

The Convergence of Alternate Controllers and Musical Interfaces in Interactive Entertainment

Tina Blaine

Carnegie Mellon University
Entertainment Technology Center
700 Technology Drive
Pittsburgh, PA 15219
011-412-268-2980

tblaine@andrew.cmu.edu

ABSTRACT

This paper will investigate a variety of alternate controllers that are making an impact in interactive entertainment, particularly in the video game industry. Since the late 1990's, the surging popularity of rhythmic and musical performance games in Japanese arcades has led to the development of new interfaces and alternate controllers for the consumer market worldwide.

Rhythm action games such as *Dance Dance Revolution*, *Taiko No Tatsujin (Taiko: Drum Master)*, and *Donkey Konga* are stimulating collaborative gameplay and exposing consumers to custom controllers designed specifically for musical and physical interaction. We are witnessing the emergence and acceptance of these breakthrough controllers and models for gameplay as an international cultural phenomenon penetrating the video game and toy markets in record numbers.

Therefore, it is worth considering the potential benefits to developers of musical interfaces, electronic devices and alternate controllers in light of these new and emerging opportunities, particularly in the realm of video gaming, toy development, arcades, and other interactive entertainment experiences.

Keywords

Alternate controllers, musical interaction, interactive entertainment, video game industry, arcades, rhythm action, collaborative gameplay, musical performance games

1. INTRODUCTION

In the past five years, a proliferation of inexpensive controller devices has surfaced to enhance player interaction predominantly with musical video games and other interactive entertainment play experiences. These controllers are for the most part, accompanied by relatively straightforward interfaces and comprised of the most economical components available. Nevertheless, a variety of sensors embedded in percussion controllers, dance pads, handheld toys, video games, mobile devices and more have been gaining in popularity and further driving sales of the hardware peripheral

gaming and toy markets. This paper will focus primarily on games and toys developed in the musical rhythm genre that are played with custom controller devices.

According to DFC Intelligence, the worldwide market for videogame peripherals, consoles and software was approximately 23 billion in 2004.¹ [1]. Despite the comparatively small penetration of game peripherals in the video game market overall, the commercial potential that alternate music controllers and associated software pose is potentially significant and relevant to the NIME community.²

2. BACKGROUND

There are many precedents in the NIME community related to creating controllers oriented toward novice play and to the collaborative musical experience. [2] Researchers at the MIT Media Lab have developed a number of playful musical controller devices prior to and as part of the *Toy Symphony* project, including *Squeezables*, *Musical Shapers* and *BeatBugs* to name just a few. [3] [4] [5] Some of these design efforts have motivated subsequent collaborations with toy companies and resulted in spin-off products such as the Fisher Price Symphony Painter inspired by Farbood and Pasztor's music composition software *Hyperscore*. [6] Other easily accessible controllers or interfaces presented in the NIME community such as *Musical Trinkets/Navigatrics* [7], *Sonic Banana* [8], *Context-Aware Sensor Doll*, [9], *SillyToneSquishFactory* [10] or *PhISEM controllers* [11] have been primarily designed for exhibition, performance, or research, with the *Jam-O-Drum* [12] being one of the few exceptions crossing over into the realm of video games.

In Wanderley and Orio's research about input devices for musical expression, they suggest using a series of simple musical tasks as a means of evaluating controllers and defining which gestures that a controller might be capable of performing. [13] They further suggest that tasks specifically related to music such as timing and rhythm have no parallels in the field of Human-Computer Interaction. However, the introduction of controllers specifically intended for rhythmic gameplay rather than explicit musical

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¹ The NPD Group reports 9.9 billion in U.S. with 1.2 billion for peripherals.

² Price Waterhouse Cooper's publication *The Outlook for Video Games* reports that 60% of all Americans over the age of six now play video games.

control or music making per se, suggest that we reconsider this theory from a different perspective.

3. OVERVIEW

3.1 Playing to Win

Gaming controllers used to trigger events as a means of “playing” music are not necessarily thought of nor have they been evaluated as “musical instruments”. In fact, the very notion of using a controller to “win” a game rather than being “played” as a musical instrument runs somewhat contrary to the notion of musical interface designed for novel performance. Yet, the physical shape and functionality of specialty game controllers in combination with rhythmic prompts displayed via an onscreen interface effectively advocate playing music to win a game. The implication is clear to players that the motivation for perfecting timing and rhythmic response is to win a game as the reward, whereas developing proficiency with an instrument to convey a musically meaningful outcome is usually the motivation behind playing musical controllers. (Figure 1).

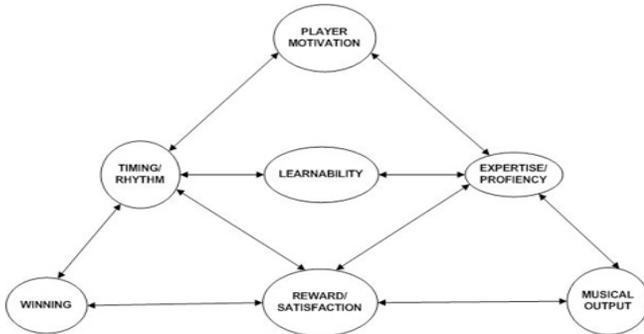


Figure 1. Motivations behind Play v. Win

Another way of thinking about this motivation is from a more social perspective, whereby the controller becomes a means of communication for developing community through gameplay or a musical medium. (Figure 2) Party games such as Karaoke Revolution, Dance Dance Revolution, Samba de Amigo, Groove, etc. thrive on feedback from community, as do most musicians with a responsive audience.

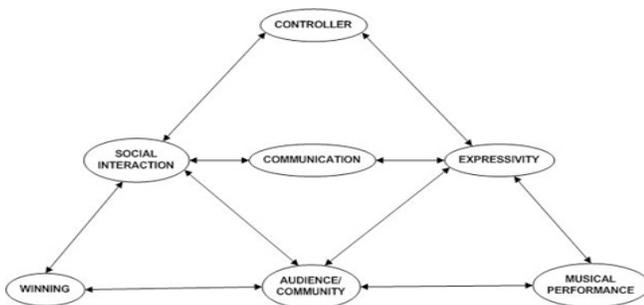


Figure 2. Social Implications of Play v. Win

Levitin suggests that musical instruments must strike the right balance between challenge, frustration and boredom: devices that are too simple tend not to provide rich experiences, and devices that are too complex alienate the user before their richness can be extracted from them [14]. In game design, these same principles of learnability are the fundamental principles of level design used to build an interest curve to engage players. As such, the

underlying design mechanics apply similarly to the role of controllers in both gameplay and musical experience.

3.2 Video Games and Education

Educator Mark Prensky refers to the youth of today as “digital natives” due to their increasing exposure and fluency in the language of computers, video games and the internet. [15] He further believes that their high degree of interaction and facility with digital technology and subsequent ability to multitask and process information has yet to be fully realized by educators. A recent report on the future of learning suggests that video games can change the nature of learning by building upon the educational properties of games while grounding them within theories of learning, social interaction and technology. [16] While there is a great deal of debate surrounding the value and assessment of video games and video game technology on learning, a recent report on ITFacts.Biz claims that 14% of kids under three play video games. [17] If this is true, it may follow that many children have their first introduction and subsequent expectations about music-making based on early play experiences with interactive toys, video games, and other media forms rather than traditional musical instruments. As a proponent of video games for effective learning, Paul Gee points out in High Score Methods:

The secret of a videogame as a teaching machine isn't its immersive 3-D graphics, but its underlying architecture. Each level dances around the outer limits of the player's abilities, seeking at every point to be hard enough to be just doable. In cognitive science, this is referred to as the regime of competence principle, which results in a feeling of simultaneous pleasure and frustration. [18]

The majority of devices and musically oriented games on the market currently are predicated upon an emerging genre of gameplay known as “rhythm action” or beat matching. These types of games leverage the “regime of competence” principle by offering progressively more difficult levels of gameplay, generally based on combinations of increasing tempo and number of cues. With few exceptions, this genre prompts players to perform a series of physical and/or rhythmic actions by integrating player feedback via custom controllers in combination with an onscreen interface to play in time with a predetermined musical sequence. In what D’Arcangelo calls a “new call and response,” the give and take of musical influence in the electronically-mediated world is stimulating the invention of new tools and techniques to give the audience a channel of response. [19] As he further posits, that turntablists have shown a way to infuse humanity into the stream of predictable recorded playback, perhaps the high level of physicality and immersion required by the responsive nature of video games and modern electronic toys are in their own way methods of overlooking the repetitive performances upon which the interactions are based.

While it is no surprise that game companies are constantly seeking new ways to extend the “gamer” demographic and attract new players, IDC consultant Schelley Olhava finds that many consumers are intimidated by traditional video game controller devices [20]. However, the creation of easy-to-use specialized controllers has helped gain inroads to new markets, as evidenced by Sony’s *Eye-Toy* which has shipped approximately 5 million

units worldwide as of January 2005.³

Extending beyond the paradigm of beat matching in rhythm action games to create greater depth and means for musical exploration and creation provides our community with a challenge to impact the nature of musical video games in a significant way. Undoubtedly, the innovation and advances within the NIME community as evidenced by the collective work of the past decades is far ahead of the curve in terms of where most video game hardware and toy companies are currently thinking. Furthermore, there is seemingly great potential to apply this collective knowledge to other areas of design to help address the parallel issues of achieving greater depth, creativity, expressivity, and emotion still lacking in many areas of interactive entertainment. To follow is a brief survey of several representative video games with custom controllers, musical interfaces and electronic handheld toys built upon the models of musical simulation, performance, and rhythm action.

4. KONAMI'S REVOLUTION EVOLUTION

Following the success of *BeatMania*, the first music rhythm/DJ simulation game that required a custom controller in the form of a turntable with buttons, the musical dance craze phenomenon known as *Dance Dance Revolution (DDR)* was later introduced in Japanese arcades in the late-90's. These games launched Konami's Bemani musical series, soon to be followed by many others including Andamiro's *Pump It Up*, that would lay the foundation for the "rhythm action" genre.

By bundling the DDR software with a game "mat", Konami created a play-at-home adaptation of its wildly popular arcade game (Figure 3). The unequivocal success of the *DDR* software was leveraged by the necessity to purchase an accompanying custom dance pad controller in order to emulate the same physical immersion and stepping actions required by the arcade version and enhance the quality of gameplay at home.

In December 2003, Konami reported that its *Dance Dance Revolution* franchise had sold 6.5 million units worldwide. [21] *BeatMania* and *DDR* unexpectedly proved the viability of alternate controllers as an option to the ubiquitous hand-held console game controller and paved the way for Konami and other publishers to take additional risks with musical games and custom controllers. In a brilliant marketing strategy, multiplayer mode requires the purchase of an additional dancepad. Because the pads take a continual beating and are under warranty for only thirty days, multiplayer competition further fuels accessory sales. The game's interface is similar in appearance to the arcade version, with a series of moving arrows determining the speed and level of difficulty for beat matching in sync to the pre-recorded musical tracks. There is also a computer version of *DDR* for consumers, but most players find that clicking with a mouse is not nearly as satisfying as being able to physically match the beats with a progression of dance moves. Perhaps most importantly, the continued success of *DDR* and most of its progeny in the rhythm action genre, is integrally linked to the community culture of audience interaction and feedback as an essential aspect of the players' experience.



Figure 3. Official and "Unofficial" DDR Dancepads

5. INFUSION OF JAPANESE POP CULTURE

5.1 Para Para Paradise

Cashing in on another Japanese dance craze of the late 90's, Konami ported *Para Para Paradise* from an arcade device to a reconfigurable infrared array controller for home use on the PlayStation2 (PS2) via USB. Each one of five sensors has a triangulated infrared array that can be positioned and its height sensitivity calibrated to detect a player's hands, arms or other body parts passing over it in sync to the music and onscreen arrows. Also known as *DDR* for the upper body while requiring minimal sidestepping with the feet, the game has a freeplay style that encourages players to flail around if they tire of the *Para Para* dance mode. Believed to be inspired by Japanese modern dance and Bon-Odori traditional Japanese dance, the game has wide appeal for young women in particular. [22]

5.2 Samba de Amigo

One of the precursors of the rhythm action trend, *Samba de Amigo* was released in 2000 for both arcades and the Sega Dreamcast video console. *Samba de Amigo* utilizes a pair of maraca controllers with an infrared transmitter mounted on each, in combination with a sensor bar positioned on a footpad to triangulate the players' range of motion (Figure 4). Players shake at "low", "medium" and "high" heights in tandem with colorful onscreen graphic cues that prompt players to follow the beat. Contestants are ranked by their "shaking" ability in five modes of game play including multiplayer "party" and challenge settings. The natural mapping behavior of the shaking motion creates a direct relationship between gesture and musical intent and thus, a low bar for entry.



Figure 4: Samba de Amigo Interface and Maracas

³ Richard Marks, personal communication

5.3 Taiko No Tatsujin

Another popular game hailing from Japanese arcades and porting over to the game console platform is *Taiko No Tatsujin* by Namco. Also known as *Taiko: Drum Master* in the North American and European markets, the game comes with a drum controller and two plastic drumsticks in order to play in time with the music. The cluttered yet simplistic interface is comprised of multicolored circles that move across the console screen with each color correlating to a specific rhythmic action (Figure 5). Red, blue and yellow circles indicate hitting the center of the drum, the rim, and a drum roll equal to the duration of the scrolling graphics, respectively. With six releases of the game in Japan for the PS2 since 2002, developers attribute the game's popularity to the fact that people are familiar with traditional Taiko drums, but rarely have the opportunity to play one. [23] Although most Americans may be unfamiliar with Taiko drumming, Namco gambled on strong interest in Japanese culture and the broad-based appeal of anime inspired characters in gameplay in an attempt to surmount this cultural divide. For opportunistic third party developers, Namco does not sell individual controllers. This situation forces players to buy another copy of the game in order to get a second controller and play with friends.



Figure 5: Taiko Drum Master Interface

5.4 Old Gorillas Never Die: Donkey Konga

Building upon the success of *Taiko: Drum Master*, Namco released a slightly modified version of its interface and game mechanics with the introduction of *Donkey Konga (DK)* for Nintendo's GameCube. The *DK* game not only revitalizes Nintendo's infamous gorilla character, Donkey Kong, but also comes bundled with a custom double headed "bongo" drum controller known as a "Tarukonga" in Japan (Figure 6). The game scales from one to four players (read: one to four controllers required for multiplayer mode) and prompts players with cues to indicate right, left or two handed double hits, in addition to handclaps detected by the controller's built-in microphone. Although the controller looks like a toy bongo drum, the heads are soft rubber and are not sonically satisfying as a standalone instrument.



Figure 6: Donkey Konga's Bongo Controller

5.5 I Am Therefore I-Toy

Sony's Eye-Toy USB camera peripheral offers its own version of rhythm action games first introduced in the basic mini games *Beat Freak* and *Boogie Down*, followed by the more challenging game *Groove*. Leveraging the popularity of music video games without the need for a handheld controller, the Eye-Toy's digital camera peripheral tracks player motions and projects their image onscreen. *Groove* presents an unencumbered gesture-based rhythm game where players swing their arms and dance around to "hit" graphical icons moving around the screen in time to the music (Figure 7). The Eye-Toy's accessibility and intuitive interface encourages high levels of physicality combined with the opportunity for multiplayer participation that helps foster a sense of community in gameplay. Almost not released at all, the surprising widespread appeal of this device and subsequent expansion of the Eye-Toy's gaming demographic far exceeded Sony's expectations. [24]

The inspiration for the Eye-Toy may have come from the Mandala GX System, which uses real-time video capture to superimpose a player's image into a virtual world displayed onscreen and the player's body becoming the input device. The development of this system originated with musical exploration in a virtual environment and evolved into more sports-oriented games.⁴



Figure 7. Sony Eye-Toy's Groove

5.6 Drum Mania/ Guitar Freaks

The Guitar Freaks controller has buttons and strings that the player presses and strums to follow a series of prompts. The DrumMania controller is comprised of five-drum pads with a small, pressure-sensitive foam pedal to emulate a kick pedal/bass drum (Figure 8). Promising percussionists have the option to purchase an official or unofficial DrumMania controller adaptation of the arcade model. An import version of Sony's Drum Mania comes bundled with Guitar Freaks so that the rhythm section can jam together on their respective controllers. While it is possible to play these games without the specialized controllers on the PS2, it is appreciably more difficult and much less fun.



Figure 8: Guitar Freaks Controller, DrumMania Arcade Controller and "Unofficial" Drum Mania controller

⁴ The Vivid Mandala GX System – Wireless Virtual Reality Games. Available at <http://www.vividgroup.com>.

5.7 Harmonix Music Systems, Beating their own Path to Success

In contrast to the rhythmic beat matching games described previously, Harmonix Music Systems took a slightly different approach by developing musical video games designed specifically for the PS2 standard controller. *Frequency* and *Amplitude* were both intended to appeal to the gaming community that already had proficiency using a handheld game controller. Rather than creating a custom controller device, the development team focused their design efforts on player's easy adaptation of the controller's functionality for musical mapping and input in a dance remix environment. In both games, the underlying game mechanics and interface work on the same premise; players activate sequences of notes placed on tracks in futuristic tunnel-shaped settings, but *Amplitude* adds shooting and "dueling" into the fray. Matching sequences of notes with button presses in time to the beat "captures" and activates automatic playback of that track. Where Harmonix adds a bit more depth to the experience is in the player's ability to chain tracks of their choosing together and engage in freeplay mode on top of these dance mix tracks once activated. An energy meter keeps track of powerups and missed notes, Points are collected by capturing notes, unlocking tracks and multipliers along the way.

The success of *Frequency* and *Amplitude* paved the way for Harmonix to pursue another popular musical genre, with the development of the *Karaoke Revolution* series for Konami. The game implements a scoring system based on pitch and rhythm, players are expected to sing on pitch at the appropriate time using a custom microphone controller for the PS2 or Xbox. Since there is pitch detection, but no voice recognition, there is a high degree of flexibility in player performance. Singing in "expert" mode is the only time players are expected to sing in perfect pitch with the lyrics moving across the screen. The interface is comprised of bars of varying heights and lengths to indicate pitch and duration of each note (Figure 9). Feedback takes the form of a song meter, an arrow to indicate how close to the pitch the player is singing, and positive or negative "crowd response" depending upon the performance. The latest release, *Karaoke Revolution Volume 3* offers a duet mode with two microphones and several varieties of multiplayer offerings that scale from one to eight players using a turn-taking protocol. As with most other games described herein, the most critical feedback is from the live crowd response.



Figure 9: Karaoke Revolution "Genie In a Bottle"

6. COMPETING TO THE BEAT: ELECTRONIC HANDHELD TOYS

Variants of a handheld toy by Hasbro called *BopIt* took rhythm action to the next level by requiring players to repeat spoken and musical commands in call and response rapid fire succession. *BeatBop* has musical commands that the players must translate into a specific action sequence with the toy. For example, hearing a drum sound means "BopIt", a slide whistle means "ZingIt" (yo-yo type of move) and a looping whistle sound means "LoopIt" (360 degree around the world), which start simply and advance to commands in multiple combinations of two to five actions. These same sounds are also associated with value points that are awarded to players in a musical scoring sequence at the end of each round of gameplay. Another descendent from this line of handhelds called *GrooveIt*, tracks player's hand motions as they pass over infrared sensors in a series of patterns called "Groove Moves" (Figure 10). Players learn how to "slide", "scratch", "zoom" and then move on to more advanced groove moves like "kung fu", "hip hop", "swirl" and the "chop". This game can be played in single or multiplayer mode, but players do not achieve expert status until they can successfully follow at least 250 command sequences in the consecutive order.



Figure 10: Hasbro's "GrooveIt" designed by KID

6.1 More Motion Music

Billing itself as the "music machine of the next millennium", Discovery's *Motion Music Maker* integrates drum, guitar and bass sounds with special effects (Figure 11). Players simply wave their hands over the infrared sensors in this futuristic looking device to make instant music that responds to motion.



Figure 11: Discovery's Motion Music Maker

Table 1. Comparison of Musical Videogame Controllers and Actions

VIDEOGAME Toy Device	CONTROLLER INPUT/SENSOR DEVICE	ACTIONS w/ INTERFACE	EFFECTIVENESS	MUSICAL EXPRESSION/ INTENTION
BeatMania	Turntable w/5-7 keys	Press keys & scratch disc to match Scrolling bars down the screen	Low-Medium Unforgiving of false moves	DJ Simulation/trigger pre-recorded samples
DDR	Dance Pad/Pressure Activated Sensors on 4 panels	Beat matching via Dancing, stepping in time to arrows scrolling up the screen	High - if players are not self-conscious	Physical Immersion w/varied musical track selection
Para Para Paradise	Reconfigurable array of 5 Infrared motion sensors	Body gestures, (arm waving) in time to arrows scrolling up the screen	Medium - most eff. Tracking upper body movements	Physical Immersion w/Eurobeat musical track selection
Samba de Amigo	Maraca Shakers/2 infrared sensors in bar on floor mat	Match icons landing in low, med, high circles w/shake gestures	Medium Sensors read height OK, noticeable latency reading position	Physical Immersion, keeping in time w/Latin tracks
Taiko No Tatsujin	Taiko shaped drum controller (Tatakoi) w/plastic drumsticks. 2 sensors in drumhead, 2 on rim	Match scrolling anime interface w/single or double hits and drum rolls	Medium - High, some dead spots on drum surface	Beat matching via Stick Drumming to J-Pop and traditional Japanese festival music
Donkey Konga	Bongo shaped drum controller w/microphone "clap-sensor"	Match scrolling icons w/right, left, double hand hits/claps	Medium-High Clapping between drum hits is awkward esp. at high speed	Beat matching via Hand Drumming w/pop, rock + Nintendo classics
BeatFreak, Groove	USB Digital Camera	Players "hit" graphical icons w/body gestures	Medium - light sensitivity causes variations in response	Physical Immersion, dancing, shaking to contemporary/classic hits
Frequency, Amplitude	PS2 Game controller, buttons	Match tunnel interface nodes w/ rapid button presses to create layered musical score	Medium - High, unintuitive for non-gamers	Hand-held device controlled by finger movement, Electronica/HipHop
Karaoke Revolution	Microphone(s) (pitch detection, no voice recognition, dual mic input in KR3)	Match scrolling bars (indicate pitch and duration) with lyrics via mic input	Medium - High Doesn't differentiate lyrics. Wide pitch variation allowance except in expert mode	Voice input, Karaoke, rockstar simulation/sing along with pre-recorded pop/rock karaoke classics.
Groovelt	Custom BopIt device w/IR sensors	Tracks player's hand motions in patterns called "groove moves"	Medium - Need 250 consecutive action sequences to reach expert mode.	Physical Immersion, 2 background grooves w/slide, zoom, scratch sounds
Guitar Freaks/Drum Mania	3 Buttons on Frets w/toggle, 5 Drum pads	Hit chords or notes displayed onscreen in time to music. Linked interface for rhythm section	N/A	Limited physicality in Music Simulation, released only in Japan.
Guitaroo-Man	PS2 Game controller, buttons	Play guitar riffs instead of beat matching, use controller like guitar, buttons as frets	Medium - High Unintuitive for nongamers	Hand-held device controlled by finger movement, Custom Japanese pop songs w/guitar leads

7. EDUTAINMENT TOYS FOR TOTS

Leapfrog's *Learning Drum* is designed to teach toddlers in four different learning modes that encourage beating the drum to trigger sequences of musical notes, flashing patterns, letters and numbers. Leapfrog also makes a learning table called *LeapStart* that helps children develop motor skills by playing piano keys, sliding a trombone and cello, pulling banjo levers, spinning maracas, tapping drums in addition to learning the alphabet and counting (Figure 12). The table interface integrates more than forty songs and switches between a learning mode and musical free play.



Figure 12: Leapfrog's Learning Drum and LeapStart Table

8. CONCLUSION

Although the controllers and interfaces described herein offer easily accessible rhythmic and musical experiences, the genre may have matured enough to allow for more complex musical exploration. In order to continue to grow and reach a wider demographic, players will need greater depth of experience and more control over their creative input, rather than reflexively following prompts. While many rhythm action games can be played without specialized controllers, the resultant gaming experience is considerably less fun. It would appear that alternate controllers have finally achieved status as a critical component of game play. This puts the NIME community in a unique position to raise the bar as to the quality and range of experiences, devices, and the expressive capabilities they inspire, particularly as it relates to music creation and education.

Mapping gestures to musical output, creating more expressive controllers, integrating multiple combinations of sensors, developing musical learning systems, adding levels that lead to expert performance, and routing signals through sound synthesis programs or adaptive audio algorithms are just a few of the ways that player experience could be enhanced. There is still much to be discovered about the motivations and implementation approaches to musical gameplay where the objective of winning takes precedence over musical exploration.

In all of these systems encumbered or not, the players' physical interactions appear to enhance the feeling of immersion in the games and distract from varying degrees of latency inherent in the responsiveness of these systems (Table 1). Generally, the latency is less noticeable at easier levels of gameplay and doesn't become problematic until faster execution at more advanced levels is required. Until studies in this area are conducted, it remains a mystery as to whether or not players are content with controllers that lack complexity but are simply fun to play.

Due to the considerable cost of development for new titles and products, the game industry has traditionally shied away from integrating more custom controllers into their games. A similar situation is true for toy companies, software, hardware and third-party developers. With few exceptions, most companies in the business of creating entertainment experiences are risk-averse. We need to pursue networking opportunities to connect the people who make musical interfaces and alternate controllers with video game developers, peripheral hardware companies, toy developers, arcades, family entertainment centers, interactive museums, theme parks and mobile applications developers of all kinds if we hope to further the field of musical interface development. Despite their engaging aspects and contributions toward the development of cognitive/social skills, there is still a long way to go toward advancing the experiential and educational affordances of interactive entertainment.

It should be noted that opportunities have arisen for third party developers to provide "unofficial" spin-off versions of controllers as accessories for games. These are often offered more inexpensively at the same or higher quality as the large developers, and bypass the need for consumers to purchase software in order to get an extra hardware device. Third-party developers are also starting to offer "upgrade kits" to take advantage of the hardware install base in arcades all over the world by providing new modes of game play, stylized interfaces, and for now, additional catalogs of popular music tracks.

Interactive entertainment is a multi-billion dollar industry with

forecasts for worldwide sales expected to increase anywhere from \$31 - \$56 billion in total revenue by 2009. [25] [26]. In light of the difficulty facing developers of musical interfaces and alternate controllers from achieving commercial success due to the historically limited market, perhaps it is time for the NIME community to consider opportunities for convergence in areas of interactive entertainment and education.

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