The Haptic iPod: passive learning of multi-limb rhythm skills

Anders Bouwer
ISLA, Faculty of Science
University of Amsterdam
andersbouwer@uva.nl

Mat Dalgleish
Department of Music, SSPAL
University of Wolverhampton
m.dalgleish2@wlv.ac.uk

Simon Holland
Music Computing Lab
The Open University, Milton Keynes
s.holland@open.ac.uk

Recent experiments showed that the use of haptic vibrotactile devices can support the learning of multi-limb rhythms [Holland et al., 2010]. These experiments centred on a tool called the Haptic Drum Kit, which uses vibrotactiles attached to wrists and ankles, together with a computer system that controls them, and a midi drum kit. The system uses haptic signals in real time, relying on human entrainment mechanisms [Clayton, Sager and Will, 2004] rather than stimulus response, to support the user in playing multi-limbed rhythms. In the present paper, we give a preliminary report on a new experiment, that aims to examine whether *passive* learning of multi-limb rhythms can occur through the silent playback of rhythmic stimuli via haptics when the subject is focusing on other tasks. The prototype system used for this new experiment is referred to as the Haptic iPod.

Haptic interfaces, whole body interaction, rhythm skills, passive learning, music computing.

1. INTRODUCTION

The acquisition and refinement of rhythm skills is generally vital for musicians. One particularly demanding aspect of rhythmic skills is multi-limb rhythms, i.e., playing different parts of a multi-stream rhythm making use of hands and feet in combination as needed. This is a central skill for drummers, but it can be of great relevance to other musicians, for example piano and keyboard players. More broadly, it has been claimed that these skills may be able to contribute to well-being, for example in improving mobility [Brown, 2002] and alertness, and helping to prevent falls for older people [Juntunen, 2004; Kressig et al., 2005].

In recent experiments, we demonstrated that the use of haptics (vibrotactile devices) can support the learning of multi-limb rhythms of various kinds [Holland et al., 2010]. These experiments featured a tool called the Haptic Drum Kit. This consists of: haptic devices (standard vibrotactiles in the original version, and more specialised tactors in the revised version) attached to the wrists and ankles; a computer system that feeds signals to the haptic devices; and a midi drum kit, which is played by the person while wearing the haptic devices.

These experiments showed that a) haptic guidance can be used with similar success compared to audio guidance to support the acquisition of multi-limb rhythms b) the combination of the two kinds of guidance is preferred to either alone, and c) that haptic guidance has advantages for certain tasks (e.g. knowing which event goes with each limb) but disadvantages for other tasks (energetic body movement can mask the haptic signals). These experiments also suggested a range of other applications.

The current experiment aims to examine whether *passive* learning of multi-limb rhythms can occur when haptic rhythmic stimuli are applied when away from the drum kit and focusing on other tasks. That is to say, we are investigating the acquisition of skills after a period of experiencing haptic stimuli while distracted by another activity.

2. BACKGROUND

Related work suggests that passive learning of musical skills is possible. Huang et al. built a system using a wireless haptic glove with vibrotactile effectors for each finger and demonstrated that users wearing the glove improved their performance at playing simple piano tunes after passive exposure to combined audio and haptic playback, while focused on another task [Huang et al., 2008]. Grindlay created a mechanical installation that employs haptic guidance by automatically moving a drum stick that the learner was holding, and showed that this supported learning of rhythms which can be played with one hand [Grindlay, 2008].

The experiment we describe here differs from these projects in the focus on multi-limb movement (hands and feet) and the type of musical materials (polyphonic multi-stream rhythmic patterns).

3. THE HAPTIC IPOD

The Haptic iPod currently exists in two versions, a portable field version and a static test version. Both versions use four 'tactor' vibrotactile devices as the haptic transducers. These are secured to limbs, as needed, using elastic velcro bands. In the static lab bench version, the tactors are driven by an audio signal from a laptop running a custom built Max/MSP program, amplified by two Behringer headphone amplifiers. For the prototype portable unit, outputs from the Max/Msp program are pre-recorded onto a solid state four track audio recording device, and this portable device, together with battery powered headphone amplifiers, is used to drive the tactors. For the present experiment, the more flexible and powerful static test prototype was used.

4. EVALUATION OF THE HAPTIC IPOD

To explore the potential of the Haptic iPod for passive learning of multi-limb rhythm patterns, an evaluation study was carried out. The full results are currently being analysed. Preliminary findings are presented below.

Participants
Fifteen people participated in the experiment, both men and women, aged 15-51. Three were experienced drummers (with approx. 10 years of experience playing the drums), five had a little drumming experience, and seven had no experience with drumming.

Setup: experimental tasks and methods
(1) The first phase was a pre-test phase, in which subjects were asked to play, as best they could, a series of six multi-limb rhythms of various levels of complexity on a midi drum kit, based on audio playback of each rhythm. These performances served as base reference levels for comparing performances in the post-test phase.

(2) The second phase was a passive learning phase, away from the drum kit and in a different room, in which subjects had rhythms silently played back via tactors attached to their wrists and ankles while they were engaged in a distraction task, i.e., a thirty minute reading comprehension test, Each subject was played just two of the rhythms in alternation during the distraction task. Different pairs of rhythms were chosen for playback to different subjects.

(3) The third phase was a post-test phase, in which subjects were asked to play again, on the midi drum kit, the complete set of rhythms from the pre-test. Clearly, this included the two rhythms to which the subject had been given addition passive haptic exposure in the second phase. Each subject's performance for all rhythms was compared to the corresponding baseline performances in the pre-test, in terms of: accuracy, timing, number of attempts and number of errors in their best attempt.
(4) Finally, a questionnaire was administered that asked about subjects' experiences during the experiment, and their attitudes towards the haptic technology.

Clearly, a key outcome will be to determine whether there were measurably greater improvements between pre-test and post test in the case of rhythms for which subjects experienced passive exposure, as compared with the other rhythms. These results are still subject to analysis. In this paper we present preliminary results from the questionnaire.

Questionnaire results
Do you like the idea of being able to feel the beat, using haptic technology?
The possible answers were; 1: I dislike the idea very much, 2: I dislike the idea a little, 3: I feel neutral about the idea, 4: I like the idea a little and 5: I like the idea very much.
Clearly, the idea of haptically feeling rhythms is appealing, since all participants answered positively to this question. Seven subjects answered I *like the idea a little*, and eight subjects answered *I like the idea a lot*. However, we must keep in mind that the volunteers coming to participate in this study are likely to be more positive towards the technology than people in general.

How comfortable was it to wear the technology?
(*1 very uncomfortable - 5 very comfortable.)*
On average, the score was slightly more positive than neutral (3.27). Scores are varied among participants, however, with ten participants scoring 4 (reasonably comfortable), one participant scoring 3 (neutral), two participants scoring 2 (a little uncomfortable), and two participants scoring 1 (very uncomfortable). Seven participants indicated it became slightly more comfortable over the course of the experiment, whereas three participants indicated it became slightly less comfortable over time; the rest indicated it didn't change.

Do you think this technology helped you to play any of the rhythms better?
(1: not at all; 2: a little; 3: a lot)
On average, the participants scored 1.88. Three participants reported a score of 1 (Not at all), whereas one reported the maximum score of 3 (A lot). Two participants did not answer this question, indicating that they did not feel that they could answer it after only experiencing the haptics for a brief period of time.

Do you think this technology helped you to understand any of the rhythms?
(1: not at all; 2: a little; 3: a lot)
The average score for this question was 2.13, slightly higher than for the previous question. Five people scored 3 (A lot), but three people scored 1 (Not at all).

When you started reading, how much attention did you pay to the pattern of the beat, compared with the reading task?
(The possible answers were; 1: no attention to the pattern, 2: some attention to the pattern, 3: about evenly split, 4: more than half on the pattern, 5: mostly on the pattern.)
When they started reading, on average, the participants paid almost as much attention to the haptic rhythmic stimuli as to the reading task (2.73 on a scale of 1: No attention to the pattern, to 5: Mostly on the pattern). Nine participants scored 2 (Some attention to the pattern), two participants scored 3 (About evenly split), three participants scored 4 (More than half on the pattern), and one scored 5 (Mostly on the pattern). The fact that none of the participants scored 1 (No attention to the pattern) indicates that it is hard to completely ignore the haptic stimuli.

When you had been reading for a while, how much attention did you pay to the pattern of the beat, compared with the reading task?
After reading for a while, attention levels to the haptic stimuli dropped slightly for most participants, to an average of 2.13 on the same scale as the previous question. Two participants now reported a score of 1 (No attention to the pattern).

Which type of information helps most to find out which drum to play when?
(*1: audio is much better, 2: audio is slightly better, 3: no preference, 4: haptic is slightly better, 5: haptic is much better)*
The participants scored 3.57, on average, indicating a slight preference for the haptic information. Five people scored 5 (haptic is much better), whereas two people scored 1 (audio is much better), indicating a wide variety in personal preferences. One person did not answer this question.

Which type of information helps most to find out which limb to play when?
(1: audio is much better, 2: audio is slightly better, 3: no preference, 4: haptic is slightly better, 5: haptic is much better.)
For this question, the preference for haptics was even stronger, with an average score of 4.29. Eight participants scored 5 (haptic is much better), while only one scored 2 (audio is slightly better). One person did not answer this question.

Which type of information helps most to find out when the pattern repeats?
(1: audio is much better, 2: audio is slightly better, 3: no preference, 4: haptic is slightly better, 5: haptic is much better.)
To find out when the pattern repeats, participants only have a slight preference for the haptic information, with an average score of 3.29. Three persons indicated a score of 5 (haptic is much better), whereas one indicated a score of 1 (audio is much better). One person did not answer.

Which type of information helps most to understand a rhythm?
(1: audio is much better, 2: audio is slightly better, 3: no preference, 4: haptic is slightly better, 5: haptic is much better.)
To understand a rhythm, participants have a slight preference for haptics, scoring 3.69 on average. Four participants scored a 5 (haptic is much better), against two participants scoring a 2 (audio is slightly better). Two persons left this blank.

Which type of information helps most to play a rhythm?
(1: audio is much better, 2: audio is slightly better, 3: no preference, 4: haptic is slightly better, 5: haptic is much better.)
To play a rhythm, there was also a slight preference for haptics, with an average score of 3.85. Two people scored a 5 (haptic is much better), against one person scoring a 2 (audio is slightly better). Two people did not answer this question.

How easy was it to play in time with the audio playback?
(1: very difficult, 2: a little difficult, 3: neutral, 4: reasonably easy, 5: very easy.)
Most participants found it at least a little difficult to play in time with the audio feedback, with a score of 1.93 on a scale of 1 (very difficult) to 5 (very easy). Seven people even found it very difficult (a score of 1), but on the other hand, three participants found it a little easy (a score of 4). Of these last three, one was an experienced drummer, and the two others also had some experience with rhythms. The other two experienced drummers scored a 2 (a little difficult), indicating that the materials were not straightforward, not even for experienced drummers.

Would you prefer audio, haptics, or both for learning rhythms?
(1: I prefer audio only, 2: I prefer both audio and haptics, 3: I prefer haptics only.)
With a large majority of eleven participants scoring 2 (I prefer both audio and haptics), there is a clear preference for having both audio and haptics (2.15 on average). Two participants scored 3 (I prefer haptics only), and nobody indicated a preference

for audio only. Two persons did not answer this question. Taken together, this suggests that haptics offer a clear added value, especially when provided together with audio.

Did you enjoy the experiment?
(1: I disliked it very much, 2: I disliked it a little, 3: I feel neutral about it, 4: I liked it a little, 5: I liked it very much.)
Overall, the majority of participants enjoyed taking part in the experiment, with a score of 4.20 on average, and eight participants scoring 5 (I liked it very much). However, two participants scored a 2 (I disliked it a little), and one scored a 3 (neutral), indicating that the positive feeling was not universal.

Open Questions
There were several open questions, which are listed below, followed by comments from participants.

Are there things that you liked about using the technology in the training session?

- “Unfamiliar feeling, tickle. Friendly appearance of the hardware - they beep slightly.”
- “It was fun to play the electronic drums.”
- “I did not perceive it as ‘training’. My instruction was to read the text. It was nice to feel the rhythm through haptic.”
- “fun to use new technology in novel ways.”
- “No. Interesting to find out about another way of learning though.”
- “I had to concentrate harder in order to be able to read the text. Of course it was a matter of decision to set the reading task as the priority.”
- “understanding the complexity of different rhythms like learning a language.”
- “clarity of the haptics. ‘seeing’ the repeated foot figure in the son clave. ‘seeing’ how the 4/5 inter plays.”
- “I had never played a drum kit like that, so was exciting. The buzzers were strong enough to feel.”
- “it helped to differentiate between the limbs, whereas using audio feedback it is often hard to separate limb function”
- “that it helped me understand the rhythm. Being able to flawlessly distinguish between which limb to use. The audio is more confusing.”

Are there things that you didn't like about using the technology in the training session?

- “The way the cables were soldered made it feel like one has to be very careful not to move too much. Wireless would be nice, I can imagine.
- “I wish I had a chance to play with haptic on.”
- “The comprehension test. Give me some maths.”
- “Maybe a bit annoying after some time.”
- “started to get a little irritating after a while due to the repetitive nature.”
- “Having to do the reading. Let's have a portable one.”
- “No dislike.”
- “I was useless!”
- “That it didn't allow for me to physically practice much, because I find it difficult to play a polyrhythm; I have to build a physical memory.”
- “that the audio made it difficult to differentiate between which drums needed to be played.”
- “The wrist/ankle strap/haptics cables are unwieldy - but that can't be helped.”

Are there things that you like about the haptic playback?

- “It makes the playing of complex patterns easier to understand. I can feel the rhythm better.”
- “Helps to concentrate on individual limbs. Being able to distinguish right and left more easily.”
- “I like the technology cause [it] assists you [to] embody the rhythm in a new promising way.”
- “knowing your left from your right. clarity of timing. Clarity of assignment of limb to time stream.”
- “Easier to concentrate on the particular rhythms within a polyrhythm (than audio only).”
- “The haptic allows you to think the process through before you actually play. It may reduce the likelihood of learning wrong patterns.”

- "that you could easily feel which drums you needed to play when and how quickly it went on to the next beat."
- "The distinction between instruments (limbs)."

Are there things that you don't like about the haptic playback?

- "Might be annoying or distracting or boring to use in everyday life. Would rather listen to actual music."
- "(Neutral) repetition gets irritating 'under the skin'"
- "just initially strapping on the legs. Portability."
- "The ankle vibrations felt weak on me and I had to concentrate hard to feel them."
- "On the paradiddle it felt that when the 2 hand buzzers coincided the right one was weaker than the left one."
- "That I didn't hear the audio at the same time."
- "that at times they got a bit annoying."
- "Slightly disorientating when a new rhythm starts playing."

Do you have any suggestions to improve the haptics as used in this study?

- "I would have liked to try the haptics while playing the drums."
- "Use it while playing."
- "Sounds are distracting -> Hard to work out where sound is coming from. Need pure vibrations."
- "None that I can think of… end of play brain drain"
- "Please go portable and wireless!"
- "Have ankle vibrodetectors that have stronger vibrations."
- "Feeling the rhythm whilst listening to the audio would be a lot better to create a more holistic understanding of the polyrhythm and the interaction needed by the limbs."
- "vary the strength of the vibrations for different limbs."

Do you have any other comments?

- "The laptop mousepad [used to scroll text and select answers in the reading comprehension test] was hard to use."
- "There was too much to take in - i.e. Sequences too long + too many + too complex."
- "Subject's familiarity with playing from score/improvising is probably a key variable."
- "Music is a universal language that can have profound impact on learning and collaboration, building community as part of an oral tradition. The most ancient form of meditation."
- "Quality of haptic 4/5 was more clear than [merely] audio signal."
- "I think participants may need a little time to practice after the haptics without the audio playback on."

5. RELATED WORK

We are unaware of any related work that shares our particular focus on using haptics for learning multi-limb rhythmic skill. However, there is a wide variety of research concerning haptics more generally. Haptics have been examined from the point of view of a range of diverse task types, including the following:

- Learning sequences of movement e.g. for manufacturing processes – without particular focus on precise timing [Gillespie et al. 1997];
- Identification of virtual objects [Jones et al., 2005];
- Learning of force skills [Morris et al, 2009];
- Learning complex 3D motions [Feygin et al, 2002];
- Sensory substitution [Bird et al., 2008];
- Training in snowboarding skills [Spelmezan et al., 2009];
- Training in the posture and bowing of violin students [van der Linden et al, 2011].

In these various studies, timing issues were not generally of particular concern. However, for our purposes, one particularly relevant finding came from Feygin at al [2002]. In this study, subjects learned to perform a complex motion in three dimensions by being physically guided through the ideal motion. The finding was that although trajectory shape was better learned by visual training, temporal aspects of the task were more effectively learned from haptic guidance.

Two projects concerning monophonic temporal sequencing were as follows.

• As already noted, Grindlay [2008] carried out work on monophonic rhythms where the system physically moved a single hand of subjects to train in playing monophonic rhythms. Haptics were shown to help significantly to improve performance of playing rhythmic patterns with one hand, and haptic plus audio guidance was found to work best.
• Lewiston's [2009] five-key keyboard was designed for a single hand in a fixed position. The keyboard uses computer-controlled electromagnets to guide finger movements during sensorimotor learning of tasks involving sequential key presses, such as typing or playing the piano. Preliminary data suggested that this form of haptic guidance is more effective at teaching musical beginners to perform a new rhythmic sequence, when compared with audio-only learning. Preliminary data suggested that this form of haptic guidance is more effective at teaching musical beginners to perform a new rhythmic sequence, when compared with audio-only learning.

As also previously noted, one key project looked at passive learning of rhythmic fingering skills. Huang et al [2008] built a system using a wireless haptic glove with vibrotactile effectors for each finger and investigated whether users wearing the glove improved their performance at playing simple piano tunes after passive exposure to combined audio and haptic playback, while focused on another task. Performances after passive exposure were found to be improved.

There are numerous systems which incorporate haptic feedback into virtual or physical musical instruments (rather than directing feedback to individual limbs). Examples can be found in O'Modhrain [2000], Collicutt et al [2009], Sinclair [2007], and Miranda and Wanderley [2006].

6. CONCLUSIONS

Our preliminary results suggest that the passive learning of multi-limb rhythms is a promising approach that may have a variety of applications. Other implications of this work can be related to workshop themes in diverse ways. Broadly speaking, it is hard to generalise about haptic interaction for much the same reasons that it is hard to generalise about visual or audio interfaces – the applications, contexts and purposes are bewilderingly varied. However, in general terms, the present work may help, for example, to identify areas where haptics are underused in mainstream HCI. While it has always been clear that haptics can be useful where eyes and ears are focussed elsewhere, the present work may help to emphasise the possible value of haptics in applications where spatial movements or temporal sequencing of movements need to be learned or communicated. It is interesting to note that that specifically rhythmic applications of haptics have been very little explored in HCI. Some of the more intricate aspects of interaction with rhythm may, by their nature, be limited to applications in Music Interaction. However, we speculate that there are applications of the rhythmic use of haptics in health, entertainment, security, safety, and other areas yet to be identified and explored. To give a simple example with no claims to originality, the vibrators in mobile telephones have essentially just two states – on and off. By using appropriate rhythmic modulations, far richer information could be silently communicated.

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