Designing for the iPad: Magic Fiddle

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ABSTRACT
This paper describes the origin, design, and implementation of Smule's *Magic Fiddle*, an expressive musical instrument for the iPad. Magic Fiddle takes advantage of the physical aspects of the device to integrate game-like and pedagogical elements. We describe the origin of Magic Fiddle, chronicle its design process, discuss its integrated music education system, and evaluate the overall experience.

Keywords
Magic Fiddle, iPad, physical interaction design, experiential design, music education.

1. INTRODUCTION
The father of ubiquitous computing Mark Weiser described a world where computing evolves from the "personal" to the "pervasive", where technology "disappears into the fabric of everyday life..." [16]. Weiser envisioned computing's evolution into "calm technology" that recedes into the background of our daily lives, empowering people without being noticed, "extending our unconsciousness". Today's personal mobile devices are becoming more powerful while our awareness of them as technology is shrinking.

The iPad, for example, engages users through a large multi-touch display and affords natural interactions that are more about "what to do" than "how". The iPad has potential to be incorporated into physical practice to the point that it is perceived by people as an extension of themselves.

The concept that people act *through* tangible artifacts, rather than *on* it, has been articulated by Klemmer *et al* and *Polanyi*, among others [7, 9]. We also share the sentiment expressed by Dourish that "tangible computing is of interest precisely because it is not purely physical. It is a physical realization of a symbolic reality" [4]; we hope to realize a tangible experience from our design of a musical instrument on the iPad by combining the physical (gesture and artifact) and the virtual (graphical interfaces and digital audio synthesis).

We are motivated by prior works that use mobile devices not simply as controllers or sensors, but as physical, tangible objects calling for meaningful gestural actions by their users [5]. One pioneering work that uses a commodity mobile device as physical musical instrument is *Pocket Gamelan* by Greg Schiemer [10]. In Schiemer's works, mobile phones are "mounted in a specially devised pouch attached to a cord and physically swung to produce audio chorusing."

Smule's *Ocarina* is another example that leverages iPhone's wide array of technologies – microphone input, multi-touch, accelerometer, real-time sound synthesis, and graphics – to create the physical experience of playing an ocarina. The Ocarina also creates a location-aware social experience by allowing its users to listen remotely to one another [13].

More recently, the Stanford Laptop Orchestra has explored possibilities in physical interaction techniques offered by mobile phones through their onboard sensors using the Mobile Music Toolkit [1]. For instance, Luke Dahl proposes a metaphor of "sound as a ball" to design *Sound Bounce* (2009), a gesture-controlled instrument that allows players to "bounce" sounds, "throw" them to other players, and compete in a game to "knock out" others' sound [3]. Another piece, *interV* (2009) by Jorge Herrera, uses the iPhone accelerometer to control sound using gestures such as gentle tilts and larger arm movements. *Wind Chimes* (2009) by Nicholas Bryan leverages mobile phones as directional controllers within a 8-channel surround sound audio system; the metaphor of wind chimes connects "physical" chimes (8-channel system) to a wind force (performer blowing air into the mobile phone's microphone input facing a particular direction) [8].

Figure 1. Playing a Magic Fiddle duet.

2. ORIGINS
The concept for Magic Fiddle began with a casual question: "can we design a violin-like instrument that is so *tangible* that users have to hold the iPad up to their face to play?" While seemingly absurd, this concept was attractive as a challenge to design such a physical interaction.

Thus we embarked on the research, design, and implementation of Magic Fiddle. The result was a unique and expressive musical instrument with game-like and pedagogical elements (Figure 1). The game aspects invite new users to start playing music with the instrument and over time, challenge users to engage a larger repertoire and strive for *virtuosity*. The pedagogical aspects present new and returning users with a fully-integrated, interactive music "teacher". The remainder of this paper presents and evaluates the process involved in creating the Magic Fiddle.

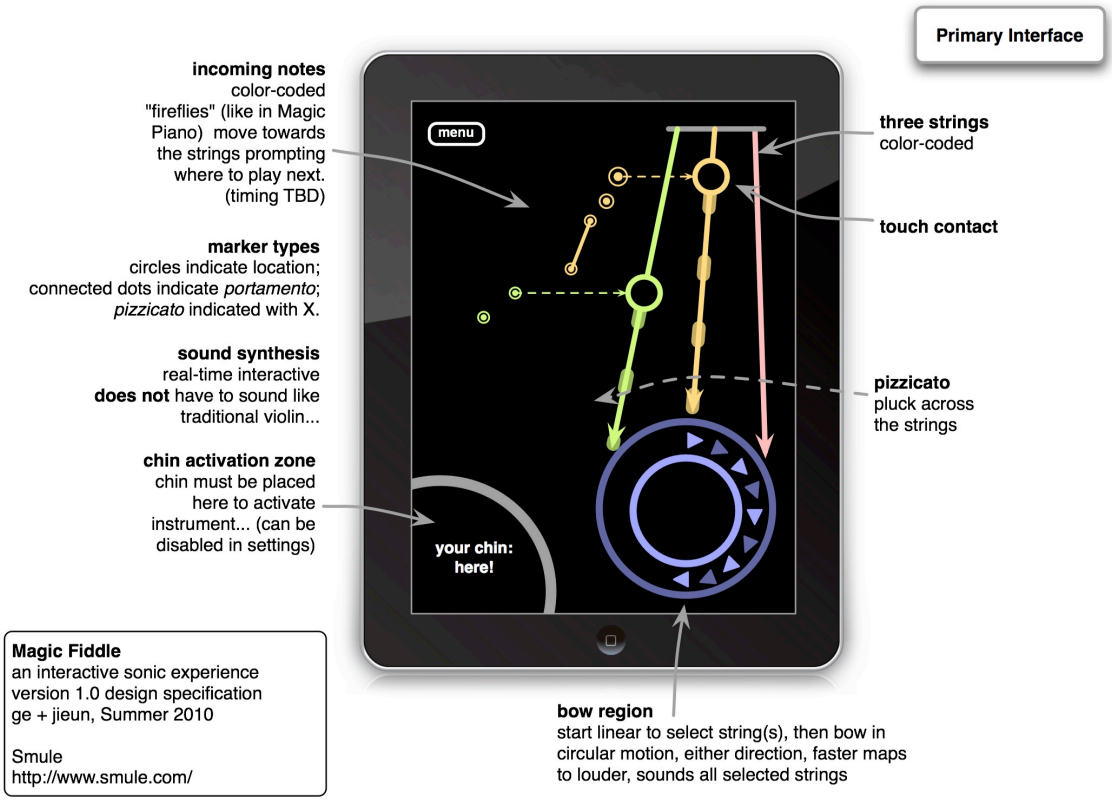

Figure 2. Preliminary Concept Design.

3. DESIGN PROCESS

Magic Fiddle was iteratively designed and implemented. We improved upon interface usability and musical expressivity by creating many prototypes. This section describes high-level issues we had to address and the implementation approaches we considered in response.

3.1 Fitting a Fiddle into an iPad

The foremost challenge we faced was re-purposing an iPad into something it was perhaps not meant to be. The iPad is physically smaller than a violin, such that "fitting" the instrument inside a screen having a diagonal length of 25cm is almost impossible. But even more critical than size is the device's affordance: a flat rectangular surface does not naturally suggest fingering and bowing as possible gestures.

We decided to use the violin as an inspiration, but not as an end goal. We began the design process acknowledging that an iPad cannot generate the same variety of realistic timbres as a physical violin, and cannot offer performers the fine-grained control required to reach comparable virtuosity in technique and expression. However, we believe that crafting a musical experience out of a personal mobile device is still "magical" in concept and, when done well, makes music performance more fun and accessible to the general public.

To make the most out of the device's screen space, and as an aesthetic preference, we modeled only the parts of a violin that are essential for controlling a violin-like sound – the strings and a bowing region – and modified them to suit the iPad.

3.1.1 Strings

Instead of having four strings like a traditional violin, the Magic Fiddle has three, at intervals a fifth apart. Because strings are more difficult to reach as they lie farther away from the edge of the screen, we decided to use fewer strings. Also, we felt that the coordination required for four strings might overwhelm novice performers.

We tested two string layouts: vertical (long) along the right edge of the iPad, and horizontal (short) along the top edge. Strings in the center or across the diagonal of the iPad were considered, but rejected because they cannot be reached if the iPad is to be held like a violin. We decided on the vertical layout to offer more pixels per note for better pitch accuracy and fit more notes into a string. The final design has three strings fanning out from top to bottom along the right-edge of the iPad, with each string having a pitch range of one octave.

3.1.2 Bow Region

The intuitive gesture for playing a note is to touch the screen, with the note ending when the finger is lifted. However, it is not obvious how to associate a particular string with a particular touch. On a violin, the bowing angle determines which string is excited, such that players are free to place their fingers on strings that are not being bowed without affecting the sound. But on a flat screen device as an iPad, it is not possible to bow at a different angle, *per se*. We had to decide between two best alternatives: having three separate bowing regions each controlling a specific string, or having a single bow region that globally controls all strings.

The former option presents further complexity in the performance mechanics, as performers must touch the bow region corresponding to the string they wish to trigger. But it has an advantage of making open strings possible. For instance, if the player wishes to play D3 (the default fundamental of the lowest string), the player would simply touch the bow region corresponding to the lowest string with the right hand and not touch anywhere along the string with the left hand. Additionally, this option allows performers to put fingers down on strings that are not currently being bowed, in preparation for upcoming notes.

The latter option of having a single bow region offers simpler bowing mechanics, and a touch-on gesture on this general region would trigger all "active" strings. We generally do not

want all three strings to sound at all times, hence this approach assumes that a string is "active" only if it is touched at one or more points. Consequently, we can no longer play open-string nor put fingers down on a string that should not be sounding.

While the former option is closer to the mechanics of an actual violin and thus preserves much of the playing style on it, we chose the latter option for simplicity. We realized that fingering the notes correctly on the left hand presented enough technical challenge to the performers, especially considering that there is no tactile feedback in playing on an iPad. We wanted to provide users with a simple playing mechanics over a realistic representation of a violin.

3.1.3 Chin Rest

Initially, the plan was to make it mandatory for a user to place his or her chin on the corner of the screen (see Figure 2), but as it turned out, different chins seem to have varying result with the multi-touch (some would not activate, even with no facial hair). So eventually we moved away from this concept.

To reward users who are holding the iPad the "proper" (and possibly the more difficult) way, we reserved the bottom left corner of the iPad screen for the chin rest, animating bubbles when a touch gesture is detected there.

3.1.4 Musical Score

We used the remaining screen space to display a musical score for the "Songbook" mode (Figure 3). In a Songbook mode, the score is visually depicted as a series of line segments (each representing a music note) moving across the screen from left to right. This animation of incoming notes guide performers when and where to touch the string, and the color of the line segments guide which of the three strings should be fingered. Plucking interactions, vibrato, and glissandi are represented with different graphics. The idea of animating a score as a series of incoming objects is taken partially from the *Leaf Trombone* instrument, but the fiddle has an added complexity of having three "layers" of the score, one per string. [15]. Additionally, a particular track may present a piano accompaniment for the performer.

3.2 Audio Synthesis

We felt that the Magic Fiddle should support distinct sounds corresponding to bowing and plucking. We experimented with using STK Bowed instrument, as well as soundfonts and custom-synthesized sounds. Though the STK Bowed instrument allowed us to directly map bow position, bow pressure, and dynamics to the synthesis model, it was difficult to control these parameters using touch gestures given a relatively small bowing region that we had to work with. Also, naturally, certain combinations of physical parameters on the STK model do not produce pleasant sounds such that the performer may feel frustrated by the lack of responsiveness of the instrument synthesized using this method.

The various soundfonts we experimented with for plucking sounded quite rich and realistic, though soundfonts for bowing sounded artificial with their strictly-regular vibratos (or the lack thereof). So we continued experimenting with other synthesis techniques, in search of a more satisfying bowing sounds.

Eventually, we synthesized the bowed string using an implementation of commuted waveguide synthesis [11], which encapsulates the modeling of excitation, waveguide/resonator, body, and air responses. In the "classic" model, these components are meant to be processed in order, where one complexity is the digital filter required to model the body. Commuted synthesis takes advantage of the linearity and time-invariance of these components to combine the body and air components into a single impulse response that feed into the waveguide. This approach reduces the complexity of the system and is efficient to implement, requiring only an impulse responses and a feedback-delay component for each string. Ultimately, we also used this method to model the plucked interactions, as it resulted in a sound that is more consistent with the bowed interaction.

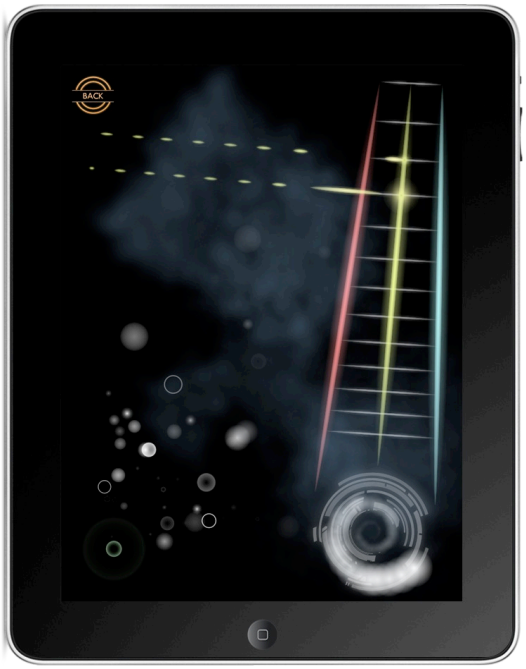

Figure 3. In Songbook mode, Magic Fiddle soft-prompts what and when to play using animated onscreen markers.

3.3 Customization for Playability

We wanted to offer flexibility in the design of our instrument, to accommodate varying levels and styles of playing. So we considered customizing various elements of the instrument, as described below.

3.3.1 Angle of string

The angle of string should be adjustable to accommodate different hand sizes. The angle would be tightened for smaller hands, and widened for larger hands.

3.3.2 Pitch snap

Performers should be able to choose the extent to which frequency "snaps" to the closest note. High pitch snap would help beginners with intonation, such that fingering on the string close to the note gets interpreted as fingering exactly on the note. On the other hand, turning off pitch snap would offer flexibility: advanced players can take advantage of this to perform with vibratos (as a pitch variation), or to play quarter tones, for instance.

3.3.3 Frets

Although violins do not have frets, the default rendering of the instrument would include fret-like horizontal bars drawn over the strings, showing the exact placement of each note on the string. Interestingly, we later found that professional classical violin players like to turn this feature off, relying on their ear to determine the exact positions that produce correct intonation.

3.3.4 Songbook Rate

The songbook rate should be changeable, to allow performers to practice songs at a slower tempo, for instance. The final implementation allows customizing the songbook playrate from four times as slow as the original tempo to twice as fast.

3.3.5 Solo key

The pitch of the lowest string to be used in the Solo mode can be set to any note between C2 and D4. When set to C2, the strings match the lower three strings on a cello, and when set to D4, the strings match the top three strings on a violin. Because the overall range of the instrument over the three strings is just over two octaves, allowing adjustments on the key makes it possible to cover a greater range of pitch, facilitating playing as an ensemble.

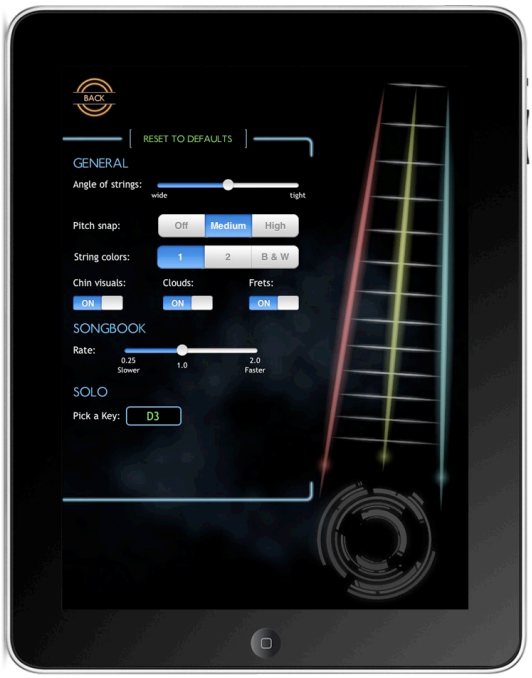

Figure 4. Customizing the fiddle.

3.4 Assisting Beginners

One of the original motivations for designing musical instruments on personal mobile devices is to make music more accessible to the general public; that is, people who do not necessarily consider themselves as "musicians". Thus, we wanted to ensure that the instrument is approachable for absolute beginners as well. Beyond the songbook mode, which allows users to choose songs of varying difficulty levels to practice and perform, we have included a "Storybook" mode for pedagogical purposes. In this mode, the personified fiddle, which the user names upon the initial launch of the application, becomes a teacher with a personality. This aspect of Magic Fiddle is discussed extensively in Section 4.

3.5 Establishing a "Flow"

If the Storybook is designed to welcome beginners to start playing the instrument, the Songbook mode offers a more competitive environment in which users polish their performance skills. Our design goal was to generate a flow experience, in which players are fully immersed in the performance with a strong motivation to improve. So we associated with the Songbook mode a game-like scoring and badge mechanism. At the end of each performance, the performer is shown accuracy (i.e. "38 of 42 notes hit") and the corresponding score (i.e. "Total Points: 38"). The individual performances are aggregated in a summary Profile, showing users statistics. A global leaderboard not only shows top-scoring users with highest aggregate points, but also includes the user herself to convey where she stands in relation to the top scorers.

4. A NEW MUSIC TEACHER

4.1 An Instrument with Personality

The first time a user launches Magic Fiddle, it plays a short tune and greets: "Hello. I am your fiddle." The text comes from nowhere; there is no avatar representing the fiddle. The iPad, which becomes a fiddle when the application is launched, introduces itself. A*nd it probably wants to be your friend.*

Throughout development, we referred to the fiddle's personality as "the voice of the fiddle." Much of what makes the fiddle likable is the way it "speaks" to the user, as if from one person to another. The voice engages users by implying a depth of character. Where motivation for self-improvement failed, the desire to connect with the fiddle would encourage users to spend more quality time with the instrument.

Since the voice was so important, Magic Fiddle exercises fine control over the way in which it is displayed. When the fiddle speaks, its words appear as white text occupying the left side of the screen. It uses complete sentences which start with capital letters and end in punctuation. Lines of text fade in at speeds which suggest calm, even speech. Though the timing and positioning are precisely specified by the writers, they vary throughout the app, because they were tuned by feel.

The fiddle speaks this way to appear intelligent, friendly, and warm. But that is only its predisposition. The fiddle can be a goofball. Sometimes it becomes preoccupied, boastful, lonely, or pleased. Its changing emotion is reflected in the writing, but also by breaking the rules described above. For example, the fiddle sometimes speaks very slowly to drive home an important point or express exasperation. When the fiddle gets excited, the text comes thick and fast. Sometimes the fiddle completes a thought, but thinks of a "zinger" and squeezes it in by scrolling everything else up by one line. In certain cases, the fiddle displays images and plays sounds to enhance its explanations. Even when its strings are silent, the fiddle has plenty of ways to be expressive.

4.2 Storybook: Integrated Teaching

The first time the user presses the "Storybook" button on the main menu, they are presented with the table of contents of "Your Very First Magic Fiddle Book". When they tap the first section header, "Holding Your Fiddle," the fiddle itself begins to teach them how to play.

This is an important mode. While other main menu options float in a general area, storybook's button is the keystone which holds the menu together, and it flashes. It is not an integrated tutorial which could be summed up in a few screens of text (which the user would surely skip). The storybook contains hours of content, covering skills as basic as holding the fiddle correctly (Figure 5), to advanced techniques like sordino.

4.2.1 iPad Fiddle Lessons

"Storybook" is actually a collection of books, each with a handful of chapters. There is one chapter per topic (for example, "Bowing" or "Upper Body Posture"). Each chapter follows a pattern: introduce a concept, practice some music which demonstrates it, then perform a piece which combines knowledge gained in this chapter with that of previous chapters. The chapter is split into sections so that the user can resume at any of these points of transition.

Once the user begins a story, however, the only level of hierarchy that matters is the book. The story flows from section to section, chapter to chapter, until the user reaches the end of the book and is sent back to the menu. The user falls into a rhythm, although they may not recognize what it is. They can back out and see the structure, but it doesn't matter in context. If the user is interrupted, the next time they tap the "Storybook" menu item, the book is opened to where they left off.

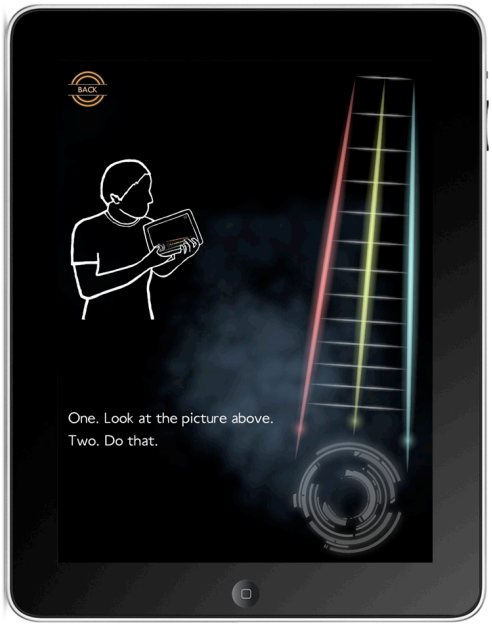

Figure 5. Magic Fiddle shows a user how it likes to be held.

4.2.2 Social Homework

Several of the chapters end with a mission for the user. These break up the normal lessons by asking the user to perform tasks which require interacting with people and places in the physical world. Although playing the fiddle by itself can be a rewarding experience, we wanted to encourage users to share the experience with others, face-to-face as a performative and social act.

After the completion of each mission, the user is asked questions about their experience. The responses indicate that gentle nudges from the fiddle were enough to inspire users to have a fantastic time with friends and family.

One mission asks the user to play "Mary Had a Little Lamb" while standing up to practice correct posture. Afterward, they are asked, "Could you sum up your experience in one word?" The top five responses were "Fun," "Awesome," "Cool," "Great," and "Nice." Here are some other notable responses:

"That was awesome. I am going to buy a real fiddle and practice what I learn from this app"

"爽" (translation from Chinese: "cool")

"A little bit harder than the actual violin"

"As a violinist, I can say its not even close to the real thing, but it was fun :)"

"The fiddle told me what to do. Awesome."

"It was so much fun. It was like playing my own violin!"

"I feel like a clown"

"Sounds like I'm making music!!!"

About 15 minutes of game time later, the user is asked to play "Twinkle, Twinkle, Little Star" in front of a live audience. The top five responses were again positive: "Fun," "Cool," "Great," "Awesome," and "Good." Some more responses are below:

"It was fun my audience (mom and dad) clapped"

"I was epic, the crowd cheered and lifted me up after I stage dived off my bed. Money and roses were thrown at me. It was pretty cool."

"Almost got a standing ovation from 2 dogs"

Unlike most of the storybook, which must be done in order, the user is free to skip missions. This gives users enough flexibility to comfortably perform the tasks required of them instead of faking their way through. This is more important for the later, more demanding missions. One asks the user to invite a friend (or potential lover) to a public play and play *L'amour est un oiseau rebelle*. Another asks them to busk outside a coffee shop while playing *Johnny Has Gone for a Soldier*.

5. IMPLEMENTATION

Magic Fiddle was developed using the Apple iOS Software Development Kit and additional third-party libraries including Fluidsynth[1] and the Mobile Music Toolkit (MoMu). The real-time graphical interface of the Magic Fiddle instrument was developed in OpenGL ES, and was optimized via additional visual cues to provide a natural feeling of fluidity and responsiveness.

Musical data (e.g., Songbook songs and Storybook snippets) is stored as MIDI files augmented with tags specifying the score for fiddle and piano accompaniment, as well as meta-data for pitch-to-string mappings and articulations. When rendering a Songbook or Storybook performance, a central scheduler synchronizes the graphics and audio and maintains a sliding window of upcoming notes. As noted in Section 3.2, the audio for the fiddle is an implementation of commuted waveguide synthesis. The piano accompaniment is rendered with soundfonts in a Fluidsynth. As in other Smule applications, Magic Fiddle presents a globe visualization that plays back performances of users playing the instrument around the world.

The applications tracks achievements (e.g., getting a perfect score on a song, or playing ten performances) and the user's position on a global leaderboard, ranked by total points earned.

The server-side components of Magic Fiddle provide storage and retrieval of user information, such as their storybook state, achievements; and maintains the global leaderboard. The latest version of all Songbook and Storybook information is stored and can be updated by the client application. Real-time telemetry data is collected from users as they interact with the application, providing opportunities for usability analysis.

6. REFLECTIONS

In the three months following its release, Magic Fiddle has been downloaded onto more than 100,000 devices. We are able to reflect on the user experience based on feedback from Storybook social homework responses, engagement data gathered via telemetry, reviews in the iPad App Store, and informal monitoring of Magic Fiddle-related posts on Twitter.

6.1 Customization for Playability

We provide an informal sample of tweets below to illustrate some different sentiments expressed about Magic Fiddle.

6.1.1 Enthusiasm

heatherlaforce: "Smule's magic fiddle is so much fun! Thankfully, it isn't too frustrating considering my musical training. It does strain the wrist however" (12/26/2010).

aprilynpodd: "I'm hooked on the iPad app: 'Magic Fiddle', Practiced for an hour today :)" (12/14/2010)

swimwims: "Amazing experience! This holiday I've spent much time to play Vivaldi on my iPad:)" (11/23/2010)

cjkonecnik: "I just opened Magic Fiddle by Smule for the first time and when I exited, 2 hours had gone by!" (11/10/2010)

6.1.2 Nostalgia of Learning Violin

MildlyAmused: "It's like being in 4th grade again. My childhood, I am reliving it" (1/2/2011)

RedNinjaTurtl: "All those years of not practicing violin... now I'm gassed up about this $3 magic fiddle app. Ridiculous. god knows how much mom & dad spent" (12/7/2010)

[1] www.fluidsynth.org/

6.1.3 Social Engagements

timmmmyboy: "Ok the whole office is cracking up at my attempts playing the magic fiddle now" (11/18/2010)
Intenso: "this year's christmas eve I'll play Silent Night for my family on my #magic Fiddle" (11/26/2010)

6.1.4 Commentaries on Instruments

danhadi: "Love Magic Fiddle for iPad. It's a new breed of musical instrument" (11/24/2010)
heatherlaforce: "Smule Magic Fiddle is challenging, but so much fun! Perhaps I should get a real violin..." (12/24/2010)
e_2productions: "The magic ipad fiddle - an insult to REAL musicians, or a great tool to bring music alive to millions?" (11/18/2010)

6.2 Professional vs. Novice Performers

The members of the St. Lawrence String Quartet[2], an Ensemble in Residence at Stanford University, were among the first to try out Magic Fiddle. Their initial response noted the lack of tactile feedback on individual strings, and that the players missed the lateral curvature of the traditional instrument's neck. The ability to bow indefinitely was appreciated. Regardless of the many differences, these professional musicians picked up the instrument almost immediately, performing Pachelbel's *Canon* as an ensemble (Figure 6).

Figure 6. The St. Lawrence String Quartet on iPads.

In contrast, one of the authors had no experience playing a string instrument and at first began playing Magic Fiddle the "improper" way, by placing the iPad on a desk and using only the index finger to finger the notes. But after several hours of practice, she learned to hold the instrument properly, fingering with all four fingers on the left hand, and realized that this posture actually allowed her to improve her performance.

6.3 Concluding Remarks

The creation of Magic Fiddle was an experiment to craft a tangible artifact that is a *physical realization of a symbolic reality*. It combines physical metaphors of a violin with the virtual elements of a game and personal music teacher. While the preliminary response has been positive on the whole, we still have much to learn from the rich data it provides about how users relate to the experience. As the computer continues to evolve, and perhaps "disappear", we strive to find the right balance between leveraging its *physicality* and *virtuality*.

[2] http://www.slsq.com/

7. ACKNOWLEDGEMENTS

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8. REFERENCES

[1] Bryan, N. Herrera, J., Oh, J., and Wang, G. 2010. "MoMu: A Mobile Music Toolkit." In *Proceedings of the International Conference on New Interfaces for Musical Expression*. Sydney Australia.
[2] Cook, P. 2001. "Principles for Designing Computer Music Controllers." In *Proceeding of the International Conference on New Interfaces for Musical Expression*.
[3] Dahl, L. and Wang, G. 2010. "Sound Bounce: Physical Metaphors in Designing Mobile Music Performances." In *Proceedings of the International Conference on New Interfaces for Musical Expression*. Sydney, Australia.
[4] Dourish, P. 2001. *Where the action is: the foundations of embodied interaction*: MIT Press.
[5] Essl, G. and Rohs, M. 2009. "Interactivity for Mobile Music Making", *Organised Sound*, 14(2): 197-207.
[6] Gaye, L., Holmquist, E., Behrendt, F., and Tanaka, A. 2006. "Mobile Music Technology: Report on an Emerging Community", In *Proceedings of the International Conference on New Instruments for Musical Expression*. Paris, France.
[7] Klemmer, S., Hartmann, B., and Takayama, L. 2006. "How Bodies Matter: Five Themes for Interaction Design." In *Proceedings Designing Interactive Systems*.
[8] Oh, J., Herrera, H., Bryan, N., Dahl, L., and Wang, G. 2010. "Evolving the Mobile Phone Orchestra." In *Proceedings of the International Conference on New Interfaces for Musical Expression*. Sydney, Australia.
[9] Polanyi, M. 1967. *The Tacit Dimension*. London: routledge & Kegan Paul Ltd.
[10] Schiemer, G. and Havryliv, M. "Pocket Gamelan: Tuneable trajectories for flying sources in Mandala 3 and Mandala 4." In *NIME '06: Proceedings of the 2006 conference on New Interfaces for Musical Expression*. Paris, France.
[11] Smith, J. O., 2010. *Physical Audio Signal Processing*. W3K Publishing.
[12] Tanaka, A. 2004. "Mobile Music Making." In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 154–156. Hamamatsu, Japan.
[13] Wang, G. 2009. "Designing Smule's iPhone Ocarina." In *Proceedings of the International Conference on New Interfaces for Musical Expression*, Pittsburgh, USA.
[14] Wang, G., Essl, G., and Pentinnen, H. 2008. "Do Mobile Phones Dream of Electric Orchestras?" In *Proceedings of the International Computer Music Conference*. Belfast, Ireland.
[15] Wang, G., Oh, J. Salazar S., and Hamilton, R. 2011. "World Stage: A Crowdsourcing Paradigm for Social / Mobile Music." *International Computer Music Conference*.
[16] Weiser, M. 1991. "The Computer for the 21st Century." *Scientific American Special Issue on Communications, Computers, and Network.*