Effects of auditory feedback on manual control in a balancing task

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Introduction — Background

Auditory perception of information about objects and processes in our surroundings from sounds they emit has been recognised as an important aspect in psychoacoustic research. [1][2] E.g., one may ask if certain types of ecological information, such as force attributes or velocities, are particularly well perceived auditorilly as compared to vision or other senses. Most existing studies in this context deal with information occurring in discrete classes such as material [3] or interaction type [4] or anyway being perceived from discrete (mostly short) auditory events (e.g. [5]). The work described here in contrast is motivated by the interest in continuous flows of information in continuous perception–action loops. One general aspect is here that such mechanisms of perception may happen unconsciously and therefore be difficult or impossible to assess by methods relying on conscious responds or "self-evaluation" of test subjects. While again most conventional psychoacoustic examinations are based on tools such as questionnaires or rating or scaling tasks, one central idea of the present work lies in measurement of motor responses on perceptual stimuli. This approach may allow conclusions on perceptual mechanisms that happen without conscious awareness of the test subject and can thus not be assessed by many other approaches.

This contribution gives a rough overview over two studies and the underlying interface and ideas; for details we refer to more extended dedicated papers [6][7][8].

The *Ballancer* interface

The *Ballancer* is a tangible audio–visual interface developed with the aim of examining mechanisms of human perception and motor control. It is based on the metaphor of balancing a ball rolling along a tilt-able track. The device is handled by the user as if balancing a small marble on top of a 1-m long wooden track whereby feedback about the movement of the virtual ball can be given through different types of visual and/or auditory feedback; figure 1 shows a photo. Details of the construction of the *Ballancer* interface and underlying theoretical thoughts can be found in [6].

Experiments and results

Several experiments have been conducted at the *Ballancer* interface with the scope of examining and assessing perceptual mechanisms in balancing control. All studies deal with a target reaching task where test subjects are asked to move the controlled ball (by balancing) into a graphically marked target area and stopping it inside here (compare figure 1).

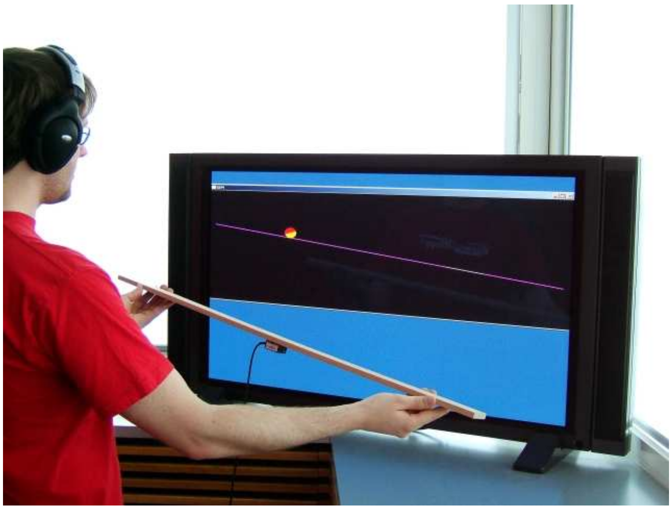

Figure 1: *The* Ballancer *in the configuration with a wide-screen display spanning the whole size of the 1*–m *physical control stick.*

In an initial study [6][7] with the scope of exploring the potential of a sound model of the rolling [9] to support such interaction of balancing–target reaching, subjects performed at displays of 4 different sizes and the target area was marked acoustically through a different, rougher surface structure. It was here found that average task performance was significantly faster with acoustic feedback than without, *at all display sizes*, with the effect getting stronger for smaller displays. When analysing further the movement trajectories during task performance in order to examine further mechanisms connected to the noted faster performance, significant differences were also found in average values of characteristic indices such as the velocity of the ball when entering the target area. Details of the study are given in dedicated articles [6][7].

The cited effects found in the initial study gave rise to the hypothesis that the improvement of task performance with sound feedback is based on auditory perception of the virtual ball's velocity. In this study sound feedback however also contained rough positional information by means of the changing surface structure and through amplitude panning. In order to test the noted hypothesis of auditory velocity perception and its relevance for control behaviour another study was conducted in which the sonic feedback reflects *only* the momentary velocity of the ball and does *not* depend on its position in any way. Furthermore the interface is here presented with somewhat "ideal" visual conditions by means of a large-screen display spanning the whole range of the physical control stick, i.e. about the range of the subject's arms and visual field. More notable, this study also addresses the question of a potential of "abstract" sonic feedback with no resemblance to rolling sounds. Another point of interest were the comparative effects of these two different types of sonic feedback, "rolling sound" vs. "abstract", on task performance and training behaviour. It was again found that sonic feedback leads to faster average performance thus proving the hypothesis of auditory velocity perception to be true and relevant for human motor control. In these performance improvements a cross-dependence between the type of sound feedback and training phase was seen. Figure 2 and table 1 show these effects. Roughly summing up the overall development of average task performance it can be said that untrained subjects were initially fastest with feedback from the rolling model while after one round of training the abstract sound feedback turned out to lead to fastest average performance. Again details can be found in a dedicated article [8].

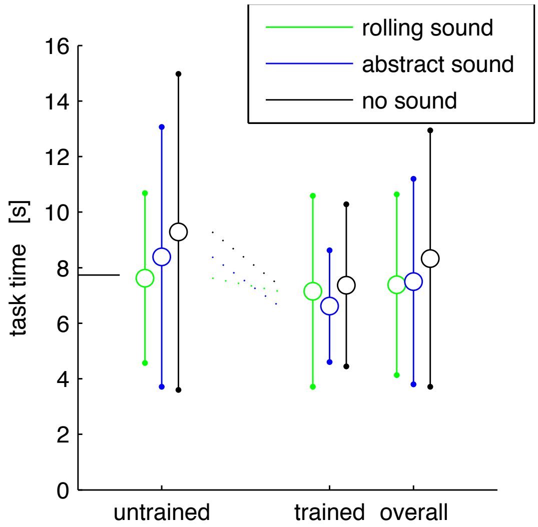

Figure 2: *Average* task times *(in* s*) across all subjects, under the different conditions of auditory feedback, over the "untrained" and "trained", and over all ("overall") games.*

Relative differences of *task times*, statistic significance				
	"untrained"		"trained"	
	as	*no*	*as*	*no*
rs δ(%)	−9.1	−17.9	8.1	−3
p	0.1345	0.0052	0.1414	0.5977
as δ(%)		−9.7		−10.2
p		0.1825		0.0206

Table 1: *Differences in average* task times *(in %) under the different conditions in the untrained and trained set. Below each difference value the according statistical significance, p, is given.*

Conclusions

Experiments with a virtual rolling ball under different conditions of visual and auditory feedback show that subjects' average control performance may improve through sound feedback. Optimisation of control movements can be ascribed to information of velocity of the controlled ball being perceived from sound feedback. This process of perception and exploitation of auditory velocity information may be even stronger with suitably designed abstract sound feedback without resemblance to a "natural" sound of rolling. An according experiment however supports the assumption that abstraction of sonic feedback may have a suppressive effect on the training curve.

References

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