Challenges for Success in Stereo Gaming: A Virtual Boy Case Study

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ABSTRACT
Stereo video stands to revolutionize the medium of videogames in the same way that stereo sound revolutionized the audio experience. It is a pending revolution. Despite years of research, development, and hype, 3D stereo video ubiquity in videogames has yet to be observed. Using Nintendo's Virtual Boy (VB) gaming platform as a case-study, we explore why the revolution hasn't yet happened. We identify six factors that played a significant role in VB's failure: its lack of defined identity as a product, a comparatively weak display, its socially isolating game experience, purported negative effects, the challenges in explaining and demonstrating stereoscopic gaming, and its lack of a must-have game. We note that the factors we identify aren't just technological and that they interact in confounding ways. Nearly fifteen years after the introduction of the VB, new technologies may address the original VB's technical shortcomings, but not necessarily the others. There is currently still an issue with raising the bar on consumer's expectations as well as encouraging game designers to explore the design space offered by stereoscopic video.

Keywords
Virtual Boy, stereoscopic, case study, virtual reality, head-mounted display, depth perception, 3D, LCD shutter glasses

1. INTRODUCTION
In interactive entertainment, 3D graphics usually refers to a rendered illusion of a three-dimensional space; the player understands objects are not *flat* because the environment rotates, giving a sense of tangible perspective. However, these graphics are not really tridimensional in their representation since the eyes are constantly focused on a single surface, such as a television display. In stereo video displays, however, each eye is presented with an independent image source such that the brain is able to interpret the perceived depth of field based on the subtle offsets between the two visual inputs. Similarly to how we use our eyes in the real world, there is a need to refocus depending on layer that is being visually examined – essentially stimulating natural eye reflexes to visual cues. Thus, the illusion of depth is achieved.

Curiously, advancements in entertainment displays have primarily addressed two issues: how to display an image and how to render (prepare) images for display. Current technology allows us to view images on larger screens with higher resolution than ever before. Similarly, the decades-old transition from 2D to 3D graphics has also been astounding, with high-end gaming computers and consoles rendering increasingly sophisticated and life-like images. Very little progress seems to have been made, however, in how we actually see virtual worlds.

This apparent lack of progress is dissociated with an upsurge of interest in stereoscopic video gaming. Popular magazine Game Informer recently discussed some of the newer technologies reaching the mass market [1] while Edge magazine explored how independent game designers are looking at what novel game experiences can be designed with stereoscopic video [2]. However, is the current excitement simply the result of unbridled optimism? Perhaps, but despite the continuous evolution in improving 3D technology, the adoption of stereoscopic technologies for gaming purposes has been preceded with a caution: videogame history seems littered with devices, contraptions, and games with unfulfilled promises to deliver the ultimate game immersion experience.

Figure 1 – Virtual Boy unit with attached controller & three game cartridges featured

In this article we explore the multiple challenges faced by stereo technologies for interactive entertainment by analyzing what is perhaps the highest-profile commercial videogame platform failure: Nintendo's Virtual Boy [3] (Figure 1). The Virtual Boy story provides insight to the largely ignored genre of stereoscopic gaming. Nintendo's early mistakes set the stage for discussing the issues that must be addressed for the successful widespread adoption of present and emerging stereoscopic technologies. In particular, we argue that the challenges aren't just technological; rather, they are the result of multiple confounding factors

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including design tradeoffs, marketing issues, game selection, and the inherent nature of a product's design. We will conclude by discussing these challenges in a broader context that includes examining upcoming technologies as well as issues of adoption in other media such as cinema.

2. BACKGROUND

2.1 Stereoscopic Videogames

Stereoscopic image viewing contraptions were in development over a century before electronic games existed. There are documented examples as early as 1844 of apparatuses for viewing still photographs in stereo, also known as a stereoscope. Videogames have been no stranger to the desire to create images that can be viewed in stereo and have employed a variety of techniques and technologies to provide a stereo video viewing experience. We distinguish these techniques by examining two things: the videogame itself (as a software product), and the type of hardware necessary for achieving a stereo video experience.

There are games that:

1. Don't provide any allowances for stereo video (i.e., most games)
2. Provide an alternate viewing mode that affords a stereo video experience
3. Are designed with stereo video in mind (can't be played or viewed properly on a regular screen)

From the hardware perspective, we distinguish:

1. Independent (stand-alone) hardware devices
2. Hardware peripherals for an existing game device
3. Non-electronic hardware devices

Our overview considers the hardware necessary to achieve a stereo video experience as different from how that viewing experience is achieved. In other words, we don't distinguish how it is that each eye sees a different picture; rather, we distinguish by type of device (stand-alone, peripheral, etc.) This approach arguably glosses over an important issue that will be discussed later: the effectiveness in producing a stereo video experience.

The 3D Imager, a peripheral for the Vectrex console, is an example of a hardware peripheral that required games to be designed with stereo video in mind. The 3D Imager, released in 1982, is a device that consists of a pair of goggles with a special spinning disc mounted in front of the eyes. As the disc spins, it occludes vision from one eye at a time. By synchronizing the discs' rotation with the drawing of images specific to each eye on the screen, the illusion of 3D could be created. Only three games were released for use with the 3D Imager: 3D Crazy Coaster, 3D MineStorm, and 3D Narrow Escape.[1]

The SegaScope 3D Glasses is an example of a hardware peripheral for which there was a variety of games designed either with stereo capabilities, or with an alternate viewing mode. The SegaScope 3-D Glasses, released by Sega for the Sega Master System (SMS) console in 1988, were designed to look like wraparound sunglasses with a small rectangular opening in front of each eye on the inside. In this case, the 3-D effect was caused by the liquid crystal lenses that would alternately darken and lighten in synchronization with the images display on the TV screen. The SMS had four games designed with stereo video support: Blade Eagle 3-D, Space Harrier 3-D, Maze Hunter 3-D, and Missile Defense 3-D. Three games were marketed as 3-D but also included a 2D mode playable without the glasses: Out Run 3-D, Poseidon Wars 3-D, and Zaxxon 3-D. Finally, Line of Fire, while not advertised as a 3-D game, included a 3-D mode that could be activated separately.

There are also examples of games with an alternate viewing mode that required a non-electronic hardware device. In 1987 Square released Rad Racer, 3-D World Runner, and JJ. Each came bundled with a pair of anaglyph glasses. Anaglyph glasses consist of two color filters, usually red and cyan. The filters are used to separate colors on a superimposed anaglyph image, enabling each eye to see an image slightly offset from the other, thus providing the perception of depth. More recently, Konami's Metal Gear Acid 2 [4] for the Sony PSP came bundled with a folding cardboard box with two eyeholes that needed to be placed over the console. When the game is switched to a special mode, the game displays two images on either side of the PSP screen (one for each eye) producing a stereoscopic effect.

Independent hardware devices for stereo video gaming are perhaps the rarest examples. As far as we know, these devices all require games that are specially designed with stereo video in mind. Nintendo's Virtual Boy is probably the most notable, though there are other examples. For instance, toy manufacturer Tomy released a series of handheld 3D gaming devices in 1983. Each was a single-game device that resembled a pair of binoculars with buttons on the top of the device [5]. The device contains an LCD display that generates two images that are directed to each viewport [6] using an internal optical pathway; patent for this contraption was granted in 1985.

More recently we have begun to see examples of games that do not offer stereo video but, thanks to 3rd party software and hardware, are playable in stereo video. For instance, 3D video card manufacturer Nvidia allows users to configure the settings of some of their video cards so as to output stereo video (viewable with 3D shutter glasses). The video card, which processes the information which is ultimately displayed on the screen, is able to modify the video data in order to generate an image that is different from what the game would normally display. Thus, the player can view the game in stereo video even though the game doesn't support that viewing mode natively (thanks to additional drivers).

The above examples are by no means an exhaustive list of games, peripherals, technologies, or techniques. However, they illustrate how stereo video is something that videogames have toyed with for a long time using a variety of technologies. None of the above examples, however, was able to achieve what could be called mass market success. Perhaps the device that had the greatest potential for success was Nintendo's Virtual Boy platform which will later be analyzed in detail.

[1] A fourth game, 3D Pole Position, was listed on the 3D Imager's packaging, but was never released commercially.

2.2 Display Technologies and Techniques

As mentioned earlier, a wide variety of techniques and technologies have been developed to provide stereoscopic images. Our brief discussion is not intended to be a comprehensive guide, instead, we seek to discuss some of the techniques that are either more commonly used or that seem to offer the most potential for mass-market adoption.

For instance, many movie theaters and theme parks that offer "3D" use phase modulated projection. Phased projectors can be used to display polarized images onto a screen. The viewer is required to wear a pair of polarized pattern glasses, allowing one eye to see the horizontal pattern and the other to view the vertical pattern. The patterns are transparent to the viewer. Similar to the anaglyph glasses, no electronic timing components are required on the glasses themselves, and the viewing experience is approximately equal from any viewing distance.

Related technologies are expected to soon become available for home use. For instance, displays and projectors capable of drawing an images at 120Hz (and higher) and compatible electronic shutter controls are becoming increasingly affordable. To view a stereoscopic image on a 120Hz compatible device, the viewer must wear a pair of electronic glasses that alternate the left and right eye shutter [7], known as an alternating visible field. What makes this technology particularly appealing for games is that it can work with an intermediary driver (similar to the way anaglyph images can be generated) by using the z-buffer to generate alternating frames, enabling the stereoscopic visual effect even when the original media source wasn't original created for stereo viewing.

Autostereoscopy, on the other hand, refers to a method of displaying tridimensional images that can be viewed without any special headgear or glasses. There are a number of different technologies that implement autostereoscopy. Some displays appear similar to conventional LCD TVs but they include lenticular lenses or parallax barriers so that each eye perceives a different image. In these cases, pixels on the screen have a different perceivable intensity and color depending on the angle that it is viewed from. Autostereoscopic displays are presently finding their way into commercial installations, such as retail stores and other venues. Naturally, in a public setting people are moving around and can see the 3D effects on autostereoscopic screens. Japanese cellphone manufacture, KDDI, is now offering dual-hinge flip phones with an autostereoscopic display utilizing OLED[2] panels.

Volumetric display technologies, on the other hand, do not rely on optical illusions or similar effects. These technologies create images in 3D space (as opposed to a flat screen) by, for example, using two or more lasers emitted at variable frequencies that, when they intersect in space, create a visible dot in space. At higher speeds, the dots can appear as one continues shape or pattern. Other approaches, such using a light field display to create floating image in a 360° display can be achieved with a high speed video projector and a spinning mirror contained inside a holographic diffuser (often times in the shape of a dome). Certain autostereoscopic displays project an omnidirectional image enabling the viewer to see the picture from any angle relative to the display (such as walking 360° around the display to examine a virtual object) [8].

There exists a plethora of other innovative and cutting-edge autostereoscopic technologies not discussed here. This hardware is mostly used in military or medical applications [e.g. 9,10] and can be considered still in its infancy stages in terms of general availability. It will likely be many more years before autostereoscopic home entertainment products are released to the consumer, or mass market.

3. NINTENDO VIRTUAL BOY

The Nintendo Virtual Boy (VB), first introduced in July of 1995, is the first and only dedicated stereoscopic video game console released to the general public. It was developed internally by Nintendo's "R&D1" group spearheaded by famed Gumpei Yokoi [11]. The VB has been referred to as Nintendo's most famous market failure since it was pulled from the market less than a year since its original introduction [12] and it failed to meet sales expectations. Its videogame library was limited to 22 unique games, with 14 released in North America and 19 released in Japan. Because of relatively poor sales figures in North America and Japan, the VB was never released in Europe and Australia. It is believed that an estimated 770,000 units were sold before Nintendo officially discontinued the product in 1996 [13]. By comparison, Sony sold over 7 million Playstations consoles worldwide by late 1996. Playstation was released a mere 79 days before the VB.

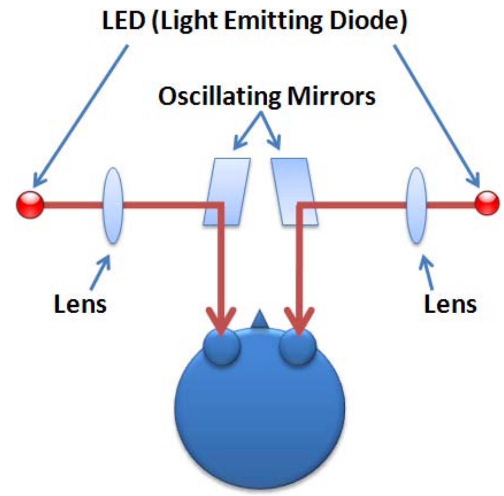

Figure 2 - Virtual Boy technical operating principle

The VB consists of a red and black plastic unit with a neoprene eyepiece that stands sturdily on a pair of metal feet (see Figure 1). VB's operating principle is based on oscillating mirrors displaying a linear array of lines, powered by LEDs (Light Emitting Diode), one for each eye as illustrated in Figure 2. By placing the face against the eyepiece, players are able to block out external light and focus on the two internal electronic displays. The main unit includes an extension port that would allow for multiplayer support.[3] The VB's controller, which also holds the 6 AA batteries required to power the system, is connected to the

[2] Organic LED (Light-Emitting Diode)

[3] The link cable for multiplayer support was never officially released.

underside of the unit. The controller has two D-pads, four buttons in the middle, an additional pair of finger triggers, and an on/off switch.

3.1 Undefined Product Identity

Virtual Boy suffered from an identity crisis during and prior to its release. The design profile of the VB is not easily classifiable and lies somewhere between a stationary gaming console and a portable unit [12]. The unit is arguably portable since it is battery powered and includes its own display. Also, the Virtual *Boy* was named as such in a clear attempt to achieve positive brand recognition with Nintendo's wildly successful portable Game *Boy* (GB) product (released six years earlier). Consumers might have perceived the VB as the spiritual successor of the multi-million selling GB device. However, with a weight of 750 grams (without batteries), the VB is a large and cumbersome device. The metal legs preclude its use in regular portable settings. You cannot play it while lying in bed, sitting on the train, etc. Portable use of the VB requires that the player not only carry the unit, metal stand, and controller but also have access to a flat surface on which to place the unit so that it won't topple or fall over.

Despite the similar name, the VB was no relative of the GB. Arguably due to technical reasons, the VB was not backwards compatible with GB. At the time of the VB's release, the original GB offered over 400 titles. The VB, however, required a new cartridge interface and therefore was not compatible with existing games.[4] Unfortunately, Nintendo missed the opportunity to convert existing GB users, who had already (heavily) invested in games for the Game Boy.

The VB was equally unsuccessful, in terms of identity, when compared with stationary gaming consoles of the time. Although the VB was reasonably priced ($251 compared to the Playstation $418 price tag, 2008 adjusted value), it lacked features that made it a competitive home device. As will be discussed later, the quality of VB's graphical output was weak and it didn't have any multiplayer games or support any multipurpose capabilities. Players looking for a new console may have been lured by the PlayStation's ability to playback compact disc music and digital video videos (VCD; MPEG-1). Print and TV ads released by Nintendo are also unclear as to whether the device was in fact portable or for home entertainment.

At the time, there was also a third alternative to consider: that of virtual reality (VR) systems. Both, the name of the device as well as a shape reminiscent of a VR helmet, implied an association to products that were, in the mid 1990s, just entering the public consciousness. However, in the realm of virtual reality (VR) systems, the VB device wasn't a helmet placed over, or strapped to the head. VR systems, such as the VictorMaxx and i-glasses, included electronic head tracking capabilities that could be used to rotate virtual environment relative to the position of the user's head. Nintendo's bulky desktop-only design lacked head (or motion) tracking, clearly separating the VB from VR systems. In an interview with the creator, Yokoi acknowledge that head tracking systems already existed at the time of VB development and were considered, however Yokoi argued, "I did not like head tracking because I experienced motion sickness" [14]. Additionally, the VB lacked the input device traditionally associated with VR: the glove.

In summary, the lack of target market identity made the VB an oddball device that failed to deliver an exceptional experience in any segment. It was a cumbersome portable device, an under-powered and solitary home console, and a VR set without gloves or head tracking. Nintendo likely realized the in-between nature of the design and left it up to the customers to decide where it fit in their gaming lifestyle, if anywhere.

3.2 Comparatively Poor Display

Sometimes great ideas and an ambitious outlook for the future are shattered by the sobering reality of practical limitations of mass-manufacturable technology at a reasonable price. The VB integrated sophisticated technology for the time and, due to cost limitations, was handicapped to using only a single color for display: red [15]. Yokoi explained that "red uses less battery and red is easier to recognize" [1]. Red LEDs were notoriously cheap to produce at the time, especially when compared to high-efficiency InGaN (indium gallium nitrate) LEDs available in green and blue. Arguably, if Nintendo had pushed back the release of the VB by about two years, the system could have boasted three colors, thus opening the possibility to a wide-spectrum display system at a reasonable cost.[5]

Table 1 – Nintendo VB Technical Specifications

Processor	NEC V810 32-bit RISC Processor, 20 MHz 1 MB DRAM; 512 KB P-SRAM; 1 KB Cache
Display	RTI (Reflection Technology Inc) SLA (P4) 384x224 pixel resolution (32 levels of intensity) 50.2 Hz Horizontal Scan Rate
Sound	16-bit, built-in stereo speakers & headphone jack
Controller	6 buttons plus & control pads
Power	6 AA Batteries (9V), up to 7 hours runtime on alkaline batteries or AC adapter (10V)
Cartridges	256k x 16 1024k x 16 ROM (512k - 2048k) 22 official games released
Dimensions	246 mm (H) × 254 mm (W) × 109 mm (D)
Unit weight	750 grams without batteries

When compared to other systems available on the market at the time, the display's color limitation likely made the VB unattractive. For example, at the time of the VB's release, the Sega Saturn offered 32,768 (15-bit) colors and even the modest Game Boy boasted 4 colors.[6]

The technology used in VB was also inferior to other options available at the time in terms of display resolution. For example, Sony's Playstation could render images at 320 x 240, and

[4] All of Nintendo's major handheld releases are backwards compatible with the earlier generation (GB Color with GB, GB Advance with GB Color, and Nintendo DS with GB Advance).

[5] Other stereoscopic technologies such as dual LCD head-mounted displays cost in excess of $800 at the time [9].

[6] Black, two shades of gray, and "white", or no color.

Nintendo's N64 had a maximum display resolution of 640 x 480, more than twice that of the VB. Similarly, the Game Boy's resolution was 160 x 144, albeit on a much smaller display. Computing power is probably the main reason for the VB's relatively low display resolutions. Although it had a relatively high-end (at the time) RISC processor, the VB was hampered by the requirements of rendering two independent synchronized video outputs. One processor had to effectively perform twice the work of a conventional console with only a single output [15].

3.3 Negative Effects

The Virtual Boy was widely criticized for being uncomfortable to play since it required the player to hunch over (see Figure 3). Additionally, it was reported to cause physiological effects such as motion sickness and eyestrain after extended periods of use [16-18].

There are reasons to believe that Nintendo was aware of potential negative effects. By the time the VB launched in the United States, it included a statement warning that extended use could cause headaches [17]. Also, most VB games include a setting that triggers a reminder to take a break after anywhere between 15-30 minutes of use [19]. The break interval is not user selectable and depends on the inserted game. VB also included a disclaimer noting that the product was not intended to be used by players under seven years of age [20].

We note, however, that to-date no formal studies have been performed to evaluate the health effects of VB use. It stands to reason that, given similar issues with motion sickness and VR equipment, some people are likely to be affected negatively [e.g. 22,23,21]. For instance, in 1992 Mon-Williams et al. released findings on the effects of similar stereoscopic head-mounted displays (HMD) in a VR system that utilizes two LCD displays. Their results suggested that even 10-minute exposures placed significant stress on subject's eyes [21]. That said, Passig and colleagues did not report any negative effects from using VB in their research. Their studies investigated whether the practice of rotating VR 3D objects (using the commercial VB game *3D Tetris*) could enhance the spatial rotation thinking of deaf and hard-of-hearing children [24]. More broadly, it is plausible that early reports of motion sickness and the mere mention of an officially printed warning label may have made consumers more cautious when considering the VB.

3.4 Isolating Gameplay Experience

Videogames, even those that are single-player, can generally offer gameplay experiences that are highly social in nature. For example, those playing at home in front of a television can share their gaming experience with friends and family members that may not necessarily take part in the game itself. This is also true with portable gaming devices where spectators can watch a player interact with the device by watching over the shoulder. Portable devices are also easy to pass around and many have games that take advantage of this mode of multiplayer interaction. Players often become immersed in games when surrounded by peers, offering strategy hints, sharing the thrill of completing a level, finding the hidden gem and the excitement of peer competitions to see who can do the best [25].

The VB, however, with its neoprene goggle interface, was designed such that only one player can view the display at a time. The goggle also ensures that the only thing the player can see is the display. Consequently, the VB play experience, while immersive, is not only isolating visually, but also awkward to share. This makes it challenging to have a collective play experience. The VB did not include a video output connection (non-stereoscopic), which could have ameliorated the challenge of allowing others to see what was going on while playing.

The VB did ship with a serial I/O interface (without the cable) for linking multiple VBs together. However, the linking feature was never implemented in any game. Most home gaming consoles shipped with multiplayer support, such that a single console allowed multiple players to play concurrently via multiple controllers. Even the original Game Boy featured a cable-link feature.[7]

VB's premature failure killed any prospects of widespread multiplayer support despite the fact that it included a port for linking devices. However, the challenges it faces for allowing players to share common gameplay experiences highlights a broader issue with the device.

3.5 Difficult to Explain and Demonstrate

It is challenging to advertise the capabilities of a stereoscopic display in traditional media such as print, television displays, or the web. Neither screenshots nor videos of stereoscopic games could convey the defining feature of the Virtual Boy: depth perception. This was one of Nintendo's challenges for getting the message across.[8] The pivotal highlight of the product could not be related to anything else available on the gaming market, and, as described earlier, screenshots of games looked worse than those of other games available on the market at the time [26].

Figure 3 - Player Position While Playing the VB

Nintendo attempted to address this advertising gap by setting up stations in retail locations to demo their product. Over 100,000 VB units shipped within in the first week of launch and 3,000 units were placed in certain Blockbuster Video and NBC locations for onsite demonstrations. Additionally, an estimated

[7] The multilink feature was perhaps most notably used in the successful Pokémon series. Players wishing to *collect them all* were required to trade Pokémon across systems.

[8] See "Virtual Boy Promotional TV Commercial" http://www.youtube.com/watch?v=MKKK6FH1vGw

40,000 people a day tested the VB through rental programs [27]. Despite Nintendo's reported $25 million marketing campaign attempt to promote and sell the VB [28], the unconventional interface made the system difficult to demonstrate to the masses. As discussed earlier, social interactivity and the ability to share the excitement of interesting gameplay are key to having a quality experience. Players that attended VB showcase venues, despite being in public settings, likely shared isolated experiences. Spectators could not collectively share the same excitement of playing a new system. Instead, each player would've played alone. Hype-driven marketing and crowds of people staring at a screen often have a ripple effect outside venues. This can lead to an increase in popularity, or at least interest, regardless of the actual quality of a given platform. Playstations' graphics, displayed on large TV sets impressed passersby, while crowds of kids huddled around a Game Boy created interest. Comparatively, the VB was at a disadvantage. Additionally, although thousands attended the demos, it is unclear whether players had enough time to familiarize themselves with the new interface which included a controller that, for the time, was unusual in its shape and buttons layout.

3.6 Lack of Killer App

Historically, successful game consoles and platforms have been able to attribute their success to a popular "killer game": a game that either effectively showcases the capabilities of the platform or is so popular that it helps drive sales of the hardware. Halo fueled the adoption of Xbox Live, Game Boy had Tetris, and most Nintendo platforms have benefited from a Mario game. Widespread adoption of non-gaming technologies have also benefited from a similar notion. Email and the web browser are arguably the killer software applications (apps) that fueled the massive adoption of the Internet. Similarly, Pixar's movies arguably played a major role in convincing studios and audiences that you can use computer graphics to make great movies even without photo-realistic images.

The selection of VB games available at launch were largely remakes of already popular and well known games. This meant that players would compare VB games against an earlier game, possibly becoming disappointed to see the lack of color support and reduced features. At launch, Nintendo did not have *the* spectacular game that could effectively showcase the full potentials of the VB. In fact, stereoscopic gaming has yet to offer a must-have, breathtaking game experience that everyone wants to try. The fact that many 3D games offer a mode for playing in regular 2D supports the notion that these games offer only marginal gameplay improvements, and not the ultimate leap-forward advance that we long to see. Developers design games for common platforms and sometimes go back to support stereoscopic displays. There is a lack of focused design and development on a ground-up stereoscopic optimized game mechanic. What would a game that is unplayable without stereoscopic video be like? This is a question that we have yet to answer, though recent interest in stereo gaming by independent game developers is encouraging [2]. It could take only one single massively popular game to change the landscape of the gaming industry.

4. DISCUSSION

Poor sales figures suggest the Virtual Boy was a failed Nintendo venture. Rather than point to a single factor for failure, we have identified and discussed six factors that led to the product's demise:

1. Undefined product identity
2. Weak display
3. Isolating game experience
4. Negative effects
5. Challenges in explaining and demonstrating
6. Lack of killer app

The first three reasons are perhaps the ones that are most specific to the VB over similar devices. VB's designer Gunpei Yokoi was reportedly dissatisfied with the device because it was rushed to market and the product wasn't tested and refined enough, forcing Yokoi to make significant compromises [14]. Given additional time for design, development, and marketing, Nintendo might have figured out how to better present the product as well as provide for a better cost-effective display and some means for creating a device that wasn't as isolating in its gameplay experience. For instance, we could speculate that the device might have been presented as an accessible virtual reality gaming system that was light enough to be worn, had a better display with more colors, and had multiplayer games available at launch.

The fourth reason, negative effects, is perhaps only partially a VB specific issue. While additional development time may have contributed towards creating a device that was less uncomfortable to use (no hunching over to play), it isn't clear that Nintendo had much of a chance at success given that, at the time, the negative effects of immersive displays was a research agenda that was being actively pursued for devices that were state-of-the-art in terms of display quality and computing power [18].

The last two factors are perhaps the most interesting since they aren't specific to the VB and deserve greater attention. The fifth factor has to do with the challenges of communicating what the experience of stereoscopic gaming is like. Without any prior understanding of what "stereoscopy" or "true 3D" means, customers likely misunderstood or overestimated the potentials of what the VB had to offer. However, is it still that hard to explain and demonstrate what stereoscopic video has to offer? Greater awareness of 3D imagery and an increase in theatrical releases of 3D movies might go a long way towards overcoming the ignorance gap. On the other hand, greater exposure, when not linked to a stand-out experience may lead to consumer fatigue or a distrust of the "novelty" of stereoscopy [1]. Anaglyph glasses, for example, were distributed at the recently released *Monster's Vs. Aliens* movie to produce 3D effects [29]. However, anaglyph glasses greatly distort the color quality of the image and their relatively weak ability to enhance the movie experience creates a negative impression that ultimately disappoints viewers. Furthermore, it is arguable that early adopters learned firsthand how crude and ineffective early stereoscopic designs really were resulting in stereoscopic displays developing a bad reputation that further complicates customer's willingness to embrace "newer" technology, even when it significantly improves upon earlier offerings.

Consumer fatigue and an understanding of video stereoscopy may be overcome. The motion picture industry is making steady progress and commitments to release titles with stereoscopic display options. To date, over 450 films have been natively recorded using stereo imagining; or rendered in the case of animated films [30]. Many new animated films offer a stereoscopic viewing option likely because of the ease of which software rendering packages enable producers to generate a stereo output. Thus, stereoscopic formats may soon become a norm for computer rendered films as it could be a very cost effective delivery option to the home entrainment market. One key player in the movie industry, DreamWorks, stated in 2007 that it will "produce all of its films in stereoscopic 3D technology starting in 2009" [31].

We hold that there is a significant difference between watching a short stereoscopic film at a theme park and having a longer exposure through feature length films seen in a regular movie theatre. The former is a novelty "oh, that was cool" experience, while the latter increasingly becomes the normal way of watching movies. At some point, people's expectations may change and traditional 3D on a 2D plane will disappoint. Consider the transition from B/W to color TV. At first, color was just "cool". Now it would be difficult to convince someone to switch back to ordinary B/W. Stereoscopic movies will alter consumer expectations. This will have a direct impact on the availability of stereo enabled technology in homes, ultimately paving the path for games to unlock new unrealized potentials. In this sense, movies may be the magic-bullet that will convince gamers and non-gamers that stereoscopic gaming can be more enjoyable.

The entry barrier for a having an interesting and extended stereoscopic video experience has also been lowered. Today people can experience stereoscopy without wearing heavy head-mounted displays or obnoxious anaglyph filter glasses. Stereo games now have the full color spectrum available for display and images can be viewed directly from a computer LCD, TV or projection setup. As a consequence, players do not need to be isolated to a small box with blinking red lights. Lightweight transparent electronic shutter glasses are also increasingly cheaper. Economics have also been favorable for adoption. On the one hand, as devices becomes cheaper, consumers are more willing to try them out without necessarily understanding what they do or what kind of experiences they may afford. On the other hand, the VB was a one-trick pony that served only a gaming purpose. Today's LCD TV and projectors with stereoscopic output options serve multiple purposes, including entertainment, computer work, recreation and home aesthetics. In other words, consumers no longer need to view stereoscopic gaming hardware as an independent entity considering the wide array of multipurpose applications screens regularly serve nowadays.

The sixth factor we identified is still an open issue. Where is the game that everyone wants to play that can only be experienced in stereo? Well, it's not here yet. Nintendo learned a good lesson from the VB venture, as their marketing strategy was greatly modified by the release of the now very popular Nintendo Wii. The Wii console includes a motion-sensitive remote and Nintendo clearly showcased the potentials of the Wii Remote by bundling the system with Wii Sports. Wii Sports does not boast any spectacular features on its own, but the system bundle and intuitive interface with the handheld hardware remote earned the system very high remarks. In fact, early television ads focused on showing people engaged in activities with the remote and the TV screen conspicuously absent. At launch, Wii hardware was comparatively underpowered. However, this rapidly became a non-issue as Wii players challenged each other using the multiplayer interface on big screens in-stores nationwide. This helped create an attention magnet that focused on the experience of playing the Wii as opposed to celebrating the technical aspects of the hardware. This is the sort of magic moment the stereo community needs to have to become successful.

5. CONCLUSIONS

Stereo games stand to revolutionize the medium of videogames by delivering a new level of immersion and expectations. Despite numerous attempts, no one has been successful at making stereoscopy part of the everyday gameplaying experience. Bursts of inspiration have produced numerous products, many of which contain a wide array of problems. Contrary to popular belief, the stereoscopic dream has repeatedly failed not only for technological and price concerns, but also because of other confounding factors. Virtual Boy, arguably the best *candidate* for making an impact failed to deliver the stereo promise because of poor product design, lack of essential features such as multiplayer support, and an unclear marketing position. It failed to excite the customer by featuring a mundane selection of games at launch that didn't adequately showcase the full capabilities of stereoscopic displays.

The most promising and affordable of all today's technologies, shutter glasses and a compatible display system, still represent an insurmountable barrier for mass adoption. Current generation alternating field glasses are transparent and relatively lightweight. However, simply wearing a pair of glasses may be responsible for deteriorating the player's experience. Portable gaming ubiquity complicates matters further by placing a burden on players to carry and put on an extra pair of viewing optics in order to enjoy gaming in non-ideal and dynamic environments. One possible solution to address the aspect of inconvenience could be targeted towards players that already wear prescription glasses; these players could upgrade to lens with built-in electronic shutters. Consequentially, these players would be ready to interact with stereoscopic displays at anytime, without having to locate and put on a special device. More research needs to be conducted in this area to access feasibility, but considering the already slim profiles of today's electronic shutter glasses, we believe this may soon one day become possible.

There are, as discussed earlier, other possibilities as well. Hardware tracking devices are being utilized to rotate virtual environments relative to a viewer's eye position, giving the illusion that one can "see" around an object. This is accomplished by determining the player's position relative to a point in space using a combination of infrared sensors, accelerometers or cameras. These implementations can be considered autostereoscopic since the user is not required to wear any special device to perceive the augmented 3D effect. Motion tracking devices could set the stage for greater 3D awareness and expectations. Additionally, gamers seeking a stereoscopic experience immediately can explore the technology bridge by playing modified versions of games such as Unreal Tournament 3 using anaglyph glasses. For those willing to explore cutting-edge quality, electronic shutter glasses are the best bet for rendering PC games in full stereo, without the color filter restrictions of anaglyph glasses. Could this latest hybrid technology trend open the door to easy widespread adoption? We don't know, but we're anxiously waiting to find out.

Although technical breakthroughs have been achieved, current generation technology has addressed many, but not all of the problems with captivating the gaming market's attention. The essence of our discussion has been to identify the problems with the way stereoscopy is being repeatedly set back not only by technology problems but also by the way the stereoscopic movement is being directed. Confounding factors, not related to hardware design, play a significant role in hampering widespread adoption, including the crucial lack of a *must have* stereo game.

History has shown that a cornerstone title can be the golden-key to unlocking the gateway to success; stereoscopic game designers have yet to find that key and unlock the door. Present stereoscopic titles fail to deliver novel gameplay experiences, thus not offering players an incentive to make the transition. Essentially stereo gaming is just the icing on the cake, rather than a new kind of pastry altogether.

6. ACKNOWLEDGMENTS

Figure 3 - Player Position While Playing the VB – Gallant, Matthew. "Gamma 3D: Virtual Boy Games." Nov 20, 2008. [Online image]. Flickr. Available: http://www.flickr.com/photos/gangles/3046662575/. [Accessed: 24 June 2009].

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