PRE-RECORDED SOUND FILE VERSUS HUMAN COACH: INVESTIGATING AUDITORY GUIDANCE EFFECTS ON ELITE ROWERS

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ABSTRACT

We report on an experiment in which nine Norwegian national team rowers (one female) were tested on a rowing ergometer in a motion capture lab. After the warm-up, all participants rowed in a neutral condition for three minutes, without any instructions. Then they rowed in two conditions (three minutes each), with a counterbalanced order: (1) a coaching condition, during which they received oral instructions from a national team coach, and (2) a sound condition, during which they listened to a pre-recorded sound file that was produced to promote good rowing technique. Performance was measured in terms of distance traveled, and subjective responses were measured via a questionnaire inquiring participants about how useful the two interventions were for rowing efficiency. The results showed no significant difference between the two conditions of main interest–the pre-recorded sound file and traditional coaching–on any measure. Our study indicates that auditory guidance can be a cost-efficient supplement to athletes' training, even at higher levels.

1. INTRODUCTION

Traditionally, verbal and visual instructions have dominated sports and exercise contexts. The last decades, however, have seen an increased interest in using auditory guidance. That is, nonverbal sound cues have been used to guide movements in various fields, such as sports [1]–[4] and rehabilitation [5]–[8]. In this paper, we describe a study in which we used a pre-recorded sound file with a rhythmic sound stimulus to guide the performance of rowers from the Norwegian national team.

The usefulness of auditory guidance has been demonstrated in studies using sound to model intended movement patterns [9], [10]. For example, Lai et al demonstrated that listening to a sound file with "beeps" in a regular pattern facilitated the participants' precision when later acting out the intended timing pattern on a computerized key-pressing task [9]. Both authentic and synthetic sounds have been used to promote learning and performance in sports. Wang and Hart let novice swimmers listen to recordings of a professional swimmer's butterfly strokes before starting their warm-up ahead of each practice [2]. This was done during a three-and-a-half-week training period. In addition, they followed a traditional coaching regime with visual demonstration and verbal instructions. On the last day of instruction, this group outperformed a control group (that received only traditional coaching during their training period) on several measures of performance and technique. Murgia et al. used a synthetic auditory stimulus, with increasing sound intensity, to help weightlifters during the different stages of bench press trials. The findings indicate that weightlifters exerted a greater degree of average power in this auditory condition than in a control condition with no auditory stimulation.

Overall, nonverbal sound emerges as a promising training tool, suited for contexts such as sports [3], [11]. Separate sounds, being part of a single sound file or auditory model, may be easily chunked and remembered as meaningful units of information [12]. Since many key actions in sports involve a series of complex movements performed in sequence, sound files containing "instruction chunks" for various parts of these movement sequences may provide an effective tool for learning and training. From an applied perspective, it is worth noting that auditory guidance can allow the coach to devote more attention to other tasks, such as observation. Auditory cues also liberate the athlete's vision, which is key to information processing in most sports.

Auditory guidance is generally under-researched compared to research on verbal or visual instructions. Even more scarce is research on how auditory interventions affect expert performers [6]. On the one hand, a shortage of research on expert athletes could be expected since they are, by definition, more distinguished and less common than athletes at lower levels. Nevertheless, research on how elite athletes respond to auditory instructions seems fruitful for several reasons. Experts have more advanced mental representations

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of skills than novices [13], and skill level seems to influence how different task conditions affect performance [14]. Second, experts seem able to recruit motor areas of the brain when listening to action-related sounds [15], and efficiently exploit movement-related information from various stimuli [16]–[20]. They may thus react differently to auditory instructions than novices. Third, while an increasing amount of knowledge has been gathered on the differences between experts and novices, less is known about differences at the expert level. For example, what are the differences between Olympic medalists and less successful international competitors? Since the stakes are high at the elite level, it seems valuable to investigate elite performers' responses to interventions, such as auditory guidance, that may improve their chances of success.

In the present study, the aim was to investigate the effects of auditory guidance on elite athletes, a group of rowers representing the Norwegian national rowing team (Team Norway). Our main, objective measure of performance was distance traveled on the rowing ergometer. However, we also composed a self-made questionnaire to give our participants an opportunity to express opinions, especially on how they compared guidance from a sound file versus a coach, beyond the mere ergometer output in the three-minute trials. Hence, subjective and objective responses to the auditory guidance condition were gathered and compared to a traditional coaching approach, namely a condition in which a national team coach provided verbal instructions. A "neutral" condition with no instruction or guidance was also included, giving us a total of three conditions. We expected both auditory guidance and traditional coaching to promote better performance than the neutral condition, since both forms of instruction have support in the literature. As for the main comparison of interest, the sound file versus the coach, we did not form any hypothesis. Even though this paper has mostly focused on the potential benefits of auditory guidance, traditional human coaching offers benefits (e.g., the ability to adapt instructions to the individual's current performance, verbal praise, confidence-boosting, etc.) that the pre-recorded sound cannot match. In sum, we took an exploratory approach to see the effects of these two forms of instruction.

2. METHOD

2.1. Participants

The Team Norway head coach invited ten available rowers to participate in our study. Nine rowers (eight male, one female) made up our final sample. The age range was 20-29 (M = 24.00, SD = 3.43).

The recruited rowers had heterogeneous performance standards. Distinguishing between different expertise levels is a demanding yet important task for researchers studying high achievers. To distinguish between different levels of "eliteness", Swann et al. suggest emphasizing athletes' performance standards (e.g., the highest level of participation) and achievements, with years of experience having secondary importance [21]. Hence, we first gathered information related to the rowers' highest level of participation and prior achievements. Then, based on our interpretation of Swann et al.'s taxonomy, we divided our participants into three levels of expertise:

- Two rowers were defined as *semi-elites*. Both had represented Team Norway in the under-23 world championships without winning a medal. They had not participated in major international competitions for senior rowers.
- Four rowers were *competitive-elites*. All four had participated in the World Cup and World Championships at the senior level, and three of them had won a medal in a World Cup competition.
- Three rowers were *successful-elites*. All three had competed multiple times in the World Cup, seniors' World Championships, and Olympic Games, and all were medalists in these competitions.

2.2. Task and Apparatus

Participants rowed individually on a Concept 2 Model D rowing ergometer in the fourMs motion capture laboratory at the University of Oslo. Our study was twofold, as we intended to gather both ergometer data and technical data regarding the rowers' movements in space. Distance traveled, measured by the rowed number of meters, was gathered from the rowing ergometer. Motion capture was performed with an optical, infrared, marker-based motion capture system from Qualisys. The participants wore a motion capture jacket with reflective markers during the experiment trials and had markers placed on some of the lower body joints. Parts of the motion capture results have been presented elsewhere [22]. In this paper, we will primarily focus on the ergometer data, mainly the distance traveled, along with questionnaire responses. Motion capture data will only be used to provide a measure of stroke rates during rowing (see the next section).

2.3. Procedure

Before beginning the experiment, the participants signed an informed consent form and warmed up using a Concept 2 rowing ergometer for as long as they preferred. After the warm-up, each rower was introduced to the lab setting and given general instructions. They were instructed to row with a rate of 26 strokes per minute in an efficient and technically sound manner. We chose 26 strokes per minute as the intended rate since this was a pace Team Norway emphasized during this particular training period. Additionally, a consistent stroke rate was beneficial for comparing the distance traveled in the three conditions. The participants had a monitor on the ergometer in front of them, with information about their current stroke rate. Before starting the experiment trials, participants were allowed to adjust the drag factor (resistance) in order to use the ergometer with their individually preferred settings in all conditions.

Each participant started in a neutral condition. Hence, participants initially rowed for three minutes without any further instructions. The order of the following two conditions (coaching and sound file conditions) was counterbalanced since these were the main conditions of interest. Between each condition, all participants took a short break of their own choice. Participants used slightly different break lengths, but we estimate that these did not vary by more than 60 seconds. We assume that slight variations in break lengths had little, if any, impact on participants' performance, due to their fitness level.

In the coaching condition, participants rowed for three minutes while receiving instructions from a Team Norway coach. This coach had worked more closely with some rowers than others, but he was familiar with all participants in the study. He was instructed to emphasize a particular aspect of the rowing technique—the "rock-over" movement that occurs in the recovery phase—but this will not be discussed in this paper. More generally, he was also instructed to coach in a manner that promoted efficient and technically well-executed rowing. A final coaching constraint was to keep a minimum distance of one meter to the rowing ergometer to not interfere with the motion capture recordings.

Annotations of the recordings show that the coach made, on average, 40 (*SD* = 5) instructional cues per rower/trial. It was out of the current scope to perform a detailed analysis of the coach's comments. However, the first author made a gross estimate by listening to the sound in the video recordings twice while taking notes on the frequency and content of instructions. The number of instructions listed was based on the average from the two note takings. Two factors made precise transcriptions and quantification difficult. First, the noise from the ergometer fan rendered some short and quiet coaching instructions inaudible. Second, it is challenging to determine which words are part of the same sentence/cue, and when a new sentence/cue begins. For our purposes, however, the current process was deemed sufficient to provide an indication of the coaching used in our study. As for the instructional content, all rowers received praise (e.g., “Good job”) and verbal technical cues (e.g., “For the next 30 seconds, we will mark the rock-over”). Other coaching techniques were also used, including vignettes/scenarios (e.g., “You are in the boat with [name]”) and nonverbal sound effects (e.g., “Schoop”). According to our estimates, the latter coaching techniques were applied unevenly across rowers. In sum, we observe that all rowers received a notable amount of instruction during the coaching condition, although it varied in terms of quantity and content. Such variability is a consequence of the fact that we left the coach with the freedom to deliver feedback in an individualized and ecologically valid manner. Although the coach had worked with some rowers more than others, we further assume that all rowers were capable of utilizing the coaching instructions, due to the skill level of both the coach and participants.

In the sound file condition, the rowers used a pair of studio-quality AKG headphones. The sound level was adjusted to be comfortably loud so that participants could hear details in the sound. When the trial started, they rowed for three minutes while listening to a custom-made sound file. All participants rowed to the exact same sound file, consisting of a short, looped sample (see Figure 1). The sample was constructed of a combination of recorded and synthetic sound. The recorded sounds were of rowing activities: naturalistic sounds of rowing with a boat on water and sounds of ergometer rowing. The synthetic sounds were selected from Kontakt 5’s “Rise and Hit” sound library. All sounds were chosen to represent elements of the rowing stroke cycle in order to guide the rower’s movements. In the process of creating the sound file, the sound designer had performed a pilot test during a training session with a Team Norway rower (who did not participate in our study) before the present experiment. In this pilot session, the rower rowed to an earlier version of the sound file on an ergometer. The feedback from this rower was used to make adjustments to the sounds. This pilot rower was chosen to aid in creating the sound file because of his technique and timing skills, deemed superior by the Team Norway head coach. The final sound file (available at http://www.henrikh.no/suppl_icad_22) was intended to promote a certain timing and rowing technique pattern as demonstrated by the pilot rower, including the rock-over movement, thus facilitating efficient rowing.

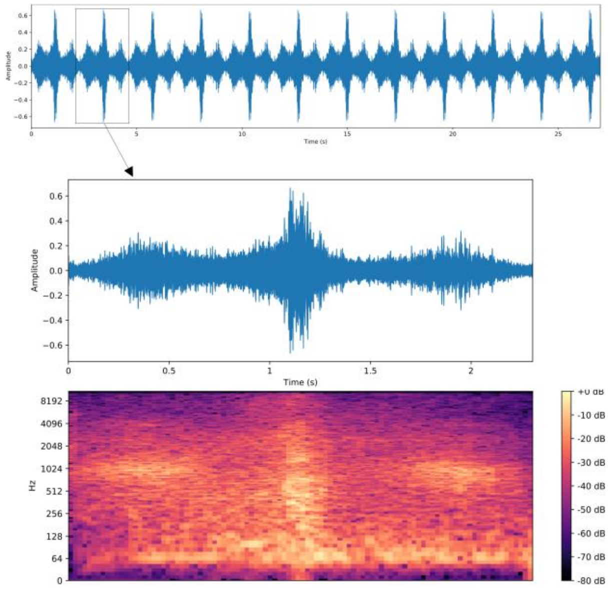

Figure 1: Waveform plot (top) of the sound file used in the experiment. This sound file was made by looping a 2-second sound file. The waveform (middle) and spectrogram (bottom) of this short sound file reveal the symmetric nature of the sound design, centered around the peak between the drive and recovery phases. Ultimately, the complete sound file provides the rower with a rhythmic figure and a clear pulse to guide the rowing technique.

After completing the three rowing conditions of the experiment, each rower filled out a questionnaire. This included questions about basic demographics and about the session. We also asked, on a scale from 1 (to a very little extent) to 5 (to a very large extent), how the participants found the coaching and sound file with regards to (a) rowing in a technically sound manner; (b) rowing in an efficient and relaxed manner (without expending unnecessary effort).

At the end of the session, a short debriefing was given by one of the project collaborators. Figure 2 summarizes our setup, key equipment, and sound in various conditions.

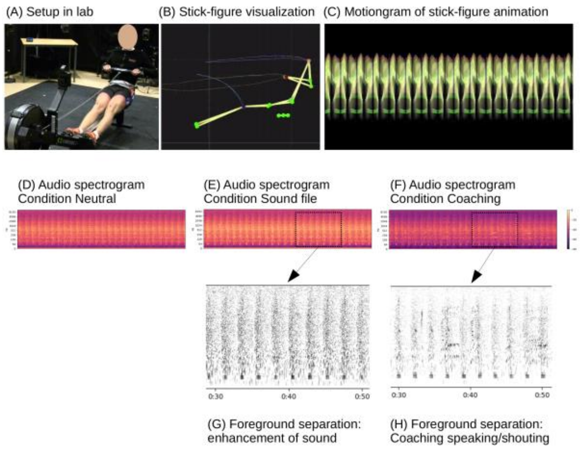

Figure 2: Illustration of (A) the ergometer in the lab, with a rower wearing a motion capture jacket and reflective markers on the lower body, (B) a screenshot of a stick figure created from the markers, as well as trajectories of the motion, (C) a motiongram of a 30s segment showing the regularity of the rowing, (D) the spectrogram of the neutral condition showing the rhythmic pattern in the noise of the ergometer, which can also be considered as the "background" noise of the sound file (E) and coaching (F) conditions. Removing the background

noise from these conditions, revealed the rhythmic regularity of the sound file (G) and irregularity of the coaching (H) conditions.

2.4. Analysis

We conducted a one-way repeated measures ANOVA to compare the distance traveled in the three different conditions. A paired samples t-test was used to compare subjective responses to the coaching and sound conditions, respectively. We also investigated descriptive statistics of average stroke rates, as a manipulation check to see if they stayed close to the target of 26 strokes per minute.

3. RESULTS

The average stroke rates for the three conditions (neutral, coaching, and sound file), excluding the first five strokes in each trial, were 25.91 (SD = 0.58), 26.21 (SD = 0.46), and 26.00 (SD = 0.02), respectively. This confirms that the stroke rates were consistent between conditions and, unsurprisingly, that stroke rates were the most consistent (in absolute and descriptive terms) in the sound condition.

A repeated measures ANOVA with Greenhouse-Geisser correction for sphericity revealed no significant effect of condition, F = 1.834, p = .210, $\eta p2$ = .186. Descriptively, distance traveled was greater in the coaching condition (M = 875.6 m) than the neutral (M = 855.0 m) and the auditory guidance condition (M = 858.4 m).

Figure 3 displays the variability in distance traveled across participants. All participants rowed further in the coaching condition than in the neutral condition. As for the sound file condition, the semi-elites and competitive elites rowed slightly further or similar distances as compared to their coaching condition performance, respectively. The successful elite rowers displayed a notable drop in distance traveled when rowing with auditory guidance. There was especially one successful elite subject that exemplified this pattern, as shown in Figure 3, by rowing notably shorter in the sound condition (806 m) than in the coaching condition (921 m). We suspected that this could be an outlier and conducted one more repeated measures ANOVA with this subject removed from the sample.

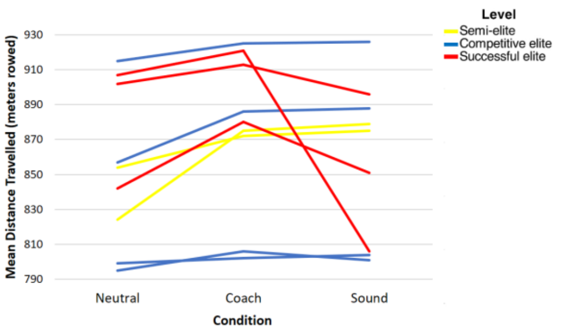

Figure 3. Distance traveled across individuals (from different elite levels) and conditions.

The new results, based on eight participants, suggested no sphericity and a significant effect of condition, F = 7.732, p = .005, $\eta p2$ = .525. Pairwise comparisons with Bonferroni correction suggested that the distance traveled was significantly greater (p = .024) in the coaching condition (M = 869.9 m) than in the neutral condition (M = 848.5 m), while the sound condition (M = 865.0 m) was not significantly different from the other two.

As for the rowers' subjective responses, paired samples t-test revealed no significant difference (p > .05) between how useful the coaching (M = 3.89) and sound file (M = 3.33) was rated, on a scale from 1 to 5, for rowing *technically sound*. Nor did ratings significantly differ when it came to the usefulness of the interventions for rowing *efficiently and relaxed* between the coaching (M = 4.11) and sound (M = 3.56) conditions. Yet, as indicated in Table 1, once again individual variability was evident.

Table 1: Subjective ratings of how useful the coaching (C) and sound (S) interventions were for rowing (a) technically well-executed, (b) efficiently and relaxed – on a scale of 1 to 5.

ID	**Elite level**	**Technique**		**Efficiency**	
		C	S	C	S
1	Semi-elite	4	3	4	3
2	Semi-elite	4	4	5	4
3	Competitive elite	2	3	3	5
4	Competitive elite	5	5	5	5
5	Competitive elite	4	5	3	4
6	Competitive elite	4	4	3	4
7	Successful elite	4	2	5	2
8	Successful elite	4	2	4	3
9	Successful elite	4	2	5	2

4. DISCUSSION

In this study, we explored the effect of using a pre-recorded sound file to promote motor performance, as compared to a more traditional coaching condition (with a human coach providing individualized instruction) and a neutral condition with no external guidance. As compared to the neutral condition, only the coaching condition was able to produce significantly greater performance, as measured by the distance traveled on the rowing ergometer. However, a closer look at our findings reveals interesting aspects related to the sound file condition. First, the coaching and sound file conditions produced results that were not significantly different in terms of distance traveled and subjective ratings. Second, a descriptive, case-by-case consideration of our sample revealed substantial individual differences in how the sound intervention was received and the results it produced.

One major difference between the two conditions was that the coaching intervention was individualized while the sound file was similar for all. This may be particularly important at the highest performance levels. As a person gets more skilled, mental representations of the skill get more refined [23], [24] and the potential benefits of one-size-fits-all interventions appear to diminish. For example, previous studies have investigated the effects of listening to experimenter-selected music while running. Results from these studies suggest that music improved affect [25] and reduced the perceived rate of exertion [26] to a greater extent in untrained individuals than in trained individuals. Our study was limited by the lack of individual sound file adaptation and that participants were not given a chance to become familiar with the sound file ahead of the trial. This allowed for controlled and equal conditions for all, but we suspect that individual adaptation could have promoted a more positive effect from the sound file intervention across participants. A familiarization period, for example a practice session with the soundtrack, is something to consider in future auditory intervention studies.

The current study explored the use of an auditory guide, that is, a pre-recorded sound file made for improving performance. A different, yet related approach would be to use interactive sonification based on converting movement data into sound. As opposed to our study, where we used sound to indicate how the performer *should* move, sonification indicates how the performer *actually* moves. Interestingly, sonification has been used to improve performance in rowing more often than most other sports [4], [27]-[30]. For example, Schaffert et al. have developed *Sofirow*, a system for sonification based on boat acceleration [4]. As the boat acceleration increases or decreases, rowers can hear changes in the sound through speakers or headphones. Both performance data and subjective responses from German junior national team rowers suggest that Sofirow is a viable sonification tool. One reason for its utility might lie in the fact that sonification offers feedback about how an individual or team actually performs, which allows performers to make self-organized and individual adjustments [31], as opposed to providing information about a (one-size-fits-all) model for how to perform.

The most significant limitation of this study is the modest sample size. This is common in research on experts, but it nonetheless calls for caution when generalizing findings. Statistical analyses were limited but nonetheless included in our study as we considered it informative to get an estimate of effect sizes (beyond mere descriptive statistics).

Further, our study involved conditions that may have affected the rowers' ability to benefit from both verbal and nonverbal instructions. First, we instructed them to row at the rate of 26 strokes per minute. This encourages a high intensity level, at which the rowers' cognitive capacity for interpreting information regarding technique might be hampered compared to rowing at lower intensity levels [32]. Second, we used a single coach who had worked with certain participants more than others. We cannot rule out the possibility that certain rowers would have benefited more if they had been instructed by their regular coach in the coaching condition. In future studies, it may also be considered to use more standardized coaching instructions. As for the sound intervention, we used headphones which may have interfered with perception of naturalistic sounds from the rowing ergometer. Speakers might therefore be a preferred option in future studies [4]. Finally, questionnaires always involve a chance of participants giving ratings that do not reflect their true opinions. In our case, participants might have been positive towards both the verbal instructions and the sound file as a form of "politeness" towards the coach and the sound file composer working with the national team at the time of this study.

5. CONCLUSION

In this study, we compared elite rowers' distance traveled on an ergometer and subjective response to conditions involving a pre-recorded sound file, regular coaching, and no instructions. The sound and coaching conditions produced similar results, and our findings showed clear differences in terms of rowing distances and subjective responses between individuals. We conclude that individual differences appear prominent and important, even within a pool of elite athletes. Further, considering its cost-benefit, auditory guidance may hold promise as a coaching tool, especially if individual differences and self-organization are accounted for to a larger extent than what was the case in our study. We call for more research on elite athletes and auditory guidance to provide further insight into these topics.

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