

1. Introduction

Advancements in technology allowed in recent years to improve rowing technique evaluation. The development of devices and analyses proceeded through the years both for out-door rowing ([5],[6]) and in-door rowing ([2]). On the device side, traditional in-door rowing simulators (e.g Concept2 ergometer¹), which typically reproduce well load but are weak in reproducing kinematic features of out-door rowing, were recently joined by new and more sophisticated ones which offer most of the out-door rowing features and, within research context, exploit virtual environment for training ([9]). In the context of the SKILLS project, the

¹<http://www.concept2.com/>

SPRINT system is being developed to transfer rowing skills from expert rowers to non-expert ones by means of multimodal technologies. The transfer is based on a digital representation of rowing skills, which allows the system to evaluate current user performance and modulate the training (that is to decide the protocol and to manage the feedback). One of the three areas of training established after the task analysis is technique optimization. Literature and recent analyses ([5], [1]) allow to say that temporal structure of body limbs motion onset during the drive phase (see [6] and [1] for detailed nomenclature) is one important feature for determining technique effectiveness. Analyses were hence carried out on the SPRINT platform in order to find quantitative indices of this temporal structure which could be used for timing training. Once models for quantitative evaluation had been available, training was designed, in particular training tools called accelerator (described in [7]) started to be evaluated. This paper shows the selection of the accelerator and the experiment carried out to evaluate it.

2. Accelerator

An accelerator exploits performance analysis, protocol design and information exchange with the user for shortening the time taken to achieve and keep high skill level. Performance analysis carried out to have a digital representation of the temporal pattern of the drive phase is shown in [4] and it is not reported. From the analysis emerged that two parameters describe experts' timing: t_b for back swing onset and t_a for arms bending onset. These parameters are defined as

$$t_b = \frac{T_b}{T_d - T_0} \quad \text{and} \quad t_a = \frac{T_a}{T_d - T_0} \quad (1)$$

where T_b is the time of back swing onset, T_a is the time of arms bending onset, T_0 is the time of legs pull onset

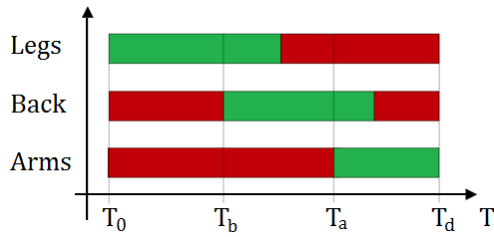


Figure 1: Body limbs temporal pattern: body limbs should be moved only in the green intervals.

and T_d is the drive phase end time. Fig. 1 shows the correct time structure according to Adam's style ([5]) along with previously mentioned parameters. The chosen information exchange is mainly composed of three parts: visual cue, auditory cue and vibrotactile feedback. Among different kinds of feedback that could be implemented the vibrotactile was selected because of its effectiveness in training motor skills [3] and because it makes the user significantly less dependent on the feedback when compared to other cues [8]. The auditory cue consisted of two beeps informing users about motion onsets, it was provided both during training and tests. During training the time elapsed between the feedback and auditory cue was supposed to inform users about anticipation or delay of motion onset. The visual cue was a number representing the stroke pace participants were performing. The training protocol was set as long as possible to avoid fatigue, which could affect performance discriminating participants on their fitness status. Feedback was always given during training, although some studies ([10]) show concurrent feedback given with 100% frequency not to be the best for learning, studies on complex skills ([11]) show this feedback frequency to be the most effective.

3. Method

Eight naive adults (aged 26.1 ± 4.9) screened for handedness and general health participated the experiment. The task consisted of rowing on the SPRINT platform following the timing given by the auditory cue at T_b and T_a . They were asked to keep their pace in the interval 15-18 spm in order to make suitable values set for timing parameters. Four participants were assigned to the vibrotactile provided group (VIB-KR) whereas the others to the knowledge of results only group (KR). The former were given the vibrational feedback during training blocks, the latter were not. All participants receive knowledge of results after each training block.

Block performance regarding back swing and arms bending was separately scored, scores increased as the

Day1	Pre S1	Training S2	Post S3	Post S4
Duration	4 x 1'	10 x 2'	4 x 1'	4 x 1'
Rest time	3 x 1' 2'	9 x 1' 2'	3 x 1' 10'	3 x 1' -
Load	NO	NO	NO	FULL

Day2	Pre S5	Pre S6	Training S7	Post S8	Post S9
Duration	4 x 1'	4 x 1'	10 x 2'	4 x 1'	4 x 1'
Rest time	3 x 1' 2'	3 x 1' 2'	9 x 1' 2'	3 x 1' 10'	3 x 1' -
Load	NO	FULL	FULL	FULL	NO

Day3	Ret S10
Duration	4 x 1'
Rest time	3 x 1' -
Load	FULL

Figure 2: The complete protocol

ratios of correct strokes over the total did. Timing error are defined as

$$e_b = t_b - \tilde{t}_b \quad \text{and} \quad e_a = t_a - \tilde{t}_a \quad (2)$$

for back and arms respectively, where \tilde{t}_b and \tilde{t}_a are the target values of timing parameters (also based on performance analysis described in [4]). Vibration was triggered when timing error exceeded the initially set thresholds, namely \tilde{e}_b and \tilde{e}_a . Given the expertise of the participants, some task simplifications were introduced: thresholds for error triggering was set high than experts performance variability and load was completely removed in the first part of the protocol.

The experiment lasted three days, two consecutive days could not be separated by more than 72 hours. In the first day people were instructed about the experiment, they were then taught how to row by means of verbal instruction and by practicing on the platform. After they familiarized with the platform and the audio cue they performed the preliminary assessment, then the training and finally post assessment tests. At the beginning of day two participants shortly familiarized with the platform than carried out pre-tests, training and post-test. In the third day participants carried out a retention test. Fig. 2 summarizes the final protocol, duration, rest time and load condition are specified for each block, participants were given longer rest time when switching load condition.

4 Analysis

Some variables were extracted to check feedback effectiveness and to find regularities in participants' behavior. Errors $e_a(i)$ and $e_b(i)$ were used for gathering the performance indices needed for the evaluation. Data were screened in the $(e_b(i), e_a(i))$ plane, called ε in the following, in this plane each point is a stroke outcome. Fig. 3(b) shows the template of the analysis along with a block outcome:

- horizontal solid lines represent alignment with the required arms timing, vertical ones are the same for back;
- horizontal and vertical dashed lines represent thresholds \tilde{e}_a and \tilde{e}_b ;
- dashed oblique line represents points where back and arm errors are the same, that is arms motion onset occur the right time after back's one, but they may be both wrong with respect to leg motion onset;
- dashed oblique lines represents points in which arms motion onset happens $t_2 - t_1$ s after back's one, under this line arms are moved before back, that is rowing sequence is flipped.

Each stroke was scored according to its position in ε : back/arms is scored one if the point lies between vertical/horizontal dashed lines. For each block i , the centroid G_i of the block's strokes set was computed in order to synthesize block performance. A centroid is defined as the point which minimizes the sum of Euclidean distances from all the strokes of the block. Each block was then scored according to its centroids positions in ε , zones mentioned in the following refer to Fig. 3(a):

- ΔG_i : distance from the target point $O(0,0)$, it takes into account both back and arms error.
- $F(G_i)$: binary variable that is one when G_i lies in one of the light blue zones. It shows if there is a significant difference in back and arms alignment with correct timing. $F(G_i)$ indicates if participants focused their attention on one limb, thus paying less attention to the other.
- $L(G_i)$: binary variable that is one when G_i lies either in orange or purple zones. $L(G_i)$ is one when back and arms errors are almost the same, highlighting that the participant coordinated well back and arms motions locking them each other.

5 Results and Discussion

Data were analyzed in order to check effectiveness of vibrotactile feedback, effects of resistance, focus on the goal and to find common behaviors among subjects. VIB-KR participant number 3 data are not always reliable due to problems with motion tracking system, they are anyway reported. Only data where rowing cycle was carried out in the correct sequence were considered since it is unlikely that participants who missed the whole stroke could be paying attention to timing.

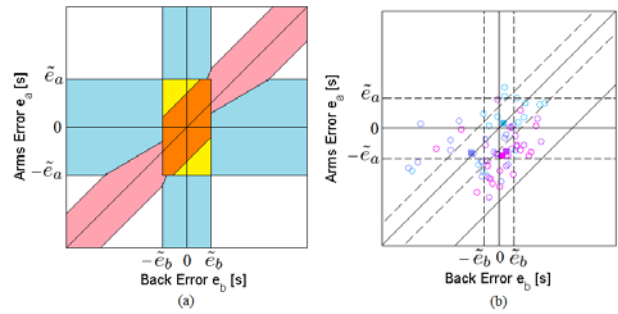


Figure 3: (a) ε plane along with score zones, light blue zones represent focused behaviour, orange and purple ones to lock, whereas orange and yellow to hits. (b) Four stroke sets samples (circles) along with their centroid (squares).

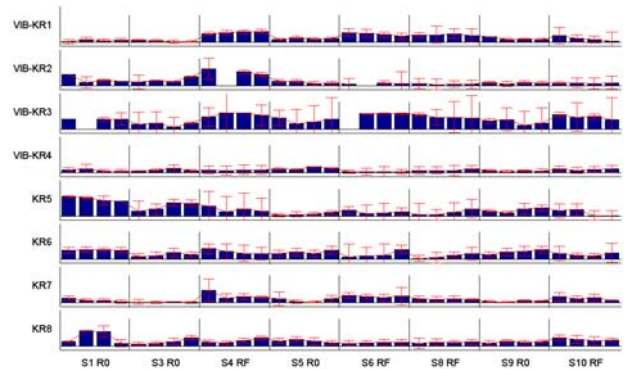


Figure 4: Average and standard deviation of ΔG_i of each participants during test sessions.

Fig. 4 shows the average of total error ΔG_i for each block of each test session for all participants. Both VIB-KR and KR groups' participants generally improve. It is possible to note that arms' error is generally lower than back's one and that lower errors are produced in no load conditions. From the graphs vibrotactile feedback does not seem to give further benefits when coupled with audio guidance and KR. Fig. 5 plots show G_i through test sessions along with their stroke sets. Each plot shows the four blocks of the session: colors go from light cyan for the first block to purple for the last. This plot allows to see that many participants, despite having no feedback on their performance, adapted their behavior in order to follow the only guidance they had left, that is the audio cue. Many of them were not able to reach the hit area (yellow or orange zones), however, they tried either to focus on one limb (e.g. participant KR7 who focused form S5 on) or to keep the right time lapse between limbs onset (e.g. VIB-KR1 during S8), they hence exploited at most audio guidance. From this

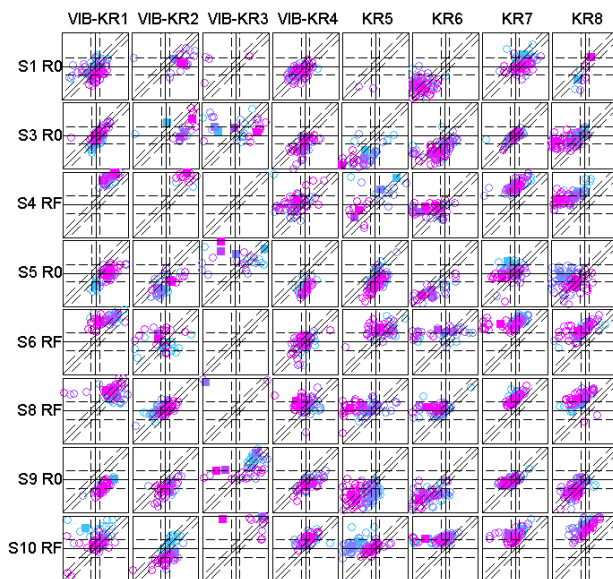


Figure 5: Back and arms timing error $e_b(i)$ and $e_a(i)$ of each participant in test sessions, (sessions 1,3,4,5,6,8,9,10 shown Fig. 2 plotted in the ε plane.

graph is also possible to see how load interferes with performance: all participants reduced (many switching from positive to negative values, that is from delay to anticipation) both e_a and e_b when load was removed across sessions S8 and S9.

6. Conclusions

This preliminary experiment showed that if audio guidance, vibrotactile feedback and knowledge of results are concurrently provided, effects of vibrotactile feedback are not noticeable. However, from this experiment some interesting considerations useful for the continuation of the experiment were drawn. First of all KR will be removed in order to amplify the effect of vibrotactile feedback. Then, since load condition strongly interferes with novice participants training, next participants will experience only one low level of load. Finally, we saw that arms are generally better controlled than back (lower errors), and it is quite common (one third of the blocks regardless experimental conditions) that arms and back behavior are locked. Therefore an improvement of learning is likely to happen if, at the beginning of training, instructions will focus participant's attention on back.

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