Design Research Seminar

Analysis of Vibrations
-Mapping a language for the hearing impaired

RAMPRASAD S
126330011 . Interaction Design

Guide: Prof. Ravi Poovaiah

IDC 2014

Declaration

The research work embodied in the written submission titled "Interactive and Game-based
Carnatic Music Lessons for Beginners" has been carried out by the undersigned as part of the post graduate program in the Industrial Design Centre, IIT Bombay, India under the supervision of Prof. Pramod Khambete.

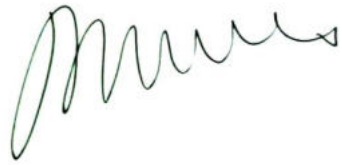
The undersigned hereby declares that this is his original work and has not been plagiarized in part or full from any source. Furthermore, this work has not been submitted for any degree in this or any other University.

I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action if need arises.

(Ramprasad S)
126330011

Approval Sheet

This Design reserch seminar project entitled "Analysis of Vibrations -Mapping a language for the hearing impaired" by Ramprasad S, 126330011, is approved in partial fulfilment of the requirements for Master of Design Degree in Interaction Design.

Project Guide: 

Date: 14.7.14
Place: IDC IIT BOMBAY

Acknowledgement

I'm sincerely grateful to my guide, Prof. Ravi Poovaiah for his constant support and patience.

Special thanks to all those who took time out and participated in the interview sessions during the research.

I would like to thank my parents for all the love, support and freedom they have been giving me right from school days.

Table of contents

Abstract

Today's mobile phones and tablets have been designed and engineered to enable concurrent vibration along with audio, flashlight and visuals on the display.
For users with hearing impairment, feedback from audio alone cannot work independently in the process of communicating. Vibrations can play a major role for such users in their interactions with mobile devices.
This design research seminar report includes a compilation of primary and secondary research done with respect to users with hearing impairment and also presents a compilation of the current trends in interaction technology with respect to vibrations. The later part of this report presents experiments done on user groups, about their perceptions of different vibration patterns (inspired from musical concepts like rhythm cycles/time signatures/*taals* and tempos) and their abilities in mapping those vibration patterns to visual or textual memory cues.

About the project

While the sense of touch is capable of processing complex stimuli, the vibration feedback used in mobile phones is generally very simple. Using more details in the vibrations that mobile phones produce would enable the communication of more information through phone's alerts. However it has been suggested that the current phone vibration motors(2010's) are not capable of presenting complex messages[1]. This design research report is about a compilation of primary and secondary research about the field and its specific uses to users with hearing disabilities. These results may help designers to understand the possibilities offered by standard phone vibration motors for communicating complex information.

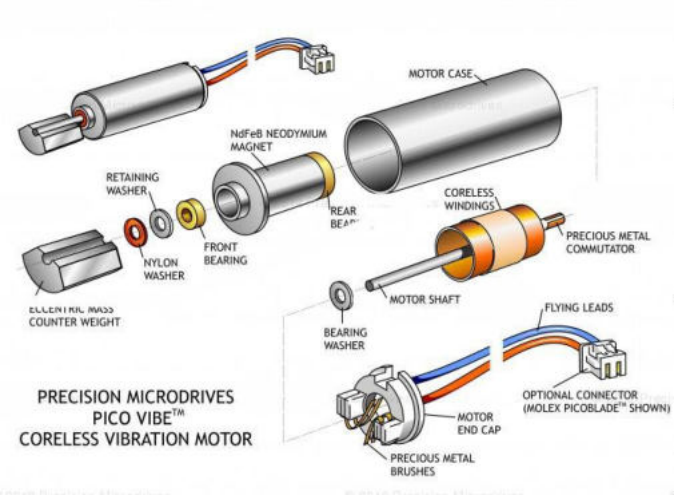
Need for the Users?

Mobile phones have become part of our daily lives. However, for users with hearing disabilities, most of the current ways of product interaction seems to be only via visual means. Functions like contact ringtones, message alerts, music listening have not been of much use for users with hearing disabilities.

This report looks at current trends and future possibilities in using vibrations and various patterns in vibrations as a communication language between the user and the mobile phone. Explorative experiments with such users, by using musical rhythms in vibration patterns to help in communication, are also discussed.

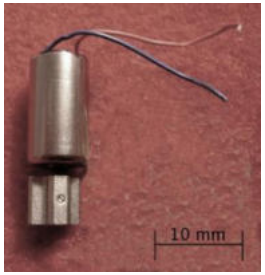
Background Study

Vibrations are used as alerts, which are a feature of communication devices to notify or accompany a notification. It is particularly common on mobile phones usually supplements the ring tone. Vibrating alerts are primarily used when the user is unable to hear the audio or the ringtone (a noisy environment or because of hearing loss). Sometimes, when the device is placed on a hard surface it can often be as loud or louder than a ringtone(depending on the surface on which it is kept).



Understanding Vibrations

Vibrations in mobile phones are produced by a small electric motor connected to an eccentric (unbalanced) weight placed inside the phone's chassis[2].



Today, almost all the mobile devices have vibration alert activated in them by default. Currently, the frequency of the vibration motor in mobile phones is approximately between 130 Hz and 180 Hz with an average at 160 Hz (rotation speed: 10000 rpm)[1].

Background Study

The vibration frequencies mentioned are obtained from the analysis of vibration motor specifications used by mobile phone manufacturing companies.

Optimal Vibration?

Most of the literature available on vibro-tactile perception focuses on direct contact with the skin (particularly the hand or the fingers) in the static state.

Human skin is very sensitive to vibrating stimuli at 230 Hz, regardless of the contact area, while it is insensitive to vibrations below approximately 100 Hz or above 600 Hz [1].

However, another experiment using a handheld phone to determine the optimal vibration frequency of a mobile phone in the static state concluded that a frequency of 140~160 Hz (avg. 151 Hz) was sufficient to enable psychophysical recognition[1].

The skin near hand and palm is more sensitive (@150hz) than most of the other frequent places in the human body

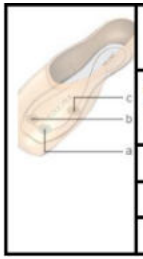
Secondary Research

Music-touch Shoes

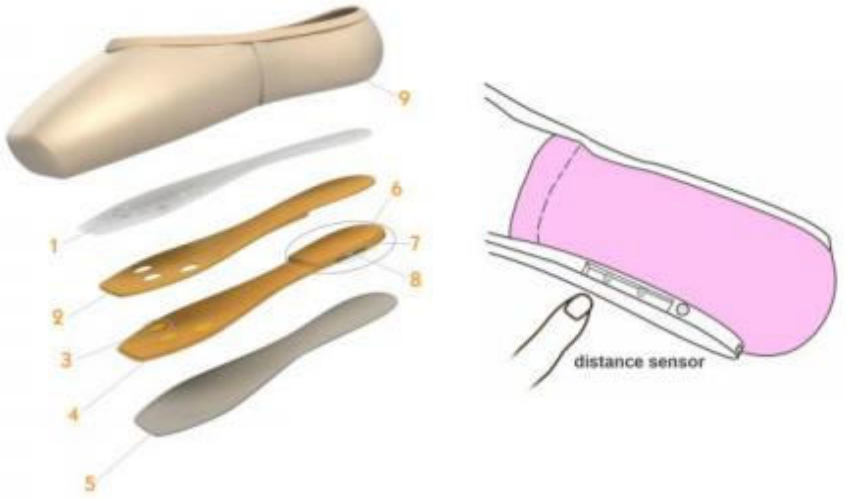
Lining Yao et al. Music-touch Shoes: Vibrotactile Interface for Hearing Impaired Dancers, *CHI'12*

Music-touch Shoes[3] is particularly designed for hearing handicapped dancers. Music-touch shoes are designed primarily to serve as a substitute for their hearing disability by interaction with other senses, such as vibrotactile sense. Because of vibrotactile sense, they can feel and move according to the vibrations on their feet's skin(like how a normal dancer would listen to music and move).

This interaction is via the shoes because feet are most directly involved in performing dance rhythm. For these users, the rhythm and the tempo/metronome of music can be communicated and perceived through vibrotactile interaction.



Common tempo		Vibration sequence	Vibration intensity
basic tempo	2 beats	a-b	Strong- Weak
	3 beats	a-b-c	S- W-W
4 beats		a-b-a-b	S- W- S- W
5 beats		a-b-a-b-c	S- W- S- W-W
6 beats		a-b-c-a-b-c	S- W-W- S- W-W



Salient Features

The shoes are controlled by a software on PC via Bluetooth. Music from computer is uploaded to the shoes. On starting, the shoes with three vibratile points give the users vibrotactile stimulation according to the rhythm and tempo of the chosen music.

While tempo is reflected by vibration's sequence and intensity, rhythm is reflected by vibration's frequency.

Secondary Study

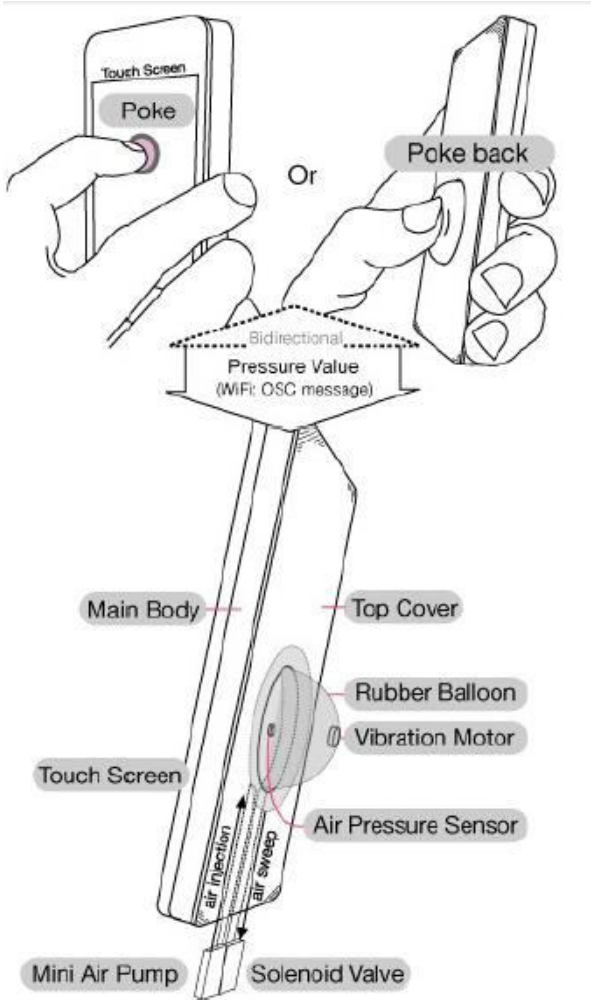
Poke

Young-Woo Park et al. Emotional Touch Delivery through an Inflatable Surface over Interpersonal Mobile Communications, *UIST'11*

Poke[4] helps to touch the cheek skin with an inflatable surface according to the other user's finger pressures and hand gestures during a phone call.

The paper on poke talks about integrating a soft and human-like remote touch technique through an inflatable surface with a mobile device. It is aimed at designing for delivering a more emotional interpersonal mobile interaction.

By including inflating patterns and vibrations from the top of the inflatable surface, Poke delivers different kinds of affective touches.



Secondary Study

Salient features

Different kinds of pokes can be delivered depending on the finger pressures and hand gestures from the one phone to another during a phone call.

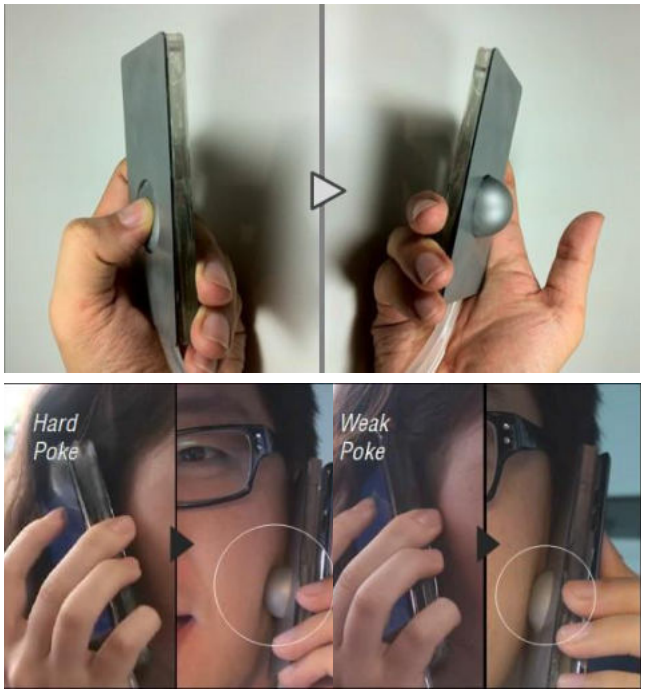
The feelings of different pokes are mapped through its inflating strengths and vibrations from the top of the inflating surface.

Role of Vibrations in POKE

A vibration motor on the top of the inflating surface can make users feel different ways of poking. This helps in developing a unique language to communicate with each other.

In the paper, the authors discuss about the different methods of poking with the device depending on the way it vibrates:

- Poke and then Shake
- Poke Back
- & Pat



Limitations?

According to the description in the paper, Poke can only serve as an add-on to the existing audio during calls with mobile phones.

The unique language that can evolve from the inflatable hemisphere can vary with different individuals and have its own limitations.

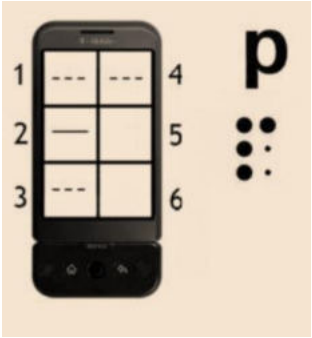
Secondary Study

V-braille

*Chandrika Jayant et al.*V- Braille: Haptic Braille Perception using a Touch-screen and Vibration on Mobile Phones, *University of Washington, 2009*

V-Braille[5] is designed for deaf-blind people who rely primarily on their tactile sense. V-Braille is a unique method to haptically present Braille characters using vibrations, on a mobile phone 's touch screen surface .

In the paper [by-R] preliminary study with deaf-blind Braille users found that V-Braille can be used to read individual characters and sentences with minimal training given.



Interface for Braille Input

Salient Features

The screen is designed as six parts, to recreate the six dots in a single Braille cell (as shown in the figure on the left).

The phone vibrates when one of the 6 boxes on the screen is touched (any point within the enclosing box represents a raised dot).

Touching dot areas 2 and 5 present stronger vibrations (shown by the solid line in Figure on the left), making it easier for users to differentiate between vertically adjacent raised dot areas.

The screen can be tapped or stroked in different sections and directions.

What it cannot do?

Multi-touch is not available for V-Braille.
For some users the learning of this method can consume more time and hard work. A tactile overlay or tangible product may prove to be better than V-Braille.

Secondary Study

Pressages

Eve Hoggan et al. Pressages: Augmenting Phone Calls with Non-Verbal Messages, *UIST '12*

For augmenting phone calls with non-verbal messages, ForcePhone : an augmented, commercially available mobile device with pressure input and vibrotactile output was created. During phone calls in Forcephone, users squeeze the side of the device and the pressure level is mapped to vibrations on the receiving phone. These pressure/vibrotactile messages supported by ForcePhone were termed as "pressages[6]".

The sides of the phone have the pressure input

Salient Features

The main aim in the idea of Pressages was to extend the boundaries of traditional phone calls by adding an additional channel of communication.

The use of pressure input and vibrotactile output over time during standard phone calls could improve value to the communication channel in real-world settings with users expressing greetings, presence and emotions through pressages.

Further, pressages could also encourage users to create and use their own codes/language to express via vibrations in mobile phones.

Why it might not work?

With pressages, it consumes a lot of time both to develop as well as learn the language (for eg., to express and map positive or negative emotions to vibration patterns).

Secondary Study

Rhythm in Interaction Design

Emilien Ghomi et al. Using Rhythmic Patterns as an Input Method, *CHI'12*

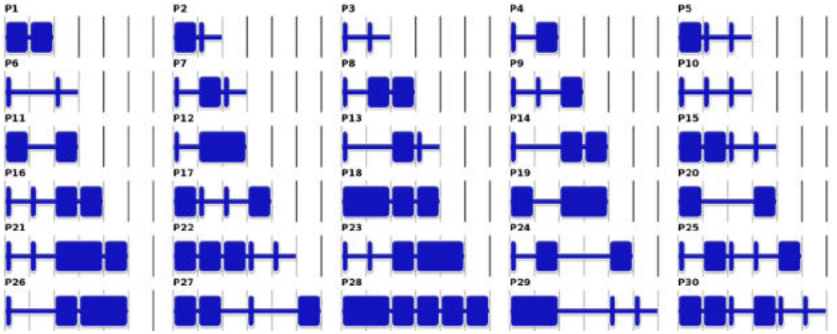
The paper on "Using Rhythmic Patterns as an input method"[7] talks about advanced uses of rhythmic patterns that have received little attention in HCI. Using rhythmic patterns is about using temporal cues in the interaction techniques. Such temporal structures convey information in situations where the visual channel or the audio channel is overloaded or even not available.

In the paper the authors discuss primarily about two main possibilities

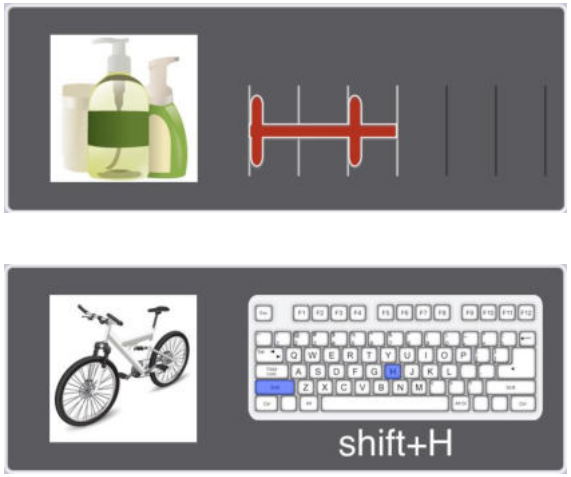
(i) rhythmic patterns can be efficiently reproduced by novice users and recognized by computer algorithms

(ii) rhythmic patterns can be memorized as efficiently as traditional shortcuts when associating them with visual commands.

These findings demonstrate the potential of Rhythmic Interaction and open the way to a richer repertoire of interaction techniques.



The different Rhythm patterns that were used in the tests



Comparison tests for input by rhythm and key press were done

Technology trends

Vibro-tactile Pattern Identification

Jonghyun Ryu et al. Improving Vibrotactile Pattern Identification for Mobile Devices Using Perceptually Transparent Rendering, *MobileHCI'10*

New vibration rendering methods partition vibrations in their perceived intensity using *perceptually transparent rendering[8]*. This can enhance the identification of mobile device vibrations produced by a vibration motor. This rendering method can improve the users' perception performance in terms of correct identification rate and the device's amount of information transfer.

To be more specific, *perceptually transparent rendering* can contribute to increasing the number of discrete vibrations that can be used for information delivery via a mobile device, e.g., for the priorities of phone calls.

Effective Vibration-Based Notification

Bahador Saket et al. Designing an Effective Vibration-Based Notification Interface for Mobile Phones CSCW '13

To convey the level of urgency of notifications and help users prioritize them, the design of mobile phone vibration alerts consider the gap length preceding or succeeding a signal, the number of gaps in the vibration pattern, and the vibration's duration affect an alert's perceived level of urgency[9].

Learnings

Insights

Vibrations in the future shall be useful for designing vibrotactile icons with higher recognition rates in order to enrich the user interface of a mobile device.

Vibrations with perceptually transparent rendering have fine variations that are also easily perceived. These can be of great value while designing for different rhythmic vibrations and tempo changes.

Vibrotactile pattern identification enhancements can bring in a whole new experience for the mobile phone users by supplementing their visual and audio sensory perceptions.

Rhythmic patterns in Vibrations can be very useful in creating mental mappings to visuals and help in remembrance.

Vibrations can be a good add-on/supplement to visual and auditory cues. Users can create their own language with vibration patterns for easy interaction.

For users with hearing and visual impairment, vibrations can become a useful means of communication with devices. However, learning to feel vibration patterns and remembrance might require some amount of practise.

Primary Study

The User Group

This design research seminar report is intended to Users with hearing disabilities.

Hearing impairment (also referred to as hearing loss) is a generalised term used when a person's hearing falls below standard hearing levels. People may experience varied levels of hearing impairment, which is described using the terms mild, moderate, severe and profound.

A hearing impairment can affect a person's ability to participate in activities of daily living including communicating with family, friends or workmates, watching television, listening to the radio or attending public forums. Assistive technology (aids and equipment) is available to assist people to participate in some of these activities.

Perceiving Sound

Along with residual hearing, hearing impaired individuals use visual cues, tactile means and rhythm based cues to feel sound (notes from direct observation and shadowing of users).

Visual Means

- Gestures- body gestures and facial expressions
- Lip reading
- Images
- Videos

Tactile Means

- Approaching Train, bus, other vehicles
- Heat response on skin while whispering close to ears
- Environment sounds, doors, thunder etc.
- Acoustic Music Instruments

Primary Study

Mobile Phone Usage

Telephones and mobile phones with features designed to assist users with a hearing impairment are available.

Features may include:

- Amplified and adjustable ring tone
- A handset amplifier
- Adjustable tone and pitch
- Hearing Aid compatible
- Hands free speaker
- Headset jack
- Flashing lights
- Vibration alert
- Text messaging

While most of these deal with tweaking or amplifying for audio perception, the last three – flashing lights, vibration alert and text messaging use other modalities to communicate with the user.

This project report mainly deals with using vibrations as a way of communication with the user.

Handset Amplifier

Hearing Aid

Flash Lights
In Mobile Devices

Bluetooth Vibration
Alert - on the wrist

Connecting the dots

Persona

Who is Mani? Nature?

Hearing Impaired person, age 27, works outdoors.
He lives in Mumbai and owns a smart phone.
He is a sales representative and gets many important and unimportant calls from many of his contacts.
His boss keeps calling him on a daily basis for office – related conversations.

Concern?

Because he works outdoors and is hearing impaired, he sets his phone always in vibrate mode so that he can easily identify calls and messages.

Need?

He has to attend some really important calls by prioritizing them and leave out some calls which are not as important.

- He needs to have many vibration alerts than just two – fast and slow, so that he has as many options as in contact ringtones.
- He needs to easily identify different vibration alerts as how one would understand contact ringtones to prioritize calls/msgs.

Connecting the dots

Using Rhythms in Vibrations

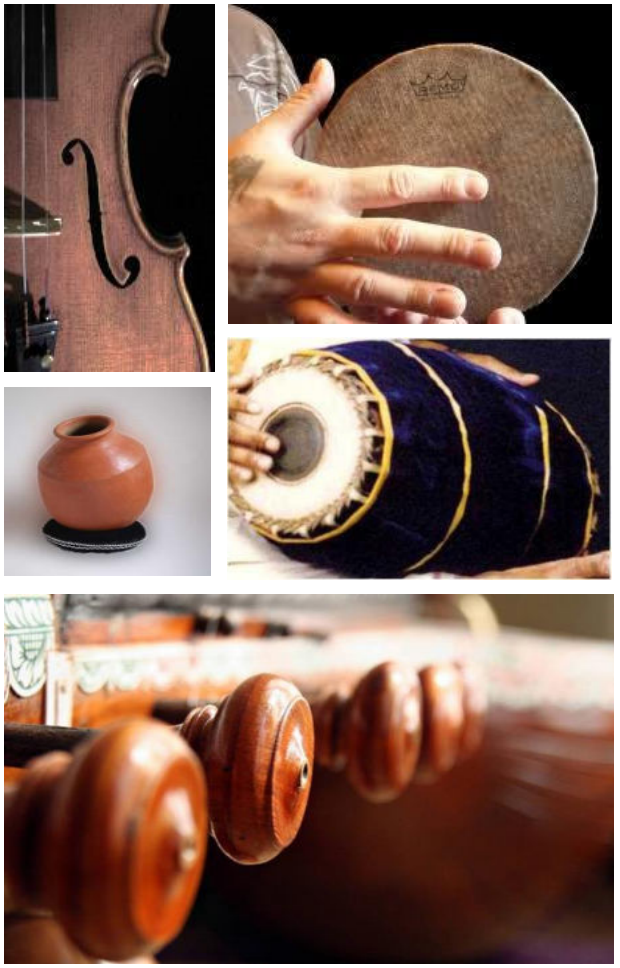
Rhythms in Music[10] :

Rhythm generally describes the temporal features of music that typically occur on the order of seconds (as opposed to the fine scale temporal features that occur on the order of milliseconds that are crucial in the perception of pitch and timbre).

Rhythms form the base of many songs and compositions as they structure the whole melody with respect to time. Rhythms have many types and they are called as rhythm cycles or time signatures. Different rhythms are used for different musical emotions(like 6/8 for march music etc.).

The idea in this project is to try out different rhythms in the vibration alerts' patterns, in order to make sure that the hearing impaired user differentiates between each of them and maps them to their respective contact numbers.

For the experiments, 4 rhythm cycles were chosen (common from both Indian music and Western Classical) and tested with users.



Experiment

The tests were conducted on users with hearing impairment by asking them to set different rhythmic vibrations as their contact ringtones and to identify the names of people calling them without having to look at the phone display.

The same tests were tried with normal users too but in a very noisy environment, so that they identify the contact name without taking their phones out to look at the display.

Vibration Composer
App Icon for Windows[11]

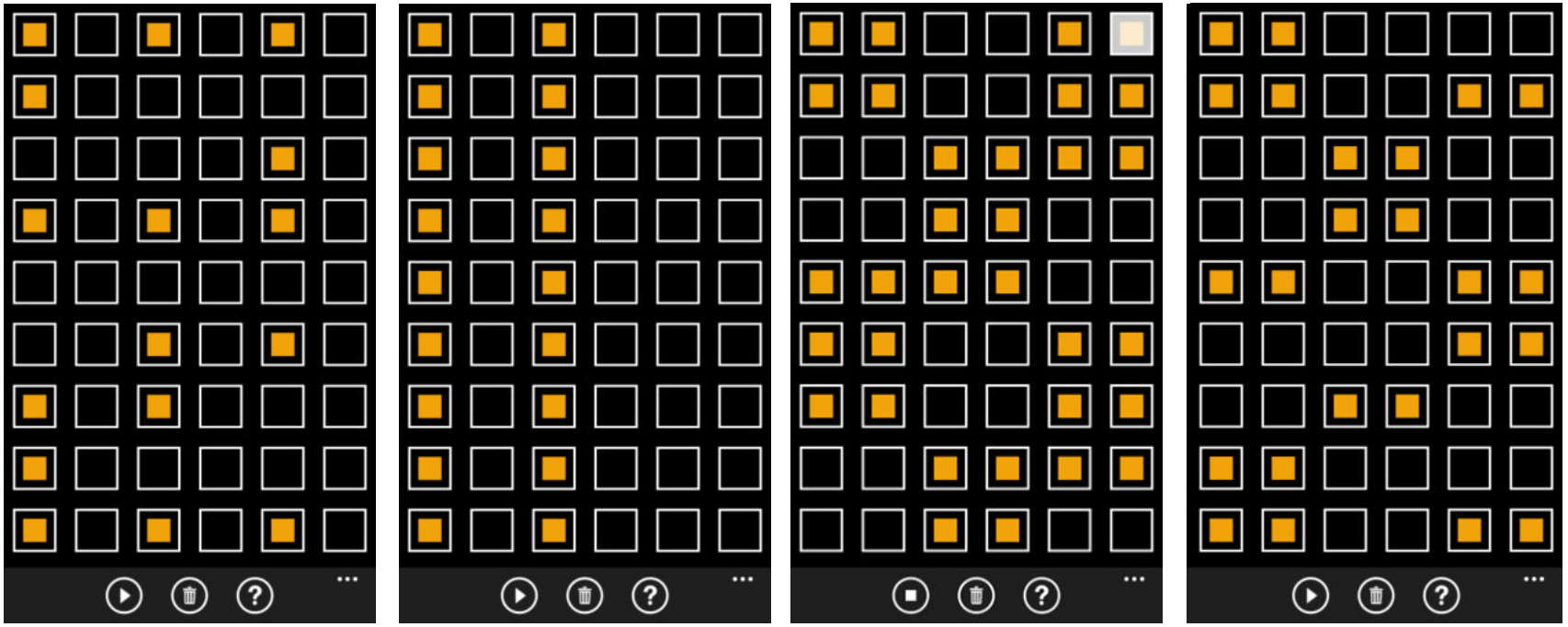
The Users?

The tests were conducted with 5 users having hearing issues (both - with and without hearing aids) and 5 users without any hearing issues(tests done in noisy environments). All the users tested were adults (above 18 age).

Methodology

The tests were done using an app called "Vibration composer"(on windows-Nokia phone). The rhythm cycles for the vibrations were set as shown in the screenshots in the following pages. 4 Contact names were assigned for 4 rhythm cycles and the users were asked to identify the names of the persons/contacts using their respective vibration rhythm cycles as clues (without looking at the display).

Experiment



Screen Shots of the different Rhythm Cycles Composed with the app “Vibration Composer”

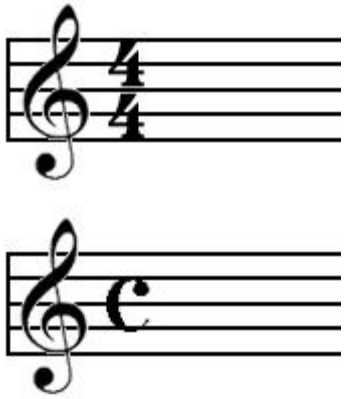
Experiment

First Rhythm Cycle – 4/4 Cyle

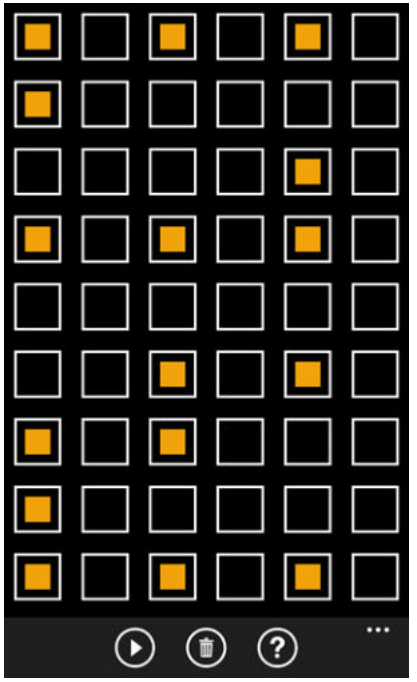
4-4 or *Eka taalam* is one of the common cycles used in both Western and Indian Classical Music. The pattern in this rhythm cycle is usually counted as

"1… 2… 3… 4… 1… 2… 3… 4…"
or "Tha ka Dhi mi Tha ka Ju nu,"

This rhythm cycle was set and assigned a simple contact name. This contact name (Ram) would be also be referred as Contact 1 in the following pages. The picture below shows how the time signature of this rhythm cycle is represented on the stave in Western Music Notation.

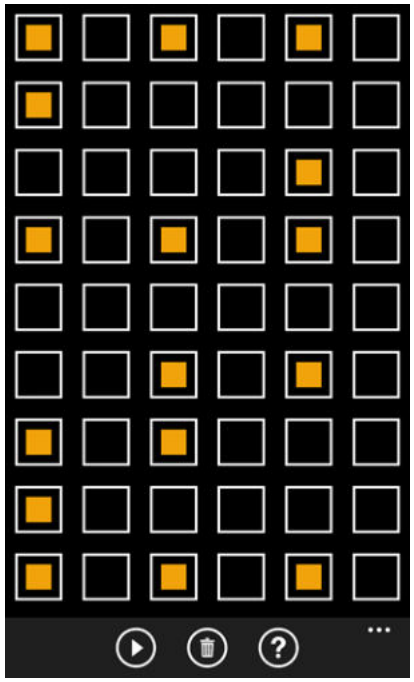


Contact 1 - RAM

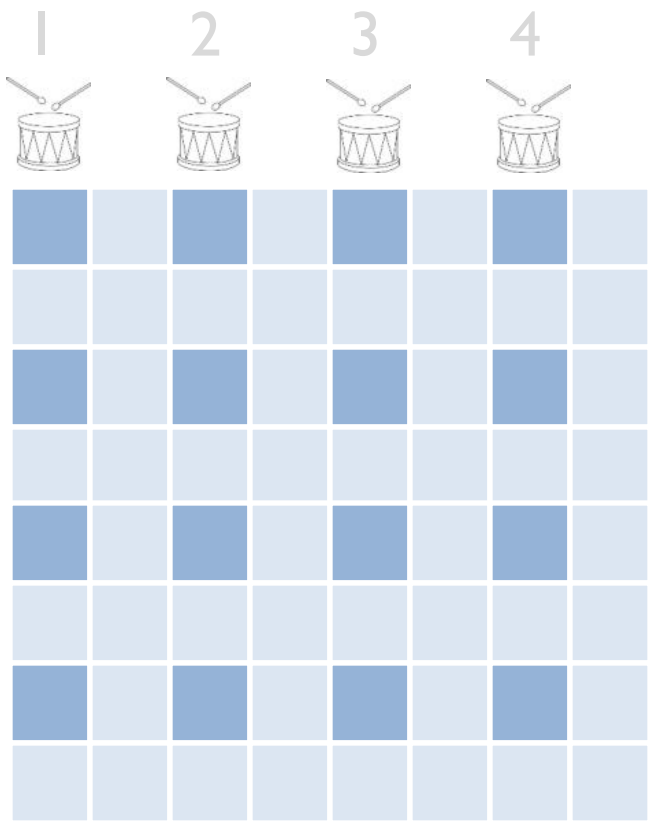


In the screen shot above, the 4-4 Rhythm-Vibration is set by selecting 4 alternate boxes for a bar and then full silence for the next bar.
Pattern - 1 0 1 0 1 0 1 0 0 0 0 0 0 0 0 0

Experiment



A clearer representation of the above pattern
is given with dark and light blue boxes on the right



The dark blue colored boxes are where the
vibrations are set in the app in yellow.

Experiment

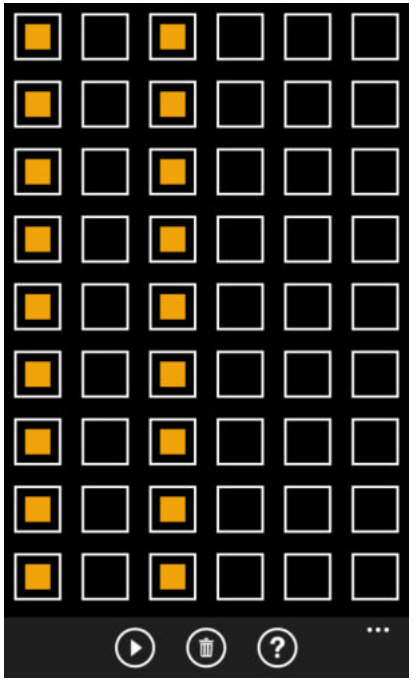
Second Rhythm Cycle – 3/4 Cyle

3-4 or *Tisra* is one of the common cycles used in both Western and Indian Classical Music. The pattern in this rhythm cycle is usually counted as

"1… 2… 3… 1… 2… 3… "
or "Tha ki ta… Tha ki ta…"

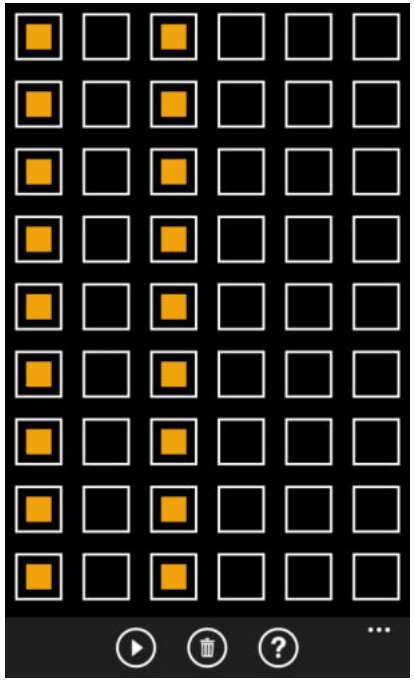
This rhythm cycle was set and assigned a simple contact name. This contact name (Shyam) would be also be referred as Contact 2 in the following pages. The picture below shows how the time signature of this rhythm cycle is represented on the stave in Western Music Notation.

Contact 2 – SHYAM

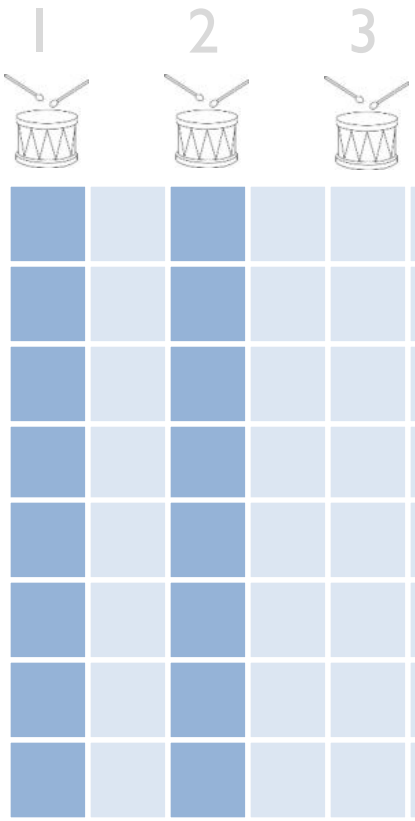


In the screen shot above, the 3-4 Rhythm -Vibration is set by selecting 2 alternate boxes and the third alternate box is kept unselected/silent to form a bar.
Pattern - 1 0 1 0 0 0

Experiment



A clearer representation of the above pattern
is given with dark and light blue boxes on the right



The dark blue colored boxes are where the vibrations are set in the app in yellow.

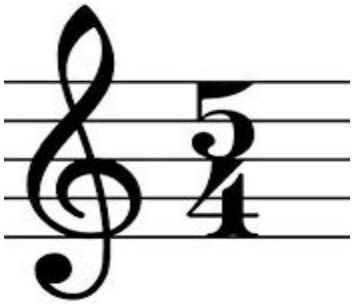
Experiment

Third Rhythm Cycle – 5/4 Cyle

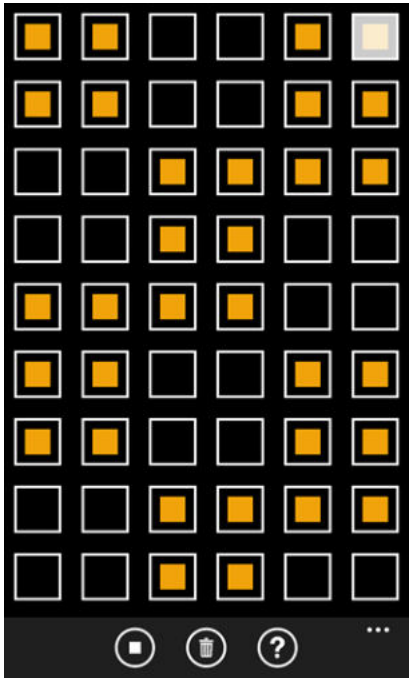
5-4 or *Kanda* is one of the common cycles used in both Western and Indian Classical Music. The pattern in this rhythm cycle is usually counted as

"1,2… 1,2,3… 1,2… 1,2,3… 1,2… 1,2,3…"
or "Tha ka Tha ki ta… Tha ka Tha Ki Ta…"

This rhythm cycle was set and assigned a simple contact name. This contact name (Sonu) would be also be referred as Contact 3 in the following pages. The picture below shows how the time signature of this rhythm cycle is represented on the stave in Western Music Notation.

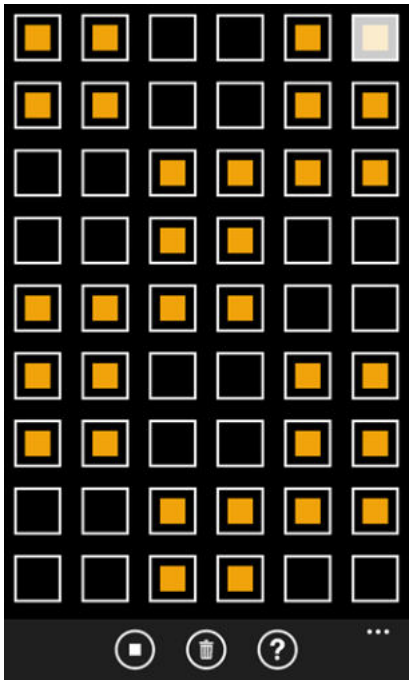


Contact 3 – SONU



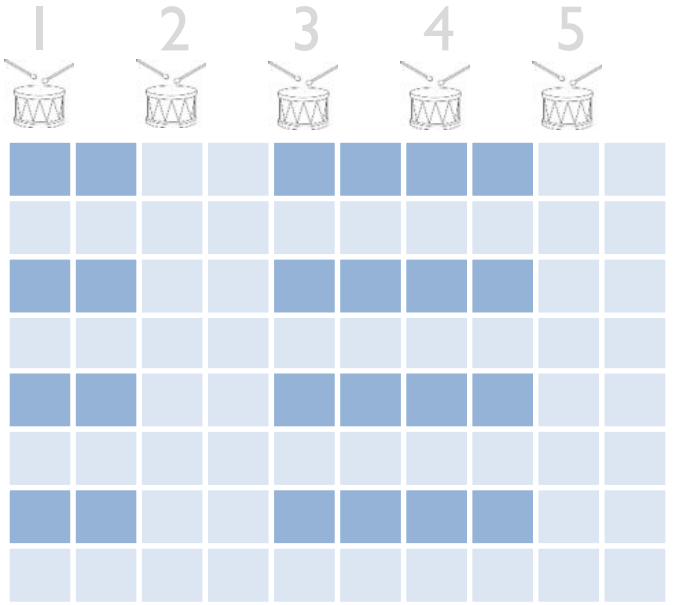
In the screen shot above, the 5-4 Rhythm -Vibration is set as - 1 0 1 1 0 to form a bar.

Experiment



A clearer representation of the above pattern
is given with dark and light blue boxes on the right

=



The dark blue colored boxes are where the vibrations are set in the app in yellow.

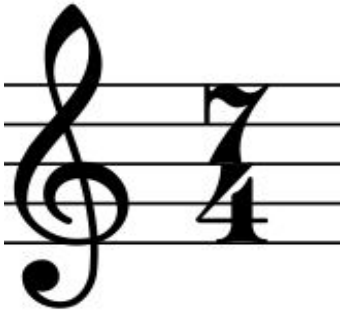
Experiment

Fourth Rhythm Cycle – 7/4 Cyle

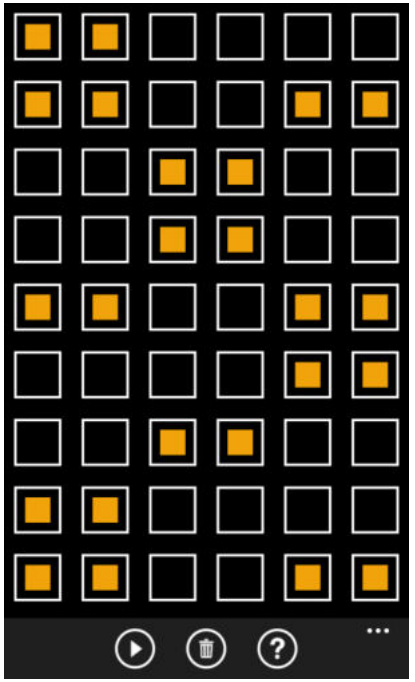
7-4 or *Misra* is one of the common cycles used in both Western and Indian Classical Music. The pattern in this rhythm cycle is usually counted as

"1,2,3… 1,2…3,4… 1,2,3… 1,2…3,4…"
or "Tha ki Ta Tha ka Dhi Mi…
Tha ki Ta Tha ka Ju Nu…"

This rhythm cycle was set and assigned a simple contact name. This contact name (Monu) would be also be referred as Contact 4 in the following pages. The picture below shows how the time signature of this rhythm cycle is represented on the stave in Western Music Notation.

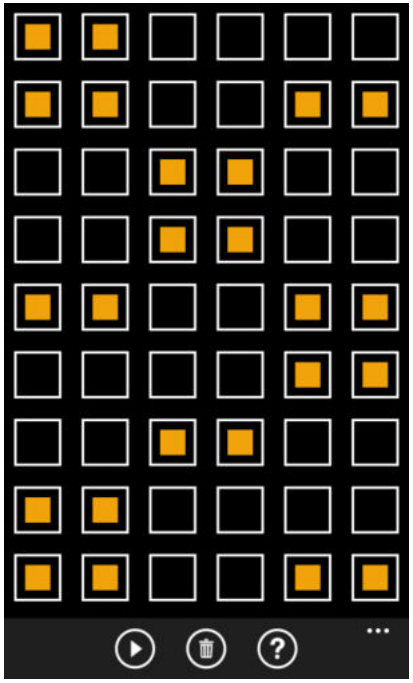


Contact 4 – MONU



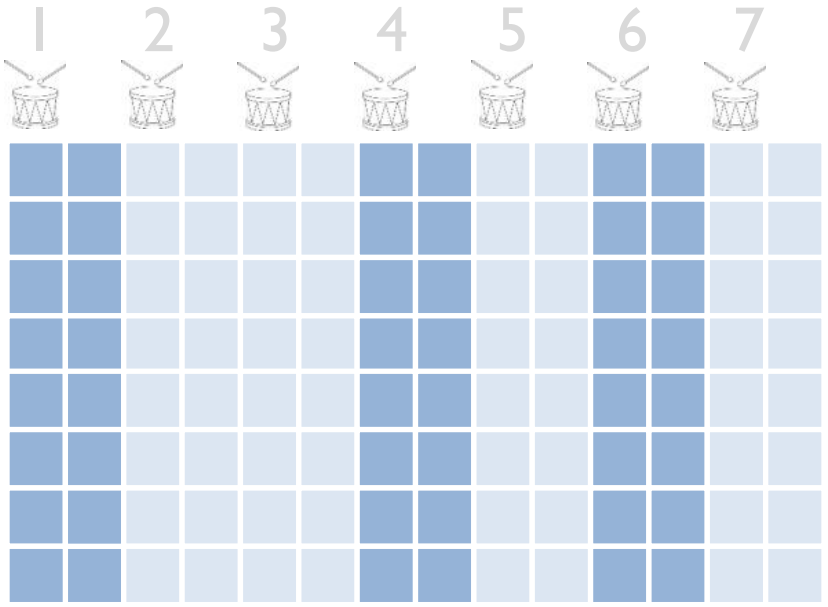
In the screen shot above, the 7-4 Rhythm -Vibration is set as - 1 0 0 1 0 1 0 to form a bar.

Experiment



A clearer representation of the above pattern
is given with dark and light blue boxes on the right

=



The dark blue colored boxes are where the
vibrations are set in the app in yellow.

Testing 1

Task

Identifying Contacts

The users were given the 4 vibration rhythm cycles and they were asked to identify each of the contact names assigned to them(by haptic feedback only). All the four vibration cycles given to the user had the same tempo values during this round tests.

Key question

Is the user able to identify the right contact names for the different vibration cycles assigned?

User Feedback 1

Only 1 of the hearing impaired users and 2 of the normal users could identify all of the different vibration-rhythmic cycles and map it to the corresponding contact names. Also almost all of the users had problems in differentiating between 5-4 and 7-4.

Insight

The Users had a problem differentiating between different rhythm cycles mainly because all rhythm cycles were rendered at the same tempo. Generally, today's mobile phones have majorly two tempo changes in the way they vibrate – one fast and one slow. If one combines rhythm cycles along with tempo changes, the user's ability to differentiate between the rhythm cycles would improve.

Combining tempo changes with different rhythm cycles might also enable us to get more number of vibration patterns(so, more number of contact tones).

Testing 2

Task

Identifying Contacts

The users were given the 4 vibration rhythm cycles and they were asked to identify each of the contact names assigned to them(by haptic feedback only). This time 3-4 and 7-4 rhythm cycles had their tempos faster (values doubled) while 4-4 and 5-4 rhythm cylces' tempos were retained as in the previous test.

Key question

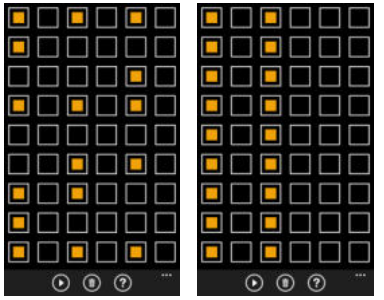
Is the user able to identify the right contact names for the different vibration cycles assigned?

User Feedback 1

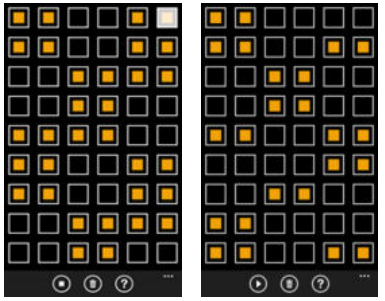
All the 10 users could differentiate between the different patterns and also identify the corresponding contact name for each vibration pattern.

Conclusion

It can be concluded that although different rhythms can be used in vibration alerts

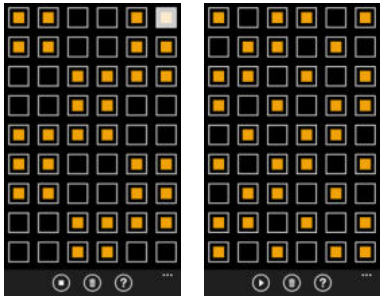


4-4 3-4



7-4 5-4

Speed X 2



7-4 5-4

Future Goals

Using Rhythms in for Vibration

Identifying Contacts

Using different Vibration alerts for different contacts is not available today in all the phones. In apple's iphone, there are a few vibrating alert options to choose from. But these are not rhythm-based or time singature-based and vary depending on the change in tempo only.

While identifying different vibration alerts (based on just tempo changes or just rhythm changes) might be very cumbersome, combining different tempos with different musical rhythm cycles may give rise to a pool of vibration alerts, each distinct from one another.

Extensions?

In music, there are plenty of rhythm cycle variations and only 4 of the many were used in the experiments mentioned in this report. Including more of the rhythms combined with suitable tempo values shall give rise to more possibilities.

Also, vibration alert-contact ringtone mapping can also be used by general users in a noisy setting.

Rhythm Cycle + Tempo

References

[1] Jinho Yim, Rohae Myung, Byongjun Lee. The Mobile Phone's Optimal Vibration Frequency in Mobile Environments

[2]*http://en.wikipedia.org/wiki/Vibrating_alert*

[3]*Lining Yao et al.* Music-touch Shoes: Vibrotactile Interface for Hearing Impaired Dancers, *CHI'12*

[4]*Young-Woo Park et* al. Emotional Touch Delivery through an Inflatable Surface over Interpersonal Mobile Communications, *UIST'11*

[5]*Chandrika Jayant et al.*V- Braille: Haptic Braille Perception using a Touch-screen and Vibration on Mobile Phones, *University of Washington, 2009*

[6]*Eve Hoggan et al.* Pressages: Augmenting Phone Calls with Non-Verbal Messages, *UIST '12*

[7]*Emilien Ghomi et al.* Using Rhythmic Patterns as an Input Method, *CHI'12*

[8]*Jonghyun Ryu et al.* Improving Vibrotactile Pattern Identification for Mobile Devices Using Perceptually Transparent Rendering, *MobileHCI'10*

[9]*Bahador Saket et al.* Designing an Effective Vibration-Based Notification Interface for Mobile Phones,*CSCW '13*

[10]*A.S. Panchaapakesa Iyer, Ganamrutha Bodhini,* Alankaras - Graded Exercises *Text Book for Carnatic Music beginner, Saralivarisai*

[11] *Vibration Composer* App for Windows.