MusicJacket: The efficacy of real-time vibro-tactile feedback for learning to play the violin

Rose Johnson
Computing Department,
The Open University,
Milton Keynes, UK. MK7 6AA
r.m.g.johnson@open.ac.uk

Janet van der Linden
Computing Department,
The Open University,
Milton Keynes, UK. MK7 6AA
j.vanderlinden@open.ac.uk

Yvonne Rogers
Computing Department,
The Open University,
Milton Keynes, UK. MK7 6AA
y.rogers@open.ac.uk

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Abstract
This research investigates the potential for vibrotactile feedback to enhance motor learning in the context of playing the violin. A prototype has been built which delivers vibrotactile feedback to the arms to indicate to a novice player how to correctly hold the violin and how to bow in a straight manner. This prototype was tested in a pilot user study with four complete beginners. Observations showed improvements in three of the four players whilst receiving the feedback. We also discuss the pros and cons of using negative feedback to enhance learning.

Keywords
Vibrotactile Feedback, Wearable Computing, Violin teaching, Motion Capture, Haptics.

ACM Classification Keywords
H.5.2 Haptic I/O; Prototyping.

General Terms
Design, Experimentation, Human Factors.

Introduction
Recently, wearable technology has been developed to determine whether it can increase awareness and aid correction of mistakes in a person's posture or body movement for various sports. In particular, the

potential of vibrotactile feedback to enhance motor learning has been shown in a number of user studies [3, 5, 7]. Spelmezan et al. [6] used patterns of vibrations across the body to indicate to participants different actions to take whilst snowboarding, reporting faster reaction times than the same instructions given verbally; Lieberman and Breazeal [5] showed that the addition of vibrotactile feedback improved participants' abilities to mimic the joint angles of a moving arm shown on screen; and Bloomfield and Badler [3] employed vibrotactile feedback to teach aspects of karate and found that participants improved significantly after receiving vibrotactile feedback.

We have developed the MusicJacket as an aid for teaching the violin [8]. It currently focuses on encouraging straight bowing by using real-time vibrotactile feedback to guide the hands. Bowing is a complex skill and it has been shown that it takes in excess of 700 practice hours to achieve a basic mastery of the motor skills involved [4]. Our goal is to see if we can enable novices to learn faster and to keep motivated. Here, we describe an initial user study assessing the MusicJacket with four complete beginners learning the violin. Experimental observations, user reflections and quantitative data from a motion capture suit [7] were collected to investigate its effects upon their playing, motivation and comfort. Here we present the qualitative data in order to examine the human response to learning with such a device.

The prototype

A detailed description of the MusicJacket prototype is given in [7, 8]. It consists of two parts: motion capture and feedback. The position of the limbs of the upper body is measured using Animazoo [1] a wearable motion capture jacket which wirelessly communicates with the computer. The vibrotactile feedback is delivered by small vibrators similar to those found in mobile phones. These are wired to an Arduino [2] which interfaces with the computer via USB.

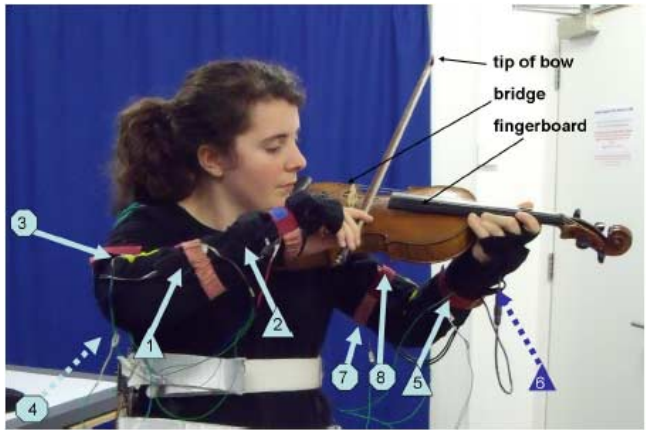

Figure 1. One of the participants wearing the prototype. The labeled vibrators positioned on the arms are: (1) move hand away from body, (2) move hand towards the body, (3) move hand down, (4) move hand up, (5) move hand left, (6) move hand right, (7) and hand up and (8) move hand down

The deviation of the position of each hand with respect to an ideal is calculated and feedback is delivered accordingly. The ideal is recorded at the start of each use. The ideal position for the left hand is given by holding the violin under instruction from a teacher. To input the ideal trajectory for the right hand an assistant holds the bow on the string and the pupil runs their hand along the bow. A straight line is fitted to this which is the ideal path for the bowing hand. The line is

drawn in the violin reference frame so that if the violin moves the ideal trajectory for the bow will move with it.

The feedback is given in sets of opposable pairs, two for each hand. Vibrators are positioned using the push metaphor (see Fig. 1) so that the user should move their hand away from the vibrations.

Method

An initial user study was run with four beginners (see Table 1). None had ever played the violin before but some did play other musical instruments. Some participants knew about the MusicJacket project prior to the study and some had already taken part in other studies involving vibrotactile feedback.

Participant	**A**	**B**	**C**	**D**
Age	20's	30's	50's	Teens
Musical experience?	Little	Some	Lots	Lots
Taken part in other vibrotactile studies?	Yes	Yes	No	No
Prior knowledge of the project?	Lots	Lots	None	Little
Speed of learning to understand feedback.	✔ ✔ ✔	✔ ✔ ✔	✔	✔ ✔
Improvement in bowing in sessions.	✔ ✔ ✔	✔ ✔	✔	✔ ✔

Table 1. A summary of the participants and their reactions to the feedback.

Participants received initial lessons, lasting 40 minutes without wearing the MusicJacket. They were taught how to hold the violin and bow and some simple bowing exercises on the D string. Over the following days they all wore the MusicJacket and received vibrotactile feedback for two sessions each approximately 30 minutes long. During these sessions the participants were encouraged to play the bowing exercises taught to them previously. This removed some of their focus from the feedback and challenged them to use more of the length of the bow. At the end of the second feedback session they were also requested to play the exercises without any feedback.

During the feedback session, changes in the participants bowing and violin hold were observed by experienced violin players. They were also encouraged informally to describe their experiences whilst wearing the MusicJacket and their opinions about its effectiveness. Most of the sessions were also videoed.

Observations

The learning experiences of each participant were found to be quite different, depending on their 'profile' and are presented individually below.

Participant A found it difficult to achieve straight bowing during the initial lessons. She has a petite build which meant she needed to extend her elbow further than feels natural as she reached the tip of the bow to keep the bow straight. However, she was always inclined to move from the shoulder and keep her elbow bent which causes the bow to move in a curve rather than a straight line. She also wanted it to be noted that she is a "very tense person" which would contribute to the elbow remaining bent. The effect of the feedback on A was substantial. Within a few minutes of receiving the feedback she began to extend her elbow much further. As well as this she began to evaluate her own weaknesses using the feedback, for example, she saw that it was always at the tip of the bow where she had most difficulty keeping the bow straight.

In the second feedback session A remembered clearly the need to extend the elbow and therefore began the session playing much straighter than she had at the start of the first session. When she received vibrations on the lower arm she tried to extend her arm further and was confused when this did not stop the vibrations. In fact the vibrations were actually indicating that she needed to move her hand back and extend her arm less. Her confusion could have been partly due to the vibrator being repositioned between the two sessions to aid comfort. Once she realised her mistake she found it easy to find the trajectory where she felt no feedback. "I'm fixing it immediately now" she pointed out with satisfaction. She described the vibration as "annoying and you want to make it stop but it definitely works" Towards the end of the first session she commented on how her lower arm felt "itchy" and "weird".

Participant B In the initial lessons B learned to hold and bow the violin quickly. He looked at where his bow met the strings and monitored this as he bowed resulting in very straight bow strokes from the beginning. In his first feedback session B received less exacting feedback than A due to a mistake in the calibration of the motion capture suit. This meant he could deviate further from the ideal trajectory without getting feedback. During this session he reported receiving feedback at the start of exercises then as he adapted himself to a straighter path the feedback would stop and would not return for the rest of the exercise. He said he did not feel conscious of the opposable pairs pushing him to the correct place, more that getting feedback "focuses attention that it's not right" and that he already had an idea of where it ought to be. He felt that having the vibrotactile feedback meant that he could shift his gaze from the bow and look around more which would be a useful outcome for learners playing from sheet music.

In the second feedback session B received more precise feedback. When he bowed on the lower half of the bow he was over extending his arm, but once the feedback was introduced he quickly brought his hand back to the correct position. When he bowed near the tip the opposite was true and once the feedback implemented he brought his hand forward. In one of the exercises he also began to talk more about being "pushed" in either direction by the feedback as he over compensated, showing the concept of opposable pairs was beginning to come into play. Once feedback was removed there was a tendency for bowing to become more rounded. Similar to A, when asked about the sensation of the vibrations he described them as "annoying - there is a strong motivation to make them stop."

Participant C Part of C's motivation for taking part in the study was the chance to learn to play the violin. In the lessons his bowing was inconsistent because he was experimenting to see how the sound changed as he bowed differently. Throughout the sessions his arms were tense and his bowing seemed quite uncontrolled as a result. He found it difficult to know how to react to the feedback and was not always certain which vibrator was going off. He felt he would like some time away from the violin to learn how to react to the vibrations because "it's not intuitive". Towards the end of the first session he did not feel that he was giving the feedback any attention at all because he was concentrating on "getting the bow to work to make the sound".

In the second session the feedback delivered was unhelpful due to a number of technical problems with the prototype. C commented on how the vibrations were not giving him sensible information. So although he had begun to understand the feedback much more, he lost faith in the system because it led him onto a bad trajectory. In both sessions he was most interested in the sound of the violin and it was with this that he monitored his success and motivated himself. This may be because he comes from a very musical background. In contrast to A and B, C never complained about the sensation of the vibrators as being uncomfortable. At the end of the second session he happened to see a recording of himself playing on screen from the motion capture system and suggested this might be more useful to see this in real time whilst learning rather than having the vibrotactile feedback.

Participant *D* learned quickly in the lesson and measurement sessions. Before the feedback commenced she could already bow with quite a straight trajectory when she was focused. She received three shorter feedback sessions because she found playing tiring. In the first feedback session, she found it difficult to understand what the feedback was telling her and it took conscious effort to work it out. In the second session she began to understand better and was able to practise all the exercises with feedback. By the end of the second session her posture holding the violin was lopsided and looked uncomfortable. This may have been caused by her reactions to the feedback.

In her last feedback session, D understood the feedback much better and her bowing began to improve. She began to extend her arm slightly more towards the tip. When she found the trajectory which gave no feedback a sense of achievement could be seen in her facial expression. She saw the lack of vibrations as a measure of how well she was playing. After managing to play with no feedback she exclaimed slightly jokingly "I was doing it perfectly!" Once feedback was removed she had a tendency to revert back to rounded bowing. D described the vibrations as "tickly". She was more concerned about the discomfort caused by fatigue from playing than the vibrations.

Discussion and conclusions

Participants A, B and D all showed clear improvement in response to the vibrotactile feedback. In the case of A it improved her bowing considerably and this improvement was still apparent four days after the last feedback session. There is much promise in using vibrotactile feedback to steer and correct learners' body movement. In this context the feedback is a negative indicator – something a player should try to eliminate to achieve good technique. In this situation there is the danger that once the negative feedback is removed players are given the sense that they are not making mistakes. Moreover, they may not be used to monitoring their playing by listening to the sound. A scaffolded approach to gradually remove feedback may overcome this. Also in a longer trial the players might have a chance to develop muscle memory so that the straight bowing path would become the natural way they played. Another risk of the negative feedback approach could be a discouraging learning experience because players may feel like they are always being 'told off'. However, A, B and D all expressed a sense of achievement when they were able to play with minimal feedback and were able to see their progress through the feedback. This indicates a satisfying learning experience. For C the experience was not so satisfying

because the system did not allow him to experiment with the bow to change the sound. Perhaps just as a teacher might adapt their teaching to match the needs of the student, the MusicJacket could offer some degree of customisability, with an option of positive feedback, using another modality (e.g. visual).

Our initial findings show that learning to understand the vibrotactile feedback is a key variable which affects the user experience of playing. For most participants the sensation of the vibrations was "annoying"; thus user experience is governed greatly by the ability of the user to control the feedback. Control comes from knowing the correct movements to make it stop. Reacting to the feedback with the wrong movement can cause players to contort themselves into awkward positions causing fatigue and making their playing worse. A and B understood the feedback quickly, perhaps due to their prior knowledge of the project and their previous experiences of vibrotactile feedback. Knowing what the feedback was telling them led to an improvement in bowing which in turn led to a sense of achievement. For example, D was much more positive about the system in the third session as her understanding of the feedback grew, which also led to improvement in her playing and a sense of achievement.

Our future plan is to trial the MusicJacket with children learning the violin, to determine if they are more responsive to this kind of feedback. We are also investigating how other aspects of playing the violin can be augmented using wearable technologies, such as how to reduce tension in the shoulders and neck or improving the bow hold. For this, we will explore other forms of feedback such as musical accompaniments, temperature actuators and visual metaphors.

In sum, our initial findings have shown how the 'negative feedback' approach using vibrotactile feedback is promising but that there are concerns about comfort, annoyance and possible dependency. An ideal training suit might be one that combines both negative and positive feedback, using various modalities.

Acknowledgements

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