# MusicCube: Making Digital Music Tangible

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**ABSTRACT**
To some extent listening to digital music via storage devices has led to a loss of part of the physical experience associated with earlier media formats such as CDs and LPs. For example, one could consider the role of album covers in music appreciation. Previous efforts at making music interaction more tangible have focused mainly on access issues. A case study is presented in which several content attributes of Mp3 formatted music as well as control access are made more visible and tangible. Play lists, music rhythm, volume, and navigational feedback were communicated via multicolored light displayed in a tangible interface. Users were able to physically interact with music collections via the MusicCube, a wireless cube-like object, using gestures to shuffle music and a rotary dial with a button for song navigation and volume control. Speech and non-speech feedback were given to communicate current mode and song title. The working prototype was compared to an Apple iPod, along the dimensions of trust, engagement, ergonomic and hedonic qualities, and appeal. Subjects rated the MusicCube higher on scales associated with hedonic qualities, while the iPod was preferred for ergonomic qualities. Results on trust measures were found to correlate with ergonomic qualities, while sense of engagement related to hedonic aspects. Subjects generally valued the expressive and tangible interaction with music collections. Next design steps will focus on increasing ergonomic aspects of the MusicCube while maintaining a high hedonic rating.

**Author Keywords**
Tangible Interaction; Multimodal; Product Design; Digital Music Collections; Mp3

**ACM Classification Keywords**
H5.2 User Interfaces

**INTRODUCTION**
In interacting with video and audio media a wide range of button-loaded remote controls are used that offer different functionalities but are very similar in physical appearance. As more and more information is becoming digital and stored on computers, new and less complex ways of interaction should be explored that will still allow interacting with media while comfortably sitting in a couch instead of in front of a computer screen. In a ubiquitous computing scenario, Ishii proposes that environments will be enriched with new physical objects called tangible interfaces [3]. Tangible interfaces offer specialized and context sensitive input devices that utilize skills for physical object manipulation. They externalize internal computer representations and facilitate interaction by making it more direct and manipulable [1].

A very clear and popular example of digital information is music. It is widely spread due to its compact format and the ease of downloading it from the Internet; people often refer to digital music as Mp3, a common compression format. One can listen to Mp3 almost anywhere. In a home situation for example a computer can be connected to stereo equipment. Unlike analogue media, Mp3 music is essentially virtual in terms of a physical representation, the physical location of the source can be decoupled from the access point or listening location. One could argue that a part of the music product and listening experience is lost with Mp3. Consider for example the act of buying a CD or LP, unwrapping it, opening the case and placing it in the player. The information on an album cover often provides an emotional expression related to the album content.

A range of concepts has been considered towards making digital music more tangible and expressive. Ideas include: (1) use of everyday object metaphors such as bottles or album covers coupled to an RFID tag reader, (2) expressive color lights to convey music rhythm, (3) multifunctional tangible control for music navigation and play mode changes, (4) use of speech output for song information, and (5) gesture control integrated in a tangible device for music control [4, 9, 10]. Table 1 provides an overview of these concepts by study reference number. Although many of these ideas seem promising in themselves, the potential usability and experiential value of a tangible interface for controlling digital content is not clear. Many of the proposed design solutions lack formal testing. Furthermore, none of the designs incorporates a wide range of concepts, such as those listed in Table 1, into an integrated working prototype. Given the appeal of new products such as the Apple iPod, the potential benefits of tangible interaction to digital music databases may be questioned.


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| Concepts \ Author ref. # | 4 | 9 | 10.1 | 10.2 | 10.3 |
|---|---|---|---|---|---|
| Use of physical metaphor | x | x | | x | |
| Music rhythm visualization | x | | | x | |
| Multifunctional control | | | x | x | x |
| Spoken song description | | | x | | |
| Use of gesture control | | | x | | x |

**Table 1. Concepts for tangible music interfaces by study reference number[1].**

As Mp3 collections are often large and thus not categorized, content-based music genre classification has been gaining importance [6]. This may affect the way people listen to Mp3 in the future, i.e. by genre or pre-defined play list instead of by album. In short, any new concept for interacting with digital music should take into account the potential use of automatic content classification.

## THE MUSICCUBE

In considering the concepts presented in Table 1 and other ideas for expressive interaction with digital music, a tangible interface called the MusicCube (MC) was developed through an iterative process of building prototypes and informally testing them with users. The MC is a rubber cube-like object with a button shaped as a speaker that can be pressed and rotated. The appearance of the MC resembles a loudspeaker as a reference to the virtual content, being music. The shape, size and material of the MC were chosen to allow comfortable two-handed interaction. Multi-colored lights and a soft clicking sound provide visual and audio feedback during interaction (see Figure 2).

### Interaction with the MusicCube

Colored-hearing synesthesia is a phenomenon whereby people experience visual images when listening to music [7]. Awareness of this phenomenon led to the idea of using color to represent play lists. The user can assign a predefined color that is considered most appropriate for a given play list. An informal study indicated that people usually listen to around four play lists, for which a cube with four color-lighted sides is sufficient.

The lights are off when the MC is off; shaking the cube causes the four color side lights to come on, indicating the cube is ready for interaction. A play list can be selected by placing the color side of the desired play list upwards. Rotating the top button allows scrolling through the songs in the play list. Music can be paused by pressing the button. The volume mode is activated by briefly holding in the button. Shaking the cube activates shuffle mode and a random song is played. Placing the cube on a surface with the top button facing downwards and pressing it causes the device to fall asleep, indicated by a fading relay activated rattle-like sound and dimming lights.

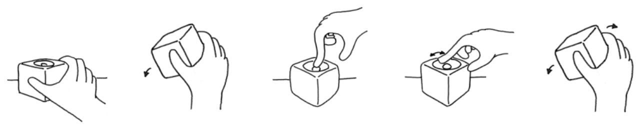

**Figure 1. Interaction with the MC (play, change play list, pause, scroll or change volume, and shuffle).**

### Feedback

To reduce demands on visual attention a speech display was chosen over a text display. Automatic speech generation, using a female voice, is used to provide feedback for play list name, song title, current function, and volume level. The color lights are used to provide feedback on volume level, with higher intensity indicating higher volume. A rotating effect between sidelights is given, with clockwise for fast-forward and counter-clock wise for reverse. Random colors in the side lights are displayed in shuffle mode. While the music is playing, lights flashing in changing colors represent the current music rhythms. A static light indicates the current play list. Non-speech click-like sounds are given for fast-forward, reverse, and volume steps.

### Prototype

A fully working prototype was built to evaluate the MusicCube design concept. A rubber-cube like shape was molded from silicone rubber. The shell is stretched over a semitransparent polycarbonate box that contains and protects the electronics and four rechargeable 3AA batteries that power the MC.

### Electronics and Software

A specially designed side-up sensor consisting of four two-way infrareds combined with a ball bearing and a

**Figure 2. The Apple iPod and MusicCube prototype.**

[1] Note: Three different design concepts are outlined by Zimmerman [10].

one-dimensional tilt sensor, are used to recognize which side of the cube is facing upwards. Four RGB LEDs provide the colored lights for each side. An aluminum turning knob is affixed to a rotary encoder with a micro switch. A relay produces the clicking sounds. Two wireless radio modules, one in the MusicCube and the other connected to the USB computer port, communicate the status of the MC. The wireless control range is about 50 meters. Control commands from the MC are interpreted via custom software developed in Java that in turn controls a music player on the PC. A program developed in Max/MSP translates the music rhythm into color signals that are send to the MC together with the control feedback signals created by the Java software. When the cube is shaken, rapid changes in status of the infrared-based tilt sensors trigger the shuffle mode.

## RESEARCH

A study was conducted to compare the MusicCube interface with the Apple iPod, along the dimensions of trust, engagement, ergonomic qualities (EQ), hedonic qualities (HQ) and appeal; these measures are explained below. To consider the value of speech output, a second variant of the MC was created which had no speech feedback.

As a consumer product, emphasis in the evaluation of the MC was placed on subjective, rather than objective human performance measures. Each of the factors listed above were thus measured using rating scales. The main research question was whether tangible and visually enriched interaction would increase appeal as compared to use of the iPod interface.

## METHOD

Seventeen individuals (5 women, 12 men) aged between 20 and 44 (mean 23.8) participated in the study. Participants did not own an iPod and had little or no experience with the product. They were university students and staff. A living room-like environment was setup with a comfortable chair for the test subjects. All observations were video taped.

Prior to the experiment subjects were asked to select one of the predefined play lists, either Fun Lovin' Criminals, Hip Hop & Rap, Pop, or Seventies & Eighties, and to specify a color to be applied to the play list. Available colors were, red, green, blue, cyan, magenta, yellow, or white. Each participant was continuously given a set of tasks, to perform on the MC without speech, MC with speech (MCs), and iPod. The start order of design evaluated first was balanced across subjects; the remaining two orders of designs were randomized. Subjects were asked to perform the tasks on each of the test interfaces, without any introduction. They were also asked to express their experiences by speaking aloud.

The eight given tasks were: (1) turn the interface on, (2) start playing the previously chosen play list, (3) change play lists, (4) scroll through songs by playing the next or the previous song in a play list, (5) change the volume of the music, (6) shuffle by playing a randomly selected song in a play list, (7) pause the music; and (8) turn the interface off. Once all tasks were performed or a 15-minute time limit was reached, subjects proceeded to the next test design. Upon concluding use of the interfaces, a questionnaire consisting of 30 bipolar verbal scale anchors along the dimensions of trust (e.g. familiarity and reliability) [5], engagement (e.g. challenge and involvement) [8], ergonomic qualities (e.g. support and control), hedonic qualities (e.g. interest and excitement) and appeal (e.g. pleasure and desirability) [2] was filled in for each interface.

## RESULTS

A factor analysis using principal components, Varimax rotation was conducted on the questionnaire results. Three resulting factors were found to be associated with 64.8% of the total variance. The relations of the measures to factors showed high consistency with Hassenzahl's results, whereby measures correlated with factors that could be labeled as ergonomic, hedonic, and appeal. However, the anchor *interest* related more to the factor appeal. Measures on trust were found to correlate with EQ, while sense of engagement related to HQ.

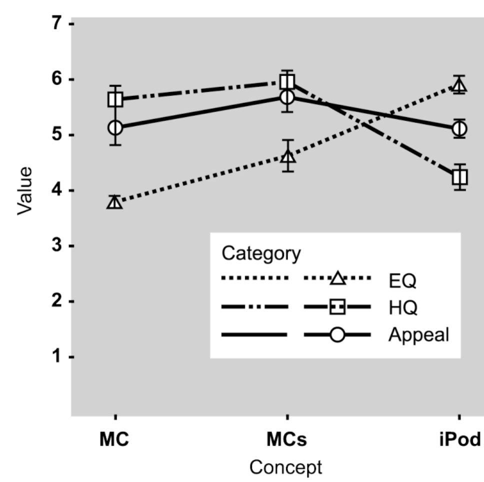


**Figure 3. Means of the factors EQ, HQ and appeal for the three design types.**

A significant main effect for design concept across measures was found, for EQ ($F_{(2,32)} = 41.928$, $p < 0.0005$) and HQ ($F_{(2,32)} = 16.631$ $p < 0.0005$) (see table 2). Both MC and MCs scored high on HQ and low on EQ. However, speech support increased EQ significantly. No significant difference in appeal between the MCs or MC and the iPod was found. This could be attributed to the averaging model for HQ and EQ [2], whereby the higher HQ for the MC compensated for the lower EQ score.

| Concept | EQ | HQ | appeal |
|---|---|---|---|
| MC vs. MCs | .002 | | .028 |
| MC vs. iPod | .000 | .009 | |
| MCs vs. iPod | .000 | .000 | |

**Table 2. Significant effects ($\alpha$ = .050) in comparing mean subjective scores across measures, using ANOVA (Bonferroni) within subjects.**

## DISCUSSION

While the MusicCube scored lower on ergonomic qualities, results of observations suggest that this was mainly due to some design flaws rather than the general concept of tangible interaction. In particular subjects had difficulties in understanding use of the multifunctional top button. Mode changes were dependent upon the duration in which the button was held down. Also, the combined use of light for rhythm and functional feedback caused some confusion, such that subjects were not able to distinguish the two aspects. The addition of speech feedback helped in disambiguating the button functionality and made the light feedback redundant. Other functions, such as shaking the cube to activate the shuffle mode, were not easily discovered by subjects.

Another important observed aspect that influenced the perceived EQ of the tangible interface was performance time. Initially during pilot studies the system did not react fast enough, such that subjects could not take advantage of direct feedback afforded by physical movement of the cube. While improvements were made to system response time, the response time in carrying out user initiated commands still lags compared to the iPod. However, comparison at a product level with a working prototype of similar finishing proved to be an important aspect in gaining information on future product potential.

Lastly, given the lack of a display in the MC, subjects were more dependent upon the music content in identifying which songs belonged to a certain play list as compared to the iPod. This would seem to imply that an automatic genre classification system should provide clear filtering, leading to unique sounding play lists.

## CONCLUSION

The success of Apple products such as the iPod lies not only in their functionality but is based also on hedonic qualities. This case study shows that by enriching interfaces and making them more challenging there is room for improvement on even very successful products such as the iPod. Users seemed to appreciate the hedonic value of the tangible interface, even though it was perhaps overly complex in expression. A balance should thus be sought between ergonomic and hedonic qualities towards improving overall appeal. Future research will therefore focus on increasing the ergonomic aspects of the MC while maintaining a high hedonic rating. Also the vast amount of songs that can now be stored on very small storage devices necessitates the exploration of new forms of multimodal interaction combined with intelligent music clustering and recommendation systems.

In considering music listening in different settings or multiple streaming of music from a content server, several MC devices could be simultaneously utilized, to access different music collections. Each cube could have its own form of expression, dynamically associated with the specific music content. Perhaps this will return part of the physical experience, as found in analogue music, to Mp3.

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