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Examining the effect of real-time visual feedback on the quality of rowing technique

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Abstract

An application is presented that provides real-time visual feedback on technique to a rower using an ergometer. The effects of using this system to support professional coaches in a genuine training scenario are investigated. This evaluation claims the system is a suitable training tool for helping to maintain consistently good technique.

Keywords: System ; Evaluation ; HCI ; Feedback ; Rowing ; Technique

1. Introduction

Providing feedback to performers on the quality of their performance and ways they can improve it is a fundamental pedagogical mechanism. The effective communication of correct technical information is the culmination of a good coach's assessment of their athlete and would help them to improve. Athletes often do not realise they are moving incorrectly which can lead to engraining faults into the technique and may cause injuries. Technology that assists rowing coaching by providing automated reporting of an athlete's technical ability in real-time can provide timely, constant, and objective supplementary support in the absence of busy coaches.

The work of [1] suggests a set of concepts when providing feedback to athletes in order for them to have a rounded learning experience: feedback should both refer to the overall competence of the performer and instruct them how to improve through allowing verification of their movements, evaluating their progress and determining

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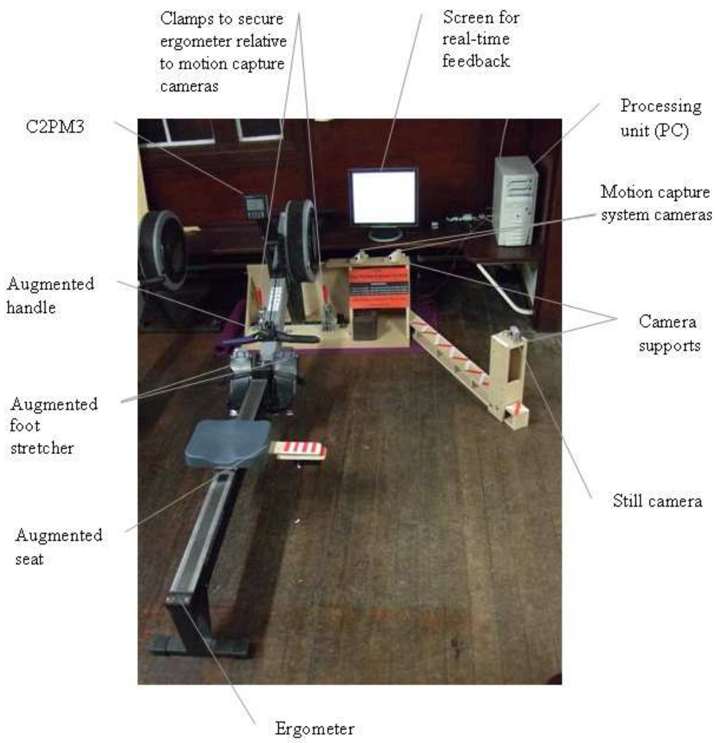
the causes of errors. They also note that feedback motivates athletes to remain involved in the training tasks and the modality and user interface of the feedback are important.

Many forms of feedback have been identified and some are successfully implemented but very little evaluation of how such feedback is received by athletes or effects their performances has been done. The work of [2] addresses the effects of feedback mode on rowing performance, claiming their tests were inconclusive, however if it is assumed all experiment participants were equally skillful the data supports the hypothesis that visual feedback is better than haptic feedback. Work in [3,4] demonstrates vibrotactile feedback through the handle of a rowing simulator is not as good as visual feedback, which is not as good as both together, if results are averaged over six experiment participants. Although the method used a rowing simulator, the evaluation did not test the feedback on an athletic performance, merely on the very different task of tracing the shape of a square whilst sitting still. There was no control used to compare performances with using no feedback and the speed profile of the trajectory is ignored. The work does not address the relationship between handle trajectory and the quality of the entire technical performance either.

This paper presents an application built using a pre-existing sensor system that provides real-time, visual feedback on aspects of technique to rowers using an ergometer. Not all feedback may be the most helpful and this work evaluates the systems effectiveness as a training tool. The rest of the paper is organised as follows: Sections 2 and 3 presents the feedback system and evaluation procedure respectively. Section 4 discusses the results of the user studies with conclusions and further work presented in section 5 and 6.

2. System description

An application to help rowers maintain consistency in the technique a coach describes, by sensing their movements and providing both real-time kinetic data and representations of ideal performances has been developed.



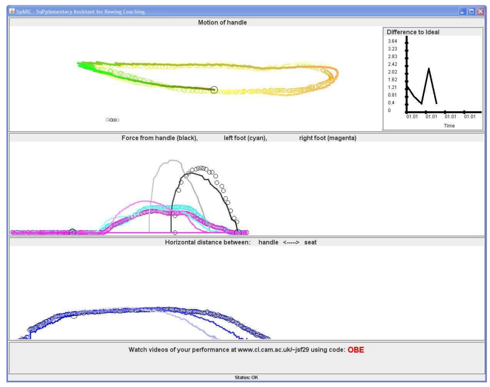


Fig. 1. (a) Photograph of the "Ergometer Motion Capture System" (EMCS)"; (b) Screenshot of the visual feedback displayed to the rower, including real-time kinetic data and representations of their ideal performance.

2.1. Sensor system

A Concept 2 model D indoor rowing ergometer is augmented with synchronized motions sensors, see Fig 1 (a). These include: An 3D motion capture system with mm accuracy capable of tracking at 100Hz, infra-red LEDs on the handle and seat within a coordinate system relative to the ergometer itself. Thin and robust FSR stuck onto the each foot-stretcher that measure the force applied through the ball of each foot at 100Hz using a Crowbow iMote and sensor board. The ergometer's performance monitor measures the force applied through the handle at 20Hz. The data is available in real-time whenever the rowers make normal use of the system.

2.2. Application

An application was written with a visual interface, see Fig 1 (b), used to display the raw motion sensor signals including a side profile of the shape of the handle trajectory (top), handle force curve (middle, black) and each foot's force curve (middle, cyan and magenta). The bottom third of the display shows a derived measurement useful to rowing technique which is the horizontal distance between the seat and handle over time. The data is displayed only for the current stroke. The application allows a coach to record all the signals for the last stroke performed and overlay it during future strokes. The intention is to aid the repetitive training of muscle memory, an important stage of kinesthetic learning, by each rower using a "target performance" recorded when under the supervision of a coach.

3. Evaluation methodology

Given that the system functions as intended and displays the expected feedback, the evaluation investigates any positive or negative effect its use has on the performance of rowers. This encompasses how important the combination of feedback mode and type are in a training tool that makes a difference to athletes' technique.

3.1. Performance metrics

To assess the abstract notion of level of technical ability for a stroke, four performance measures are proposed:

- Force – Area under the handle's force-time curve, representing the energy supplied to the ergometer.
- Efficiency – As above, normalized by the total kinetic energy of the rower estimated from the movements of the handle and seat.
- Approximated similarity to ideal performance using a metric based on the tempo-spatial similarity of a handle trajectory, a key component of the body motion.
- Consistency – As above, using the centroid of the set of strokes as an target performance.

3.2. Experimental method

Five amateur rowers were used with age range 25-41 years and experience ranging from 1½ to 12 years. Two professional expert coaches were used from the Great Britain rowing association. The method below was repeated for each rower, however to date only 2 rowers were able to complete steps 6-10 for logistical reasons.

1. Athlete familiarized with research, system and experiment
2. Athlete rows, making full use of ergometer and system, whilst coached by the experts until they are satisfied substantial progress has been made.
3. Current stroke is recorded as a representation of the athlete's personal target performance.
4. Athlete breaks for 30 minutes.
5. Expt. 1: Athlete instructed to row at comfortable rate using coached technique and 2 types of feedback in the given order:
    - 5.1. No feedback (blank screen)
    - 5.2. Full visual feedback (real-time data with overlaid target performance)
6. Athlete continued training as normal without access to system for 5 weeks.

7. Expt. 2: Athlete instructed to row at comfortable rate using coached technique and 3 types of feedback in the given order:
   7.1. No feedback (blank screen)
   7.2. Visual feedback (real-time data and no target performance)
   7.3. Full visual feedback (real-time data with overlaid target performance)
8. Expt. 3: Athlete instructed to row at race-pace using coached technique and 3 types of feedback in the given order:
   8.1. No feedback (blank screen)
   8.2. Visual feedback (real-time data and no target performance)
   8.3. Full visual feedback (real-time data with overlaid target performance)
9. Athlete rows for at least 2 minutes at high rate immediately after step 8, until they report they are fatigued.
10. Expt. 4: Athlete instructed to row at a comfortable rate but fatigued using coached technique and 3 types of feedback in the order given:
    10.1. No feedback (blank screen)
    10.2. Visual feedback (real-time data and no target performance)
    10.3. Full visual feedback (real-time data with overlaid target performance)

4. Discussion of results

4.1. Qualitative observational results

All users report via questionnaires that the system didn't obstruct their performance and were more confident they were performing technically well when feedback was provided, being able to apply their understanding of it that they had learned during the coaching session.

4.2. Quantitative study of the effect of feedback on performance measures

The results of the experiments are given in Table 1. Considering the experiment for each rower and type of rowing in turn, the average performance calculated by each metric over all strokes is shown for different types of feedback. A hypothesis is: "Increasing the amount of feedback available will improve the rower's performance.

The presence of feedback is shown to have some effect on the performance. Changes within 1 standard deviation (s..d.) are discounted, changes near 1 s.d. are considered evidence of slight effect. Over 1 s.d. is interpreted as significant support for/against the hypothesis. Change within a performance is not shown in Table 1. An interesting example is shown in Fig. 2 where rower 3's force curves' energy varies in accordance with the hypothesis, by deteriorating without feedback and visa versa.

Using feedback just after coaching seems to have little effect on all the performance metrics, some rowers slightly deteriorating with its addition, apart from rower 2 where it was significantly helpful for all metrics. After prolonged solo training, quite significant increase in force, efficiency and rower 4's similarity to the target performance are evident, especially when ideal performances are displayed. There is also a slight decrease in consistency when using the system, possibly due to the reminder of coached habits.

During race-paced rowing, a noticeable correlation exists between increased feedback available and similarity to target performance, with consistency increasing slightly. Surprisingly rower 4's race pace efficiency is much lower when a target is displayed than when just live feedback is present. At speed, any changes in technique would make a bigger difference; in this case perhaps the displayed target wasn't ideal or was off-putting.

During fatigued rowing, having more feedback also significantly improves similarity to a target performance and slightly improves consistency. Rower 4 also shows a slight increase in force and efficiency with target performance feedback available.

Table 1. Results for 4 experiments, 4 performance metrics, 2-5 rowers and 2-3 types of feedback (C1-3). The mean and standard deviation for the metrics over all the strokes of a session are given. Values are rounded to 3 significant figures. Some data was lost due to a sensor fault.

Expt	Metric	Rower 2			Rower 4		
		C1	C2	C3	C1	C2	C3
1	1	2660, 207		2840, 127	2980, 786		2754, 632
	2	289, 33		334, 31	268, 70.1		234, 37.9
	3	2.09, 0.44		1.56, 0.46	1.14, 0.35		1.56, 1.12
	4	0.47, 0.27		0.58, 0.28	0.70, 0.32		1.07, 1.34
2	1	2870, 613	3340, 1870	8350, 8860	2540, 134	2870, 951	2800, 643
	2	1890, 151	2040, 1090	4870, 5780	322, 20.6	321, 77.4	352, 61.1
	3	1.43, 0.32	1.38, 0.23	1.81, 1.15	3.55, 0.32	2.55, 1.66	1.59, 0.62
	4	0.71, 0.44	0.73, 0.30	1.28, 1.49	0.62, 0.19	1.79, 1.80	1.06, 0.43
3	1	no data	no data	no data	2670, 169	2610, 110	2520, 148
	2	no data	no data	no data	576, 45.2	589, 47.9	248, 19.2
	3	6.20, 0.46	5.45, 0.35	5.52, 0.30	6.25, 0.19	6.16, 0.25	6.11, 0.21
	4	1.09, 1.12	0.97, 0.47	0.80, 0.84	0.72, 0.39	0.81, 0.40	0.66, 0.29
4	1	no data	no data	no data	2390, 198	2440, 126	3110, 582
	2	no data	no data	no data	928, 106	928, 89	1268, 294
	3	2.24, 1.12	1.31, 0.28	1.12, 0.20	4.17, 0.57	3.54, 0.32	1.48, 0.55
	4	0.89, 1.45	0.69, 0.31	0.49, 0.26	0.93, 0.85	0.63, 0.32	1.29, 0.98

Expt	Metric	Rower 1			Rower 3			Rower 5		
		C1	C2	C3	C1	C2	C3	C1	C2	C3
1	1	3260, 91.0		3020, 177	2900, 87.4		2930, 104	21500, 38400		26600, 43600
	2	71.0, 4.00		65.0, 7.00	344, 23.1		328, 18.9	4220, 7485		5343, 8781
	3	2.75, 0.90		2.82, 0.60	1.48, 0.41		1.89, 0.39	1.00, 0.83		1.69, 0.51
	4	1.08, 0.72		0.75, 0.44	0.59, 0.38		0.53, 0.38	0.86, 0.82		0.81, 0.44

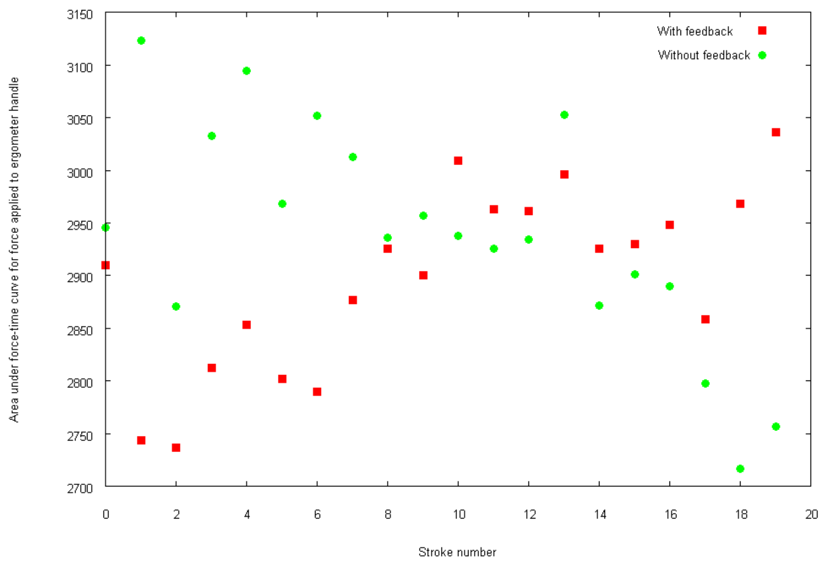


Fig. 2, Example of how the force performance metrics changes though a session from Expt 1 for rower 3.

5. Conclusion

An application was written using a sensor system that functioned as desired by providing real-time feedback on kinetics of a rowers performance when using an ergometer. Based on the small data set collected using the system, an amateur boat club and professional GB rowing coaches, the system is of some use in helping rowers to maintain a consistently good technique as described by a coach, especially when the athletes suffer from extended absence of their own coach or become fatigued.

6. Limitations and Further Work

Experiments are soon to be completed that address the limitations of this work, including the small dataset used to evaluate the system and the approximation of performance similarity. More athletes are continuing to participate in the data collection and an evaluation of the approximation of algorithms to a measure of overall rowing performance similarity is ongoing. Decomposition of feedback to evaluate different mechanisms such as haptic displays would also be interesting.

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References

[1] Iskandar, Gilbert, Wills. A Framework for Pedagogical Feedback in the Motor Skill Domain. The 9th IEEE International Conference on Advanced Learning Technologies 2009; 37-39.

[2] Erp J, Saturday I, Jansen C. Application of tactile displays in sports: where to, how and when to move. EuroHaptics 2006.

[3] Ruffaldi E, Sandoval-Gonzalez O, Filippeschi A, Frisoli A, Avizzano C, Bergamasco M. Integration of Multimodal Technologies for a Rowing Platform. IEEE International. Conference on Mechatronics 2009.

[4] Ruffaldi E, Filippeschi A, Frisoli A, Sandoval O, Alberto C, Massimo A, Bergamasco M. Vibrotactile Perception Assessment for a Rowing Training System. Third Joint Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems 2009; 350-355.