<u>(r)Evolution in Brain-Computer Interface Technologies for Play: (non)Users *in Mind*</u>

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ABSTRACT

This dissertation addresses users' responses to the introduction of Brain-Computer Interface technologies (BCI) for gaming and consumer applications in the early part of the 21st century. BCI technology has emerged from the contexts of interrelated medical, academic, and military research networks including an established computer and gaming industry. First, I show that the emergence and development of BCI technology are based on specific economic, socio-cultural, and material factors, and secondly, by utilizing user surveys and interviews, I argue that the success of BCI's are not determined by these contextual factors but are dependent on user acceptance and interpretation. Therefore, this project contributes to user-technology studies by developing a model which illustrates the interrelations between producers, users, values, and technology and how they contribute to the acceptance, resistance, and modification in the technological development of emerging BCI technologies. This project focuses on human computer interaction researchers, independent developers, the companies producing BCI headsets, and neuro-gadget companies who are developing BCI's for users as an alternative interface for the enhancement of human performance and gaming and computer simulated experience. Moreover, BCI production and use as modes of enhancement align significantly with social practices of play which allows for an expanded definition of technology to include cultural and epistemic dimensions of play.

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Introduction:

In the first decade of the twenty first century several pioneering companies developed and marketed inexpensive headset controllers to the general public. These headsets are a class of electroencephalography (EEG) based technologies called Brain-Computer Interface technologies (BCI), which function by measuring electrical output from the brain and linking that output to specified computer and mechanical functions.[1] [2] These functions vary from controlling software commands, such as killing zombies with brain waves in videogames, to moving actual physical objects with a crane.[3] A BCI describes a system of communication between a machine and a biological system, and is further categorized as either non-invasive or invasive, whereby in the latter category electrodes are in direct physical contact with the nerves, and in the former system electrodes are placed on the surface of the scalp. These headsets are classified as non-invasive BCI's and provide an alternative form of control that reorient user's actions by harnessing the electrical activity emitted from the brain to initiate computer commands rather than using manual controllers such as keypads, buttons, and joysticks. BCI technology has led to the emergence of new modes of computer based interaction to enhance the interfacing options of users for

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[1] Two main platform companies, Emotiv, co-founded in 2003, and NeuroSky, founded in 2004, have developed non-invasive brain-computer-interface hardware and software for multiple actors: game and software developers, researchers, educators, and medical practitioners. See http://www.emotiv.com/index.html & http://www.neurosky.com.

[2] EEG technologies were initially applied in medical and behavioral sciences for cognitive therapy. Traditional EEG technologies and neurofeedback methods are used to map brain functions with corresponding bio-signals to allow subjects to change their brain frequencies to create a condition called "operant conditioning." BCI technologies are based on the same EEG technology but most BCI developers utilize the technology to create unique forms of computer interface *control* rather than change subjects' brain frequencies.

[3] Square Enix has developed a video game called *Juddeca*, which is a BCI controlled first person shooter & Neurosky set the Guinness world record for linking their Mindwave headset with a crane and moving the heaviest object to using BCI technology. See: "NeuroSky Mindwave Sets Guinness World Record for 'Largest Object Moved using a Brain-Computer Interface,'" last updated April 12, 2011, http://neurogadget.com/2011/04/12/neurosky-mindwave-sets-guinness-world-record-for-largest-object-moved-using-a-brain-computer-interface/1820

education, training, medicine, social media, and gaming. This project traces and explores users' responses to the introduction of BCI technology and these companies' attempts to incorporate BCI technologies into social markets for gaming and consumer applications.[4] And although BCI technologies represent an ambivalent technology, in which companies are marketing to a variety of potential users, some of the early economic successes, initial acceptance, and diffusion of BCI technologies are occurring within the domain of gaming and toy development and through social practices of play.[5]

The purpose of this project is to contribute to user-technology studies by revealing how, and in what ways users identify with and attach values to BCI technologies through their practices. The identification processes by which users appropriate, resist, and reconfigure BCI technologies reveals how BCI technologies are both shaped by and shaping of users in ways that uphold and reinforce group values but, simultaneously, transcend designers' intentions, uses, and expectations of technological inevitability.

Project Introduction:

This project focuses on the users, their responses to, and practices with BCI technology, but includes an analysis of the technology, and company representations of both BCI technology and users. Currently, the majority of BCI technologies are based on electroencephalography (EEG), a technique which measures electrical signals from the brain when an electrode is placed on the scalp.[6] The brain emits a range of particular electrical frequencies, which have been

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[4] Designers have expressed intentions to link users' emotions to correspond directly to character activity in digital games. See: Don Clark, "Mind Control for Video Games," *Wall Street Journal*, March 7, 2007 and see: Matt Peckham, "The Future of Videogames: The Future of Control" *Electronic Gaming Monthly* 215, May 2007, 48-50.
[5] BCI technologies have initially been distributed to consumer markets for gaming and toy applications such as Mattel's game *Mind Flex* and Uncle Milton's *Star Wars Force Trainer.*
[6] BCIs are being developed based on other measuring techniques such as functional magnetic resonance imaging

categorized, measured, and associated with particular types of mental states, thoughts, and actions. For example, Alpha waves (8-12 Hz, or cycles per second) are associated with concentration, and Theta waves (4-7 Hz) are associated with creativity and relaxed states.[7] BCI technologies, most of which are housed in simplified headsets, measure these electrical frequencies and can be programmed to correspond to a variety of software and hardware commands. The companies manufacturing these headsets have included software development kits (SDK) for program developers individual projects (For example, the measurement of an alpha wave within a BCI system can function as an action for running a fan motor [8]). There are several companies who manufacture these BCI systems and more continue to emerge, but two key producers of BCI hardware technology are Emotiv and Neurosky. This project focuses on these two companies and the introduction of its headset technologies, which includes its marketing representation of BCI's to users.

One of the first companies to emerge was Emotiv Systems Inc., an Australian company headquartered in San Francisco, and was co-founded in 2003 by Tan Le, Allan Snyder, Nam Do, and Neil Weste, with the intention, "…to introduce the immediacy of thought to the human machine dialogue."[9] The company's goal is to develop a technology that reorients the interaction between computers and humans by utilizing the electrical signals generated from the human brain. Emotiv has developed a wireless head set called the EPOC which includes 7 pairs of electrodes and a gyroscope to track head movement. Other features of the EPOC headset

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(fmri), see: Da-Huan Li et al. "fMRI-BCI: a Review," J*ournal of Electronic Science and Technology of China*, 78-81.

[7] For extended discussion of EEG frequencies see: John N. Demos, "Review of Common Banded Frequencies," Chp. 7, In *Getting Started with Neurofeedback*, (New York: W.W. Norton, 2005):112-121.

[8] The Mattel's game called Mind Flex is based on this correlation. The fan increases in velocity as the users' alpha waves also increase, which causes a foam ball, placed over the fan, to hover higher or lower. The user controls the height of a "floating" ball in order to navigate an obstacle course.

[9] "Company Overview," Emotiv Systems Inc., accessed June 24, 2010, http://www.emotiv.com/corporate (This section on the website has changed)

include the ability to detect and recognize 30 different "emotions" including facial movements.

> Based on the latest developments in neuro-technology, Emotiv has developed a revolutionary new personal interface for human-computer interaction. The Emotiv EPOC is a high resolution, neuro-signal acquisition and processing wireless neuro headset. It uses a set of sensors to tune into electric signals produced by the brain to detect player thoughts, feelings and expressions and connects wirelessly to most PCs.[10]

The other major BCI developer, NeuroSky, was founded by Stanley Yang with the goal to integrate BCI technologies into consumer applications. NeuroSky has developed several headsets, the MindWave, MindWave Mobile, and MindSet, which it markets directly to the public.[11] While NeuroSky offers these products directly to consumers (as does Emotiv) the company's main approach for BCI diffusion is to license its platform or hardware technology directly to private developers and companies, and work with these companies to develop its own consumer products which it sells directly to the public. NeuroSky has had success licensing its platform technology to Mattel and Uncle Milton, in which both companies released products in 2009.[12] Mattel developed and marketed a game called Mindflex, whereby users attempt to navigate a ball thorough an obstacle course by controlling their brainwaves. The Company Uncle Milton developed a product called the Star Wars Force Trainer, whereby the user causes a ball to rise and fall by controlling their brain waves.

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[10] "EPOC NeuroHeadset," Emotiv Inc., accessed Aug. 29, 2010, http://www.emotiv.com/apps/epoc/299/

[11] See the NeuroSky store for hardware at : http://store.neurosky.com/collections/hardware

[12] Scott Stein, "Moving Objects with Mattel's Brainwave-Reading Mindflex,"CNet, June 26, 2009, accessed Mar. 12, 2013, http://news.cnet.com/8301-17938_105-10274050-1.html & see: Mark Baard, "May the force be with you, for just $130," Boston Globe, June 15, 2009, accessed March 28, 2013, http://www.boston.com/business/technology/articles/2009/06/15/may_the_force_be_with_you_for_just_130/ and for product websites see: http://mindflexgames.com/ & http://unclemilton.com/star_wars_science/

Photo 1: (From left to right) Earliest to latest development stages of Neurosky's MindSet headset. Photo courtesy of Tansy Brook and Neurosky Feb., 2011. Used with permission. See: Appendix H.

The production of BCI technologies and headsets presents ambiguous possibilities for user practices. And although BCI companies are actively defining a variety of potential users and markets, whereby the initial diffusion of consumer BCI's is occurring through the practice of play and with games, exactly how and where BCI's will stabilize within social practices and domains remains unclear.

Problem Statement:

Therefore, the central problem for this project, as well as for BCI companies, revolves around the issues of the diffusion and acceptance of BCI technology. Underlying the issue of BCI acceptance is the related academic problem of defining the limits and conditions of user agency in the development and appropriation of technology. One basic problem within the field of science and technology studies (STS) centers on articulating the relevant relations between the producers, developers, users, and technology itself, including the degree to which each agent and artifact shapes technological production and social activity (I will address the issue of technological agency in more depth in chapter 2). Also underlying the issues of BCI diffusion are the naturalized assumptions about technological progress and the inevitability of technological advances from those who produce BCI technologies (engineers, computer scientists, etc.). An aura of excitement surrounds BCI technology and many users see the potential such that: "It's (BCI) an important part of the future of humanity."[13] Moreover, where and how these technologies become common place within domestic spaces and widely appropriated by end users largely remains ambiguous. In order to track the trajectory of BCI use and development and clarify whether BCI enthusiasm matches user acceptance my research will focus on the areas in which BCI's are being developed with particular attention to the area of gaming and related practices of play. Moreover, in order to address the problem of BCI diffusion and public acceptance this project will investigate how BCI technologies are being used and who is using them.

Project Questions:

Based on the problem of BCI acceptance I intend to analyze the development and diffusion of this technology in order to answer one primary question and several corollary questions: 1) how have the social values and practices of users shaped the acceptance and development of BCI technology? And 2) how is BCI technology shaping social and individual practices? 3) What are the material and contextual factors which led to BCI development? And 4) I would like to answer why the founders of these companies foresee the "mind" and BCI's as the next step in user interface control. In order to answer this question I first need to identify the contextual features which led to the development of this technology, for whom, and for what

[13] User survey response, March 30, 2011. 14: 03: 08.

purpose, with the hope that this case will reveal new meanings and approaches to understand the relations between users and developers of technology and how they utilize knowledge and cultural values to shape technology. As such, this case builds on and contributes to recent research in STS and user-technology studies which has revealed how technological development is not a determined linear process whereby passive users adopt successful technologies, but where users, and even non-users, are active and implicated agents of change who contribute to the development of technology through resistance, reconfiguration, modification, consumption, and domestication of technology.[14]

Thesis:

BCI development has emerged within the context of interrelated medical, academic, and military research networks including an established computer industry whereby the practices between human-computer interactions is an actively occupied economic and cultural space in which new computer, media, and gaming devices have been successfully diffused to consumers.[15] However, the existence of this economic-cultural space for human-computer interfacing has not guaranteed the success of wide spread BCI diffusion. I argue that the emergence and development of BCI technology in the early 21st century are based on specific economic, socio-cultural, and material factors. But secondly, the success of BCI's are not determined by these contextual factors but rather are dependent on user acceptance and

[14] Oudshoorn, N & T. Pinch, "Introduction: How Users and Non-Users Matter," in *How Users Matter: The Co-Construction of Users and Technologies*, ed. Nelly Oudshoorn et al. (Cambridge, Mass: MIT press, 2003). And see Oudshoorn, N & T. Pinch, "User-Technology Relationships: Some Recent Developments," in *The Handbook of Science and Technology Studies*, ed. Edward J. Hackett et al. (Cambridge, Mass: MIT Press, 2008) 541-566. Oudshoorn and Pinch have outlined several user based approaches and methodologies utilized in STS literature and other fields to describe technological development: Innovation studies, Sociology of Technology, Feminist, Semiotic, and Media and Cultural approaches.

[15] According to Nielson ratings as of May 2012 over 50% of cell phone users are smart phone users, which provide multiple interfacing options. And according to ESA as of 2011 49% of US households own a game console. 38% of households play games on smart phone or wireless device. http://www.theesa.com/facts/pdfs/ESA_EF_2012.pdf

interpretation.

First, the economic success of gaming, which includes industry generated revenue as well as the widespread user adoption of alternative modes of interfacing for gaming, such as Microsoft's Kinect for X-box consoles, which uses a motion detecting camera, and Nintendo's Wii system, which uses motion based controllers, have expanded and established a receptive social environment in which alternative forms of gaming control, such as BCI technologies, may become domesticated. Further, fixed and successful gaming technologies such as Microsoft's Kinect have provided a platform for individual projects by hackers and developers. Do- it-yourself websites have been set up by hackers which provide step by step instructions to reconfigure BCI headsets. Software and hardware developers can create their own projects from tethered appliances.[16] Therefore, BCI technology offers a source for user modification by similar developer networks. These social networks allow for the possible adoption of BCI's from established groups who are involved in gaming, especially those who participate in occupational networks of Human Computer Interaction (HCI). The occupational relations of software developers and hard ware designers who are immersed in networks of production are generating new consumer based products that center on user friendly software built on platform hardware.

The cultural factors which allow for BCI development to be considered a possibility is 1) the widespread social activity of users who play and use computer, media, communications and gaming devices and 2) a pervasive technological enthusiasm about the enhancement of the body and experiences through technology. This technological enthusiasm provides a grand narrative to guide a host of workers from educators and medical researchers to software engineers and

[16] Arturo Vidich and Sofy Yudiskaya, "How to Hack Toy EEG's," *Frontier Nerds: An ITP Blog,* accessed Dec. 24, 2013, http://frontiernerds.com/brain-hack. This blog site offers step-by-step instructions to hack BCI technologies for individual projects. A guide to hack Neurosky's Mind Set, Mattel's Mind Flex, and Uncle Milton's Force Trainer.

designers.

However, the success of BCI diffusion is contingent on BCI producers and lead users. How producers of BCI technologies represent the capabilities of their technology to lead users, without exaggeration and the overpromise of the technology will be crucial.[17] In addition, how these producers interpret and represent the interests of these lead users will also be critical in constructing a space for the adoption of BCI technology. Finally, how and for whom lead users in turn construct end user applications of BCI technologies will depend on how the technology represents and aligns with the established values and current practices of that particular group of technological users.

This latter point allows me to claim that the adoption of BCI technologies in general, and in particular for gaming control, depends on how this technology resonates within pre-existing social relations and practices, or is in accord with the expectations of users and the functional capacities of gaming technologies and interactive control. Consumer practices and user values need not match developer representations of users or their values for the domestication of BCI technology. However, the possible functions of BCI technology, given the ambivalent status of this emergent technology, has to similarly align with a pre-existing group values and practices in order for the artifact to become incorporated into game play, or for any use. In the context of gaming the technology has to maintain and enhance game play in some significant way. In reference to BCI technologies for gaming, Warren Spector, a game designer expressed, 'Why replace a well understood interface with an unfamiliar one?'[18] Therefore, any socio-technical

[17] Tansy Brook (NeuroSky), Interviewed by Tristan Cloyd, March 08 2011, Transcript Appendix F. Ms. Brook indicated that public perception about BCI technology requires a realistic understanding of their capabilities as an enhancement of computer control and not as a replacement. Accordingly, social expectations about BCI technologies already pose an obstacle to its acceptance, in that expectations exceed what BCI's currently offer.

[18] Matt Peckham, "The Future of Videogames: The Future of Control" *Electronic Gaming Monthly* 215, May 2007, 48

failure is the result of a total de-resonation with exiting user values and practices. *Techno-cultural resonation* is an expression of the triadic relationship between an artifact, its (non)users, and developers, when a group adopts a technology based on a set of pre-existing user group values. *Techno-cultural resonation* is an expression of the degree to which the material characteristics and capacities of an (un)stable technology correspond with the social values, customs, practices and expectations of relevant users and with the representations, technical values, or presumed uses by designers (that is high correspondence makes adoption likely, and vice versa). However, TCR as a relation does not exclude the emergent possibilities of new values or practices, but rather, the emergence of new values and practices can coincide with users' initial interaction with a new technology. TCR as a concept contributes to a methodological approach for understanding socio-technical relations by identifying key relations in the way users' link valued modes of behavior to artifacts, and consequently, delineates the processes by which users identities are linked to the uses, acceptance, and interpretation of artifacts. Further, the consequence of TCR as a model of technological development establishes technology as a cultural source of value and meaning which mediates and moderates social behavior.

Contribution to Field of STS:

What can a study about the development and domestication of BCI technology reveal about socio-technical development? 1) My project makes a methodological and theoretical contribution to the existing body of literature in socio-technical development of (non)user-technology studies.[19] And 2) my project links STS theories of user technology studies to the

[19] For user-technology cases of resistance see: Kline, "Resisting Consumer Technology," 51-65, and Laegran, "Escape Vehicles?" 81-100; for semiotic configuration approach see Woolgar, "Configuring the User," 59-99; for

recent academic interest in game studies which take users and gamers as the object of methodological inquiry. Game studies are revealing how play, as a mode of action, is integral for understanding the use of video games as a cultural artifact and practice. [20] The shift from work to play can contribute to STS theoretical approaches for understanding the contemporary cultural meanings of technology, such that play acts as useful conceptual link for understanding current technological production, social values and practices, and human identity.

Moreover, linking STS with game studies becomes more significant when certain quantitative and qualitative points are delineated. According to The Entertainment Software Association (ESA), the total combined sales for computer, console, and other formats for video games in the U.S. in 2011 were 16.6 billion dollars.[21] (The ESA is an association between several media related corporation that gathers and monitors statistical, economic, and demographic information related to media, computer and video game use and consumption). From 1999 to 2011 sales have tripled from 5.5 billion to 16.6 billion.[22] Based on ESA estimates from 2010 67% of households (within the U.S.) engage in some form of computer related video game (this includes word games, online, etc.). The increasing ubiquity of gaming technology included within social and individual practices and habits warrants an increased focus on gaming technology and practices as a legitimate area of STS research. In addition, video game technology covers over 40 years of social history, in which a generation has been and currently interacts with media technologies and video games as naturalized modes of life.

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history of domestic use of technology see: Cowan, "More Work for Mother," for social construction of technology see Bijker, "The Social Construction of Bakelite."

[20] Several methods and areas of analysis have been identified in game studies. See Simon Egenfeldt-Nielson, Jonas H Smith, Susana P Tosca., *Understanding Video Games: The Essential Introduction*, (New York: Routledge, 2008),1-11

[21] See Industry Facts at http://www.theesa.com/facts/pdfs/ESA_EF_2012.pdf

[22] See comparison of historical sales information from http://www.theesa.com/facts/pdfs/ESA_Essential_Facts_2010.PDF & http://www.theesa.com/facts/pdfs/ESA_EF_2012.pdf

Chapter 2:
User-Technology Studies Literature Review

Introduction to User-Technology Studies:

This project builds upon and contributes to scholarship within STS which explores the role of users and non-users in shaping the development of technology. User – technology studies have moved beyond early technology models, which emphasized linear modes of development and de-emphasized the role of the user by positioning them as passive recipients of industry developed technology. The issues underlying socio-technical models of development center on articulating the relations between user agency and technological change. Identifying these relations contextualizes the emergence of the technology in terms of the social, material, and epistemic conditions which constrain and or enable the development, appropriation, diffusion and or failure of a technology. User-technology studies and approaches have contributed to an expanded understanding of these socio-technical relations by revealing the active role users play in technological development and diffusion, and exposing the indeterminacy of technology by focusing on the contextual basis of technological development. This literature illustrates the complex and diverse ways in which users and non-users play critical roles in technological development, through the appropriation, modification, reconfiguration, and domestication of technology, and further, through technological resistance.[23]

This literature emerges from different disciplines but shares as its research subject user-technology relations as a common point of departure. Trevor Pinch and Nelly Oudshoorn have identified and outlined several user centered approaches which provides the methodological and

[23] Nelly Oudshoorn and Trevor Pinch, "Introduction: How Users and Non-users Matter," in *How Users Matter : The Co-Construction of Users and Technologies,* ed. Nelly Oudshoorn et al. (Cambridge, Mass: MIT Press, 2003), 1

theoretical framework for this projects literature review.[24] By outlining various user-technology approaches these authors have, "… present(ed) studies of the co-construction of users and technologies that go beyond technological determinist views of technology and essentialist views of users' identities." [25] Their academic aim reveals the general problems and issues within the field of user-technology studies, that of technological determinism and user agency.

<u>Underlying Issues in User-Technology Studies:</u>

Technological Determinism is a concept which holds that the development of technology is inevitable and its material forces and properties act as an autonomous force, based on necessity, which determines social behavior. The notion of technological determinism has two dimensions or, rather, is based on two premises*: determination by the base* and *unilinear progress*[26]. The first dimension, *determination by base,* is the idea that technology, once established, determines work processes and social relations. Or in other words, social institutions must adapt to the "imperative" of the technological base. Adopting a technology necessarily constrains one to adopt certain practices that are connected to its employment. This idea is crudely summarized by Marx's description of the relations of economic production, "the hand-mill gives you society with the feudal lord; the steam-mill society with the industrial capitalist."[27] Closely following this first dimension is the second dimension of technological determinism which assumes that the development of technology progresses from simpler forms to more advanced forms. This is called *unilinear progress*, the idea that technical progress

[24] *Ibid.* 1-24
[25] *Ibid.* 3
[26]The notion of unilinear progress has additional distinctions: A) technical progress proceeds from lower to higher forms of development B) development follows a single sequence of necessary stages. For additional discussion of these two premises see: Andrew Feenberg, *Questioning Technology* (New York: Routledge, 1999), 77.
[27] Marx, "The Poverty of Philosophy," 219-20

follows a unilinear course, a fixed track, from less to more advanced configurations. This dimension is similar to early positivistic understandings of science as a progressive accumulation of knowledge, and by extension technology is essentially applied scientific knowledge. The simple conclusion from these two dimensions establishes the outcome of society and technology as inevitable, and that individual actions and choices are limited, as either a discoverer of natural truths or as an inventor based on necessity.

The implications of strong technological determinist perspectives reveal the second issue addressed in user-technology studies: the role of individuals in technological development. What role do people have in shaping technology if the outcomes of science and technology are determined by revealing the natural world through scientific inquiry, and by addressing societal needs through technological advances? The roles of individuals are very limited based on the implications of these perspectives, which poses problems for any democratic society which utilizes science and technology as a means for social progress.

The issues of technological determinism and user agency themselves as well as the responses to these general issues cannot be addressed extensively in this introduction.[28] However, the pertinent dimensions of these issues can be explicated by introducing user-technology approaches which have revealed that these relationships are not monolithic, nor inevitable, and that user roles are pluralistic and active, instead of singular and passive. Consequently, these approaches contribute toward undermining crude determinist notions of technology and simplistic representations of users.

User-technology studies have revealed that technological development is not determined but based on contextual factors, such as location, that is where the technology was developed;

[28] For additional discussions of technological determinism see Heilbroner, "Do Machines Make History," 335-45. And for a recent discussion see Wyatt, "Technological Determinism is Dead," 165-180

who is involved, the developers, users, and representatives; the values and goals of those involved; and the artifact itself, what the technology is and what its uses are. In other words, the where, the who, and the what, are contingencies which shape the direction of technology. In regard to the notion of determinism it is important to note that while user-technology studies have made contributions toward illustrating the variety of ways user agency manifest in technological development, scholars acknowledge the limitations of user agency. For example, David Morley warns of "romantic voluntarism", admonishing researchers to avoid celebrating user agency without critical understanding of cultural and technical limitations. [29] How and why these technologies are developed is partially influenced by these dimensions. Several approaches and methodologies address these dimensions differently with varying strengths and weaknesses.

So the questions emerge: do the choices between two technological solutions actually represent and define user agency and freedom? Does the use of a new technology redefine or radically fracture larger social or economic modes of behavior? Or do the technological solutions to problems actually perpetuate and reproduce established social and economic activities, such that the use of technological artifacts become as naturalized within social and individual activities as cultural values do such that any new solution is a taken for granted manifestation of the system? How is the activity of a hacker, who uses a computer, radically different from a student who uses a computer? At micro level the hacker may use it for different reasons such as to offer free software to users which may undermine capital goals such as monetary accumulation, but at a macro level the production of software for computer based interactivity promotes the production of further computer based activities and economic production which promote the development of computer based hardware and software. The issue of user agency within technological development has been criticized by critical theorists in the 1940's and later

[29] Oudshoorn and Pinch, "Introduction," 16

in the 1960's, who argued that any technological solutions, including resistances, were actually determined by the larger economic system and cultural industry, such that the choices where already given.[30] This point illustrates the constant tension between articulating user agency and technological determinism, which are two aspects of the same dimension. The academic approaches don't always directly address these dimensions in these terms but these two issues are underlying all these approaches.

<u>User –Technology Approaches:</u>

I am indebted to Trevor Pinch and Nelly Oudshoorn for outlining many approaches within user technology studies, and based on their taxonomy of approaches I outline the field and reveal my approach: a cultural approach.[31]

However, I cannot address all the approaches and literature which encompass user technology studies, primarily approaches in the field of Information Systems studies (IS) and Information communications technology studies (ICT), which employ cognitive models, based on Social Psychology in order to understand how users make choices within an information-computer based work environment. These approaches are interventionist, often focus on lead users, and employ quantitative methods to understand limitations within a work based environment. Some of these approaches have extended user- cognitive based models by applying and appropriating the related STS concept of social actor to users.

Social actors exercise limited discretion in ICT choice and use, since in their

[30] For examples of critical theorists see: Marcuse, *One Dimensional Man,* and Adorno and Horkheirmer, *The Dialectic of Enlightenment.*

[31] I am outlining their taxonomy of approaches. See: Oudshoorn, Nelly, and Trevor Pinch, "Introduction: How Users and Non-users Matter," in *How Users Matter : The Co-Construction of Users and Technologies,* ed. by Nelly Oudshoorn and Trevor Pinch, (Cambridge, Mass: MIT Press, 2003) 1-24

> multiple and aggregate roles, organization members articulate the preferences of a collection of actors, not just individual biases.[32]

This literature published in management information systems journals, can provide valuable insight for researchers studying work within institutional systems. Closely connected to this research is another approach, which Pinch and Oudshoorn have identified as *Innovation studies*. This is another intervention approach that identifies lead users in industry product development to better understand market research. [33]

One of the first approaches within STS to draw attention to the role of users in technological development was the Social Construction of Technology (SCOT) developed by Trevor Pinch and Wiebe Bijker.[34] In simplest terms, SCOT is a theory which maintains that the creation of technology is based on the social groups who initially develop, use, and attach meaning to an artifact. By extension, this approach presumes that any technological outcome could have been different given the social groups and values involved. This methodological presumption is based on the concept of *symmetry* from the sociology of knowledge, which SCOT applies to technological development in order to explain how users contribute to the outcome of technological artifacts. [35] Therefore, the notion of symmetry is a methodological response to the historical realization that various competing solutions are available for any given problem. In this sense, SCOT posits that the outcome or solution to any technological development or problem, whether a 'failure' or 'success', cannot be explained solely in terms of whether it "works" based on some internal technical value or ontological representation or category such as efficiency or

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[32] Kling and Lamb, "Reconceptualizing Users as Social Actors," 218. And for an additional case see: Beaudry and Pinsonneault, "Understanding User Responses."
[33] See Von Hippel, "The Dominant Role of Users in the scientific Instrument Innovation Process" and *The Sources of Innovation*
[34] Pinch and Bijker, "The Social Construction of Artifacts," 17-50
[35] See the Strong Programme in Bloor, *Knowledge and Social Imagery*, 1976.

truth, but rather the technological result must include an explanation of the cultural context and *relevant social groups* who attach a particular set of values and meaning to that artifact. The various meanings that social groups may attach to an artifact, refers to an artifacts' *interpretive flexibility*. According to SCOT, the interpretive flexibility of an artifact diminishes as its design and use *stabilizes* through a set of various *closure* mechanisms, such that one particular design becomes predominant over others. Their studies of the bicycle, fluorescent light, and Bakelite have revealed how technological artifacts are not the inevitable result of necessity but rather their outcome is based on competing sets of values from relevant groups who shape the design and use of an artifact.

The strength of SCOT lies in its methodological process of identifying the relevant groups who contribute to the *initial* stages of the development and interpretation of technologies, whereby the artifact lends itself to interpretive flexibility. However, critics have identified several weaknesses whereby SCOT underestimates: the effect of technology within society once established, the role of less visible users such as end users and non-users, and finally, the approach underrepresents the power relations of those who have access, and or reject technology, all of which can shape technological development.

First, SCOT minimizes the larger effects of technology within society by focusing on the initial users and their interpretative agency in constructing technology. Langdon Winner has argued that technologies are not unendingly interpretable or under the direction of users and developers. Technological systems and artifacts often narrowly limit their uses and constrain outcomes once established. Langdon Winner has argued this point about nuclear technology whereby solutions for its control are determined by certain unavoidable characteristics and which require a highly controlled political and physical arrangement.[36] Regardless of whether Nuclear power is used for electricity to distribute to peaceful residential communities or used as weaponry deterrents against political foes, its adoption rigidly defines future actions. In addition, the development of any technology must also be understood as a response to a problem emerging from within a given system, and once adopted has effects beyond the decision of users and developers. Therefore, a range of technological ends emerge from an established technological system, and moreover those ends become means for new ends. This criticism highlights the limitation of user agency within any established socio-technical system.

SCOT's concept of closure has also been criticized for being "too rigid" in that it closes down the role that other users play in reinterpreting a technological artifact and its prescribed uses. Mackay and Gillespie have pointed out that users' actively modify and reinterpret stable technologies. Pinch and Kline responded to this criticism with a study of users who modified the Model T, whereby they argue that users are active agent of technological change.[37] The link between end users and developers was made more explicit in Pinch & Bijker's concept of *technological frame* which is a shared set of group techniques and concepts employed by groups to solve problems. This technological frame can be shared by many different users and developers who have multiple identities and values.[38] This concept addresses the mutual co-construction of an artifact by users and developers.

And finally, SCOT has been criticized for its failure to address or explain the unequal power relations by which technologies are distributed and or made available to varying groups, which include the exclusion and restriction of users and the politics of non-use. Moreover,

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[36] Langdon Winner, "Upon Opening the Black Box and Finding it Empty: Social Constructivism and the Philosophy of Technology." *Science Technology & Human Values* 18, no. 3 (1993): 362-378.
[37] See Mackay and Gillespie, "Extending the Social Shaping," and Kline and Pinch, "Users as Technological Agents."
[38] Wiebe E. Bijker, *Of Bicycles, Bakelites and Bulbs,* 102-03

SCOT's methodological strength of focusing on the initial relevant users ignores less visible users, and even non-users, such as those who actively resist or reject technologies. The neglect of these other users has been picked up by feminist approaches and scholars.

Feminist scholarship and approaches, like SCOT, reflect a shift away from determinist perspectives and passive representations of users by emphasizing the active role users play in shaping technology. In particular, feminist approaches were employed to correct the largely absent account of the role of women in the history of technology. Early investigations in technology studies often focused on the innovator and artifact, largely ignoring both the role of users and the impact of technologies on women. Feminist scholars advocated that technology studies focus on the use and user of technologies. The feminist, "turn to the users," approach was a response to technology studies research focus on industrial production and work place practices. Ruth Cowan's influential study on how women consume and use technologies in everyday households marked a major contribution in the field.[39] Cowan's concept of *consumption junction*, a place where consumers make choices between competing technologies, broadened the research domain in the history of technology to include social histories and gendered interpretations of technology by end users in domestic contexts. In general, feminist scholars, starting in the late 70's and early 80's, broadened the category of users in technology studies to include the active participation of women in the domestication, development, and diffusion of everyday technologies thereby expanding the diversity of the research subject.

The feminist contribution of recognizing the diversity of users complicates both mapping and understanding the influence of users in socio-technical relations. However, recognizing that users are not homogenous not only highlights the importance of how users conceptualize of a technical artifact differently, but reveals the importance of the process by which users get

[39] See Ruth S. Cowan, *More Work for Mother*, and "The Consumption Junction," 261-80

defined in a development network. The process of defining who a user is in a network can restrict or promote use and access to an artifact.

> "The very act of identifying specific individuals or groups as users may facilitate or constrain the actual role groups of users are allowed to play in shaping the development and use of technologies"[40]

Moreover, who and how users are defined reveals the various socio-technical paths by which an artifact may fail or become successful. Understanding how diversity shapes the success or failure of technical production reveals the points at which user agency and technological obduracy strengthen and weaken, and consequently the points at which individuals can intervene in technical production and thus the ways that different users are affected by technology. Moreover, the point at which social actors can intervene in technical production illustrates the feminist political goal of increasing the role of women and less visible groups in technological development.

Feminist sociologists, building on the concept of diversity, have expanded the notion of relevant users by introducing a taxonomy of user categories, which distinguishes between more standard users, such as lead users, and less standard positions, such as end users and implicated actors. Identifying these less standard positions illustrates the varied power relations in technological development. One of the most significant categories is the addition of the *implicated actor*, introduced by Adele Clarke, who are those actors affected by action but not present or who are silent.[41] This category becomes important for understanding how new and

[40] Oudshoorn and Pinch, 'User technology Relationships: Some Recent Developments," 546
[41] Casper and Clarke, "Making the Pap Smear," and Adele Clarke, *Disciplining Reproduction*, 267

ambiguous technologies are actively marketed by innovators and companies toward potential end users and implicated actors. Who becomes a user reveals who may or may not have access, and who chooses or rejects a technology. This point illustrates other important actors, the role of non-users in technological development, who also shape the direction of technology by their voluntary or involuntary rejection of technology.[42] Further, factors such as race, gender, or class, become relevant dimensions in assessing socio-technical relations which establish technological production and use.

Feminist scholars have also made important conceptual contributions to describe the discursive socio-technical relations between subjects and objects. Donna Haraway used the term cyborg to describe the way boundary categories between objects and subjects have become blurred, such that human and technological boundaries have become hybrids. The notion of a hybrid illustrates the way that bodies are transformed through technological practices. In regard to this project BCI technology represents a cyborg technology in which the boundary between the technology and subject are so physically intertwined that they mutually co-constitute each other.

Another important approach in user- technology studies is the extension of semiotics to technology studies. Semiotics is the study of how meaning is created from signs to things. In semiotic approaches technologies are interpreted as text whereby users act as readers of artifacts. Central to semiotic approaches are two concepts, "configuring the user" and the concept of script, both of which illustrate how users interpret (read) an artifact (text) and conversely how an artifact restricts how much can be "read", or rather how an artifact limits use and interpretation. The concept of "configuring the user" was introduced by Steve Woolgar in a study about

[42] Sally Wyatt, "Non-Users Also Matter," 76. Wyatt illustrates that Non-use isn't always a matter of deprivation of access or inequality. Non-use is voluntary and involuntary. Four categories voluntary: 1)resister, 2) rejecters; and involuntary: 3) excluded 4) expelled.

computer usability trials in order to explore the "machine as metaphor" and to understand the way users make sense of a new technology.[43] Woolgar examined the procedures that delimit the processes of interpretive flexibility, which in contrast to the SCOT approach emphasized the closure and stabilization of an artifact by relevant users in constructing an artifact. Woolgar concluded that "… the design and production of a new entity…amounts to a process of configuring the user, where 'configuring' includes defining the identity of putative users, and setting constraints upon their likely future actions."[44] Woolgar's emphasis on the agency of designers and the limitations set by machines was criticized for ignoring the processes by which users configure designers, which ultimately de-emphasizes the role of users and less visible users in the development process.[45]

The second idea in semiotic approaches, the concept of script, has been developed by Bruno Latour and Madeleine Akrich to express how artifacts constrain and enable human action. Latour and Akrichs' approach focuses on the design process. They argue that designers predict a range of users' skills, interests, and behavior when designing an artifact. In this approach, artifacts serve as scripts which frame certain types of actions, that can transform, create or reinforce certain behavior and, or norms. Akrich argues that these representations of potential and future users and uses are embedded in the design of the artifact: "Technical objects … simultaneously embody and measure a set of relations between heterogeneous elements…" however, the goal of the script approach is to illustrate how artifacts "participate in building heterogeneous networks that bring together actants of all type and sizes, whether humans or non-humans"[46] In this regard, the script approach, as a network approach, challenges constructivist

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[43] Steve Woolgar, "Configuring the User: the case of Usability Trials,"58-99.
[44] *Ibid.* 59
[45] MacKay et al. "Reconfiguring the user: Using Rapid Application Development," 737-57.
[46] Akrich, "The De-Scription of Technical Objects," 205-6. And see: Akrich and Latour, "A Summary of a

approaches, by extending action to non-humans. Moreover, both script and configuring approaches are concerned with how designers inscribe their views of users and use in technological objects, but script approaches are broader than configuring approaches by attributing more agency to users and non-actants in a development network. Script approaches also focus on the potential for user resistance toward designer intentions or artifact scripts, as well as reinforcement of design script.

The final approach in user-technology studies are cultural and media approaches which start with and focus on the consumption and interpretation of technologies by users over previous approaches discussed that focus on the artifacts, the design process and/or the designers' intention and representation of users. Early cultural and media analyses by Critical Theorists stressed the dominance and monolithic influence of the established technological and economic system which produce cultural products to significantly shape and determine user actions, whereby users and consumers were perceived as passive recipients of economic and technological production. However, later cultural & media approaches have emphasized users' ability to reinterpret artifacts, and the freedom and agency of users to create culture.[47]

> It is within the sphere of everyday life that individuals and groups can be agents, able, insofar as their resources and the constraints upon them allow, to create and sustain their own life-worlds, their own cultures and values.[48]

Cultural approaches presume that user practices with technologies are not simply utilitarian, technical, or economic but technologies also serve cultural and symbolic functions in social

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Convenient Semiotics of Human and Nonhuman Assemblies."

[47] See: Storey, *Cultural Consumption and Everday Life*, and Silverstone, "Design And Domestication."

[48] Roger Silverstone, "Introduction," 2

activities. Cultural and media approaches assume technologies must be culturally appropriated to become successful and functional. Moreover, cultural approaches presume that the diffusion of technology is better understood as consumption activity whereby users actively negotiate their identities through consumption activities. In effect, the consumption of a technological artifact is a cultural activity which involves the process of domestication, whereby a previously unknown product is incorporated into social activities. Therefore, consumption is a form of technological and cultural production, as well as economic production.

Conclusions about User-Technology Approaches:

Any general conclusions about user-technology approaches illustrates that any one approach cannot adequately address every research limitation. However, this summary does demonstrate the relevant issues that need to be identified with any approach. The analysis of user-technology relations should identify not only the dominant actors within a technological network but 1) those invisible actors and hidden voices who are affected by and who influence the direction of technology, which includes social factors such as class and gender, as well as technical factors. Moreover, addressing the relations between dominant actors and those in less visible positions entails the need to explicate 2) the power relations within any socio-technical network that can lead to the development, access, or restriction to a technology. The issue of access introduces the need for a complex taxonomy of 3) non-use and use, which includes users who voluntarily and involuntary accept a technology, as well as those who reject and resist a technology. In addition, any approach must identify the limitation of users' actions or rather 4) how technology constrains users' actions. Identifying the points at which users actions are constrained can define the limit and possibility of user intervention. Further, any approach needs to distinguish between the functions of technological utility and 5) the symbolic function of an artifact within culture and social groups, that is a user's capacity to give meaning to an object. Addressing users or subjects points of view, over the design of an artifact or the designers' points of view, illustrates alternative directions of technological outcomes and modes of user agency.

The current trends in user technology approaches reflects an orientation toward micro level analyses, whereby moments of user agency and social changes are promoted over user limitations and the large technological effects and reinforcement of established cultural modes of action and techno-economic systems. Moreover, current approaches focus on descriptions of group complexity over grand narratives and social theories. But I do believe the larger macro level question is still pertinent and at the root of every study: to what degree does user agency within a micro level context disrupt large scale economic uses of technologies? Does the disruption, re-appropriation, and or modification of established technologies, over long term help to erode an established technological and economic system? Of course I can't adequately or appropriately address this tension here, and would be lucky to adequately address this issue in an academic lifetime. History has shown that a reorientation of values attached to any technological system or artifact do occur as well as fundamental shifts in that system. However, if the means for critical analyses and critique of technological and economic systems by users and the public, in general, remain largely subsumed under established systems and institutions which promote dominant modes of production, capitalist values, and which employ rhetoric of technological inevitability as social progress, then radical change and fundamental ruptures in socio-technical and economic systems remain elusive, as well as illusive. And while monumental shifts in the fundamental structure of an economic system remain episodic, the introduction of new technologies inevitably alters social habits both generationally and intra-generationally.

Therefore, I believe the important initial short term goal and prescription for researchers of user-technology studies is descriptively identifying these socio-technical changes with the introduction of a new technology, which entails identifying how users make sense of a technology, and the values they attach to it. Achieving this goal starts with case studies which focus on of how users interpret, appropriate, re-modify, and resist, new technologies within an established cultural and economic system. Technologies are cultural artifacts and as artifacts of meaning these objects can be used to redefine users' identities, *rearrange* social habits and customs, as well as *maintain* class and gender categories, and established customs by reinforcing values in socially functional ways. Secondly, the researcher needs to identify the impact of that technology, socially, politically, economically, as well as ecologically. Researchers should prescriptively attempt to link socio-technical changes within larger descriptive narratives. Understanding and defining the links between the values attached to a technology and how that technology is used marks the point at which technologies objectively change social behavior and the way technologies reinforce larger cultural narratives and economic system.

One final research goal is to identify the way actors impose ideology onto technological use and development, and the consequences those uses and development have within society; in order to understand the discrepancy between the subjectively rational ideals imposed onto technologies and the objectively social consequences of that technology. In simpler terms, the meaning or ideal a user attaches to an object does not mean that the object functions in that ideal way. Actors impose their ideology onto action and artifacts to fit that social world view. Sally Wyatt has pointed out that narrative of technological determinism is invoked by technological actors who promote and justify a particular direction in the path of technological development as inevitable.[49] The way users make sense of, identify with, and use technologies marks the establishment of a particular technological perspective which invariably fails to incorporate other major factors within that technological perspective. The tendency to justify the outcome of technology by focusing on the singular and positive benefits of a technology over the actual variety of conflicting consequences is best described as a *technological synecdoche*, in which the affirmation of technology supersedes all other outcomes and conditions and deemphasizes the situational conditions and the choices involved in technological outcomes.[50]

I believe a weakness in case studies and user-technology approaches is failing to identify the discrepancy between what one perceives to be doing with technology, how a group of users or user make sense of it, and how that technology objectively impacts other actants in a technological network, which may not align at some social or ecological level. For example the user of cars, attach the value of freedom, to the technology, in the face of environmental impacts of carbon emission and global warming, or users who attach the ideal of individual freedom to information and computer technologies, which disregards the environmental and social consequences of those who process E-waste, the erosion of privacy and identify theft in an digitally connected world. Actors impose their ideology onto action and artifacts to fit that social-world view, and where solutions are defined in terms of the system, such that technological solutions are invoked as an inevitable fix to the problem, even though the problems themselves emerged within the economic and technological system. The degree to which awareness and feedback is shut down within a cultural system, and whereby the process of analyzing technological and social consequences is disrupted, represents a breakdown of socialized forms of reciprocation and accountability, and can be expressed as a techno-cultural

49 Sally Wyatt. "Technological Determinism is Dead," 167

50 This concept is a modification of James Clifford's characterization of cultural ethnography as a synecdoche. See: Clifford, *The Predicament of Culture*, 1988.

pathology. When reflexive and critical processes for feedback become limited or shut down then techno-cultural pathologies emerge.

BCI for Play: A Cultural Approach

It is important to reiterate that this project is primarily focused on users and their responses to BCI technologies for computer and game interfacing. BCI development for medical functions, which serve to replace and enhance the mobility of people with disabilities, requires further analyses and additional criteria to evaluate its uses, development, and or success. For users with disabilities BCI's offer the possibility of control where previously there were few if any options. For users who interface daily with games and computers BCI's offer more ambivalent possibilities. Therefore, this project analyzes the success and or failure of BCI technologies in everyday interfacing practices with computers and gaming. As one BCI user predicted, "In their current incarnation, I think they will have a small but necessary impact on a small population, such as locked-in syndrome patients, but little impact for the general public other than peripheral amusement for gaming."[51] Aside from the accuracy of such speculation about the future of BCI's, what is certain are that users are critical for determining the success of BCI's in everyday interfacing practices, not only as end users but as innovators and designers of new products and uses.

Therefore, I have chosen a cultural approach because the premises of these approaches best frame this project: that technology must be incorporated into everyday life to be successful and that users are critical in determining the success of technology. This case involves the analysis of a set of users who are consuming BCI technologies, developed by companies, to further develop additional BCI products, such as BCI software applications. These companies

[51] User survey response March 23, 2011 9:03:17

offer BCI hardware products and existing software applications directly to consumers, in an online store, which are both created by the company and third party developers whereby users act as designers and innovators.[52] Therefore, my analysis starts with users, their interpretation, and consumption of BCI technologies. The purposes of BCI products are far from established, nor is there widespread diffusion of BCI technologies in everyday life. However, its success is dependent on user appropriation, reinterpretation and domestication into everyday life.

This project contributes to cultural approaches in user-technology studies in several ways. For one, this project adds to a number of studies that illustrate that user consumption is part of the process of technological development, whereby the distinction between design and use are blurred in practice.

> It is becoming increasingly evident that technological innovation is not a matter only of production, and that consumption and use are essential components of the innovation process.[53]

The development of BCI products is a co-productive process whereby users consume and develop BCI products simultaneously as consumer- producers. In this sense, this project illustrates the contributions of user-centered design of BCI's and the dissolution of the conceptual distinction between design and use. Consumption of BCI Hardware is a first step for many user developers to create and develop new software applications and uses and often involves reconfiguring the device. As one respondent stated, "Teenagers and hackers will be the

[52] See http://store.neurosky.com/collections/applications for applications accessed Oct 28, 2012.
[53] Roger Silverstone, "Design and the Domestication of ICTs," 1

ultimate developers of software and hardware in this arena as I see it." [54] Therefore, BCI development is contingent on groups of users and individuals who consume, interpret, and reinterpret BCI's in order to modify them for further production, consumption, and use. Moreover, BCI development and innovation is not just occurring within occupational networks but within a loosely tied network of individual developers and innovators. However, the reinterpretation of BCI's by users and developers involves a process that goes beyond an understanding of 'use' but includes a process more aligned with modes of resistance.

In this sense, this project contributes to a body of literature from scholars who have expanded the field of user-technology studies to include the activities of non-use and resistance as critical dimensions in technological production.[55] In particular this project contributes to user-technology studies by including the *social activity of play* as a critical process in technological development, acceptance, and resistance. The activity of play becomes central both in the production of technology through user- centered designs, and a key path to the appropriation and acceptance of BCI technologies in the form of games. Users are being familiarized with an unfamiliar and new technology through the activity of play.

Through work and play users define the limits and capacities of BCI technologies. These boundaries illustrate the tensions within BCI production as users simultaneously accept and resist BCI technologies. User acceptance is moderated by a general and pervasive sense of enthusiasm for BCI technology, "I've been waiting a long time for that (BCI) technology." [56] And one respondent declared BCI's to be "exciting" and "futuristic." [57] Coupled with user excitement is the expectation that, "BCI's will profoundly change human-computer interaction and give

[54] User survey response 3/22/2011 18:52:23
[55] See: Kline, "Resisting Consumer Technology," and Bauer, *Resistance to New Technology*.
[56] User survey response March 14,2011 17:07:18
[57] User survey response March 27,/2011 5:44:57

science a new tool to do online experiments." [58] and further, "It's… (BCI) an interesting new technology that I could see taking off."[59] However, user expectations and enthusiasm for BCI technologies potentialities are tempered as limitations emerge. One respondent complained: "the main limitation is the accuracy needed for cognitive detections to work"[60], and more than one respondent complained, "Wearing a headset looks cool but is not so comfortable." [61] One statement, by a respondent, represents the central issue for this project, " I see consumer acceptance being a big factor (limitation),"[62] particularly in regard to game interfacing. "So called Brain reading peripherals have come and gone," within the gaming industry whereby users have an established history of resistance and have rejected several brain reading devices which failed to enhance game play.[63] An important part of this larger project is a comparison of the factors which led to past rejection of peripheral reading technologies and the current factors which led to its development and renewed interest. Moreover, whether any previous limitations which led to its rejection, resemble the current limitations of BCI use, will lend deeper understanding to the trajectory of BCI use and development. Ultimately, how the current limitations of BCI technologies for game play translates into user rejection remains to be seen.

The notion of play not only helps articulate user modes of resistance and acceptance of BCI technologies, the concept of play contributes to refining and expanding a definition of technology in a contemporary cultural context. And although play has many definitions and characteristics, which require elaboration, play is a fundamental activity of humans and

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[58] User survey response April,12, 2011 5:06:20
[59] User survey response March 23,/2011 13:21:22
[60] User survey response March 14, 2011 17:07:18
[61] User survey response March 27, 2011 5:44:57
[62] User survey response March 23,2011 13:21:22
[63] Matt Peckham, "The Future of Videogames: The Future of Control" *Electronic Gaming Monthly*, May, 2007, issue 215, 50 & in same issue for several gaming-interfacing "failures" see Seanbaby, "Devices of Future Past: Before Their Time and Still Crap," 92-93: examples include *Mind link* by Atari 1984 and *Bio-sensor* by Nintendo N64 1998..

expressions in culture. [64] The diffusion of information and computer technology into social and cultural activities highlights how technologies are not just about labor and work but about leisure and play. The activity of play embodies both definitive and indefinite boundaries. For example, through games, play involves rules, sets of skills, knowledge and goal setting. Conversely, play is also free, exploratory, inquisitive, undefined, and expressed as amusement. These competing yet complementary dimensions illustrate the constructive domain of users' involvement with BCI technologies. Play as a social activity appears to be central in the appropriation of BCI technology by users and developers alike. The notion of play provides a framework to understand uses that go beyond definitions of technology as "humanity at work." [65] Homo Ludens is the obverse of the Homo Faber, however the work of man is intertwined with the play of man. Technology is not just humanity at work, it is humanity at play as well, and therefore, to understand technology we must understand the cultural dimension of play.

<u>Methods:</u>

I have adopted a combination of data collection methodologies for this project: 1) I posted an online questionnaire for BCI users (72 responses: See Appendix D & E), 2) I utilize printed and online media articles, including online user forums, 3) I conducted a telephone interview with a company representative from NeuroSky (see Appendix F), and 4) I utilize secondary texts on EEG research & history, including gaming history to contextualize the reemergence of BCI/EEG related technology. These methods serve to highlight the relationships between the users, producers, and BCI technology. The online questionnaire and web forums provide first hand perspectives from users of BCI's. Company websites, interviews, and online

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[64] Johan Huizinga, *Homo Ludens.*
[65] Pitt, *Thinking About Technology,* 11

articles provide information about BCI technology, and illustrate their intentions for BCI uses as well as the company's marketed representations of BCI users. Lastly, secondary texts about EEG /BCI technology provide information about BCI technology, and contextualize the reemergence and development of BCI/EEG related technologies.

Since, the conceptual frame of this project assumes that the success of BCI technologies is contingent on user acceptance, the best way to gather data and answer questions concerning the development and acceptance of BCI technologies was from the users themselves. Therefore, collecting data from BCI users and developers was essential for this project. I posted my questionnaire on Emotiv and Neurosky's online forums and had minimal user response. I received increased user feedback when Tansy Brook, a Neurosky representative disseminated my user questionnaire through their company's email listserv and network of users and contacts. The cooperation and contribution of Neurosky has been critical to this project. The online questionnaire has provided quantitative data, demographic information, as well as qualitative data about BCI user practices, problems, and intentions.

I have also utilized online web forums & discussions to provide additional feedback from users about BCI technologies. Both Neurosky and Emotiv provide online forums, with a community administrator, in which developers and users can ask questions, provide feedback, and discuss their projects, problems, and solutions with BCI products. These online based resources require minimum effort to access and illustrate the co-productive development process between users and company facilitators. For example, in the Emotiv forum on gaming, a user asked if it was possible to utilize the technology for multiple cognitive commands, whereby the administrator replied, "There's no reason (*apart from user skill*) that the method could not extend to 12 detections."[66] Indeed, users are vital to the success of the implementation and perpetuation of this technology in which Emotiv and Neurosky actively highlight user successes and facilitate user development.[67]

I also utilize BCI company web sites, media articles, reviews, and journalistic publications which provide descriptive information about BCI technologies and products. I focus primarily on products from Emotiv and Neurosky. Their company sites reveal their intentions and expectations about BCI users and the direction for BCI development. These two companies are relying heavily on strategies to present these technologies to a discursive network of potential users with the goal of diffusing these innovations into domestic, educational, and academic domains. Further I have conducted an interview with Tansy Brook the information officer at Neurosky (see appendix F), which has provided deeper insight into the expectations and limitations about their plans for future development and BCI uses. And lastly, I utilize secondary texts about EEG & gaming which provide valuable and necessary contextual information to make sense of the current emergence of BCI technologies.

The goal of these methodologies is to reconcile the expectations and practices with BCI technology, particularly in regard to gaming control, with the marketed representations of users and expectations of BCI technology presented by companies. In other words, these methods help compile data in order to compare specific descriptions by users about how the technology actually works and performs with companies expectations and technical descriptions about BCI's uses. Further, these methods illustrate the conceptual frame and concept of Techno-Cultural Resonance (TCR). These relations can be expressed and described through the notion of TCR.

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[66] http://emotiv.com/forum/messages/forum16/topic579/message3363/ accessed June 2, 2010

[67] The home page of Emotiv has a link to a user/designer who successfully utilized the EPOC headgear and software to control a robot. See: http://twitter.com/emotivsystems/statuses/12894100558 and http://www.robodance.com/ and also see: http://company.neurosky.com/category/news/

To reiterate, the basis of this project is to expand the conceptual understanding of the role of users as active subjects in the development and domestication of an ambiguous technology. The myriad ways in which subjects conceptualize and interact with new technologies reveals the cultural values, expectations, assumptions, and criticisms about how a technology works or should work. In addition, initial encounters with new and ambiguous technologies reveals the performative scripts in which groups are already interacting with established technologies and the cultural values and scripts through which individuals and groups mediate their social relations with a new technology. Focusing on user subjects and the cultural values that individuals and groups attach to an artifact reveals how much of the success of a technology depends on user values. Further, the recognition that artifacts come to embody cultural values which then serve as a means to perpetuate identities and modes of behavior reveals that changing the momentum of established technologies is not just an issue of negotiating and understanding the economic and structural boundaries of a technological system, but illustrates that the cultural boundaries as well helps to maintain the foundations of a technological system. Moreover, in regard to new and ambiguous technologies, the cultural values of groups are critical frameworks through which the success of artifacts depends.

Chapter 3:
The Rise of BCI's for Consumers: A Brief History of EEG

Introduction:

The purpose of this chapter is to contextualize the rise of EEG based BCI technologies for gaming and consumer applications from what historically have been used for medical applications. In general, BCI technologies are based on EEG techniques therefore the history of BCI starts with the origins of EEG and neurofeedback practices. Therefore, I will provide a brief history of key developments in EEG and neurofeedback research in order to make sense of the emergence of the BCI industry, its distinct goals, the companies who are developing EEG based BCI technologies and the users who are appropriating these technologies for consumer applications. Given that the history of EEG and neurofeedback is a complex hybrid of disciplines, knowledge and practices, and, "…is built upon the cornerstones of technology, electronics, behaviorism, physiology, and neurology,"[68] this chapter cannot adequately address the extensive history of EEG and neurofeedback practices, developments, and debates. Moreover, while neurofeedback and BCI research share a common history, and similar practices, the goals of each industry represent substantial differences. Therefore, this chapter will highlight the disparate goals of the BCI and neurofeedback industries as well as their similarities. The primary goal of the BCI industry is to establish EEG- based technologies as an alternative user interface (UI) for those with disabilities, but a secondary goal is to introduce BCI technologies as alternative UI's through consumer applications. This chapter will attempt to answer an important question which arises when considering BCI development: Why develop a technology for a "healthy" consumer population that was originally intended for people with disabilities?

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[68] Demos, *Getting Started with Neurofeedback*, 15.

Aside from obvious economic considerations, what other factors are contributing to the development of BCI technologies for healthy users?

EEG: The Brain, Body, and You

However, before a discussion notating the differences between the BCI and neurofeedback industries, a simplified description of the elements which make their practices possible becomes necessary. Both industries rely on measuring the electrical activity generated from the nervous system and brain. Measuring the electrical activity of the brain however does not translate into an understanding of the brain, such that Michael Cole noted that"…the relationship between what is going on in the brain and what we observe at the scalp is not completely understood." [69] Regardless of this conceptual gap in understanding, researchers have the ability to map and measure electrical activity of the brain through several techniques, the most common of which is the practice of Electroencephalography (EEG). In simplest terms, EEG is the practice of measuring and recording the electrical activity of the nervous system or brain. In professional terms "The electroencephalograph is a graphical representation of the neuronal activities in the cerebrum." [70] This graphical representation is used to classify the electrical activity of the brain in terms of different brain wave frequencies.

In order to make sense of how the electrical activity of the nervous system can be measured and represented by an EEG, I will give a simplified description of electro-physiology of the nervous system and brain. Electrical activity starts with nerve impulses (also called electrical action potentials) which are generated at the cellular level of neurons. Chemical neurotransmitters either excite or inhibit the neural membrane, which changes the permeability

[69] Coles and Rugg, "Event Related Potentials: an Introduction," 3.
[70] Demos, *Getting Started with Neurofeedback*, 25.

of the membrane, thus becoming more susceptible to the exchange of potassium and sodium ions within the cell which then creates an electrical charge.[71] Brains waves are generated by this two part process of excitation and inhibition. This cycle starts when an excitatory neurotransmitter excites the cell, thus causing an excitatory postsynaptic potential (EPSP), and stops when an inhibitory neurotransmitter is released thus generating an inhibitory postsynaptic potential (IPSP). These cellular events, collectively, happen spatially among many neurons, and or temporally at a single site, and can be measured in a variety of ways, most commonly with electrodes placed on the scalp, and recording the electrical activity in terms of amplitude as microvolts and cycles per second as frequency (hertz, HZ).[72] Brain waves are the byproduct of neurochemical activity between neurons, and an EEG is an indirect measurement of brain activity and the nervous system.

The basic structure of the nervous system is composed of cells called neurons, which collectively forms a network through the body. The nervous system has two main divisions 1) the central nervous system, (CNS) which includes the brain and spine, and 2) the peripheral nervous system (PNS). The PNS is also divided into two parts: the somatic nervous system (SNS), which controls voluntary functions, and the autonomic nervous system (ANS), which controls involuntary functions (i.e. heartbeat, etc.). The ANS is composed of the sympathetic system, which initiates or activates functions, and the parasympathetic system, which stops or deactivates processes. Further, the brain is composed of various structures, the cerebellum, which controls motor functions, the cerebral cortex, which coordinates higher reasoning functions, and other various supporting structures, such as the limbic system, which regulates emotions,

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[71] For more a more in depth discussion see: Demos, John, Chp.2 “Brain Basics and Body Anatomy and Physiology,” In *Getting Started with Neurofeedback*, 23-56. And Cantor, David, S. “An Overview of Quantitative EEG and its Applications to Neurofeedback,” In *Introduction to Quantitative EEG and Neurofeedback*. Edited by James R. Evans, et al. (San Diego, Calif; London: Academic, 1999), 3-27.

[72] Demos, *Getting Started with Neurofeedback*, 70. Usually slower frequencies have higher amplitudes (microvolts)

memory, and a subject's survival mechanism or flight or fight response. The limbic system is also composed of the thalamus, and the hypothalamus which is the control center for ANS. The interaction between these biological systems and organs generate the brains waves which can be measured by EEG.

> The thalamus and other cortical localities create EEG rhythmic activity. Signals move upward toward the cerebral cortex, then back downward again to the thalamus, over and over again…the total rhythm caused by millions of communicating neurons. One sensor placed on the scalp can pick up a portion of this rhythmic activity at the cortical level. The information is then sent to an EEG unit that displays the end product: Brain waves.[73]

An EEG is a "recording of raw unfiltered brain wave signals,"[74] and the raw EEG is composed of distinct frequency bandwidths. Part of the process in EEG recording is using electronic devices to amplify and then filter the raw EEG into these discrete components. The BCI and neurofeedback industry rely on properly recording particular brain wave frequencies in order to achieve particular goals, (which will be discussed later.) Signal amplification and filtering are two important processes for neurofeedback and BCI devices and practices. (However, these two processes pose technical limitations, and consequently represent potential obstacles when considering user acceptance of games and consumer BCI devices, which will be discussed later in this chapter).

Through signal amplification and filtering, researchers have identified several common frequencies which are correlated with a variety of functions. The most common brain wave frequencies are: delta, theta, alpha, beta, sensorimotor rhythm (low beta), and gamma

[73] *Ibid.* 28.
[74] *Ibid.* 69.

frequencies. Delta waves are correlated with sleep and have a frequency of 1-4 Hz (cycles per second). Theta waves have a frequency of 4-7 hertz and are associated with creativity and spontaneity. Theta frequency is also correlated with inattention, and distractibility, and consequently with Attention Deficit Hyperactivity Disorder (ADHD). Alpha frequencies range from 8-12 Hz, also called the Berger wave, or Mu wave, and is associated with meditation, inner calm, and peace (relaxed and alert). The sensorimotor frequency (SMR) ranges between 12-15 Hz and is associated with internal orientation. (Barry Sterman pioneered work with SMR also called Low Beta.) Beta waves range from 13-21 Hz and are associated with focused, analytic, and externally oriented states. High Beta waves range from 20-32 Hz, and are associated with peak performance, over thinking and cognitive processing, and are also correlated with Obsessive Compulsive Disorder (OCD). The final common waves are gamma frequencies which range from 38-42 Hz and are correlated with mental sharpness during problem solving.[75] These are the most common electrical frequencies that are utilized by practitioners of neurofeedback.

While this project focuses on EEG based devices it is important to note that electrical activity is emitted from various locations in the body and in different ways. Practitioners of neurofeedback have a host of techniques and practices in which to measure the activity from both the body and brain: EcoG, Fmri, EMG(muscles) EOG (eye), ECG (heart) as well as EEG. The development of BCI's which rely on measuring electrical activity other than from EEG are being currently being developed, by companies such as Neurosky:

> …Our bodies are the most complex machines, yet the data they measurably generate is less than that of a simple calculator. As amplification, noise, manufacturing techniques, mental state algorithms and other areas advance,

[75] *Ibid.* and See: Chp.7 " Review of Common Frequencies," 112-21.

> innovation will accelerate, We are leading the charge in EEG, (brainwaves), EMG (Muscle), EOG (eyes), and ECG(Heart), bio-sensing. [76]

While these measurement techniques offer the opportunity for BCI technological development and different levels of control, the fact that the body emits electrical activity from various locations, poses a technical problem for any recording technique and control interface, because any desired signal is usually interrupted by other frequencies and is technically defined as "noise". The same technical limitations which exist for EEG and neurofeedback practices threaten BCI technologies as well and ultimately pose a problem for user acceptance, and will be discussed later.

This is an oversimplified description of brain activity and wave functions, but illustrates what neurofeedback researchers are attempting to understand, measure, and control. By identifying these discrete frequencies through EEG measurements, and correlating those frequencies with normal and pathological states and physiological functions, researchers attempt to control and ultimately alter this activity through technological systems designed to provide feedback to subjects for medical and therapeutic purposes. Therefore, the goal of neurofeedback is premised on the assumption that subjects can change the frequencies of the brain, and consequently by doing so elicit behavior and cognitive changes. Through neurofeedback techniques one can achieve "correct mental states". However, what constitutes a "correct" mental state, given the recognized diversity in the range of individual frequencies of a particular state, proves problematic. The history of neurofeedback as a method to treat behavioral and cognitive disorders marks the beginning of a separate history and project. Critical debate concerning the efficacy of neurofeedback techniques circulates within psychiatric and medical

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[76] "Future Development," Neurosky, Accessed Feb. 13, 2013, http://www.neurosky.com/Future.aspx

fields. [77] Given the controversial reputation of the neurofeedback community and its research, the BCI industry highlights their unique identity by stressing how EEG based BCI technologies have different goals, even though both industries apply their practices and technology for medical purposes.

Origins of Mapping the Electric Mind: The Briefest History of EEG [78]

From the beginnings of EEG history, the measurement of electro- physiological activity has been correlated with medical and scientific purposes and knowledge. One of the earliest moments in EEG and biofeedback history is Richard Canton's experiments with animals in 1875. Although observations of the electrical activity of the nervous system had been detected earlier in 1848 by Duboi-Raymond, Canton was the first person attributed with detecting and correlating fluctuations in the electrical output of the brain with particular mental activity. Fifty years later in 1924, Hans Berger recorded the first EEG from the human scalp, in which he measured and recorded raw data emitted from brain activity onto paper, an electroencephalogram. Berger was the first to filter and identify 2 distinct patterns; the alpha and beta wave. He correlated alertness and thinking with bursts in the beta frequencies between 13-30 cycles per second (Hz). He published his paper in 1929, and hypothesized that abnormalities recorded in an EEG reflected clinical disorders.

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[77] Russell Barkley, an ADHD specialist has dismissed the notion the neurofeedback can help. See: Katherine Ellison, "Neurofeedback gains popularity and Lab Attention," Oct .3 2010, accessed Feb, 05, 2013, http://www.nytimes.com/2010/10/05/health/05neurofeedback.html?pagewanted=all&_r=0See,.

[78] For history of EEG/neurofeedback/QEEG methods See: Cantor, David, S, "An Overview of Quantitative EEG," 3-27; Barlow, *The Electroencephalogram*, 1-4; Demos, *Getting Started with Neurofeedback*, 15-21.; Schwartz, Mark S. et al. "A Historical Perspective on the Field of Biofeedback," 3-19.

From Measurement to Voluntary Transformation: From EEG to Conditioning

However, the birth of modern neurofeedback, or what was initially called EEG Biofeedback, started around 1960. Several key events during the 1960's helped establish neurofeedback practices for therapeutic purposes. Prior to the 1960's EEG was best used as a tool to confirm abnormal or measure cognitive activity. Further, physicians assumed that the autonomic nervous system (ANS), the involuntary activities of the body, could not be consciously controlled.[79] Neal Miller, an American Psychologist, challenged this assumption

> …Neal E. Miller and collaborators opposed the traditional wisdom of the autonomous nervous system (ANS) as autonomous and independent of voluntary control of the somatic central nervous system (CNS). Miller (1969), in a landmark paper in Science, challenged that view that voluntary control is acquired through operant (instrumental) conditioning whereas modification of involuntary ANS functions is learned through classical (Pavlovian) conditioning, a distinction first emphasized by Skinner .[80] [81]

Partly inspired by Neal Miller's challenge other researchers started to investigate a subject's ability to consciously control involuntary functions. Around 1962, Joe Kamiya, was trying to determine whether conscious control of brain waves was possible. In a foundational

[79] This is an important debate/issue in bio/neurofeedback history. Whether a subject can voluntarily control or change involuntary body and mind functions regulated by the Autonomic nervous system. (ANS). See Demos, "History and Evolution of Clinical practice," Chp.1, in *Getting started with Neurofeedback*, 16. and see Schwartz and Olson, "A Historical Perspective on the Field of Biofeedback and Applied Psychophysiology," 4.

[80] Birbauer, "Breaking the Silence: Brain–Computer Interfaces," 518.

[81] Neurofeedback is based on the learning theory of operant conditioning, a concept developed by B.F. Skinner from the ideas of Ivan Pavlov who described classical conditioning of a subject. All biofeedback techniques are designed to either inhibit or promote the voluntary control of an internal state through external stimulus. Through a system of rewards and punishments a subject learns to control brainwave activity (i.e. internal state). Through classical conditioning a subject learns to associate two unrelated stimulus by involuntarily responding in the same way. The classic example: a dog salivates (involuntarily response) when presented with food (stimulus). The sound of a bell, an unrelated stimulus is presented with the first stimulus, food. Eventually the dog learns to respond, salivate, to the sound of the bell without food. See Skinner, *Science and Human Behavior,* 1953.

experiment for neurofeedback, Kamiya demonstrated when subjects were made aware of bursts of alpha frequencies through verbal reinforcement they could eventually control alpha frequencies.[82] His study marked one of the first applications of early biofeedback training loop, in which the instrument records a biological activity, the trainee is reinforced by correct changes, and most importantly voluntary control of a biological activity is achieved. Kamiya's experiment was important in establishing the basic biofeedback loop, upon which all biofeedback modalities are based.[83] [84] Kamiya contributed further to the field of neurofeedback in 1968 when he published an article in the magazine *Psychology Today* discussing the ability to consciously control brain waves which helped popularize neurofeedback.[85]

Another important contribution came from a study conducted by Barry Sterman in which he accidentally discovered that seizures could be controlled. In his experiment Sterman injected cats with Hydrazine to produce seizures, but the cats learned how to resist seizures (40 out of 50 cats controlled the seizures). Based on the EEG readings, cats controlled the seizures by increasing the sensorimotor rhythm frequency, which causes a decrease in motor activity.[86]

These events helped lead to a pivotal meeting of EEG researchers in Santa Monica in 1969,which included Joe Kamiya, Barry Sterman, Thomas Budzynski, Barbara Brown, and many other EEG biofeedback pioneers.[87] These researchers established a professional society[88] and formally defined the field and called it *Biofeedback*. The term biofeedback is used to encompass a wide variety of therapies, which includes EEG biofeedback, or neurofeedback.

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[82] Demos, *Getting Started with Neurofeedback,* 17. And see Budzynski, "From EEG to Neurofeedback," 66-67.
[83] Demos, *Getting Started with Neurofeedback,* 18.
[84] *Ibid.*17: The typical feedback loop is 1) in instrument records a biological activity, 2) a trainee is reinforced when a desired activity occurs and 3)voluntary control of biological activity
[85] See: Kamiya, "Conscious Control of Brain Waves," *Psychology Today* 1, no. 11, April 1968, 56-60.
[86] See: Sterman, et al. "Suppression of Seizures," 89–95.
[87] Budzynski, "From EEG to Neurofeedback," 67.
[88] "About AAPB," The Association for Applied Psychophysiology & Biofeedback, accessed Nov 7, 2103, http://www.aapb.org/i4a/pages/index.cfm?pageid=3279

Therefore, neurofeedback is a subdivision of biofeedback which aims to alter the activity of the central nervous system (CNS).

> Biofeedback is a self-regulation skill: trainees learn to regulate aspects of ANS functions. Neurofeedback is form of biofeedback. It is always used in reference to the cerebral functions. It relates either to the brain's electrical activity or to the cerebral blood flow (CBF). The term *biofeedback* may be used to encompass all feedback therapies, including neurofeedback.[89]

Biofeedback practices typically use techniques to measure and alter activities related to the peripheral nervous system (PNS) which affects bodily activities both voluntary and involuntary activity.

> Biofeedback training promotes greater control of the cerebral cortex and the ANS. Biofeedback gives the trainee power to control unconscious or involuntary physiological processes. [90]

This meeting helped establish the field of biofeedback and its therapeutic goals of conditioning individuals to achieve correct or normal states by regulating internal involuntary physiological processes.

However, neurofeedback practices and research would not have continued without developments in computer technology. Frank Duffy, E. Roy John, & Robert Thatcher, during the 1970s and 1980s developed Quantitative EEG and large normative databases. The ability to

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[89] Budzynski, "From EEG to Neurofeedback," 59.
[90] Demos, *Getting Started with Neurofeedback*, 25.

critically identify individual frequencies, assess the range in frequencies, and consequently correlate individual patterns with normal states was beyond a researchers ability to simply "read" raw data from an EEG paper printout, and required computational functions and algorithms, which provided the ability to filter and process large amounts of data. The development of large normative databases and QEEG gave researchers the ability to compare brainwaves from an individual with a large group or population, "QEEG data acquisition is the process of gathering EEG data from multiple scalp sites."[91]

These computer and database developments helped researchers expand neurofeedback practices. However, the popularity of neurofeedback has waxed and waned over the years. One reason was the rise and success of pharmaceutical treatments, and secondly were critics concerned about the efficacy of neurofeedback treatments. But around 1993, a second gathering of researchers met and led to resurgence in the popularity of neurofeedback and expanded the professional domain and influence of neurofeedback.[92] [93]

There are several trends which emerged from neurofeedback research but remain contiguous with BCI goals and practices. The first trend is the use of EEG based BCI's applied to medical applications, second is the rise of the heath consumer who value practices which improve and enhance the health and well-being of living, and third is the use and development of faster and more powerful computing hardware, software and algorithms for brain wave signal

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[91] *Ibid*,19. For more info on QEEG see: Thatcher, Robert W. "EEG-DataBase-Guided NeuroTherapy." 29-63; and Budzynski, Thomas. "From EEG to Neurofeedback," 73;.and Laibow, "Medical Applications of Neurofeedback," 84.

[92] "About ISNR," ISNR, accessed Mar.15, 2013, see http://www.isnr.org/about-isnr/about-isnr.cfm. The International society for Neurofeedback and research emerged around 1995 and established its current name in 2002.

[93] There is an estimated 7500 mental health professional in US who offer Neuorfeedback. See: Katherine Ellison, "Neurofeedback Gains Popularity and Lab Attention," October 4, 2010, Accessed Mar. 3, 2013, http://www.nytimes.com/2010/10/05/health/05neurofeedback.html?pagewanted=all

acquisition and processing.[94] However, before discussing these contiguous trends, I will delineate the distinct goals of the BCI industry and define a BCI. Further, I will introduce the key actors who are directly shaping the development of BCI applications for consumers: platform companies, individual developers, and professionals within the field of Human-Computer Interaction (HCI). Consequently these actors are expanding BCI uses by introducing these applications through established consumer domains of entertainment, gaming, social media, and by building on digital platforms for smart phones, computers, and toys.

Changing Control: From Internal Transformation to External Manipulation

The field of BCI emerged from EEG and biofeedback traditions and their medical orientation: "The…root of BCI research is intimately tied to the tradition of biofeedback and instrumental-operant learning of autonomic functions."[95] Yet, the goals of neurofeedback are aimed at conditioning subjects to attain "normal" functioning, while the goals which have emerged for BCI's are aimed at providing alternative forms of control for subjects with disabilities:

> The main goal of BCI is to replace or restore useful function to people disabled by neuromuscular disorders such as amyotrophic lateral sclerosis, cerebral palsy, stroke, or spinal cord injury. From initial demonstrations of electroencephalography-based spelling and single-neuron-based device control, researchers have gone on to use electroencephalographic, intracortical, electrocorticographic, and other brain signals for increasingly complex control of cursors, robotic arms, prostheses, wheelchairs, and other

[94] For a recent article about EEG algorithms see: Lotte, F. et al., "A Review of Classification Algorithms for EEG-Based Brain-Computer Interfaces," *Journal of Neural Engineering* 4, no. 2 (2007): R1 doi:10.1088/1741-2560/4/2/R01

[95] Birbauer, "Breaking the Silence: Brain–Computer Interfaces," 268.

devices.[96]

Based on this goal BCI's offer promises for those with disabilities in several areas in which applications are currently being developed: communication, (an EEG controlled speller called IntendiX, developed by Guger technologies), locomotion (Wheelchair), environmental control, and movement control (prosthetic arms). [97]

However, a secondary goal has emerged aimed at providing BCI technologies to healthy users as alternative interfacing options with computer and consumer products. Applications developed based on this secondary goal have emerged from developers in the field of Human-Computer Interaction, a sub field of computer science, which focuses on design and users expectations.

> Beyond the traditional definition of Brain-Computer Interfaces, HCI researchers have already started to push the boundaries of what we can do… The HCI community has also been particularly successful at systematically exploring and creating whole new application areas.[98]

The developers in this field have played an important role, for interpreting, translating, and modifying BCI technology for consumers which will be discussed later in this chapter and in chapter 5 as well. However, both of these ends, those aimed at disabilities, and those aimed at healthy users, focus on developing forms of user control. However, the latter goal goes beyond applications for control but rather toward the development of applications which are intended to

[96] Shih, et al. "Brain-Computer Interfaces in Medicine." 268-279.
[97] *Ibid.* 271. And see: Graimann, et al. "Brian-Computer Interfaces: A Gentle Introduction," 18.
[98] Desney and Nijholt, "Brian-Computer Interfaces and Human-Computer Interactions," 6

enhance user experiences and dissolve the boundaries between human-computer interfacing. This issue will be developed later in this chapter, and again in chapters 4 and 5, but first I will provide a brief definition of BCI's and their history.

BCI Definitions:

Given that BCI's and Neurofeedback technologies share such a similar history, questions arise as to what makes a BCI unique? What defines a BCI? There are varying definitions,[99] Jonathan Wolpaw, a research physician, states "A direct brain-computer interface is a device that provides the brain with a new, non-muscular communication and control channel."[100] A BCI by-passes the brain-motor pathways, and instead links brain electrical activity to an external device.

> A BCI is a communication system in which messages or commands that an individual sends to the external world do not pass through the brain's normal output pathways of peripheral nerves and muscles. [101]

More specifically a BCI is a system of control which "…accepts voluntary commands directly from the human brain without requiring physical movement and can be used to operate a computer or other technologies."[102] In spite of the varying definitions there are several common features which constitute a BCI. First, it is necessary that a BCI directly record the electrical activity from the brain, second the device provides the user with feedback, third the feedback must be in real time, and last, the system must rely on intentional control. Any device that only passively detects frequencies without intent is not, technically, considered a BCI technology.

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[99] For other definitions see: Graimann et al. "Brian-Computer Interfaces: A Gentle Introduction" 3-4
[100] Wolpaw, et al. "Brain–Computer Interfaces for Communication and Control,"767–791.
[101] *Ibid.*769.
[102] Graimann et al. "Brian-Computer Interfaces: A Gentle Introduction," 4

The two key features which characterize a BCI as unique are in real time and intentional control.

> Instead of depending on peripheral nerves and muscles, a BCI directly measures brain activity associated with the user's intent and translates the recorded brain activity into corresponding control signals for BCI applications. This translation involves signal processing and pattern recognition, which is typically done by a computer. Since the measured activity originates directly from the brain and not from the peripheral systems or muscles, the system is called a Brain–Computer Interface. [103]

This is a generalized description of a BCI; however, BCI's can be further divided into additional categories. BCI's are classified as either *invasive*, in which an electrode is implanted within the brain, or *non- invasive*, in which an electrode is placed in the scalp. This latter classification can be further subdivided as either endogenous or exogenous. *Endogenous* BCIs are based on a subject learning to intentionally change brain activity, *exogenous* BCIs utilize brain activity which is generated by a subject when presented with an external stimulus.[104] This latter type of BCI is based on the fact that electrical activity is generated by a subject when presented with an external stimulus. These are called Event-Related Potentials (ERP). One of the most commonly evoked ERP's which BCI and HCI researchers are developing for BCI commands is the p300 frequency. This frequency is generated based on subject recognition and reaction to an external stimulus. Researchers at Dartmouth College have developed a BCI application for a smart phone which utilizes the p300 frequency whereby a user can choose and dial a desired contact based on

[103] *Ibid.* 3
[104] Edlinger, et al. "Brain Computer Interface," 1007

stimulus recognition.[105] These are rather recent BCI developments and definitions; however, BCI's emerged much earlier.

A Brief History of the Rise of BCI's: Minds to Manage Machines

Early work in BCI development began in the 1970's and followed a medical teleology of providing a technological communication path for those with disabilities. The term *Brain-Computer Interface* is credited to Jaques Vidal and a research team, working at UCLA, who received a grant through a division of the Department of Defense, from the Advanced Research Projects Agency (ARPA)[106] and the National Science Foundation (NSF). His work marks one of the earliest descriptions of a BCI:

> Can these observable electrical brain signals be put to work as carriers of information in man-computer communication or for the purpose of controlling such external apparatus as prosthetic devices or spaceships? Even on the sole basis of the present states of the art of computer science and neurophysiology, one may suggest that such a feat is potentially around the corner.
>
> The Brain Computer Interface project… was meant to be a first attempt to evaluate the feasibility and practicality of utilizing the brain signals in a man-computer dialogue while at the same time developing a novel tool for the study of the neurophysiological phenomena that govern the production and the control of observable neuro-electric events.

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[105] Kristina Grifantini, "Mobile Phone Mind Control," *MIT Technology Review*, Mar. 10 , 2010, accessed Apr. l 3, 2013, http://www.technologyreview.com/view/418258/mobile-phone-mind-control/

[106] ARPA is now called Defense Advanced Research Projects Agency DARPA

> The long-range implications of systems of that type can only be speculated upon at present. To provide a direct link between the inductive mental processes used in solving problems and the symbol-manipulating, deductive capabilities of the computer, is, in a sense, the ultimate goal in man-machine communication. [107]

However, some consider Dr. Grey Walter, a neuroscientist who is credited with identifying theta waves, as having described the first BCI in 1964, without actually calling it a brain-computer interface.[108] However, BCI development did not escalate until the 1990's, driven by high performance, low cost computer power and EEG equipment which can be used in real time and for closed-loop data processing.[109] BCI research and publications within the medical community exploded in the late 1990s and early 2000's where between the years 1996-1998 there were less than 50 peer-reviewed articles published about BCI's, but starting around 1999 publications arose exponentially, in which 400-500 articles were written between 2008-2010.[110] This rise in BCI research occurred primarily within the medical field.

However, the accession of BCI's for consumers is being influenced by three key actors: independent developers, those in the field of Human-Computer Interaction (HCI), and platform companies who have developed low cost EEG helmets and made available to the general public. These actors are appropriating and reinterpreting BCI's for new applications for consumers.

The Rise of Neuro-Companies: Developers, Devices, & Applications

The key groups responsible for the emergence of EEG based BCI devices and neuro-

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[107] "Vidal,"Toward Direct Brain-Computer Communication," 157-58. And for more early research see: Vidal, "Real-time detection of brain events in EEG," 633-641.

[108] The first BCI was described by Dr. Grey Walter in 1964. See: Graimann et al. "Brian-Computer Interfaces: A Gentle Introduction," 2.

[109] Edlinger, et al. "Brain Computer Interface," 1003.

[110] Shih, et al. "Brain-Computer Interfaces in Medicine," 270

gadgets are 1) the platform companies who have developed portable, low cost, commercially available headsets, 2) the companies developing neuro products based on Emotiv and NeuroSky headsets and technologies, 3) HCI user-developers who are utilizing the cheap headsets in order to build BCI software applications for established technologies (ie smart phones, video games) and 4) independent hobby developers, who are creating new products and applications. The relationship between the platform companies, end users, HCI user-developers, and EEG-based BCI headsets will be developed in more depth in chapter 5. However, there are several important considerations which become apparent when considering the development and purpose of BCIs by these fundamental groups: 1) the limitations of these devices are redirecting the development of BCI applications, 2) these BCI limitations are being translated into pre-exiting uses and values for users in order to reorient the value of BCI's as an alternative interface, 3) the values of gamers and HCI developers along with the limitations of BCI's are reshaping games, and 4) the generalized user-developer profile reveals that a particular set of group values are structuring the promotion and development of this contingent technology. However, a brief description of the current synchronic circumstances will help make sense of 1) how BCI technologies offer an opportunity for alternative computing and gaming interfaces for consumers and users, 2) the expanding areas of interest for users and developers of BCI's, and 3) the history of these platform companies and BCI devices.

Smart Phones, Computers and Video Games: Established and Emerging End Users

Several background features help illustrate why these platform companies are developing consumer headsets. The first is the enthusiasm about BCIs, which becomes very apparent in the user surveys discussed later in chapter 5, whereby a pervasive enthusiasm and tone of excitement are present in developers and early adopters' comments. One respondent from this projects survey has created a website called Neurogadget.com which posts interviews, reviews, and press releases about BCI developers, technology, and events. This theme is also present in press articles about the subject.

> …though much works remain to be done. Many who have witnessed these recent successes are confident that similar but more sophisticated BCI technologies will eventually become routine and widespread.[111]

Yet, beyond the enthusiasm are the established users and social groups surrounding computers, video games, mobile phones. BCI's have emerged at a time when the presence of smartphone, computers, and video game are ubiquitous and their uses solidly entrenched in social behavior and economic production. The average US household owns at least one pc, home video console or smart phone, 33% of gamers play on smart phones, and 25% of gamers play on a hand held device.[112] And according to Neilson ratings for 2012 over 50% of US cell phone users have smart phones. [113] These conditions make the introduction of an ambiguous interface technology to consumers feasible, and are currently being developed on smart phone platforms. The pace at which the technological landscape changes has created an environment in which everyday users of computing and media devices are partially receptive to these new technological forms, especially as users learn how these device and applications serve to enhance desired aspects of their lives, such as social communication, for mapping and navigation, for photo documentation,

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[111] Peter Estep, "The Expanding Mind, " *Seed Magazine,* May 17, 2010, accessed Dec.31, 2012, http://seedmagazine.com/content/article/the_expanding_mind/

[112] "Essential facts" ESA, 2012, http://www.theesa.com/facts/pdfs/esa_ef_2012.pdf

[113] Jon Fingas, "Nielson: Over 50 % of US Mobile Users Own Smartphones," Engadget, May 7, 2012, http://www.engadget.com/2012/05/07/nielsen-smartphone-share-march-2012/

and for entertainment and play. These circumstances, have allowed for the proliferation of BCI's devices and applications from third party developers. The pace at which EEG based BCI gadgets are being produced, marketed, modified, and even halted, illustrates the depth of interest in establishing brain-computer interfaces for everyday use. Moreover, the pace of these development trajectories also illustrates the difficulty in tracking the BCI gadget phenomenon, and therefore I will only briefly outline some of the EEG-based BCI gadgets and developments, and focus on the two most influential platform companies who are producing BCI headsets for developers and consumers: Emotiv and Neurosky.

NeuroSky and Emotiv: Headsets for the Future

Emotiv and NeuroSky were not the first to release an EEG-based BCI headset. One of the first headset controllers released to consumers was the Neural Impulse Actuator (NIA), developed by OCZ and released in 2008.[114] However, OCZ is primarily a company which produces solid state drives, and due to investor pressures, the company stopped producing the NIA controller in 2012 and sold it to BCI Net. BCI Net is promoting their product but development has been delayed due to investment problems.[115]

In 2009 both Emotiv and NeuroSky released BCI headsets to the public, which have spawned a number of BCI devices and applications for consumers. The companies NeuroSky and Emotiv are critical actors for enabling the development of BCI technologies and applications for consumers. These companies do not identify themselves as BCI companies, nor as EEG companies, but rather as platform companies in which they produce hardware and software kits

[114] Scott Watson, "OCZ Preps Neural Headband Controller for Release," The Tech Report, Jan. 14, 2008, http://techreport.com/news/13928/ocz-preps-neural-headband-controller-for-release.
[115] Theo Valich, "Future for Brain-Computer Interface Endangered by a Ponzi Scheme Investor," BSN, Apr. 12, 2011, http://www.brightsideofnews.com/news/2011/4/12/exclusive-future-of-brain-computer-interface-endangered-by-a-ponzi-scheme-investor.aspx

which can be developed for BCI or neurofeedback purposes. In fact, Emotiv did not hire EEG experts when developing their products.[116] Rather, Emotiv hired experts from other fields such as computer science, artificial intelligence, mathematics, and digital signal processing. In this sense, these companies partly break with EEG disciplines and history by relying heavily on marketers, software and hardware designers, and computer engineers. Overall, these companies have provided low cost, portable, and flexible, hardware, which previously cost thousands of dollars and have enabled independent hobby developers to produce new products.

The important difference between these two companies is how each company represents the capabilities of their technology. Ultimately, a more in depth comparison between the two companies and how they represent their products will be required to understand their successes and failures with the promotion of each device or application, but one important distinction for understanding user acceptance and resistance is the representation of BCI technology as an enhancement or replacement for user interface control. Several other dimensions become important as well; the emphasis on simplicity or complexity, and the representation of thought control or states of mind also become critical dimensions for representing BCI capabilities. However, for this project, the availability of these BCI headsets to consumers and developers illustrates that these companies are playing a role in shaping the outcome of BCI technologies for everyday users. Moreover, there are fundamental differences between each company's technologies which will be discussed briefly.

Emotiv define themselves as a "neuroengineering company"[117] and have chosen to develop one of the more sophisticated helmets available on the market. The EPOC headset was revealed in 2008 at the Game Developers Conference but released in 2009. The EPOC

[116] David Freeman, "Reality Bites," Inc. Magazine, last updates Dec. 1, 2008, accessed Dec. 31, 2013, http://www.inc.com/magazine/20081201/reality-bites.html
[117] "About Emotiv," Emotiv Systems Inc., accessed April, 4, 2013, http://www.emotiv.com/about/

Neuroheadset, which cost US $299, has 14 sensors, and a gyroscope to track head movements. They first released the EPOC headset to researchers and developers in order to have applications available prior to offering it to end users for use, but now market to developers, academics, educators, and entrepreneurs. Emotiv currently has two headsets, the EPOC and the EEG Neuroheadset, designed for EEG research. They also have several bundled software and hardware package editions: education, developer, and enterprise.[118]

In contrast, Neurosky chose to develop headsets with one sensor and thus are emphasizing the value of simplicity in their headsets. They describe their technology as "…simplified EEG…" or rather:

> …our technology is a platform technology. We have an Asics chip that we've created so we've taken all of the… data collection, amplification, filtering and put it in a chip form. In the past you would have to have… a big computer to have been able to do all the processing. But, what we've done is we've distilled it down into a microchip so that…first of all it makes it much more powerful second of all it makes it much cheaper.[119]

Moreover, they have developed several technological principles based on the notion of simplicity in their design: 1) easy to use, 2) non-invasive, 3) single-dry sensor, 4) untethered mobility 5) access to both raw data or algorithmically optimized data, and 6) open platform for any industry.[120] Thus, by reducing cost and minimizing complexity in design, Neurosky is attempting to reach as broad a user base as possible, which is readily apparent in their current

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118 For all editions see: "Emotiv Store," Emotiv Systems, accessed Mar 12, 2013, http://www.emotiv.com/store
119 Tansy Brook (Neurosky) , Interviewed by Tristan Cloyd, March 08 2011, Transcript Appendix F.
120 *Ibid.*

marketing slogan: "Bio-Sensors for Every Body."[121] They have released several platforms headsets all with a single sensor, and starting from cheapest to most expensive I will briefly describe each headset. The *Mindwave* headset was released in 2011 and costs $79.99. [122] This headset is designed for both non-developer consumers and developers and is prepackaged with readymade applications with the ability to develop additional applications. The second headset is *Mindwave Mobile* and was released in 2012 and costs $99.99. This headset has wireless Bluetooth capabilities and is marketed to build on Apple and Android platforms for smart phone applications.[123] Currently, there are over 100 software applications for Mindwave. The last headset, the *Mindset* released in 2009 and costs $199.99, which provides the most options and is marketed specifically for developers and researchers and comes with a software development kit (SDK) and provides the most options for development and research.

> The mindset… has … chip….technology (called) sync gear. And sync gear …out puts three different types of data. The first one is the algorithms that we created …*intention* and...*meditation.* The second is the brain wave power spectrum bands which are alpha, beta, theta, delta and gamma. And those are the various hertz ranges… then the last one is the raw brain wave…Typically it's the researchers who take that technology who have familiarity with EEG's.[124]

While both companies have developed their headsets to process the major neurofeedback brain waves used by EEG researchers, they have also developed unique proprietary software algorithms which define the limits of a desired brain wave pattern. As described above,

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[121] "Neurosky Home," Accessed March 13, 2013, http://www.neurosky.com/
[122] "NeruoSky Products," NeuroSky, accessed April 27, 2013, http://store.neurosky.com/products/mindwave-1
[123] *Ibid.*
[124] Tansy Brook (Neurosky), Interviewed by Tristan Cloyd, March 08 2011, Transcript Appendix F.

Neurosky has developed two algorithms: intention and mediation, which correlate closely with alpha and beta waves. Emotiv has designed 3 algorithmic suites, *Expressiv* suite , which detects facial expressions, *Affectiv* suite, which detects the emotion, and the *Cognitiv* suite:

> The Cognitiv suite reads and interprets a player's conscious thoughts and intent. Gamers can manipulate virtual objects using only the power of their thought! For the first time, the fantasy of magic and supernatural power can be experienced.[125]

These algorithmic sets illustrate the difference between each company's development strategy in which to reach users and developers. NeuroSky, emphasizing simplicity, and a limited range of options, while Emotiv, emphasizing a wide range of complex options. How developers utilize these algorithms becomes important for the development of BCI applications and ultimately whether the representation of their products match their promised functions will influence the acceptance or rejection of BCI technologies for domesticated uses. These company representations will be developed in more depth in chapter 5, in which a direct relation between the company's representation of their BCI product and its expressed functions and the interpretation from users and third party developers will be shown to have a significant impact on the acceptance of BCI development and use. In particular, Emotiv's emphasis on complexity affected a contract with Sony, and based on a user review of the EPOC headset, the company's representation of the functions of their headset fails to match user expectation.

[125] "Education Edition," Emotiv Systems, accessed Feb 18, 2013, http://www.emotiv.com/store/sdk/bci/education-edition-sdk/

Neuro-Companies and Gadgets:

The second set of actors shaping the development of BCI's for consumer applications are the neuro-companies, who have received licenses to modify the technologies developed by NeuroSky and Emotiv. And while Emotiv is one of the most well-known BCI platform companies, actively promoting its products at conferences and the media, the company NeuroSky has been more successful diffusing their products to consumers and end users, in large part due to their partnering strategies with other corporations. They have partnered with established companies such as Mattel, Uncle Milton, Titan, and Toshiba, who have released BCI based neuro-gadgets and toys.[126] They have also partnered with and helped new BCI companies develop products such as Interaxon, Mindgames Ltd., NeuorCog, Personal Neuro devices, and Neurowear. This latter company has produced several popular neuro products, one called Necomimi, released in 2012 which is a brain controlled helmet with cat ears that move.[127] These companies are promoting and translating the functions of BCI's for consumer through established narratives of the utilization of technology to enhance the body and one's self by the introduction of BCI neurogadgets as games and toys.

In addition to these company partnerships, Emotiv and NeuroSky have formed developmental relations with researchers in HCI departments at various Universities.[128] Neurosky is keenly aware of the tenuous nature of this ambiguous technology and the need for collaboration:

> Researchers meet developers meet consumers: Our open platform is a marketplace gathering of early adopters of all walks. From visionary game developers to university

[126] "Partners," NeuroSky, accessed Feb 4, 2013, http://www.neurosky.com/People/Partners.aspx
[127] For a list of products and projects see: "Projects," Neurowear, accessed Mar, 13, 2013, http://www.neurowear.com/projects/.
[128] For university affiliation see: "Academics," NeuroSky, accessed Dec 5, 2012, http://www.neurosky.com/Academics/WhatWeDo.aspx

algorithm mathematicians to medical research scientists; everyone will find a buyer in the BCI value chain. [129]

HCI Researchers and Developers:

Human Computer Interaction researchers located within universities are the third set of actors contributing to the development of BCI's. These HCI researchers are bridging the gap between BCI research for medical purposes and BCI use for healthy population of consumers and gamers.

> …BCIs are moving beyond communication tools for people who cannot otherwise communicate. BCIs are gaining attention for healthy users and new goals such as rehabilitation or hands-free gaming. [130]

> The HCI community has also been particularly successful at systematically exploring and creating whole new application areas…this community has sought scenarios in which technology can augment everyday life in some way. [131]

These researchers are focusing on factors beyond mere BCI proof of concept and the accuracy of control rather, HCI researchers are evaluating users' experiences with BCI's and attempting to develop applications in accord with these experiences.[132]

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[129] *Ibid.*
[130] Graimann, et al. "Brian-Computer Interfaces: A Gentle Introduction," 2
[131] Desney, and Nijholt, "Brian-Computer Interfaces and Human-Computer Interactions," pp 5-6
[132] See Laar, et al. "Perspectives on User Experience Evaluation of Brain Computer Interfaces,"600-09. And for player experience evaluation using NeuroSky's headset see: Coulton et al. "Brain Interaction for Mobile Games," 37-44.

> While the BCI community has largely focused on the very difficult mechanics of acquiring data from the brain, HCI researchers could add experience designing interfaces that make the most out of the scanty bits of information they have about the user and their intent."

HCI developers are utilizing the Emotiv and Neurosky headsets to develop these BCI applications for gaming, smart phones and social media applications.[133] For example, researchers at Darmouth have developed a Neurophone from Emotiv's EPOC Headset.[134]

<u>Independent Developers:</u>

The last group of actors influencing the direction of BCI development is the independent developers, who are consuming BCIs platform technologies for individual projects. In particular, these user-developers are building applications based on the headsets of NeuroSky and Emotiv and modifying BCI technologies to develop games and toys. For example, Steve Castellotti developed the project *Puzzle Box,* which is an open source software kit and a how-to-build guide for BCI projects.[135] His goal is primarily educational and aimed at introducing users interested in BCI's and neuroscience. He has built a BCI controlled helicopter using NeuroSky's Mindwave headset and a robot controlled car using Emotiv's EPOC.[136] Another, example of an independent development is by Peter Freer who instead of developing or utilizing an EEG headset has developed a watch, called Body Wave which can measure EEG activity.[137] This last

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[133] See "Brain Interaction for Mobile Games, And "Playing with your Brain: Brian Computer Interfaces and Games"
[134] Kristian Grifantini , "Mobile phone mind control," MIT Technology Review, March 31 2010, accessed, Mar 15, 2013, http://www.technologyreview.com/view/418258/mobile-phone-mind-control/
[135] "home," Puzzlebox, accessed April 20, 2103, http://orbit.puzzlebox.info/
[136] "Neurogadget interviews Steve Castellotti," Neurogadget, by Andrew, Dec 31, 2012, accessed Feb 2, 2013, http://neurogadget.com/2012/12/31/neurogadget-interviews-puzzlebox-founder-steve-castellotti/6668
[137] "Bodywave," Freerlogic, accessed, Mar, 13,2013, http://www.freerlogic.com/body-wave/

development will be discussed more in chapter 5, in which this modification will be analyzed in terms of user resistance to EEG based BCI helmets.

From Neurofeedback History: Continuity in BCI Development

In addition to the major actors discussed above there are several trends from neurofeedback traditions that are also shaping production and consumption of BCI's and which remain contiguous with emerging BCI developments. One, is the use of EEG based BCI's for medical applications, second, is the development of applications for the health consumer who value practices which improve and enhance the health and well-being of living and third, is the development and use of faster and more powerful computing hardware, software and algorithms for brain wave signal acquisition and processing. And the last similarity has to do with the limitations of any EEG based device, whereby acquiring the desired signal in real-time is both a technical and biological limitation.

Primarily, BCI developments are being sustained by the established research and institutional networks oriented toward the medical and therapeutic goals to aid those with disabilities. And though this project does not adequately address BCI development for disability, there are BCI technologies being developed for disabilities outside research and medical fields which are aimed at the consumer. The company G-Tec (Guger technologies has developed the first commercially available BCI speller, called IntendiX-speller.[138] This product works based on the event related potential P300 frequency, and is intended to help those with locked-in syndrome.

A secondary medical goal which is in accord with neurofeedback practices are the BCI developments aimed at therapy. Neurofeedback has developed into two branches: *cognitive*

[138] "Intendix Home," Intendix, accessed, March, 13, 2013, http://www.intendix.com/

therapy, which attempts to correct abnormal EEG patterns, and *dynamic therapy* which attempts to train subjects to control EEG patterns to enhance personal growth and or maximize performance such as in athletics.[139] The development of BCI's for therapy is partly due to the emergence of alternative therapies and the heath consumer who seek alternatives to pharmaceutical based medicine. The rise of this type of consumer lead to renewed interest in neurofeedback training, not only for those seeking alternatives to treat illness but also for those trying to optimize health. [140] This socio-cultural trend has emerged from baby boomers concerned with health and longevity concerns. This demographic has been targeted by innovators, companies, and developers as a market for potential products, and applications. For example, the company Personal Neuro Devices has developed an application called *Transcend*, and the company Brain Athlete has developed a visor to help monitor peak performance and concentration during sports activities.[141]

The military has also influenced the development of dynamic therapy, through DARPA funding of their interests in performance enhancement and therapies to combat stress. During the latter years of the Vietnam War, "A number of these DOD grants were given to biofeedback researchers to improve performance under stress. Thus, was born the idea of peak performance training." [142] The emergence of BCI's was also based on DARPA grants, and the military

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[139] Demos, "The History and Evolution of Clinical Practice," 21. Cognitive therapies are in effect techniques for treatment of metal deficiencies, and focus on changing abnormal EEG patterns in subjects with epilepsy, ADHD, and autism. Dynamic therapies attempt to train subjects for performance related activities. However, the underlying assumption of dynamic therapies and cognitive therapy interventions are similar, in that subjects have not attained "normality" or peak potential. Regardless of where neurofeedback interventions are applied the net effect is control of brain wave states. The epistemic boundary which maintains these dual branches, normal vs abnormal, is blurred through certain applications.

[140] Laibow, "Medical Applications of Neurofeedback." 85-86.

[141] "Home," BrainAthlete, Accessed mar 18,2013, http://brainathletesports.com/. And see: "Products," PersonalNeuro, accessed, Feb. 9, 2013, http://personalneuro.com/products.htm. And Neurosky also sells their apps. "Products," NeuroSky, accessed Mar.13, 2013, http://store.neurosky.com/products/transcend. It is important to note that these products are built using an Neurosky headset and ASIC chips and are therefore based on their Meditation and Intention algorithms discussed in earlier chapters.

[142] Budzynski, Thomas. "From EEG to Neurofeedback," 69. Budzynski and his colleague received a grant during

continues to be involved in new BCI applications. One such example is the software application called *BioZen* developed by the national center for TeleHealth and Technology, a division of the DOD designed to help services members use the benefits of neurofeedback therapy. [143]

The third similarity is the continued technological development and use of faster and more powerful computing hardware, software and algorithms for brain wave signal acquisition and processing. One of the most important developments is the Fast Fourier transform algorithm and analysis chip developed in the mid 1960's which allowed processing of large amounts of raw data and could convert averages of volts into specified bands. Another important development in EEG capacities was the establishment of Quantitative EEG (QEEG) databases in the 70's and 80's whereby information was collected from multiple subjects or scalp sites. QEEG allowed comparison of individual electrical activity with a population. Some of the early pioneers in neurofeedback research, including Frank Duffy, James Thatcher and E. Roy John, developed the Brain Electrical Activity Mapping (BEAM) in 1980's which was a technique that produced colorful images and maps of brain activity.

Computer and microchip development has enhanced performance and calculation capacities, reduced the size of devices, and increased the storage and processing capacity. The Internet and microchip industry boom in the 1990's influenced the production and development of smaller and more powerful microchips capable of calculating and storing information faster, and continues to benefit the production and development of BCI's. As mentioned earlier, NeuroSky developed and sells an Asics chip which contains several algorithms capable of

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the early 1970's to develop EEG training protocol to train officers to sleep under stressful conditions.

[143]This application works on Neurosky's sensors and technology. See: Jonah Comstock, DoD's new Android app connects to wearable devices for biofeedback," Feb. 4, 2013, accessed Mar.20, 2013, http://mobihealthnews.com/20155/dods-new-android-app-connects-to-wearable-devices-for-biofeedback/. Also for more health biofeedback apps see: "Mobile Applications," National Center for TeleHealth and Technology, accessed mar12, 2013, http://www.t2health.org/products/mobile-apps

processing brain wave activity and which has enabled the production of numerous BCI applications and products.

Lastly, BCI technologies share EEG based technical and biological limitations. The technical problems with EEG based include recording issues due to "noise" or artifacts which are undesired electrical signals emitted from the movement of eyes and eyelids which occur at same frequencies as other important desired frequencies and ultimately can contaminate the recording.[144] The development of algorithms has aided in-signal processing by filtering noise. The company NeuroSky discusses on their website how their headset deals with the issue of noise:

> Extrapolating EEG brainwave signals from noise requires both a reference point and an electrical circuit grounding. The grounding makes the body voltage the same as the headset. The reference is used to subtract the common ambient noise through a process known as common mode rejection. The earlobe is a location that experiences the same ambient noise as the NeuroSky forehead sensor but with minimal neural activity. Hence, it is crucial that the ear connection be securely fit. [145]

Several other interrelated issues include: *electrode placement*, proper *contact of sensor*, the *Information Transfer Rate* (ITR), or the speed at which information is presented back to user. Having a good electrode contact is essential to ensure fast ITR of real-time processing of brain waves to the user. These issues cause problems for the design of headsets, especially with the one-size-fits-all model, although adjustable, developed by Emotiv and Neurosky. In addition,

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[144] Coles and Rugg, "Event Related Potentials: an Introduction," 3-5

[145] " Brainwave Technology," NeuroSky, Accessed, Mar 12, 2013, http://www.neurosky.com/AboutUs/BrainwaveTechnology.aspx

both Neurosky and Emotiv have developed dry sensors, where in the past to ensure good conductivity, wet sensors were required.

Moreover, there are several biological limitations for EEG devices; the first is the diversity in the range of EEG frequencies between individuals. The development of algorithms can accommodate these variations, but this limitation means that in order to use any EEG BCI device requires both training of the user and generating an individual profile in order for the technology or device to recognize the user's unique pattern. And the most important limitation is *BCI illiteracy* whereby it is estimated that between 15% and 30 % of the population is unable to control BCI's. However, attempts at solving this problem are being addressed by researchers who:

> ..have presented a novel method for Machine Learning based brain–computer interfacing which overcomes these problems(BCI illiteracy). It replaces the offline calibration by a 'co-adaptive calibration', in which the mental strategy of the user and the algorithm of the BCI system are jointly optimized. This approach leads some users very quickly (3–6 mins) to accurate BCI control.[146]

There is an assumption held by BCI researchers, HCI developers, and companies as the techniques of mapping the brain are further refined, and where technical limitations, such as BCI illiteracy, are overcome then newer BCI innovations will improve and become more precise and accurate, allowing more precise control by users. This assumption has led to the development of other mapping techniques for BCIs beyond EEG which include fMri and PET.

[146] Blankertz,"Towards a Cure for BCI Illiteracy," 1

Beyond Technological Control toward Technological Enhancement:

However, the question still remains: will developments and improvements in these technical areas help overcome the limitations of BCI devices to increase user acceptance of BCI technologies as an alternative for computer/machine control? Eliminating technical limitations may not be the only factor in overcoming user acceptance of BCI's. Considering the current limitations of BCI control, which often translates into a lack of precision and involves various periods of training, HCI developers and companies such as NeuroSky have expanded the range of BCI possibilities by redirecting rhetoric away from expectations of control and toward the broad, yet appealing, notion of enhancement. In other words, BCIs are being promoted as a technological means both to develop bodily and mental capacities, skills such as meditation and focus, and further to erode the boundaries between the machine and body in order to promote a seamless technologically embodied experience. The notion of enhancement is not only a goal but has become a value itself identified by developers, producers, and users in BCI development which is shaping dialogue within human-machine relations of development and use. While the value of control is fundamental to both BCI's and gaming, the value of enhancement as a way to define the performative consequences of BCI's with a player's experience has become especially important and is redirecting the development of BCI for games and consumer applications. Associating BCI's and BCI applications with this value becomes an important way for overcoming users and gamers resistance to BCI limitations.

While these BCI's and BCI applications are being described in terms of enhancement, it is important to note the flexibility in BCI development. The production of BCI products designed for consumer applications are built on two approaches, one in which users intentionally try to control a system and the other approach is to build systems and products that passively monitor the users cognitive state as they behave in the world.

> Rather than building systems in which users intentionally generate brain signals to directly control computers, researchers have also sought to passively sense and model some notion of the user's internal cognitive state as they perform useful tasks in the real world. [147]

The producers of BCI platforms, such as Emotiv and NeuroSky have identified several domains of use based on these two approaches. In an interview with Neurosky, Tansy Brook characterized five domains of use. First, and discussed previously, is the domain of *control*, for disabilities, and environment control, etc., second, is *conditioning*, such as neuro therapy, third is *monitoring*, which is being developed for applications such as brain fingerprinting, lie detection, and internal body monitoring (i.e. monitoring delta waves which are associated with sleep while driving a car in order to trigger an alarm to wake a driver) fourth is *adapt*, which is described as machine empathy whereby the machine responds to users mental state. [148] And finally, *evolve* which is the notion of performance enhancement.

However, the rhetoric surrounding all these uses and domains can be characterized in terms of the notion of enhancement. Moreover, BCI development and applications actually are being described in terms of enhancement. For example, in a paper assessing user experiences with BCI's HCI researchers at the University of Twente claim, "The aim of such applications is

[147] Tan and Nijholt, "Brian- Computer Interfaces and Human- Computer Interaction,"12
[148] BCI adapting capacities have been illustrated by HCI researchers who have utilized BCI's with the MMORPG game World of War Craft in which a character changes into an animal when a player is stressed. See: Gürkök, et al."Towards Multiplayer BCI Games," (2010). And see: van de Laar, et al. "Experiencing BCI Control in a Popular Computer Game," (2003).

to create positive experiences that enrich our lives rather than only provide reliable control." [149] The neuro-companies described previously in this chapter such as Neurowear and Personal Neuro Devices (PND) are building applications based on the notion of enhancement to develop these technologically embodied experiences. Neurowear describes its brain wave controlled product: "Necomimi is the new communication tool that augments the human bodies and abilities."[150] Necomimi are mechanical cat ears mounted on a headset which move based on NeuroSky's algorithm of meditation and attention and when a user is meditative and relaxed the ears move down, and when a user is focused the ears point up and rotate. This product can also be used in conjunction with an application in which a user can mark on a Google map where they have had a relaxing experience, and share with other users, akin to Facebook social media.

> The technology behind this app is called "neuro tagging". It consists of using smartphones and neural sensors to register how people "feel" in their current place, based on biological information such as neural waves and heartbeat. NeuroWear believes that neuro tagging brings a new value to the places being tagged."[151]

Another Neuro company promoting BCI's as enhancement technologies:

> Personal Neuro Devices (PND) is an Ottawa-based neuroscience company focused on brain-computer interface technologies. PND applies scientific advances in neuroimaging and psychology to create smartphone apps that enable people to achieve high level wellness and to obtain a greater awareness of how brain function affects their well-

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[149] Van de Laar, et al. "Perspectives on User Experience Evaluation of Brain-Computer Interfaces," 600

[150] "Projects/necomimi," Neurowear , accessed Mar. 20, 2013, http://neurowear.com/projects_detail/necomimi.html#ShopList

[151] Projects/ neuro tagging map," accessed Mar.20, 2013, http://neurowear.com/projects_detail/neuro_tagging_map.html.

being.[152]

The value of enhancement and the promotion of well-being are being attached to game production as well. HCI researchers see the role of BCI's for gaming as a way to elevate this value:

> …the most popular and immediate use of recent BCI technology is found in game entertainment industry. Since computer game is not a simple fun-play, but a form of life…one's quality of life is determined by how much fun factors he can enhance in his everyday life. [153]

In an Interview with Tansy Brook from NeuroSky, she describes the companies aim to integrate BCI's and games:

> And so from a gaming perspective again we're kind of relooking at…changing the paradigm. We're looking at this and saying okay this is more of…something that changes the experience rather than something that replaces the technology that already exists…and so….we look at it as an enhancement. And actually could do some pretty powerful things, but again like we were saying before the challenges to get people educated about the technology and understanding…what it can do and can't do. [154]

The intentional aims as well as the genuine actions to develop BCI technologies and applications which serve to enhance the computer-human relationship, reveal the values,

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[152] "About," Personal Neuro, accessed Mar. 21, 2013, http://personalneuro.com/about.htm
[153] Yoh, et al. "Neurowander: A BCI Game in the Form of Interactive Fairy Tale," 389
[154] Tansy Brook (Neurosky), Interviewed by Tristan Cloyd, March 08 2011, Transcript Appendix F.

assumptions and the current conceptual role of technologies in human lives, which is no longer just to provide increased control but these technologies are necessary to enhance the capacities and potentialities of both machines and people. This relationship is assumed to be fundamental in both the symbolic and functional meanings of the individuals and social groups involved in BCI use and development. The removal of any barriers in human-computer communication are not only desired but assumed to be necessary. The ambiguity of the rhetoric of enhancement parallels the same ambiguity surrounding the function of BCI's allowing a conceptual space for the individual user to imagine and project their own ideals, values, or practices of which they want to enhance. The ultimate goal leading to practices of immersion, where by the perception by the user and the interaction between the user and machine are seamless. In terms of games, the practice of play is a fundamental activity through which users achieve this condition. Therefore the enhancement of experience is an integral condition for playing games. The goal of BCI enhancement is in accord with the goal and value of gamers and their practices of game play. The next chapter briefly illustrates this connection between video games and BCI's.

Chapter 4:
The Rise of BCI's for Consumers II: A Brief History of Video Games

Introduction:

The purpose of this chapter is to contextualize the current rise of BCI consumer applications and devices for gaming and computer use by illustrating how 1) brain-computer interface technologies, and developers, both independent and from HCI networks, are connected to video games. In other words, I will show how BCI development connects with gaming production. Moreover, I will briefly illustrate this by identifying certain values and characteristics associated with video games and game play which correspond to BCI development and use. 2) I will illustrate an early example in gaming history of a failed "mind" reading controller, an unreleased product by Atari called the Mind Link, which serves as a cautionary tale about users and technological development. Finally, drawing on conclusions from game researchers who have illustrated that U.S. consumption of home video game consoles preceded home computer purchases from 1977-2000 contributed to the formation of a new kind of consumer, one increasingly accepting of novel and alternative user interfaces and technologies. Gamers may be prone to playing with novel interfaces such as BCI's as long as these technologies perform in ways that resonate with established group values and enhance game play.

Game Studies and Game Complexity:

This chapter cannot address the extensive history of video games nor the emerging field and academic work in video game studies.[155] The recognition of video games as a significant

[155] For Journalistic and popular histories see: Kent, *The Ultimate History of Video Games*, 2001; Poole, *Trigger Happy,* 2000; Herz, *Joystick Nation,* 1997; Asakura, *Revolutionaries at Sony*, 2000. For a social history of video games see Williams, *A Brief Social History of Game Play*, 2005. For Political Economy of games see Kline, *Digital*

cultural artifact and research subject has gained serious academic attention, including the concerns over the behavioral effect of video games on players.[156] Games studies have demonstrated the importance of games through a variety of approaches. One example, based on learning theory, by James Paul Gee who argues video games are a form of literacy that embody a set of skills which reflect a cultural mode of thinking and learning, "Video games—like many other games are inherently social…" and Gee argues video games teach 36 principles of learning (i.e. Active learning principle, design principle, etc.). Moreover, video games require you to adopt modes of thinking in order to confront obstacles and novelty and by doing so video games can provide "good learning of hard challengeable things."[157] Interpreting video games as a media form that can provide leaning skills has also been picked up in classrooms, in which playing video games has helped students learn to set and complete goals and teach the important lesson of learning through failure.[158] Beyond learning theory, video games have also been analyzed through media theory, the political economy of communication, and cultural studies. Stephen Kline (et al), in his book *Digital Play*, argues that the emergence of video games has not been determined technologically but developed as a dynamic relation between varied interests and tensions. Kline interprets gaming through Raymond Williams' concept the "… 'circuit of capital,' which involves the ongoing process of making and selling commodities in order to

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Play, 2003. For additional introduction to theories and history of games, play, and games studies see: Wolf, *The Medium of the Video Game*, 2001, And *The Video Game Theory Reader*, 2003; and Mäyrä, *An Introduction to Game Studies, 2008;* Egenfeldt-Nielsen, *Understanding Video Games*, 2008; and Salen and Zimmerman, *Rules of Play, 2003.*

[156] For articles on the effects of video games violence see Craig et al., "Violent Video Game Effects on Aggression," 151-73, and "Video Games and Aggressive Thoughts," 772-90, and "Effects of Violent Video Games on Aggressive Behavior," 353; and for effects of video games on social roles see: Dill et al., "Video Game Characters," 851-864. However, much work has been done to show these studies overemphasize the effects and correlations between violence and video games are no less harmful than TV or other media forms, and rather that the concerns over the effects of video games illustrates a long history of public concern with new media forms. See: Williams, "The Video Game Lightning Rod," 523-550.

[157] Gee, *What Video Games Have to Teach Us,"* 7

[158] Sara Corbett, "Learning by Playing : Video Games in the Classroom," New York Times, Sept. 15, 2010, accessed Dec. 31, 2012, http://www.nytimes.com/2010/09/19/magazine/19video-t.html?pagewanted=all&_r=0

accumulate profit."[159]

The range of theories in which to analyze and make sense of video games illustrates their complexity, and difficulty as a research subject, focusing on hardware or software, content over context, or types of users given the diversity of gamers. To illustrate the demographic complexity, according to the Entertainment Software Association report in 2012, 37% of gamers are of the age of 36 and over, 32% are under 18, and 31% are between the ages of 18- 35. Moreover, the characterization of gamers as the nerdy male teenager has clearly been undermined by the reality of the fact that 47% of gamers are female. Moreover, 49% of households own a game console, and this percentage is even higher when you consider the use of smart phones and online computer gaming. And these games include a wide range of genres from role-playing to puzzle and word games, from adventure and sports to fighting and shooting games. [160] Given the diversity and complexity of games and gamers the question arises how do you define a video game? What is a video game? A brief history of some of the recognized moments in video games history will illustrate the difficulty in categorizing what constitutes a video game.[161] However, certain features characterize video games which will connect them intimately with the practices of HCI and development of BCI's for consumers.

What is a Video Game? Brief Definitions and History:

As more scholars delve into games studies, the factors and people contributing to the birth of video games history has continued to expand and emerge earlier in history. Recently, an early patent found in 1947, has been inducted into video game history, whereby Estle Mann and

[159] Kline, "*Digital Play*,".23
[160] See ESA report 2012 at http://www.theesa.com/facts/pdfs/ESA_EF_2012.pdf
[161] Wolf, "*The Medium of the Video Game,"* 14

Thomas Goldsmith patented a cathode ray tube entertainment device.[162] However, most histories start with early work and collaboration emerging from academic, industrial and military networks, and consider the development of *Spacewar!* in 1962 by an MIT student Steven Russell to be the first video games, which utilized toggle switches as a controller on a computer[163] The first commercial arcade game was developed 10 years later by Nolan Bushnell called *Computer Space*. In 1966, Ralph Baer, a military contractor, developed a console and game that could be used with a television. He eventually licensed the technology to Magnavox who released the first home console in 1972 called the *Odyssey*, and used paddles for controllers.[164] The term "video game" started to appear in periodicals around 1973.[165] The popularity of video games increased with the hit game PONG in 1972, which was released by the new company Atari and created by Nolan Bushnell and Ted Dabney. Eventually Atari would release the most popular home console the Atari VCS 2600 (Video Computer System), which used a joystick as a controller and would come to dominate the home console market until the 1983 video game industry crash. This early history illustrates the various spaces in which video games were being developed and used and the diverse modes in which they could be played. Video games are a hybrid technology that cut across many domains in which they are being used from private spaces in homes, to public spaces in arcades, from manipulating graphics with toggles switches using an early computer, to using paddle controllers to control action on a television.

Nintendo's successful release of the Nintendo Entertainment System (NES), which utilized a controller pad eventually, resurrected the video game industry in 1985. The success of the NES illustrates that despite the 1983 crash, a new consumer had emerged willing to adopt

[162] Mäyrä , *An Introduction to Game Studies*, 40.
[163] See: Wolf and Perron, Mark, *The Video Game Theory Reader*, 2. And Kent, "Super Mario Nation," 35-48.
[164] Kent, "Super Mario Nation," 38.
[165] Wolf and Perron, The Video Game Theory Reader, 2.

new technologies.[166] This trend in developing various interfacing options continues, as shift in motion based controllers have become popular. Examples such as the Nintendo Wii remote controller, introduced in 2006, is a device resembling a TV remote, and has increased the range of interface options for video games. As the Nintendo president said “There are people who would never touch a (game controller) but anyone would pick up a remote.”[167] Other examples are the release and economic success of Microsoft’s motion controller *Kinect* released in 2010 for the XBOX 360, in which a camera detects the motions of a player. More recently devices are shifting to hand held portable, smart phones, and tablets, such as Nintendo’s Wii U, and Sony’s PSP portable.

Given the diverse range of modes upon which users interact with devices and play games, a simple definition of video games becomes difficult. Instead, scholars in video games studies define games by their various characteristics, and although the terms and classifications can vary the key features are: algorithm, player activity, interface, and graphics.[168] Algorithms refers to the program which contain the codes and procedures controlling the games graphics. The second element is player activity, and is the core of video game experience. This is the most important component from a gaming design perspective. Moreover, player activity can be divided into two other areas: Diegetic activity: which is what the avatar player does as a result of player activity, and extradiegetic activity; what the player is physically doing to achieve a certain result. The third component is graphics which refers to the visual display on a screen, and is associated with space in games which the players navigate. The final component is the interface, which is not the graphics, but rather “the interface is… a junction point between the input and output, hardware and software, and the player and the material games itself, and the portal through

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[166] Williams, “A Social History of Video Games,” 2005
[167] Mark MacDonald, “Remote Controller,” *Electronic Gaming Monthly* 198, Dec. 2005, 27.
[168] See: Wolf and Perron, *Video Game Theory Reader*,14-17 for discussion of these elements.

which player activity occurs."[169] Together, these gaming components need to contribute to game play, which is fundamental to the gamer's experience, and which ultimately directs how they engage with interface technologies and the digitally simulated game world. However, play is another concept that has multiple dimensions and makes it difficult to define. A brief taxonomy of play will be discussed further in chapter 5.[170]

However, these key features of video games and gaming experience align similarly with the goals of BCI's and the developers in HCI. The central features in BCI and HCI research center around user activity and the interface device. How these components are conceived and developed, in terms of making BCI's, is important for understanding its introduction to consumers through games. Moreover, these components help make clear the features which might aid in user acceptance and what leads to user resistance of BCI's. And much like other new technologies introduced in the past, the prescribed intention of a technology is usually resisted and oriented toward existing social patterns. As Ronald Kline notes about the introduction of new technologies in rural America, "the telephone, the automobile, radio, and electrification did not determine social change in a prescribed manner. Instead, farmers contested efforts to urbanize rural life by resisting each technology, then weaving it into existing cultural patterns to create new forms of rural modernity."[171] In regards to playing games, how BCI's correspond with the key elements of games becomes important for their acceptance.

[169] Wolf and Perron, *Video Game Theory Reader*, 15
[170] See: Salen and Zimmerman, *Rules of Play*, for fundamentals of game design and pg. 304 for variation of play in game design and pp 73-76 for game and play definitions.
[171] Kline, "Resisting Consumer Technology," 51

Translators of Games and BCI's: Human-Computer Interaction Researchers and Independents[172]

The role of Human-Computer Interaction researchers (HCI) in the history of video games has early beginnings. One of the first HCI contributions to video gaming was in 1952 when a PhD student, A.S. Douglas programmed the first graphical computer game known to exist, called *Nougats and crosses*, a version of tic-tac-toe, which was displayed on a cathode ray tube monitor. He was writing his dissertation on human computer interaction.[173] Researchers in this field have helped develop and continue to introduce new modes of interfaces technologies. In the past they helped develop the now ubiquitous mode in which users interact with computers, the graphical user interface (GUI), which entails manipulating objects on a screen with a pointing device. The GUI was first demonstrated by Ivan Sutherland, in 1963 who was working on his PhD at MIT. Other examples of HCI research include, the mouse, and the development of computer aided design (CAD). HCI researchers are working on interfaces that rely on gesture recognition, Virtual reality, 3-D, and now include BCI's.

These HCI developers are currently bridging the gap between BCI research and use for medical purposes to non-therapeutic uses for consumers and gamers. With the merging of the fields of human-computer interaction (HCI) and BCI new applications are being developed for entertainment and education which may be interesting for disabled *and* abled users.[174] In particular, a group conducting research at the University of Twente in the Netherlands, who include Hayrettin Gurkok and Anton Nijholt, are introducing BCI's into gaming by translating some of the values and motivation for playing games through a BCI interaction framework.

[172] Human computer interaction is an interdisciplinary field of computer science, focused on design and interface between humans and computing. There are varying names: Human Media interaction, machine learning, etc.
[173] Mäyrä, *An Introduction to Game Studies***,** 40.
[174] Laar, "Perspectives on User Experience Evaluation of Brain-Computer Interfaces," 600-09

> ..we will try to transfer some knowledge from the games and the BCI communities into a shared preliminary framework to make them aware of each other's research. From the games community, we will show some game playing motivations which can be satisfied by the features of BCI.[175]

These HCI researchers are utilizing user experiences and identifying key values which motivate gamers to play games, and which can be correlated in BCI production. They have identified 4 key values which include: challenge, fantasy, flow (immersion), and sociality.[176]

Another important development group who is translating gaming values into BCI production is independent developers. For example, Lat Ware is an independent developer who has developed a video game that uses Neurosky's Mindwave, called *"throw trucks with your mind"* [177] He has introduced his project online on Kickstarter.com in order to fund the project which is in a prototype phase. Utilizing Neurosky's algorithms of intention and meditation, characters on the screen can lift things in the environment when they are calm, and throw things when they are focused. However, the BCI headset is only augmenting user control, navigating the game environment, and selecting and aiming the characters power will be performed by using a mouse and keyboard. According to Lat, "games like this are about simple wish fulfillment."[178] Lat's interpretation and use of BCI's illustrates the key users' values identified by HCI researchers of those who play games. In particular, the choice to use BCI's to enhance the players experience by fulfilling the fantasy of telekinesis, and using BCI control for limited actions, mediates the values of flow (immersion) in gaming experience, and addresses the limitation of BCI control while still providing a challenge. Addressing and mediating these

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[175] Gürkök, "Brain-Computer Interface Games: Towards a Framework, "374.
[176] *Ibid.* 374-375
[177] Drew Prindle, "Throw Trucks with Your Mind. Need We Say More?" *Neurogadget.com*, last modified Mar.12, 2013. http://neurogadget.com/2013/03/12/throw-trucks-with-your-mind-need-we-say-more/7476
[178] Lat Ware, "Throw Truck with your Mind," *kickstarter.com*, accessed Apr. 12, 2013. http://www.kickstarter.com/projects/1544851629/throw-trucks-with-your-mind

values illustrates the necessary threshold for overcoming user and gamer resistance, especially when disruption of control can affect all aspects of gaming dimensions (algorithms, player activity, interface, graphics) and break the users' experience of play.

Values and Goals of Game Play: Immersion via BCI Enhancement

In order for BCI's to be accepted as an alternative interface for games, BCI's need to demonstrate performatively to gamers how it can contribute to the experience of game play. When all the game elements contribute to good game play, the user experiences immersion in the game. Janet Murray describes the immersion of computer mediated experiences as "…being transported to an elaborately simulated place…" [179] Obviously, the experience of immersion is not resigned to computer simulated experiences, but occurs through users experience from multiple media forms, such as storytelling, reading, or gazing at art work. However, immersion in computer simulated worlds has been noted as being unique both culturally and historically, in which a whole generation have naturalized computers as objects through which to experience things. Sherry Turkle, in her book *Life on the Screen,* utilizes empirical evidence of users' experiences on the internet to illustrate the allure or "seduction" of interfacing with games and computers, in which they experiment or play with multiple simulated identities. Computer simulated experiences are a place in which users project an idealized self, where enhanced abilities and characteristics can be explored in order to create an optimal experience. The notion of optimal experience has been characterized by psychologist, Mihaly Csikszentmihalyis as "flow." This description has come to define experiences and play in video games, in which states of concentration and satisfaction are maximized. [180] The goal of computer and video game

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[179] Murray, *Hamlet on the Holodeck,* 98-99.
[180] For a summary of flow see: Egenfeldt-Nielsen, *Understanding Video Games,* 149. And Csikszentmihalyi, *Flow:*

experiences align with the production of BCI's for consumers in that they are being promoted as alternative interface for the enhancement of self both experientially and physically.

HCI researchers are demonstrating how BCI's can contribute to the experiential enhancement of game play by contributing to states of immersion. HCI developers recognize limitations of BCI as controller for gaming, and are drawing on users experiences with games to address the limitations of BCI as a peripheral interface controller. If a peripheral controller disrupts play then gamers will resist it. As, Sony's eye toy developer Dr. Richard Marks claims, "People don't want to encumber themselves to play… If it's not natural it's not desirable,"[181] leading designers and developers to make BCI's as natural and unencumbering as possible. HCI researchers are attempting to overcome possible limitations by demonstrating through comparative experiments with BCI's and other controllers it can promote immersion in game play, and also offer a unique immersive experience which corresponds to the values of gamers and designers:[182] "…usability alone does not imply user satisfaction…especially, in entertainment technologies factors such as fun, affect, engagement, and immersion play a crucial role in user satisfaction." [183]

Failure of Control: The Atari MindLink (A Cautionary Tale)

There is a chapter in video game history of failed interfaces. In 1984 a group of engineers working for Atari made a step toward the introduction of an alternative interface for gaming to consumers similar to a brain computer interface. They developed a system called the Atari Mind link system, which used infrared sensors mounted in a headband strapped to a player's head,

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The Psychology of Optimal Experience, 1990.

[181] Matt Peckham, "The Future of Videogames: The Future of Control" *Electronic Gaming Monthly 215*, May 2007, 50.

[182] Hakvoort "Measuring Immersion and Affect," 115-28

[183] Gurkok et al., "User Expectations and Experiences of a Speech and Thought Controlled Computer Game," 1

which could detect electrical signals generated by a player moving the muscles in his head. However, the MindLink System and games, *Bionic breakthrough* and *Mind Maze* were never released. And According to Atari:

> Atari was ahead of its time. With innovations such as these and given time for refinement and newer design technologies the idea of the MindLink system would've grown into a successful peripheral. [184]

Moreover, Atari claims that only a few prototypes were made available to test. And, according to Bill Lapham, one of the MindLink engineers:

> The original first-off unit did not work very well because once the user was comfortable with the system (10 minutes or so) his muscle reactions would overdrive the system. To counter this we redesigned the signal amplifiers to step down the signal amplification to reach a useable level.[185]

Based on this and how the user interacted with the game, and given these engineering modifications, several reviewers have commented how difficult it would be to sustain game play by twitching muscles in your head and these were the reason that Atari stopped development. "MindLink was controlled by twitching one's eyebrows. Scheduled for release in 1984, player headaches and unappetizing games were among factors that convinced Atari to shelve its plans."[186] However, one optimistic reviewer of MindLink illustrates the important factors of

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[184] "The Atari MinLink: The State of the Art for your Mind," *Atarimuseum.com*, accessed Mar.10, 2013. Mindhttp://www.atarimuseum.com/videogames/consoles/2600/mindlink.html
[185] *Ibid.*
[186] Rob Beschizza, "NeuroSky Repeating 25-Year Old Atari MindLink," *Wired*, Posted Dec. 12, 2007, http://www.wired.com/gadgetlab/2007/12/neurosky-repeat/

game play and what the gaming experience entails.

> I'm glad that the MindLink existed, even in its aborted form. Gaming is all about escapism and about the creation of things new and exciting, about experiencing things you've never experienced before. In that sense, both of these products succeeded; they inspired excitement and progress, even if they were inherently flawed and anything like that should be embraced. Though it would be nice if they didn't inflict actual pain on people. Might be worth taking note of that one, developers… less pain, *more game please*…[187]

His comments highlight the values discussed previously in this chapter and what gamers demand and value in games: new things (new modes of interfacing with technology), escapism (immersion), and more game. Another reviewer claimed, "The MindLink translated brainwaves and facial movements into *useless frustration.*"[188] However, it remains unclear if the MindLink would have been successful or even worked according to gamers' expectations. In 1984, Atari sold their company to Traimel technologies Ltd. due to their financial problems from the 1983 video game industry crash, and terminated the MindLink system. Most scholars attribute the 1983 video games industry crash, to poor management decisions at Atari, in which they produced too many games, often of poor quality, that were not consumed.

One important distinction here is that Atari spent millions in research to produce a peripheral controller, only to have it unreleased. According to Atari, prior to the Traimel purchase, its research team had several peripherals in development. However, current development with BCI's is emerging from third party developers who are often independent and

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[187] Paul Izod, "Gaming Fail – Atari MindLink," Posted Monday, Feb. 25, 2013, http://www.zero1gaming.com/2013/02/25/gaming-fail-atari-mindlink/

[188] Seanbaby, "Devices of the Past: Before Their Time and Still Crap," *Electronic Gaming Monthly 215,* May 2007, 93.

fund the project themselves. In this since the independent developer users are providing proof of concept BCI's before any major company utilizes them.

Conclusion: Rise of an Interface Generation

The video game industry was resurrected, however, largely due to the successful release of the Nintendo Entertainment System (NES) in 1985. The industry has continued to develop and grow ever sense. The impact the gaming industry has had on culture and social activities over the last 40 years is hard to ignore. The success of video games both economically and as an established cultural practice are important contextual factors contributing to the development of BCI technology. Video Game systems have incorporated a variety of ways for users to interface with games. BCI technologies provide a novel way to interact with computer based technologies which is in accord with the trend in gaming history to develop and use novel modes of interaction. Gaming scholar Dmitri Williams has illustrated how video game development and use influenced computer development and use. Moreover, a comparative analysis between consumption of home computer consoles and video game consoles between 1977-2000 revealed video game consumption preceded computer consumption:

> Since their inception, video games have been harbingers of the shift from analog to digital technology for both consumers and producers. They made major portions of a generation comfortable and technoliterate enough to accept personal computers … electronic bulletin boards, desktop publishing, compact disks and the Web, and have pushed the development of microprocessors, artificial intelligence, compression technologies, broadband networks and display technologies... Games functioned as stepping stones to the more complex and powerful world of home computers… Notably, games *preceded* computers at every step of adoption, and

have continued to be in more homes since their arrival. Games functioned as stepping stones to the more complex and powerful world of home computers.[189]

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Therefore, video games have helped initiate a new generation into accepting alternative user interfaces and technologies, whereby they become accepted and naturalized artifacts and normalized modes of human computer interaction.

However, In regard to the introduction of BCI's a generation of interface users alone will not guarantee its success. Some of the biggest resisters to new interface are actually considered some of the more serious gamers, who value control in gaming. For hardcore gamers the use of BCI peripherals may be resisted precisely due to their lack of precision. In a fairly recent NY times articles, "hardcore" gamers are advocating a return to hand held controllers such as pads and joysticks and rejecting motion controllers, which they consider to lack precision and skill, or in other words whereby game play turns to "Slop."[190] However, the addition of motion controllers has initiated and expanded the category of users in video games to those who are typically considered non-users, and who do not consider the lack of control an issue.

However, there are some larger industry related issues. One has to do with that fact that BCI peripherals are not domesticated technologies within the video game community. BCI's have not been included in or developed as alternative interface peripheral for home consoles such as Soy's PlayStation or Microsoft's X-box. Considering the population size of gamers the potential for profits and for BCI diffusion for use for non –therapeutic uses is substantial. However, a couple prohibitive obstacles are the cost to develop a console which accommodates

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189 Williams, "A Brief Social History of Game Play," 4-5.

190 Stephen Totilo, "Less Flailing, More Precision: the Joy of Joysticks," *New York Times*, July 6, 2012, accessed Dec. 31, 2012, http://www.nytimes.com/2012/07/07/arts/video-games/less-flailing-more-pushing-the-joy-of-joysticks.html

BCI peripherals. Secondly, there are the issues of software development to support of BCI inclusion for home console. To date only proof-of-concept games for consoles exist, which still hold the largest gaming market. Lastly, is the need to develop systems which adapt to BCI illiteracy.[191] As indicated in this chapter and the previous chapter, HCI researchers and independent developers are main actors pushing for potential users (non-users) in gaming for BCI use. They have illustrated that BCI helmets and devices can function within game content to adequately satisfy gamer values and expectations.

Moreover, Brain computer interfaces for consumer devices such as games and toys have emerged in a context whereby large economic interests serve as motivation for developers and platform companies to embrace the possibility of BCI as a viable option for computer and video gaming interfaces. In 2011, US video game sales exceeded $16 billion while total consumer spending including hardware and accessories was over $24 billion. Sales globally are expected to exceed $76 billion in 2013.[192] For large gaming developers such as Sony, Nintendo, or Microsoft to include BCI peripherals in their gaming platforms requires a network of software developers to support such an addition. In addition, the incentive for economic gain is minimized by the cost to develop next generation consoles, usually every 5 years, with heavy research costs. And one company, Sony has made the announcement in 2011 that they will not develop BCI peripherals.[193] Yet, alternative gaming interfaces appear as a viable alternative as the global unit sales of home consoles have decreased from 76 million units in 2008 to about 36 million units in 2012.[194] This decline in 2012 is primarily due to the fact the market for home consoles have been

[191] Blankertz, "Towards a Cure for BCI Illiteracy," 1-2

[192] See: "Essential Facts," *ESA.com,* accessed Dec 15, 2013, http://www.theesa.com/facts/pdfs/esa_ef_2012.pdf and see: "Video Game Indusrty: Market Research Reports, Statistics and Analysis," *Reportlinker,* accessed, Nov, 12, 2013, http://www.reportlinker.com/ci02073/Video-Game.html

[193] "Sony is Not Interested in Brain-Controlled Games," *Neurogadget.com*, Mar.18, 201, accessed Dec, 13, 2013., http://neurogadget.com/2011/03/18/sony-is-not-interested-in-brain-controlled-games/1361

[194] "Global Unit Sales," *Statista.com*. accessed Dec 5, 2013, http://www.statista.com/statistics/214670/global-unit-

saturated and the release of next generations consoles for Sony PlayStation and Microsoft Xbox were delayed. The Sony PlayStation 4 and Microsoft XBox One were both released in November 2013.[195] Regardless, of whether console sales increase again, the economic and cultural success of consoles, and peripherals such as Kinect, has opened new domains of game play where a broad range of users have appropriated alternative platforms such as smartphones, portables, and online gaming. This shift in gaming platforms offers the opportunity to develop alternative interfaces such as BCI technologies.

Regardless, of whether users ultimately accept BCI's as an alternative video gaming interface, BCI's are being introduced and tested through modes of play in the form of games and toys to a generation of computer interface users. Games and play are important modes of social activity through which users become familiarized with novel technologies. This trend appears to be continuing as a recent BCI "neurogaming" conference converged in San Francisco in May 2013, which included companies such as Leap Frog which develops toy based learning technologies.[196]

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sales-of-video-game-consoles/

[195] " Fans Go Nuts At PlayStation 4 Release," *HuffingtonPost*, posted Nov. 11,2013, http://www.huffingtonpost.com/2013/11/15/playstation-4-release_n_4280599.html & Brett Molina, "Consumers Line Up for Xbox One," *USA Today*, Nov 22, 2013, accessed Nov 18, 2013, http://www.usatoday.com/story/tech/gaming/2013/11/21/xbox-one-launch/3671181/

[196] See: Neurogaming conference at http://www.neurogamingconf.com/#!2013/c13yx

Chapter 5:
Play as Techno-Cultural Production: User Acceptance and Resistance to BCI Technology

Introduction:

The main point of this chapter is to illustrate the relations involved in BCI production and consumption. In particular, I focus on a set of users involved in the production and use of BCI's, mostly developers who are consuming and producing BCI applications and devices, as well as their responses to company representations of BCI technologies, including the material and physical limitations of BCI technologies. This chapter also makes several corollary arguments, the first of which, in regard to BCI choice, users partially resonate with BCI functions that match their social values and practices surrounding fantasy fulfillment and self enhancement both experientially and performativity, yet often fail to meet technical expectations of control. Therefore, the choice to develop and use BCI's is based on cultural values and practices rather than technical efficiency. Lastly, I illustrate that play is a significant activity in BCI technological production and use, and hence a form of technology.

This chapter also utilizes data from my user questionnaire.[197] Based on the questionnaire I reveal user attitudes about technical limitations contributing to the resistance of BCI's, which has led to examples of modification of BCI design. Moreover, user responses also reveal some of the cultural values, practices, and optimistic attitudes surrounding BCI's which are aiding in its acceptance. Moreover, developers are promoting BCI's as potential alternative computer-interface through the consumption of BCI headsets and the development of BCI software applications. User decisions to develop and appropriate BCI's as an alternative interface cannot be understood simply as choices between two viable and competing technologies primarily

[197] See Appendices D, E, and F

because EEG based BCI's have material limitations which offer less accurate control as an interface technology. Therefore the choice to develop and use BCIs as an alternative can be made sense of by understanding the cultural values and practices which moderate user actions, and which are directing users to pursue BCI's. These technologies are being made sense of through values associated with modes of enhancement, both experientially, to promote the sensation of immersion in computer interfaces through game play, and through therapy to develop peak performance.[198] These modes of enhancement center on the use of BCI technologies for the reproduction and promotion of the self. Moreover, the promotion of enhancement is being reproduced through practices of play, which is through the construction of games and applications.

Therefore, I argue that the social practice of play is an important process of consumption, both as a means and as a goal, which is shaping and has shaped the technological development of BCI's. This chapter provides a preliminary discussion of play by briefly defining play and its relation to technology. Play is a practice through which users come to negotiate the limits, and possible uses of BCI technologies. Moreover, play is a mode through which users attach values to BCI's that correspond to their expectations of BCI functions. Hence, play is a means by which users accept, resist, and consume BCI technologies. Play is also a goal toward which HCI developers and producers structure applications for BCI's. Therefore, I am arguing that play is a form of technological practice, critical to innovation.

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[198] There is a growing social trend called "quantified self" in which individuals utilize technologies to monitor body functions and modify behavior to promote the enhancement of self. See: http://www.ted.com/talks/gary_wolf_the_quantified_self.html and also see the Neurosky Interview in Appendix F for a discussion of Quantified Self.

Company Representations of BCI Technology:

In previous chapters, I illustrated the historical context of BCI development and how it emerged from several socio-technical domains, which included medical, military, gaming, and computer development. This chapter builds on this historical context by highlighting some user responses to BCI technologies gathered through surveys. However, briefly illustrating and reiterating company representations BCI's will provide a context in which to interpret user responses.

In chapter 3 I introduced several important distinctions between the companies, Emotiv and NeuroSky's, representation of the capabilities of their BCI headsets. The first distinction is the representation of BCI technology as an enhancement or replacement to other interface controllers, the second represented distinction, is the emphasis on simplicity or complexity, and finally, the representation of BCI's as devices which are controlled by either thought or states of mind. Together these three distinctions shape the domain of user expectations, and consequently shape our understanding of user resistance and acceptance of BCI functions.

As indicated earlier, the company NeuroSky both characterizes and built their headsets based on the value of simplicity, designing their headsets with one sensor and with command functions based on algorithmic sets that can be correlated with states of mind (e.g. meditation and attention) rather than thoughts. An excerpt from an interview with Neurosky representative Tansy Brooks reveals the correlation of its design to the representation of their headsets as a simple technology:

> We picked intention and mediation because they were the easiest for people to do... first of all from a user interface point of view… it's easier when people first start to be able to start using the technology usually say within 15 minutes of practicing, you know in worst case scenario, I would

> say people tend to get the hang of it. So they can… try a number of different tactics… to get a response from the technology until they figure out which one works best for them and then they can repeat it more easily…that was important for us to try to make it easy as possible.[199]

NeuroSky's choice to emphasize simplicity in design both for input and output has led to successful partnerships with companies who have diffused these Neuro-products into the market.[200] NeuroSky representative, Tansy Brook, discusses its flexibility in adjusting the algorithms with its co-partner Mattel in producing the MindFlex:

> …the other thing is…about making these algorithms is it helps us to bridge the gaps into industries who don't have any background in neuro feedback or EEG in general…you know when we're working with the game developer or working with the toy companies like Mattel, they can just take the value that comes from the algorithm which is, its analog data and we released it in a range of um zero to 100. So, you know, it's important to point out that the technology is analog it's not digital so it's not ones and zeros. So if someone is interested in using one of the algorithms they would set a threshold. For example with the toys, I don't know what the exact value is but, say for Mattel's toys they set the threshold much lower, say they set it at a 30 before the ball starts going up. They concentrate it at least…at a 30…you know before… the ball starts moving and then maybe at a 60 it goes higher and higher. You can set….a response within a device on these different thresholds and if you want to make it more difficult you can do that as well…[201]

[199] Tansy Brook (Neurosky) , Interviewed by Tristan Cloyd, March 08 2011, Transcript Appendix F
[200] The president of Neurosky announced in 2011 they expected to ship 5 million units of brain reading units. Dan Smith, "Speaking at Wired 2011: Stanley Yang," *Wired*, Aug. 23, 2011, http://www.wired.co.uk/news/archive/2011-09/wired2011/stanley-yang
[201] Tansy Brook (Neurosky) , Interviewed by Tristan Cloyd, March 08 2011, Transcript Appendix F

In contrast, the company Emotiv chose to develop headsets which have the capability for multiple commands, and consequently Emotiv developed a very complex headset. The choice to develop a complex technology with multiple command options led to a partnership failure. Emotiv's president Tan lee, revealed in a 2010 Wired magazine interview, that negotiations with the company Sony failed based on Sony's demand to make the headset simpler:

> The most logical partner, Sony, seemed to want a simpler version of the technology. After long negotiations, Tan and Nam rejected the partnership. 'Dumbing down our technology just to get the Sony name is risky,' Tan says. 'This is our first product ever, our coming out to the world. If we launch something that is perceived to be too simple or not exciting, it could taint the perception of the entire category of brain-computer interfaces as capable of delivering an awesome experience.[202]

This decision to opt for complexity and thus reject this partnership may be a key moment in BCI history, whereby an opportunity to diffuse BCI technologies to an established consumer group with the help of a company who produces the PlayStation, one of the most popular video game consoles distributed throughout the world, was missed. Video game consoles are still the dominant form in which gamers interact with video games. Emotiv missed an opportunity to have a hardware company include a BCI peripheral for its video game console package. Gaming and software developers build applications based on these console packages. If a BCI peripheral was added to the hardware console package the opportunities to develop BCI games for a broader audience would have emerged. Currently, however BCI games are proof of concept and

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[202] Neal, Pollack, "Mind Control: How a £200 Headset is Redefining Brain-Computing Interaction," *Wired*, Nov. 23, 2010,**http://www.wired.co.uk/magazine/archive/2010/12/features/mind-control?page=all**

being developed by HCI developers and independents. Emotiv risks continued resistance and rejection by users and developers in order to emphasize complexity in its design and capabilities.

Aside from Emotiv's emphasis on complexity, the marketing representations of its algorithm software package and BCI headset performing based on thought rather than brain states illustrates another problematic issue for user acceptance. For instance, thinking the word 'lift' can be correlated with several types of user EEG states, for example, such as alpha frequencies, which are associated with intention, or theta frequencies, which are correlated with creative or daydreaming states. Two people could be in different states but thinking the same thought or word. Emotiv represents their headset and algorithmic Cognitiv suite as thought control:

> The Cognitiv suite reads and interprets a player's conscious thoughts and intent. Gamers can manipulate virtual objects using only the power of their thought! For the first time, the fantasy of magic and supernatural power can be experienced.[203]

Emotiv's representation of its BCI as thought controlled is also illustrated in press reviews. For example in 2007 prior to EPOC's release, the headset was represented as:

> A helmet that harnesses the power of mind reading. Unlike earlier technologies which can only detect basic and well-known mental states such as 'concentration", Emotiv can simultaneously differentiate between particular thoughts such as 'push' and 'lift' and emotions such as 'excitement' or 'calmness.'[204]

[203] "Developer Edition," Emotiv Inc., accessed Nov. 23, 2013, http://www.emotiv.com/store/sdk/bci/developer-edition-sdk/
[204] "EPOC Headset For Emotiv," Ideo, accessed May, 5 2011, http://www.ideo.com/work/epoc-headset

In order to achieve this differentiation of thought, the headset requires a training period in which a user sets up a unique profile to correlate his thoughts, brain waves, with computer commands. However, user interaction reveals a tension between their expectations and Emotiv's representation of its headset. To illustrate the tension I highlight a user review of the EPOC headset from an online videogame site.

An Interface Controller for Less Control: A Consumer Review of a BCI Headset

Through this user's review of the EPOC headset I reveal the tension between the company's representations of the headset as a thought controlled controller and the expectation of the user to control computer commands through thoughts as the headset fails to meet the expected and represented function of the headset. However, the reviewer's initial impression of Emotiv's EPOC headset is one of enthusiasm and excitement:

> There's no denying the unique thrill of watching something move on my computer screen just because I thought about it. I giggled the first few times it happened. My friends who were over when I un-boxed and hooked up my EPOC on day one kept saying stuff like, "Wow, that's so freaking weird. And cool." It really does feel a little bit like magic, although less so because you're wearing a web of 16 saline-soaked sensors clamped down onto your skull by a plastic headpiece that connects wirelessly to your PC via a USB dongle. So really you feel like a cyborg, which is just as good as magic in my book.[205]

The unbridled enthusiasm by the user about the potential and use of BCI technologies is easily

[205] Rick Dakan, "Review: Emotiv EPOC, Tough Thoughts on the New Mind-Reading Controller," *JoyStiq,* Jan. 17, 2010, http://www.joystiq.com/2010/01/27/review-emotiv-epoc-tough-thoughts-on-the-new-mind-reading-cont/

discernible in his tone. Moreover, the reference to magic correlates with the values identified earlier in chapter 4, in which gamers value technologies that enhance the experience of human computer interaction, whereby the desire to fulfill individual fantasies, becomes concrete through BCI use. And in this sense the BCI technology resonates with the user's value system and expectation for a computer-interface technology.

However, this initial enthusiastic resonance is tempered by the time delay in which the user has to learn how the device works and more importantly, the user is unable to consistently repeat commands. He explains that "It is definitely not a pick up and play controller…. you have to train it." [206] Through this initiation process user resistance is revealed as the functions of the headset fail to meet his expectations. The headset is packaged with several training and practice games, one in which you practice lifting and push a stone in a simulated environment, and one in which you try to rotate, and even make disappear, a floating orange cube. In this review the user discusses his experience with the floating orange cube:

> But the star of the show is the brain sensing, which you train with the help of a 3D orange box floating in virtual space on your monitor. The EPOC software allows this cube to move up, down, forward, back, left, and right as well as spinning in different directions. You have to train the device in each of these motions, *choosing a thought (Up! Up! Up!) and visualizing the cube moving over and over again while the EPOC studies your brain activity. The instructions suggest you might want to make a hand motion as well,* but it didn't seem to make much difference in my training regimen. You can also have the cube animate the action you're trying to train, which helps you visualize what it is you're thinking so hard about.

[206] *Ibid.*

When that cube slides to the right or recedes into the background with nothing more than a flashing thought, it's amazing. When you stare at your computer and try and think the same thought over and over again and nothing happens, it's as frustrating as can be. We develop skills in part by learning from our mistakes.

The core problem with training and using the EPOC is that it's nearly impossible to know what you're doing wrong when all you're doing is thinking. I mean, I think I'm thinking what I'm supposed to think, but nothing happens. I'll spam out "Right" over and over again with my mind and the cube just sits there.

Then I glance to the right to select a different movement to train and the cube flies in that direction. OK, maybe I shouldn't think so hard. I clear my mind and try to just think "Right" for a second, sort of in passing. That doesn't work. Then it does. But then it doesn't again. My friends who also tried (the software smartly lets you set up multiple user profiles) all had similar results. Clearly we weren't doing it right, but there was no way of knowing what we were doing wrong.[207]

This review illustrates that the representation of the BCI headset as thought controller only tenuously meets the expectation of the user. Emotiv representatives have acknowledged the EPOC is not intended to replace other controllers, which implies it has limited capacities. Given the limitations of BCI as controller many in the BCI community feel BCIs hybrids will emerge in which computing devices laptops, smart phones, gaming consoles will have ports which accommodate BCI’s. However, the risk of misrepresenting EEG based BCIs through the overpromise of its capacities poses a problem for user acceptance, and potential for user resistance. In an interview with a NeuroSky representative she expressed concern over the

[207] *Ibid.*

misrepresentation of BCI’s:

, .. but with people making claims about the technology that are unfounded and then people have a bad experience with technology…it stifles adoption….so there is definitely a lot of concern …different companies and research groups with companies…more…are taking on…to educate the public about the technology but not doing a good job. And we fight to actually try to be, and here’s my…my marketing hat, we fight to be pretty good stewards of that…we try to be as clear as possible about the reality of what the technology can do and what it can’t do…but it is a serious concern. And we even face it. Like we have to deal with it when people are like “Well I thought this was possible” and it’s like…uh no, you’re being misled. So…industry wise that’s pretty important…[208]

Cloyd: You said there are BCI Companies that are hindering the diffusion of it by their misrepresentation?

Neurosky: Yeah… it seems like people saying… “oh you know this group is making these games that they claim make you smarter” but it hasn’t been proven so it makes the rest of us look bad or things like that.

Cloyd: And so….there are others (companies) that are not as…. productive, in some sense?

Neurosky: Yeah… between the two of us, us and Emotiv do I think get quite a bit of attention, but there is a lot…I wouldn’t say they’re doing the same thing as us but there are other smaller groups. And then……I’m not going on the record to dig Emotiv but I would……I think

[208] Neurosky interview See appendix:

> sometimes they can be misleading…. I mean…they're good for us. It's good to have them around. I'm actually glad that they're around to a certain extent but there are times that they're misleading and it's not……it can be troublesome. [209]

Given the limitations of BCI's as a thought controller Emotiv's choice to emphasize complexity and utilize a sophisticated headset with multiple command options there is an increased probability whereby user expectations and values fail to correlate with representative and actual functions. As the review indicates, this BCI headset partially fails to meet the expected function of a BCI as a useful controller, one in which ease of use and repeatable actions are achievable.

This review reveals that gamers value and expect an interface controller that is easy to use. And while the point was made in chapter 4 that video game use has created a generation conditioned to and receptive to novel interfaces and devices, which can be helpful for the introduction of ambiguous technology such as BCI's, the allure of novelty in itself nor the conditioning of groups to technological novelty alone does not influence the acceptance of unique interfaces, but the ease of use in promoting game play. HCI researchers mediating BCI production are aware that novelty alone cannot guarantee user acceptance and understand how complexity, which hinders ease of use, can cause user resistance.

> It is important to note that the driver for adoption of these Mimetic interfaces is not the technology they employ but rather their shallow learning curve for new players, which is in contradiction to the claims of some BCI researchers that gamers are predisposed to seek out novelty.[210]

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[209] Tansy Brook (Neurosky) , Interviewed by Tristan Cloyd, March 08 2011, Transcript Appendix F

[210] Coulton,"Brain Interaction for Mobile Games," 37

I would argue the combination of gamers familiarity with the introduction of novel devices for gaming, as indicated in chapter 4, and the value of ease of use, are factors contributing to BCI acceptance. By exploring new interfaces and gaming devices users find ways to promote and enhance game play and their experiences. Gamers also value an achievable challenge, not strictly ease of use or a shallow learning curve. Ultimately, the device must enhance the experience of gameplay, which is a combination of challenge, ease of use, and recognition that novel interfaces can enhance experience. However, while technical functionality fails to meet user expectations of company representation of BCI's, user expectations of BCI's are in accord with cultural practices and values associated with play, such as fantasy, immersion, and enhancement of self.

User Responses to BCI's: Resistance and Acceptance

While the previous review focused on Emotiv's EPOC headset the following responses are primarily based on user surveys that were disseminated to NeuroSky's contact list. However, similar attitudes and issues arise from user responses to NeuroSky headsets. The first similarity is the enthusiasm and excitement surrounding the headsets, secondly is the resistance to the material and the functional limitations of the headsets.

This survey was sent to approximately 2800 users using Neurosky's social media account of Twitter and their email list.[211] I had 72 respondents which makes a response rate of 2.5 percent, and ultimately quantitative assessment unfeasible, but based on the questionnaire, the average BCI user is white, male, between 26-35 graduate degree, either working as independent developer, or within a corporate structure. (See appendices D, E, F) However, more quantitative work and calculation are required to assess the accuracy of BCI user profiles. Although the

[211] From correspondence with Neurosky representative they sent the survey to approximately 2800 contacts.

qualitative responses to the questionnaire provide useful insight into user and developers attitudes toward BCI's, and reflect the limitations and attitudes identified in BCI and HCI literature explored in chapter 3.

Through the surveys it becomes clear that the potential for BCI uses resonates sharply with developers and users. Users in the surveys express tremendous excitement and enthusiasm about the potential uses for BCI's. As one respondent stated: "I am fascinated by this technology, and the potential that it has." [212] Another, respondent dramatically expressed the importance of BCI's:

> From my point of reference, and many others with whom I have communicated and interacted with over the past 30+ years, this is perhaps among the most relevant and important realms of endeavor that we, the human species, can embark upon. [213]

These expressions of enthusiasm indicate that BCIs serve as a sort of technological symbol in which users desire to overcome tactile motions and replace them with disembodied commands. The shift from bodily control to mind control captures a common cultural narrative of technological progress and human advancement. As one respondent expresses "This is last user interface from touch to thinking."[214]

Aside from the enthusiasm associated with ideological visions of a hands free world, several respondents expressed enthusiasm about more practical applications about the potential benefits of BCI's for gaming: "I hope that…it can aid in game development by helping understand a player's actual mental state during play testing. In the future I hope that it develops

[212] User survey response Mar. 26, 2011: 20:02:43
[213] User survey response Mar.22, 2011: 19:51:50
[214] User survey response Mar 22, 2011 18:49:56

to a point where the mind can be a controller for a game."[215] And users see BCIs' as: "exciting, futuristic, (and) it could help…..influence videogames and general future applications."[216] But user enthusiasm is often tempered by technical limitations. Some of these material limitations have generated modifications by developers.

Technical Problems: Signal and Design Limitations

There are several technical factors affecting user acceptance of EEG based BCI's, most introduced in previous chapters, such as signal processing and acquisition, information transfer rate, as well as unmet expectations of represented BCI functionality, as indicated in the previous user review. However, one of the largest issues indicated in user surveys has to do with signal limitations, as one respondent succinctly sums up problems with EEG interfaces, "EEG itself is its own limitation. There is only so much you can do with such a signal, unfortunately".[217] Another respondent claimed "As a general interface the lack of tactical feedback is a limitation."[218] Developer frustration with EEG signal processing is indicated throughout the survey, as one developer complained that it "takes time to get a good signal: dabbing electrode contact points with water helps. Movement artifacts are an issue that's tough to get around." [219] Moreover, there are problems with "latency between thought and action, too much continuous concentration for action-latching the thoughts through programming algorithms."[220]

However, a second limitation has to do with a design issue. Even if developers improve signal processing and information transfer rate, the issue of wearing a helmet poses a social and

[215] User survey response Mar. 23, 2011 13:21:22
[216] User survey response Mar. 27, 2011 5:44:57 AM
[217] User survey response Mar. 23, 2011 9:03:17
[218] User survey response Mar. 27, 2011 5:44:57 AM
[219] User survey response Mar. 30, 2011 14:03:08
[220] User survey response Mar. 24, 2011 10:31:45

fashion issue. Most (non)users would resist wearing a headset or head device, causing one respondent to declare that the problem was "Annoying headgear."[221] Moreover, the problem of limited head set adjustability contributing to signal inaccuracy raising concern that "Physical boundaries must be addressed as well – e.g. devices for children or smaller sized adults, [and] units for physically disabled people and the aged/infirmed. [and the] Current one size fits all is not valid when sensitive sensors are used."[222]

Modification Based on Design Limitations:

The design limitations of headsets, in some examples, have led to BCI acceptance and modification, rather than rejection. One respondent suggested a need not only to redesign the headset but use other forms for the body, "I have noted that these…BCI devices are sensitive to function on other parts of the body not just head gear. Suggestion: make bracelets or bands. Personal experimentation has revealed devices remain functional when worn on areas such as the leg. further testing required."[223] Another developer, based on resistance to head devices, modified EEG based BCI's. An independent developer, Peter Freer, has developed an EEG-based wrist band and armband called Body Wave.[224]

> … everyone complains about comfort and so on. So I started looking into the problem and I noticed that there were so many different manufacturers making headsets, and nobody wanted to wear them… and [people] were just too embarrassed to wear them in public…We'll wear things on our wrist, like a wristwatch, and we'll wear an armband, but we are not going to put a headset

[221] User survey response Mar. 22, 2011 18:21:51
[222] User survey response Mar. 23, 2011 13:42:16
[223] User survey response Mar. 22, 2011 18:41:49
[224] See http://www.freerlogic.com/body-wave/

on and parade ourselves in public.[225]

Redesign of BCI devices based on user resistance to headsets may be the first step to overcome user resistance to the more problematic technical and functional limitation of signal acquisition and lack of control. Moreover, the acceptance of watch based BCI's may be aided by recent innovations from the company Samsung, that released a Smart Watch called Galaxy Gear, which is capable of utilizing software applications and is used as a phone.[226]

<u>Gamer Acceptance or Consumer Resistance:</u>

While some users may be resistant to headsets and devices, another group may actually embrace headsets, users who are accustomed to peripherals. Gamers provide an exception to design limitation of helmets and the resistance to "annoying headgear." They utilize peripheral devices quite often for game uses in which they "turn…limitations into challenges [and]…deal very well with less than perfect control signals." [227] Not all users consider wearing headgear as problematic, in fact one respondent expressed how, "Wearing a headset looks cool.." [228] Peripheral devices are often utilized by gamers to enrich the experience of gaming. One reviewer of gaming peripheral devices expressed its benefits:

> …While fans tend to justifiably focus their attention on new releases and new hardware, sometimes things slip through the cracks, things that should and could have a big impact. Things

[225] Drew Brindle, "Brainwaves and Bobsleds: a talk with Peter Freer," Neurogadget.com, Feb. 12, 2013, "http://neurogadget.com/2013/02/12/brainwaves-and-bobsleds-a-talk-with-peter-freer/7081 peter freer CEO body wave made a wristband EEG-bci

[226] "Samsung galaxy Gera Smart Watch sell 800,000 Units in 2 Months," Apple Insider, Nov. 18, 2013, http://appleinsider.com/articles/13/11/18/samsung-galaxy-gear-smart-watch-flops-with-just-50000-units-sold---report

[227] User survey response Apr. 12, 2011, 5:06:20

[228] User survey response Mar. 27, 2011, 5:44:57 AM

> that make the gaming experience better all around. Some of those things are essential to the gameplay experience, things like a keyboard or a mouse for PC gaming. Others are just enhancements to the experience, things like gaming headsets, or in one case a gaming chair. [229]

A second reviewer of gaming peripherals reiterated the benefit of gaming peripherals:

> The beauty of high-end gaming peripherals isn't so much that you can be the envy of all of your friends….but that you feel elevated… making sure you have the best experience possible and you're more competitive in-game than the next person. [230]

Gamer's acceptance of BCI headsets and devices center on expectations of performance. However, these expectations may require re-configuring about BCI functionality, thus deemphasizing its limited control, and stressing its ability to maximize fantasy fulfillment in game use. Reconfiguring this expectation, may also mean a reconfiguration of game design for BCI headset and devices, and thus what gaming possibilities are about. As indicated previously, HCI developers, and companies such as Neurosky, are attempting to reconfigure expectations about BCI functions and possibilities to match user values of experiential enhancement. Yet, even with user resistance to BCI functionality users are maintaining interest in BCI's, as one observer indicated:

> …when I was at the "Next" conference here in San Francisco a few years ago, lots of people, especially middle school and high school age kids, were extremely interested in participating in a neural interface "push the ball over the line" demo, it was one of the most popular items there. I

[229] "Best Gaming Peripherals of 2012," Digital Trends, Dec.18, 2012, http://www.digitaltrends.com/gaming/best-gaming-peripherals-of-2012/ "Gaming peripherals: the unsung heroes of the gaming world.
[230] Alan Henry, "Are Premium Gaming Peripherals Worth Your Money?," tom's Hardware.com, Nov. 25, 2009, http://www.tomshardware.com/reviews/gaming-peripheral-mouse-keyboard,2467.html

> don't think lack of interest will be a problem.[231]

However, in regard to gamers what may contribute to rejection of BCI's are lack of applications that maximize play and enhancing experiences, because "…people don't play games to meditate. They play to get a 'buzz'." [232]

BCI's offer gamers a method in which to enhance experience, yet BCI's for daily use by other consumers and (non)gamers poses a greater challenge for BCI acceptance.

> The limitations that I see is (its) acceptance and resistance to believe that (what) they see is important… to show (that) BCI's (are) not (just) for people with physical limitation(s) and (to) demonstrate the benefits in their daily life.[233]

And another respondent to the questionnaire foresaw consumer acceptance as a problem due to social implications such as privacy issues.

> I see consumer acceptance being a big factor. If one can use the device to actually control a game character, gamers will be all over it. However the general populace might be concerned for privacy invasion and the like.[234]

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[231] User survey response Mar. 22, 2011 19:51:50
[232] User survey response Mar. 23, 2011 11:37:43
[233] User survey response Mar,.27, 2011 9:13:10 PM
[234] User survey response Mar. 23, 2011 13:21:22

Techno-Cultural Resonance: A Cultural Approach for the Consumption and Production of BCI's

As mentioned previously the main point of this chapter is to illustrate the relations between the users, producers, developers, artifacts, values, and practices, contributing to BCI use and production. This section interprets the relations in BCI production and use through the conceptual model introduced in chapter 1, techno-cultural resonance, which is an attempt to provide a symmetrical analysis of technological production whereby users, producers, and artifacts mutually constitute technological trajectories. An analysis of BCI relations reveals, 1) a tension between user expectations of BCI functions and producers representations and 2) the choice to use EEG based BCIs are not based on technical efficiency and function, rather are based on the practice and associated values play and the desire for self enhancement. As demonstrated in chapter 3 and 4 the values connected with practices of play are intended to enhance users experience through the immersion, fantasy, challenge, and sociality. And 3) the value and practice of play both mediates use and moderates production.

This method, as a cultural approach, stresses user agency and focuses on how consumption directs technological development, or rather illustrates how consumption is a form of production, whereby users have a degree of freedom in determining the value and use of technologies. Yet, "While the strength of a cultural approach is the emphasis on user agency, "…by focusing on use, (it) implicitly accept(s) the promises of technology and the capitalist relations of its production." [235] and consequently illustrates a limit to the approach. However, the productions of BCI technologies are not emerging simply to fulfill the promises of technological progress through economic and social necessity (although BCI's for disabilities serve this need) rather, its production for everyday consumers is also being shaped through the cultural reproduction of the shared value and practice of play. The practice of play illustrates a degree of

[235] Wyatt, "Technological Determinism," 69

user agency in that it defines the limits of BCI's, and thus contributes to BCI acceptance and modes of resistance.

Interpreting BCI User Case Dimensions Through TCR:

TCR is model/cultural approach used to identify the actors and relations in the development and use of an ambiguous technology. TCR as a methodological concept builds upon earlier works by user-technology theorists and contributes to a methodological approach for understanding socio-technical relations by identifying key relations in the way users link valued modes of behavior to artifacts, and consequently, delineates the processes by which users identities are linked to the uses, acceptance, and interpretation of artifacts. Further, the consequence of TCR as a model of technological development centers on the establishment of technology as a cultural source of value and meaning which mediates and moderates social behavior.

To reiterate the concept introduced in chapter 1: *Techno-cultural resonation* (TCR) is an expression of the triadic relationship between an artifact, its (non)users, and developers, when a group(s) adopts a technology based on a set of pre-existing user group values. *Techno-cultural resonation* is an expression of the degree to which the material characteristics and capacities of an (un)stable technology correspond with the social values, customs, practices and expectations of relevant users and with the representations, technical values, or presumed uses by designers.

Based on TCR as a conceptual model, this case study illustrates that that in many ways users resonate with the represented values of BCI's, as a mode to enhance experience, but fall short of technical and functional expectations. The producers of BCI headsets have represented these controllers as thought controlled interfaces however, the use of BCI's has led to user and developer recognition that BCI's are limited as controllers. In this sense the represented capacities of BCI's fail to meet the expected functions of BCI users. This has led to resistance in both end users, those using end products, and developer-users, those consuming BCI headsets in order to develop additional software products. In regard to user acceptance of technology Kline and Lagren illustrate how:

> …resistance occurs in situations where prescribed uses and symbolic meaning attached to technologies by their producers or promoters do not correspond to the gender relations, or the cultural values and identities of specific groups of people. [236]

Although in this case the prescribed uses of BCI's as a thought controller fail to meet user expectations however, the represented value of BCI functions as a way to enhance user experience and performance do correspond to and resonate with user expectations and practices. BCI's match developer-users enthusiasm for the ability to fulfill the enhancement of self through fantasy and immersion in a computer simulated domain through the enjoyment and practices of play. Therefore, the value to enhance experience corresponds to BCI's material capabilities, although not the prescribed function of control. These values resonate with both end users and with developer-users who are augmenting BCI software to accommodate BCI hardware limitations. The value and practice of play coupled with the material and functional capacities of BCI's as mode to augment user control resonates with identities of users. Therefore, the relations between users, BCI's developer and producers, represent a partial resonation between these entities. In other words, the relation between the expectations of users and the represented technical functions of BCI's as a viable alternative interface, as well as between the represented

[236] Oudshoorn et al., "Introduction,"19

values of BCI's by producers, to fulfill modes of enhancement, with the existing practices of play and values of users, simultaneously leads to both user acceptance and resistance to BCI's.

The usefulness of TCR as a method to articulate the relations between artifacts and subjects needs to be explored in more depth. My attempt here to focus on the cultural values and practices which are moderating production and mediating use. I use the term moderate to refer to the way play serves as a value that shapes and define the limits of BCI functions and hence BCI production. I use the term mediation to refer to the process in which play serves as the mode through which BCIs are experienced by end users. I believe the subtle yet, important distinction between moderate and mediate, help distinguish between the function of play for the end use of BCIs and production uses of BCI's, that is between end-users, such as gamers, and user-developers, such as HCI and BCI developers. This is not to say developers practices are not mediated by the activity of play, here too the limits and potential functions can be explored with BCI's, or that the value of play does not moderate the end-users BCI interaction. However, the set of relations between users and BCI devices, usually in form of toys, games, social applications, is more evident and characterizable as the mediated activity of the play. Whereas, developers, and BCI producers have identified user values generated by play, through user studies and games, and utilize these values in ways that moderate decision making in the production and representation of BCI's.

<u>Function of Play in BCI Production and Use:</u>

First, play serves as an activity in which the boundaries between user expectations and the limits of artifacts are defined, play as a form of use, mediates the activity between an artifact and the end-user. This is apparent where end users, those not developing software applcations for

BCI devices, interact with devices and games through play, and recognize the limits of BCI control. These actions of use initiate a process of production based on resistance. Ronald Kline calls "these actions 'transformative resistance' because they help to create technological and social change." [237] Production is the outcome of the process which starts with user engagement with BCI hardware and software through the activity of play in which they recognize the limits the function and design of BCI's. Through play end-users reproduce values (immersion, fantasy), which configure developers and producers to shape BCI applications around the reproduction of play.

Secondly, play shapes production such that it serves as a value which structures how artifacts are developed, and in this sense the developer is an interpreter and mediator. Bruzheze and Schot have argued that mediators are critical in the development of technological development:

> …central to our perspective is a focus on the medication process between production and consumption. We…characterize this mediation process as a process of mutual articulation and alignment of product characteristics and user requirements. [238]

Developers serve as mediators and translators of BCI's for consumers. Chapter 3 illustrated how developers in HCI networks are serving as mediators or translators for BCI technologies to users such as gamers in the (re)production of BCI's. Therefore, developers act as mediators between users and BCI's in which play serves as a moderating value aligning BCI functions and limits with user expectations. However, these developers are also users and

[237] Kline, "Resisting Consumer Technology," 53
[238] Schot, et al. "The Mediated Design of Products," 231

consumers of BCI's and as the surveys above illustrate developers are significant actors shaping the development of BCI's by identifying various limits and defining potential uses.

Some BCI User-Technology Case Implications:

This case has shown how limitations of BCIs have redirected the development of BCI applications, and well as how BCI limitations are translated into pre-exiting uses and values (i.e. less control into enhancement), in which developers act as translators of user requirements and values. Moreover, the values of gamers and HCI developers are reshaping games to include BCI's for the augmentation of interface control. Independent developers, such as Lat Ware, are an illustration of how developer and BCI's reshape games.

Secondly, this case illustrates the generalized user-developer profile of those consuming and producing BCI's, are middle aged white, males, which means a particular set of group values are being utilized to promote and develop this contingent technology. Less visible users from different social and class positions, such as woman and minorities, would reflect a different set of values and reorient BCI production and use. However, based on this case profile the value of enhancement is being promoted for health, performance, and experience.

Third, BCI use and development illustrates a constrained form of user agency, in which user values, associated with practices of play, are configuring developers and producers to redevelop BCI's around these values and practices. The subject arises as to the question of whether these values and practices themselves are the outcome of the larger processes and system of the political economy of consumption, such that the reproduction of technologies of play is rather the outcome of political and economic practices. David Harvey observes that media technologies and the values that surround them, such as the television, are (re)generated by these larger systems.

> For television is itself a product of late capitalism, and as such has to be seen in the context of the promotion of a culture of consumers. This directs our attention to the production of needs and wants, the mobilization of desire and fantasy of the politics of distraction as part and parcel the push to sustain sufficient buoyancy of demand a consumer markets to keep capitalist production profitable.[239]

The question arises whether BCI production and use is an illustration of larger economic forces, and not user agency, because BCI technologies are being produced in order to reproduce the practice of play and promote desire, and enhancement. While BCI's are certainly being developed for economic interests to promote enhancement, and desire, the modes of production and use, are not simply moving uni-directionally from industries to consumers, and hence reflects a degree of individual agency within a larger political economy. This case illustrates that the production and use of BCIs are emerging not only from larger companies, but the location of work and play has shifted to include the home office and workshop, and small groups. The boundary between play and work, both private and publicly has eroded, whereby an exchange of ideas is occurring between heterogeneous groups via social media and the internet.

<u>A Brief Description of Technology:</u>

Before I discuss the ways that play functions as a technology, I need to discuss the notion of technology. Defining technology proves just as challenging as defining play, and therefore cannot discuss technology as thoroughly and significantly as the notion warrants. However,

[239] Harvey, *The Condition of Postmodernity*, 61.

certain characteristics of technology overlap with aspects of play and by highlighting these common features a richer understanding of technology and play can emerge based on the current historical context. To reiterate, I am specifically building on Joe Pitt's definition of technology as humanity at work, introduced in chapter 2. This definition reflects most assessments and discussions of technology, which center around tool use and the activity of work, both domestically and industrially, for example, in Ruth Cowan's analysis of domestic technologies that affect housework, which she calls the "work process,"[240] and industrially with large-scale technological systems, such as Thomas Hughes and David Nye's histories of the American electrical system. However, I provide a corollary to this definition and argue conversely, that technology also includes humanity at play. I believe this dual definition, illustrates what is central in locating and centrally defining technology which is *technology is a cultural activity*.

> Whatever science and technology are, they must be understood as historical phenomena that must be seen in the specific *socio-historical contexts* that give them their distinctive characteristics. Since social context change over times we should therefore assume that science and technology, seen as historical phenomena in changing social contexts, will change themselves.[241]

My argument that play as a cultural activity and value have become an integral part of technological use and production has important implications for understanding technology in the current socio-historical context. This recognition leads to important questions such as, how does play as a technological activity shape our social relationships, in work, in school, in everyday life. I will discuss some of these questions in the concluding section of this chapter. First,

[240] Cowan, *More Work For Mother*, 11
[241] Pitt, *Thinking About Technology*, 28

however, I will briefly highlight four general characterizations of technology.[242]

The first and most common usage for understanding technology distinguishes it as an artifact or hardware, which includes tools, such as a screwdriver, hammer, and more contemporarily, a computer. Moreover, this usage entails the distinction between natural objects and a non-natural objects, and usually assumes technology is the result of human fabrication. However, the categorization of technology as a uniquely human domain has been challenged in which the boundaries and similarities between human and animal fabrications draw some comparability yet, understanding technology as a cultural product limits that comparison. Technology is more commonly associated with artifacts and social systems in which artifacts are produced and used, yet it is also embodies forms knowledge, techniques, and methods. This leads to the second characterization of technology which refers to a set of methods, procedures, knowledge, or techniques. Jacques Ellul defines *technique* as "the totality of methods rationally arrived at and having absolute efficiency."[243] However, this formal characterization of knowledge and technique need not be the outcome of efficiency and may emerge from other values as well, such as a set of methods generated to perpetuate values of quality or durability. The third usage of technology refers to systems of manufacture and distribution which include all the resources, equipment, and skilled people involved in a network which generates a types of software or hardware. These include production of computers, microchips, automobiles etc. As a generalization, a system of manufacture refers to the experts, scientists, and innovators involved in the production processes of physical artifacts. The last characterization refers to technology as a socio-technical system of use, such as a network of roads for vehicles, the internet, or social media and communication, in which the emphasis is on social interaction, consumption, and the

[242] Kline, "What is Technology," 215-18
[243] Ellul, *The Technological Society*. v

generation of meaningful symbolic associations. In a general sense this refers to the end users and consumers of hardware generated from manufacturing systems.

However, the boundary between these four characterizations is tenuous such that the relations between an artifact, production, use, and knowledge, are neither uni-linear nor act as discrete entities and rather, mutually constitute each other in multidirectional processes. Taken together these general characterizations lead us to the more fundamental characterization of technology *as a cultural activity*. The socio-technical methods, processes of use and production are based on rational, functional, and symbolic values that are woven into the fabric of human relations. These products and systems are employed and developed because certain values are emphasized over others which direct development in those areas, not simply, or solely for the production of an artifact to serve some utilitarian necessity or function for humanity.

Relatedly, technology as a cultural activity becomes a source for the exploration of personal identity as well, such that technology as a value and activity becomes a means by which individuals develop and reinforce social conceptions of the self and personal identity. The identification process can be seen in self-representations as well as marketing strategies and processes, for example self-identification with computers is illustrated through an explicit difference made between those who use personal computers that is PCs or those who use I-mac computers by the company Apple. Technological activity as mode of self-identification embodies value and knowledge production, in which individuals develop skills and knowledge to enhance the self. There are "…different ways in our culture that humans develop knowledge about themselves:"[244] The scholar Michel Foucault refers to this set of knowledge as :

> …technologies of the self, which permit individuals to effect by their own means or with the help

[244] Foucault, *Technologies of the Self*, 17-18.

of others a certain number of operations on their own bodies and souls, thoughts, conduct, and way of being, so as to transform themselves in order to attain a certain state of happiness, purity, wisdom, perfection, or immortality.[245]

Play as Technology:

Including the dimension of play within a framework of technological production and a definition of technology presents the opportunity of enriching our understanding of technology in terms of the cultural meanings and uses of technology. I cannot adequately address the subject of play in culture or define play in its heterogeneous forms, which include its connection to child development, language, ritual, rules, and culture.[246] This would be a potential topic developed later and in more depth. However, a brief discussion of play becomes essential for this case because, BCI's are being produced and introduced through games and toys in order to reproduce the activity of play, and moreover, framed by users and developers through the rhetoric of play. Discussing and identifying some elements of play will provide a nexus toward understanding technology and the technological development of BCI's and user acceptance and resistance. However, I will briefly introduce some early theorists and conceptions of play.

Brief Definitions and Theoretical History of Games and Play:

There are two important distinctions when discussing the notion of play. First, a conceptual difference exists between play and games, although the understanding of each concept requires understanding of the other such that they are interdependent. The second

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[245] *Ibid.* 18

[246] For other definitions of play and games: see Mead, *Mind, Self & Society*, for play and conception of self in child development; see Dewey, *Democracy and Education*, for relations between work and play; see Bateson, *Steps to an Ecology of Mind,* for play as communication; see Jenkins, "Games, The New Lively Art," 175-92, for aesthetics and art in games; and see McLuhan, *Understanding Media*, for games as cultural extensions.

distinction is made between serious activities in which work becomes a primary comparative concept, and the activity of play, which typically is associated with non-serious activities.

The first distinction in discussions of play is the difference between games and play. In some languages the two words are versions of the same word such as in French, for "to play" and "game" is "à jouer" and "jeu," and in German, the word for play is "spielt", and for game is "spiel." And some early theorists of play do not differentiate between games and play. However, different words are used in English which offers distinct categories.[247]

The definitions of game and play that I utilize to make comparisons to technology are from game designers and scholars who build their definitions based on multiple theoretical perspectives. Katie Salen and Eric Zimmerman define a game as "..a system in which players engage in artificial conflict defined by rules that results in the quantifiable outcome."[248] This definition of games entails multiple dimensions, such that games are composed of a system in which players interact with the system, which is an artificially constructed boundary from real life, of which there are rules in which players engage in conflict with quantifiable goals and outcomes.[249] These theorists point out the relations between play and game are quite complex such that games can be a subset of play or play can be a subset of games. However, the useful comparison based on their definition is that games are analogous to a technological artifact or hardware in which there are purposely constructed boundaries but multiple ways to interact within those boundaries. Play can be compared to technology as a set of values, knowledge, skills, and ways in which we use and interact with games. These analogies favor games as a subset of play, which is intentional because this is a discussion and argument for play as a form

[247] Salen and Zimmerman, *Rules of Play*, 72.
[248] *Ibid.* 80, and for additional information of defining games see 71-91. Also see Egenfeldt-Nielsen, et al., Chp. 3 in *Understanding Video Games*, and Mäyrä, Chp. 2 and 3 in *An Introduction to Games Studies.*
[249] Salen and Zimmerman, *Rules of Play*, 80

of technology. However, games have multiple components other than just play, such that, to understand games, a framework in which play is a subset of games would be more productive.

Again, I utilize and build on the meaning of play articulated by game designers, they define play as, "...free movement within a rigid structure."[250] This definition is useful in articulating how play as an activity can be connected to user agency, forms of resistance, and modes of individual action, reason, and the imagination, in which users creatively interact with familiar elements in unfamiliar ways. Moreover, I would add that play is free and exploratory movement between structures as well as within. This last distinction is a feature unique of what is called transformative play which I will discuss later in this section.

The second distinction, is that play is a non-serious activity and therefore separate from activities such as work and everyday life. As indicated earlier, technology is typically associated with work, and therefore activities that are considered serious. Moreover, technology is usually associated with serious, work related activities in which its production is based on rational, formal rules, knowledge and techniques and is not usually associated with related forms of play as a set of values and an activity. However, a strict boundary is hard to maintain when we understand that play is not separate activity from normal life such that it shapes social interaction and influences cultural practices and values.

Two early socio-cultural theorists who argue that play is outside ordinary life, are Johan Huizinga and Roger Caillois. Their emphasis, on the separation between ordinary life emerges from their project goals and disciplinary perspectives in which they both were concerned with how play functions within sociological and cultural domains, such as in ritual. Johan Huizinga published his dissertation in 1938 entitled "Homo Ludens" or "Man the Player", in which he

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[250] *Ibid.* 304, This definition is based on 1) game play: play within a game, 2) ludic play: "Playing" activities, more than games, 3) being playful: spiritness, state of mind. 302-304

characterizes play, and games as a "Magic Circle," which is conducted outside ordinary life, rule bound, not serious, utterly absorbing, without material interest or profit, operates within its own boundaries of time and space, and creates social groups of separate themselves.[251] The second theorist Roger Caillois also characterizes play as outside ordinary life. Caillois builds on Huizinga's works, in his 1958 book, "Les Jeux et les Hommes," and published in English in 1961, as "Man, Play, and Games." Roger characterizes play as free, separate, uncertain, unproductive, rules, and make-believe.[252]

There are limits to this characterization of play, and games, as a separate domain of ordinary life. Games and play affect life in real ways, such as affecting moods, values, skills such that even ethical frameworks can be learned.[253] For example, as one blogger described about playing the game Dragon Age:

> …the game is remarkably coherent in advancing a particular worldview—one that I *think*, from my conversations with my BFF (a recovering philosopher), would correctly be described as utilitarian. As you play the game you are forced to make moral choices, and sometimes there is no purely "good" option. Instead you have to decide what kind of sacrifices you're willing to accept in the name of the greater good. This is, from my perspective, what the game's *about*. It has multiple interweaving storylines—potentially hundreds of them—but the main plot elements all reinforce the same theme: There is no victory without sacrifice.[254]

[251] *Ibid* pg 75, and for additional summary see Egenfeldt-Nielsen et al. *Understanding Video Games*,24-25, and for the original source see Huizinga, *Homo Ludens*.

[252] Caillois also refers to four forms of play: agon, (competition), alea, (Chance), mimicry, ilinx (vertigo), and two types of play, Ludus: structured activities, and paidia :spontaneous, and unstructured. Also for an extended summary see: Salen and Zimmerman, *Rules of Play*, 75-76. And see: Egenfeldt-Nielsen, et al.,*Understanding Video Games*, 25-28

[253] See Gee, *What video games have to teach,* 2003, and see: Egenfeldt-Nielsen, et al., *Understanding Video Games, 25*

[254] Shannon Phillips, "Dragon Age Postmortem: Oh, Alistair," (blog), Sept. 8. 2010, http://shannon.users.sonic.net/blog/?p=1223

Aside from ethics, play and games increasing affect the economy, and are advanced for material, gain where, even "artificial" and objects separate form this world are bought and sold on ebay and online games sites to be used in Multi-Massive-Online-Role-Playing-Games (MMORPG's).[255] Moreover, gamers interact with other avatars based on social, class, and gender assumptions.

However, Huizinga and Caillois conceptualization of the separation of play from ordinary life has some merit. It's clear that play and games affect ordinary life however, their emphasis on the separation of play, may have more to do with the recognition that play as an activity is a constructed space to explore possibilities and limits, in ways meant to separate themselves from "normal" moral and social contexts, not that the play is an impermeable nor immutable space. In this sense, they may be right, not to the extent that social, moral, and economic values and practices, do not shape play, but rather that the activity of play is unique mode of action which creates a space in which free exploratory activity occurs in which to test boundaries of objects.

Others theorists, such as philosophers, note the importance of play and its function in skill and knowledge production and in social development, and ultimately how play actively effect ordinary life. John Dewey notes the importance and function of play in work and in educational curriculum.

> ... Play and work correspond, point for point, with the traits of the initial stage of knowing, which insists…in learning how to do things and in the acquaintance with things and processes gained in the doing… It is suggestive that among the Greeks, till the rise of conscious philosophy, the same

[255] For examples of buying and selling game items see: http://www.mmosale.com/wow-game-items-c-172_173.html

word… Was used for art and science.[256]

Moreover, Dewey stresses how play adds deeper meaning of ordinary activities in life.

> Play and art add fresh and deeper the meaning to usual activities of life... For their spontaneity and liberation from external systems permits to them an enhancement and vitality of meaning not possible in preoccupation with immediate needs.[257]

And further, of the moral importance of play as a form of activity which is necessary for "re-creation." Dewey notes how activities of play mediate tensions of moral routine and work.

> The service of our employees to engage in these impulses in ways quite different from those in which they are occupied in employed in ordinary activities. The function is to forestall and remedy the usual exaggerations and deficits of activity, even of moral activity which permit a stereotyping of attention.[258]

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Another philosopher, George Herbert Mead, also stressed the importance of play not only its effect on everyday life, but in the production of the Self. In his book "Mind, Self and Society," Mead argues that the self arises in a child's development and that play serves as contributing factor in the learning process in which the child comes to understands normal social human activity and communication.[259]

Most recently, the scholar Brian Sutton Smith, in his book the "Ambiguity of Play"

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[256] Dewey, *Democracy and Education*, 203
[257] Dewey, *Human Nature and Conduct*, 111-12.
[258] *Ibid.* 112
[259] Mead, *Mind, Self and Society*, and for summary of Mead see Egenfeldt-Nielsen, *Understanding Video Games*, 30-31

classifies the cultural usages of play under seven distinctive rhetorics of play, rather than under one definition:

> In what follows, the rhetoric's that are the focus of this work will be called popular ideological rhetorics… The popular rhetoric's are large-scale cultural "ways of thought" in which most of us participate in one way or another… The larger play rhetorics are part of the multiple broad symbolic systems-- political religious social and educational--through which we construct the meaning of the cultures in which live.[260]

The seven rhetorics include *play as progress*, play usually associated with social development for children; *play as fate,* such as chance; *play as power*, such as sports and athletics; *play as identity*, such as community celebrations festivals maintain identity and community of players; *play as imaginary,* which involves the idealization of imagination flexibility creativity and sustained by positive attitudes toward innovations; *the rhetoric of the self* usually associated with forms of play that are solitary in order to increase desirable experiences; and *play as frivolous* as such activities and frivolous and foolish.

These ideological rhetorics in which we make sense of play are helpful in understanding the connection between play as an activity which is a form of technological use and production, In particular play as imaginary, play as self, and play as progress. "The rhetoric of progress, the rhetoric of the self, and the rhetoric the imaginary constitute the modern set of rhetorics with a history largely elaborated ideologically only in the past 200 years." [261] The interaction between these domains illustrates the features of play which contribute to an understanding of play as

[260] Sutton-Smith, *The Ambiguity of Play*, 8-9. And for the seven rhetorics: play as progress, play as fate, play as power, play as identity, play as the imaginary, play as self, play as frivolous, 9-11.
[261] Sutton-Smith, *The Ambiguity of Play*. 11

technology. In particular, the rhetoric of play as self links to the cultural values shaping BCI production and use. Play of self is defined as:

> …forms of play in which play is idealized by attention to the desirable experiences of the players- their fun, their relaxation, their escape- and the intrinsic or the aesthetic satisfactions of the play performances. [262]

Contributing to play of self is the imagination, through which the self seeks desirable experiences which test the rules of an artificial world, bringing with them a set of values and knowledge from the real world, which in turn shapes the progress of the self and which produce skills and reproduce values. However, to what end remains indeterminate although play as an activity is an experience through which individuals are trying and testing whatever the limits the game or circumscribed domain of play permit.

The process under which an individual engages in play leads to possibilities of change or transformation. The philosopher Hans James says the "role of play is not to work comfortably within its own structure but rather constantly develop structures through play." [263] This process is called *transformative play*, and at these moments the link between the technologies of self, sets of values and practices learned through play, and hence as a technological activity, the notion of transformative play links to forms of use and production in which limits and boundaries are resisted or accepted. Transformative play is a type of play that occurs: "when the free movement of play alters the more rigid structure in which it takes place."[264]

This notion proves useful in this case because we can see practices of play with BCI

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[262] *Ibid.* 11
[263] Hans, *The Play of the World,* 5. And for a summary see: Salen and Zimmerman, *Rules of Play,* 305.
[264] Salen and Zimmerman, *Rules of Play*, 305

technology that reinforce or promote the ideal sense of self. In games one is allowed to develop abilities outside of normal capabilities. Company representations of BCI's promote the idea of BCI's enhancing the self, with meditation and performance applications. Or in the case of EEG devices, such as Necomimi's EEG- controlled cat ears, in which playfulness and interaction with the device come to mark an expression of self. As one respondent claimed his interaction with BCIs was "Not only both work and play, but also potentially transformative."[265]

Forms of Play as Technology:

My argument is not that play is the only mode of action in which artifacts are developed, but rather is a contributing mode of action in technology. The point is to demonstrate how play as less a visible mode of action contributes to technological development and use. The first way play overlaps with definitions of technology is, play as technique, skill, and knowledge. In this sense, the notions of scientific hypothesis, methods of trial and error, or technological tinkering, are closely associated with whimsical activity of play. In the previous discussion of play we saw how play as a mode of action through which a person undergoes experience, not passively but actively, with goal oriented focus, and simultaneously as a mode moderated by social skills and values that shape the direction of the goal. This means that emergent properties can arise through play such that new skills and knowledge are produced in which play mediates subject-object relations. The mediation of play between users and artifacts generate knowledge and skill sets, as can be demonstrated with video games. One example is a study by the U.S. Army's telemedicine and Advanced Technology Research Center which reported that "surgeons who play video games three hours a week have 37% fewer errors and accomplish tasks 27% faster." [266]

[265] User Survey response, Mar. 22, 2011, 19:51:50
[266] Reuters, "Nintendo Surgeons More Precise?" reposted in *Wired,* Dec. 19, 2004.

And the most pervasive form of play as technology is play as cultural activity, both in production and use. This has led to the production of artifacts, which in chapter 4 illustrated how play of video games helped push development in graphics, chip speed, and user interfacing. The implications of play as cultural activity are not that domains within culture are circumscribed as sacred and immutable, as in ritual functions, which increasingly the secularization of sacred functions has eroded those spaces, but rather through these domains new values emerge, in which the pursuit of users to transform themselves generate the reproduction of identities and the production of new directions in which to develop play.

Conclusions of Technology as Play:

Including play as a form of technology returns a technological definition to some earlier conceptions. Based on earlier Greek definitions, the term *Techne,* is used to designate productive skill as opposed to theoretical knowledge (*episteme*) (science and theory). Techne occupied a space between mere experience and theory (immutable/certain). Techne as productive knowledge was a "becoming" and 'what was to be," it designated a realm separate from *chance* (tyche) or instinctive ability (physis). Techne occupied a space between *nature* and *chance.*[267] In this sense play, as a skill, is closely associated with the notion of techne.

Play is an informal, yet integral, social activity involved in the technological production of BCI's and within the current socio-historical context. I am not suggesting that play is the singular activity involved in technological production but the concept of play can serve as a corollary to expand the definition of technology, and go beyond definitions of technology associated with work processes and production in public and private spaces. In particular, play,

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http://www.wired.com/medtech/health/news/2004/12/66086
[267] Garrison, *Dewey And Eros*, 8-9

both as a cultural value and practice is shaping the development and the consumption of technologies.

This has important implications for questions surrounding the goal of technological production. If technology is to serve the practical goals and needs of society then how is the production of technologies which enhance simulated experiences with computers meeting this goal? Is the production of technologies aimed at promoting the fulfillment of immersive computer simulated experiences a practical and reasonable goal for social progress? The implications of the use of BCI's for play will be discussed more in chapter 6, in particular the ethical implications of using BCI technologies for enhancement. However, based on this BCI case it's clear that play is a mode of techno-cultural production.

Chapter 6:
The Implications of BCI's for Play

Introduction:

This case demonstrated how BCI's have emerged from medical fields into consumer domains for alternative computer and gaming interfaces. This transition is due to the cultural and economic success of gaming, the overlapping narratives between these domains which center on the goals of performance and experiential enhancement, and the technological enthusiasm about the potential to control devices with the mind. Material and technical factors have also contributed to their development, including the availability of computer software and hardware, increased portability, and decreased cost, which has afforded a degree of flexibility in their technical functions and software applications, which align with existing user values and activities of gamers, developers, and various media consumers. Yet, certain philosophical, ethical, and social implications emerge when considering BCI technologies and their use.

Philosophical, Ethical, and Social Implications of BCI Use:

There are some important implications to consider with the BCI development practices of correlating software and hardware functions with brain mapping and imaging techniques. If technological mapping is a partial representation of the body and brain, and that representation provides the basis for BCI commands, then the expression of that particular BCI command starts to reinforce individual particularities over the potential diverse expressions of an individual's bio frequencies. In other words, through continued use of BCI's particular frequencies are reinforced over others. Even though the BCI developers and companies producing neuro products only intend to provide alternative forms of control for users, the consequence of using BCI's may impact users beyond designer intention.

This conclusion is partially based on the assumptions that operant conditioning of the autonomic nervous system (ANS) and central nervous system (CNS) actually occurs. As indicated in chapter 3, there is some controversy whether long term conditioning of the CNS actually occurs. However, even if long term conditioning of the CNS does not occur, at the very least the short term conditioning of individual behavior in the form of habits becomes significant. Thus, the emergence of habits and a set of embodied skills will develop reinforcing particular electrical modes or states. The conditioning of the ANS and CNS is the goal of neurofeedback. For example, the goal of ADHD Neurofeedback training is to diminish theta activity, which are frequencies correlated with ADHD, and reward beta waves, frequencies correlated with attention and focus. However, frequencies are correlated with a variety of brain states and modes of thought, where theta activity is also correlated with high creativity and artistic states.

Given the assumption that the use of technologies contribute to the building of skill sets and knowledge, for example just as repetitive use with tools can develop increased skills and knowledge, then by extension the use of technologies such as BCI's can contribute to the development of a set of skills, and knowledge. However, what sort of skills or knowledge is being developed when one frequency is developed over another?? What sort of individual emerges? What sort of social habits emerge? What sort of "thinking" states are developed and promoted over others? What are the implications of such developments? These questions become difficult to answer because the use of BCI's through play occur as invisible transformations yet will manifest as normal modes of social activity, and become translated into naturalized forms of cultural life.

However, users, developers, and policy groups are asking similar questions and have similar concerns as well. In the user surveys some respondents expressed concerns over the consumer use of BCIs: “Companies do brainwave training and have very little idea what they are doing, yet market as though they do. Eventually someone will have negative side-effects due to such.”[268] One survey respondent expressed that there will be problems with consumer acceptance of BCI’s “due to ideas of tracking and "intrusion" misuse.”[269] The social concerns surrounding privacy and misuse of BCI’s oddly has been demonstrated by the same people who have these concerns. A group of international researchers have shown how a captured signal from common EEG- based BCI devices can be mined for data which can be used to significantly increase the odds of guessing personal data such as pin numbers for an ATM account (Signals captured for instance from NeuroWear’s Neurotagging software introduced in chapter 3). They increased the odds of figuring out private information over random guessing by presenting stimulus to users and analyzing the corresponding signals.[270]

In addition, the concern that non-therapeutic uses of EEG based BCI’s and neurogadgets may have consequences beyond the goal of enhancement and control has lead the independent policy advising body of the Nuffield Counsel on Bioethics to issue a report. The council outlines several key interests concerning the use of BCI’s surrounding issues of privacy, the promotion of autonomy, and the public understanding of neuro-technologies.[271] In an extensive 300 page report it outlines a host of considerations in regard to the use of BCI’s and neuro-technologies for therapeutic and non-therapeutic uses, which includes military use for interrogation, therapeutic and non-therapeutic neural enhancement, and BCI use in media and video games. The issue of military use reflected concerns from respondents in the user survey as well. One respondent

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[268] User survey response March 23, 2011 11:37:43
[269] User survey response March 23, 2011 20:49:12
[270] Damon Poeter, “Scientists Warn of Brain Hacking Via BCI Gadgets,” *PC Magazine,* Aug.30,2012, assessed July 2013, http://www.pcmag.com/article2/0,2817,2409160,00.asp
[271] “Neurotechnolgy,” Nuffield Council on Bioethics, Last modified May, 2013 http://www.nuffieldbioethics.org/neurotechnology

expressed concerns about, “Overly cerebral applications, military applications or control applications which generate profits for the unscrupulous.”[272] The council has advised the European Commission to consider classifying these devices as medical devices regardless of their marketed use, primarily because there is limited evidence about the effects and uncertainty surrounding the represented benefit of neural enhancement.[273]

Biomedicalization of BCI’s:

Based on this uncertainty it is important to consider the use of BCI’s for therapy in conjunction to BCI’s for non-therapeutic uses. BCI’s are being used or can be used for therapy However, most artifacts defined as BCI’s for therapy are marketed as training devices or software to help develop or enhance performance, memory, skills. There are several HCI studies which have documented “improvement” of subject’s performance.[274] So the distinction between BCI’s use for training as opposed to therapy is simply a difference in the description of use rather than its substantive use, in which those uses for therapy are subjects to be treated for sickness or abnormality compared to healthy users who use devices for enhancement. However, the characterization between therapy and enhancement is problematic. The standards of what constitutes classifications of “normality” are historically and culturally contingent. Are the uses of BCI devices an enhancement or a treatment?

Describing the current uses of BCI’s illustrates what has been observed sociologically as the recognized distinction in the history and cultural practices of medicine and has been characterized as the shift from medicalization to biomedicalization. That is shift from external

[272] User survey response 3/22/2011 18:31:05
[273] For ethical concerns about BCI’s see: Rutger Vlek et al., “Ethical Issues in Brain–Computer Interface Research, Development, and Dissemination.”
[274] For one BCI study on performance see: Lee-Fan Tan, et al. “Effect of Mental Training on BCI Performance.”

control to internal *transformation*, in which, "Innovations and interventions are not administered only by medical professionals but are also 'technologies of the self,' forms of self-governance that people apply to themselves."[275] The use of BCI's reflects this socio-historical trend.

Future Directions:

While this project emphasized the agency of users in the design, production, and appropriation of BCI technologies in the domain of gaming and consumer applications, the subject of this project provides the potential for many different approaches and studies. One of the most important areas for future studies is the impact of BCI's in the medical field. BCI's offer increased mobility and control for those with disabilities.[276] There have been many cases in which BCI's are being used successfully as assistive technologies, from opening doors,[277] and operating wheel chairs,[278] to controlling appliances in the home.[279] A future study which focused on users with disabilities and how they interpret BCI technologies would provide further insight on issues of BCI acceptance, technological development, and the relations between identity construction and technological objects.

Moreover, the use of EEG technologies within the medical field provides the opportunity for a more developed project to articulate the professional division and history of the BCI industry and the neurofeedback industry and their unique identities and influence on the acceptance, development, and impact of these technologies in society. The main distinction

[275] Adele Clarke, "Biomedicalization,"165
[276] Pasqualotto, et al. (2012). "Toward Functioning and Usable Brain-Computer Interfaces ," 89-103
[277] Miki Fairley, "BCI Devices Open Doors for People with Disabilities," accessed Oct.15 2013 http://www.oandp.com/articles/2009-02_10.asp
[278] "Brain-Computer Interface Can Help Those with Disabilities," AMS Vans, last modified Mar. 29, 2011, http://blog.amsvans.com/brain-computer-interface-can-help-those-with-disabilities/
[279] Jeremy Ford, "Though-Wired Allows Disabled to Control Home Appliances with Mind Alone," last modified May 5, 2011, http://singularityhub.com/2011/05/01/thought-wired-allows-disabled-to-control-home-appliances-with-mind-alone/

between BCI and Neurofeedback technologies is the direction of control, in which BCI technologies are designed and intended for users to control machines and neurofeedback technologies are designed and used to control or change the electrical frequency or output of users. Neurofeedback technology has been used in conjunction to treat a variety of disorders: ADHD, epilepsy, Autism, etc.[280] Some controversy surrounds the use of these technologies for treatment, in terms of their efficacy, safety, and privacy for subjects.[281] However, the use of neurofeedback technologies provides an opportunity to explore the impact of these unique technologies on individuals and society.

In addition to an expanded study of the history and development of BCI and Neurofeedback technologies in the medical field and their impact on individuals and society would be future studies contingent on the wide spread diffusion of BCI's in society. If BCI's are successful then understanding the transformation of social habits through the use of BCI technologies would bring important insight into the cultural values which are directing technological development. And conversely, if BCI's fail to have a widespread impact, then understanding how they "failed" would reveal important insight the ways users resist and reject technologies.[282]

Beyond BCI uses for medical purposes and disabilities BCI platforms companies, such as Emotiv and Neurosky, have identified market trends and user and potentials. BCIs are being designed for consumer applications built on two approaches, one in which users intentionally try to control a system and another approach is to build a system and products that passively monitor

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[280] See: Mirjam E.J. Kouijzer, "Neurofeedback Treatment for Autism Spectrum Disorders," Tim Williams (Ed.), (InTech, 2011), accessed Nov 15, 2013, http://www.intechopen.com/books/autism-spectrum-disorders-from-genes-to-environment/neurofeedback-treatment-for-autism-spectrum-disorders-scientific-foundations-and-clinical-practice

[281] Carole Jacobs and Isadore Wendel, "Pros, Cons, and Controversy," accessed June 13, 2013 http://www.netplaces.com/adult-add-adhd/healing-through-neurofeedback/pros-cons-and-controversy.htm

the users cognitive state as they behave in the world.

> Rather than building systems in which users intentionally generate brain signals to directly control computers, researchers have also sought to passively sense and model some notion of the user's internal cognitive state as they perform useful tasks in the real world.[283]

This flexibility in BCI use serves as possibilities for future research subjects.

Conclusions: Mindful Thoughts

Finally, several general points can be made about this case. The first has to do with how BCI's are being introduced as toys to new generation of users, and a generation in which digital interactions are naturalized modes of life. Such that interaction with computer mediated devices are "normal." In a contemporary socio-historical context, play is intimately connected with computerized devices such that the "magic circle" of play is no longer separate from the world. Consequently, modes of play are shaping our social relationships and have become integral facets of modern life. With the exception of concerns about video game violence, which is a typical concern with a long history in media effects, the public concern and understanding of play is often considered innocuous, however this case has illustrated play serves as an ideological value shaping the production of BCI technology and often is directing what devices we use to mediate our lives.

A third implication of this BCI case has illustrated that the production of technologies and devices are developing through small groups and independent developers which marks an interesting historical return of the inventor who develops his idea and innovation in his garage or

[283] Desney Tan and Anton Nijholt, "Brian-Computer Interfaces and Human-Computer Interactions," 12

workshop, albeit with new contextual modes of communication. In the 21st century, the workshop has become the living room and household office that is connected to other household offices via the internet and communication networks in which ideas are exchanged and developed. This locations and spaces in which people are developing and using technologies illustrates a degree of user agency in which users are operating outside corporate and industrial centers of production.

Moreover, I believe this case represents one of many examples of a larger historical narrative in which there has been a shift in ideology in discussions of progress from advancement to enhancement. Moreover, this marks a cultural shift from technological advancement as a form of progress, that is development and physical material sophistication which often equals social progress, toward the use and development of technology for enhancement as a form of progress, in which the objects of transformation shift from material hardware to the body. This narrative has overlapped with medical domains and computer mediated consumer domains such as video games and entertainment technologies.

And lastly, the development and use of BCI's has generated increased interest in the development of mapping techniques, such as functional magnetic resonance imaging (fMRI), and the desire by researchers to shift toward devices which carry out control functions based on measuring brains waves, to actually reading thoughts and emotions.[284] The production of BCI devices has precipitated the development of more techniques to map the mind, and with it more possibilities for understanding how the mind works, regardless of the type of progress it promises. Increasingly, conferences and research orientations are directed towards the subject of the mind. For instance, a conference just convened in Finland, called Mind Trek that was

[284] Kerri Smith and Nature Magazine, "Mind Reading Technology Speeds Ahead," *Scientific American*, Oct. 23, 2013, accessed Nov. 28, 2013, http://www.scientificamerican.com/article.cfm?id=mind-reading-technology-speeds-ahead&page=2

composed of leaders and innovators, academics, businessman, policymakers, and corporations in order to discuss future possibilities for technologies of the mind.[285] The directions taken and the developments made in these areas are perpetuated by the enthusiasm about the enhancement of the mind and have led to a form of justificatory technological determinism, in which the mind is an inevitable step in the evolutionary stages of technological progress. With recent commitment by the United States and the Obama administration to fund the mapping of the brain these research and development paths will continue .[286] For many scientists and technologists the mind as both an object of fantasy and reality has become an object to transform and understand, and consequently, the mind has become science and technology's final frontier.

[285] See http://www.mindtrek.org/2013/
[286] John Markoff and James Gorman, "Obama to Unveil Initiative to Map Human Brain," *New York Times*, April 2, 2013, accessed Nov 28, 2013, http://www.nytimes.com/2013/04/02/science/obama-to-unveil-initiative-to-map-the-human-brain.html?_r=0

Appendices

Appendix A: IRB Consent Form

Title: (R)Evolution in Gaming & Computer Interface Control: (Non)Users in Mind

Principal Investigators:

Tristan Cloyd
PhD Candidate in Science and Technology Studies at Virginia Polytechnic Institute
Dr. Joseph Pitt
Professor in Philosophy at Virginia Polytechnic Institute

Purpose:

The purpose of this study is to collect empirical data from participants who are directly and/or indirectly involved in the development and use of neurofeedback technologies, or what has been called brain-computer interface technologies (BCI). This data will be complied from telephone interviews, online forums and questionnaires. The main goal of this project is to trace the history of these new BCI technologies and their uses, in particular gaming control. Ultimately, this project seeks to track the people who have developed and are developing this technology to answer why and how this technology was developed. And further, to investigate the ways BCI technologies are being used and changing social relations. The pool of research subjects are key companies, which includes Emotiv and NeuroSky (and possibly Cyberleaning Technology and OCZ technology), and the different users of BCI technologies. Therefore, identifying users of this new technology, and consequently locating participant demographics, is one goal of this project.

Procedures:

A) Interviews:

The method for collecting data from BCI developers will be compiled through telephone interviews with company founders, developers and communication officers, which include one initial interview and possibly one follow up interview based on consenting participants. The telephone interview will consist of an hour to an hour and a half (However, this may vary).

B) Online Questionnaires

The method for collecting data from users of BCI technologies will consist of an anonymous online questionnaire located on a secure site (SSL) at:
https://spreadsheets.google.com/viewform?formkey=dE5IX2hkYmdQTmFURUY2eGpYWVBVNmc6MQ
Links to online questionnaires will be distributed through email lists via cooperating companies and posted on company website forums at http://www.emotiv.com/forum and http://support.neurosky.com/discussions. The online questionnaires will consist of several questions the first of which are designed to collect nominal data (race, age, gender, occupation, training). The second part of the questionnaire consists of additional questions that will compile qualitative data related to the use, intention, and design consideration of users of BCI technologies. This questionnaire should require no more than 30 minutes to complete.

Risks:

This study may pose possible emotional, social, and legal risks due to interview questions and online questionnaires dealing with occupational inquiries into BCI development and their use. In particular, legal risks may emerge with questions related to inquiries into interdepartmental conflicts over design choice, and licensing negotiations between

BCI companies and other companies which seek to utilize BCI technologies. However, subjects may withdraw at any time or choose not to answer questions for protection of company patents and information, and or to reduce any personal anxiety that any question may pose.

Benefits:

The benefits of the project primarily include social and educational contributions in the history and sociology of technology (or in the field of Science and Technology Studies). Generally, the benefits *may* include greater awareness and knowledge pertaining to the relations between users and developers in the production of technology and the way that users make decisions about including technologies in their lives. However, there is *no promise* or guarantee that information gathered from this study may enhance knowledge about company's users beyond which each company already has or has acquired. Therefore, no promise or guarantee of benefits has been made to encourage you to participate.

Please check if you would like a summary of the research results when available.

Extent of anonymity and confidentiality:

This project is primarily historical; therefore the investigator would prefer the identification of key historical figures in the development of new brain computer interface technologies primarily for historical accuracy. However, this project also entails a sociological evaluation of developers and user participants. Therefore, the anonymity and confidentiality of users participating in online surveys will be maintained due to the nature of the demographic and occupational information collected. Moreover, any interviewee may choose to omit their name and maintain there anonymity and or restrict sensitive information therefore maintaining confidentiality.
At no time will the researchers release the results of the study to anyone other than individuals working on the project without your consent. It is possible that the Institutional Review Board (IRB) may review this study's collected data for auditing purposes. The IRB is responsible for the oversight of protection of human subjects involved in research.

Compensation

Due to limited funding this project provides no financial compensation for participation in the questionnaires and interviews and therefore, is strictly voluntary.

Freedom to withdraw

The subjects are free to withdraw from interview, questions, and questionnaires at any time.

Subject's responsibility

"I voluntarily agree to participate in this study. I have the following responsibilities:"

- To answer questions accurately and to the best of my knowledge, but within rational consideration of legal and occupational obligations.

Subject's permission:

I have read the consent form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my consent:

Signature

Contact information:

Dr. David M. Moore,
IRB Chair
moored@vt.edu
(540) 231-4991

Tristan Cloyd
tcloyd@vt.edu
Home: 540-626-5513
Cell: 540- 818-1993

Dr. Joseph Pitt
jcpitt@vt.edu
(540) 231-5760

Appendix B: IRB Approval Letter

Virginia Tech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24060
540/231-4606 Fax 540/231-0959
e-mail irb@vt.edu
Website: www.irb.vt.edu

MEMORANDUM

DATE: February 16, 2011

TO: Joseph C. Pitt, Tristan Cloyd

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires October 26, 2013)

PROTOCOL TITLE: (R)Evolution in Gaming & Computer Interface Control: (Non)Users in Mind

IRB NUMBER: 11-119

Effective February 16, 2011, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the new protocol for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:
Approved as: **Expedited, under 45 CFR 46.110 category(ies) 6, 7**
Protocol Approval Date: **2/16/2011**
Protocol Expiration Date: **2/15/2012**
Continuing Review Due Date*: **2/1/2012**
*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:
Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

*Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

cc: File

Appendix C: Interview Questionnaire

1) What is your technology?
    a. How would you describe the technology?
        i. How many different technologies have you developed? What are they? Why? For whom?

2) How is this technology different from previous/existing neurofeedback technologies?
    a. What key features make this technology different?
    b. How is your technology similar to existing EEG technologies?
        i. How different from medical EEG uses?
    c. Given that EEG technology has been available for several decades what factors or considerations allowed for this technology to be marketed and developed now?

3) How did you come up with the idea for this technology?
    a. What considerations and factors allowed you to perceive a need for this technology?
        i. How did you identify needs of marketplace?
    b. What political, economic, or social factors helped in the development and diffusion of this technology?
    c. Who did you conceive as a market for this technology?
        i. Was your conception of who would use this technology influence how you would develop and implement this technology? In what way?
        ii. Do you have a specific target market? Or conceive of many potential users?
            1. Who is your user base? Companies? Individuals? Lead users? End-users?
            2. How do you represent these users? (How do you see these users and market to them?
            3. What help do you give to: Users? Developers? Clients?
    d. In what ways has this technology been developed and/or used by others?
        i. In what ways do you speculate that this technology will be used or developed by others?

4) Who helped in the development?
    a. Who played pivotal roles in its development?
    b. What are the background disciplines of the designers/founders?
        i. Were there any unexpected benefits and or problems with different designer backgrounds and/or training in the production of this technology?
    b. What experience did designers have in neurofeedback technology?
        ii. Was this experience necessary, valuable?
    c. What disciplines (career backgrounds) helped in the production of this technology?
    d. In what ways did hardware and software developers play pivotal roles?

e. How many or what significant changes occurred during development?
    i. In helmet design? (Mindset?)
    ii. In software design?
    iii. In hardware design? (Think gear, Mindset)

f. What material factors helped designers produce this technology?
    i. How did you come up with "technology principles?"
        1. And what steps or factors led to development of this technology that meet the key "technological principles" as stated in your website? (Portability, lower cost, ease of use, accuracy)?
        2. Was it an obstacle in development to achieve these criteria?
    ii. One key problem your company website identified was distinguishing "noise" from a "signal". In what sense was this an obstacle for achieving your specified criteria? (Portability, ease of use, etc.)?
        1. Is this obstacle ubiquitous in all BCI development?

g. What are/were the final designs for your technology when you released it into market?
    i. What factors led to the final designs of your technology?
    ii. Were there other options? If so what were they?

6) <u>What was the company's vision/philosophy for this technology?</u>
    a. Has this changed? If so why?
        i. Does work environment match the company vision/ philosophy? If not, how?
    b. How was the name Neurosky derived?
    c. What is project millennium?
        i. What is Mindball?
    d. What direction did the company want to go with this technology?
    e. Do the designers/members of the company envision different directions for this technology? What are these differences? Who/whom?
    f. What key events/contracts/breakthroughs happened in your company?
        i. What led to these?
    g. Several articles in popular press (electronic gaming monthly) have identified this technology as the next stage in video game control.
        i. What factors has your company identified as essential for making this diffusion a successful reality?
        ii. Why does your company think this technology is the next step in video game control?

7) <u>How important (if any) have users been in developing the technology?</u>
    a. Feedback/ forums?
    b. What criticisms have been directed toward the technology?

i. In regard to video game controls?
ii. In regards to a research method/technique?

8) What obstacles or limitations, if any, do you see for the wide spread diffusion of BCI technology?
    a. Are you aware of any BCI "Failures?" Why did they fail?

9) What potential do you see for the wide spread use of BCI Technology?

10) The medical uses of QEEG and Neurofeedback technologies often focus on changing the mental state of subjects (i.e. in ADHD to reduce Theta waves, Autism, epilepsy); what experts call operant conditioning. If general users of BCI technologies have no pre-existing conditions and are not using BCI technologies for treatment, what are the implications of using BCI technologies?

    a. Can you comment on How BCI technologies might train users to focus and change the modes by which they think?

Appendix D: User Survey Questionnaire

https://spreadsheets.google.com/viewform?formkey=dE5IX2hkYmdQTmFURUY2eGpYWVBVNmc6MQ

Race/Ethnicity

- Black
- Asian
- White/Caucasian
- Latin/Hispanic
- Native American
- Pacific Islander
- Other:

sex/gender

- male
- female
- Other:

Age

- 18-25
- 26-35
- 36-45
- 46-55
- 56-64
- 65-above

Income

- below 15000
- 15000-24999
- 25000-34999
- 35000-49999
- 50000-99999
- 100000-200000
- 200000-above

Education Level

- High School/GED
- Some college

- Associates degree
- Bachelors degree
- Graduate degree
- Doctorate degree
- Other:

Occupational location

- Corporate/ company
- Institutional/ academic/ educational
- Medical/ Reasearcher
- individual/ independent developer/ user
- Other:

(optional) name of Institution or company

interests/hobbies

Skills/training

Please define your role in relation to Brain-computer Interface (BCI) technologies

- Casual/hobby developer
- professional developer
- business person
- consumer
- gamer
- academic
- researcher
- trainer
- Other:

How did you learn about this technology?

- conference
- journal
- magazine/news article
- internet/web

- ☐ person
- ☐ Other: ____

Why did you choose to use BCI technology?

What do you want to accomplish with BCI technology?

- ☐ product development
- ☐ business
- ☐ software application
- ☐ hardware development
- ☐ gaming
- ☐ training
- ☐ medical
- ☐ research
- ☐ education
- ☐ Other: ____

How have you used BCI technology?

- ☐ product development
- ☐ business
- ☐ software application
- ☐ hardware development
- ☐ gaming
- ☐ training
- ☐ medical
- ☐ research
- ☐ education
- ☐ Other: ____

In what areas do you think this BCI technology can be used/developed most successfully?

- ☐ gaming

- ☐ training
- ☐ medical
- ☐ research
- ☐ education
- ☐ Other:

Is your project/use for work or personal?

- ○ work use
- ○ personal use
- ○ both

What impact do you hope that your BCI product/use will have?

Have BCI company administrators/representatives contributed or aided with your project or interests?

- ○ yes
- ○ no
- ○ Other:

How have BCI company administrators/representatives contributed or aided with your project or interests?

How have your ideas aided in BCI development?

What limitations, have emerged when using/developing this technology? a) How did you solve/confront the limitations?

What benefits have you identified when using this technology? a)What benefits, if any, will emerge from using this technology?

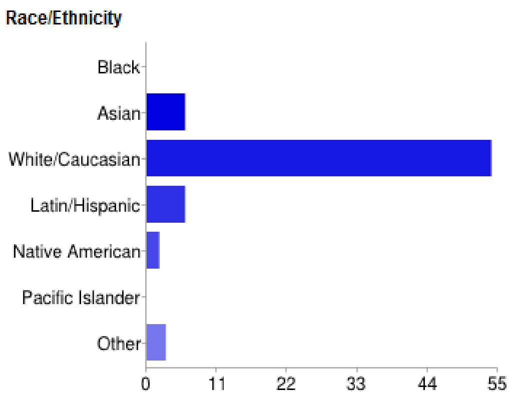
What limitations can you foresee emerging from BCI technologies (Uses, consumer acceptance, etc?)

Do you consider your interest and interaction with BCI technology as work or play? Both?

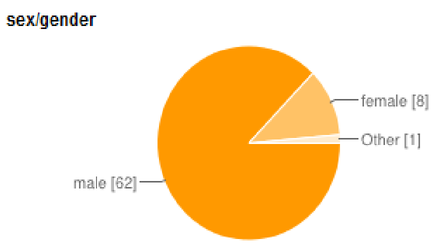
- ○ work
- ○ play
- ○ both
- ○ Other:

Additional comments

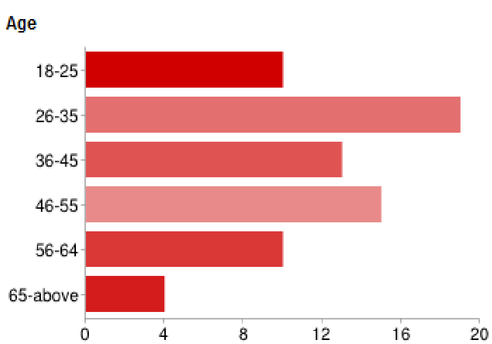
Appendix E: User Survey Summary: n=71 N=2800



Black	0	0%
Asian	6	8%
White/Caucasian	54	76%
Latin/Hispanic	6	8%
Native American	2	3%
Pacific Islander	0	0%
Other	3	4%

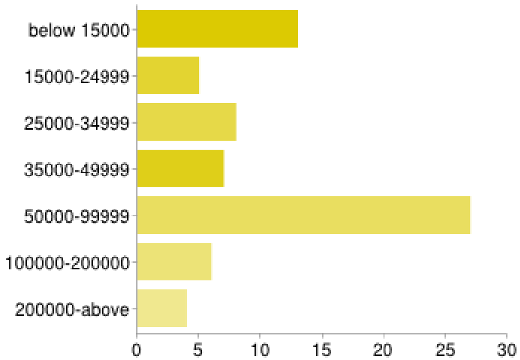


male	62	87%
female	8	11%
Other	1	1%



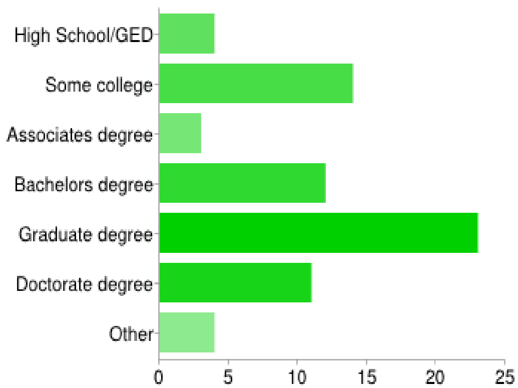
18-25	10	14%
26-35	19	27%
36-45	13	18%
46-55	15	21%
56-64	10	14%
65-above	4	6%

Income



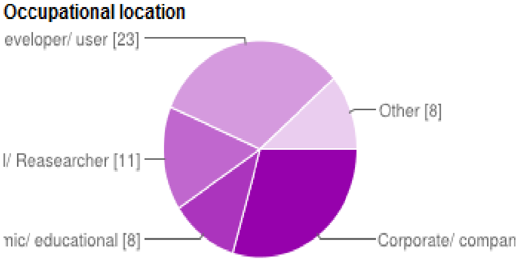
below 15000	**13**	18%
15000-24999	**5**	7%
25000-34999	**8**	11%
35000-49999	**7**	10%
50000-99999	**27**	38%
100000-200000	**6**	8%
200000-above	**4**	6%

Education Level



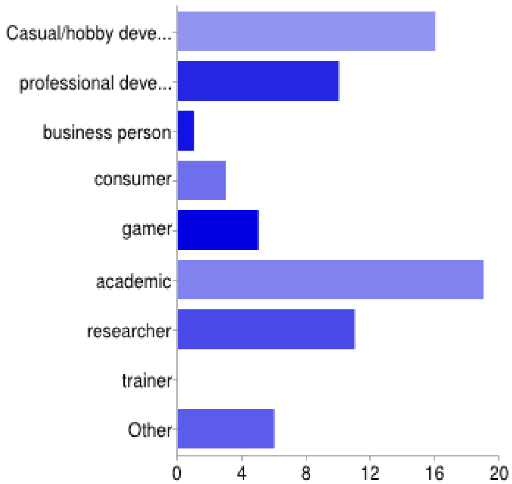
High School/GED	**4**	6%
Some college	**14**	20%
Associates degree	**3**	4%
Bachelors degree	**12**	17%
Graduate degree	**23**	32%
Doctorate degree	**11**	15%
Other	**4**	6%

Occupational location



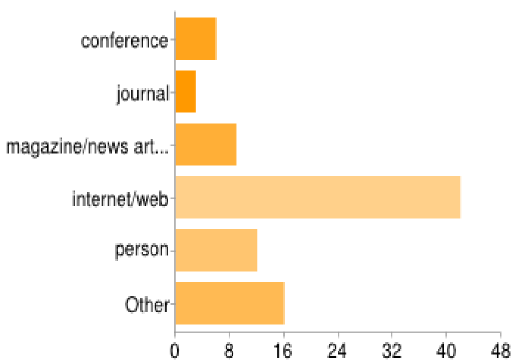
Corporate/ company	**21**	30%
Institutional/ academic/ educational	**8**	11%
Medical/ Reasearcher	**11**	15%
individual/ independent developer/ user	**23**	32%
Other	**8**	11%

Please define your role in relation to Brain-computer Interface (BCI) technologies



Casual/hobby developer	**16**	23%
professional developer	**10**	14%
business person	**1**	1%
consumer	**3**	4%
gamer	**5**	7%
academic	**19**	27%
researcher	**11**	15%
trainer	**0**	0%
Other	**6**	8%

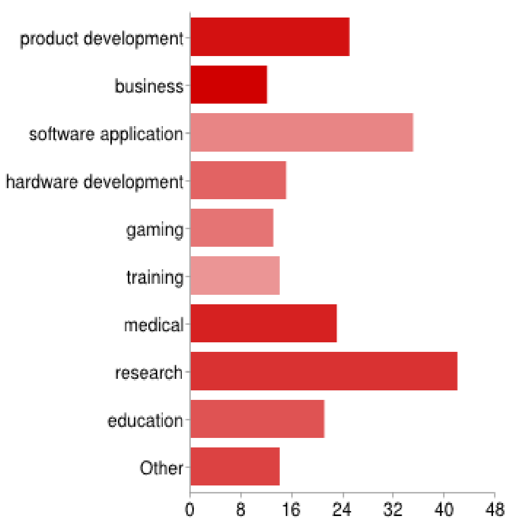
How did you learn about this technology?



conference	**6**	9%
journal	**3**	4%
magazine/news article	**9**	13%
internet/web	**42**	60%
person	**12**	17%
Other	**16**	23%

People may select more than one checkbox, so percentages may add up to more than 100%.

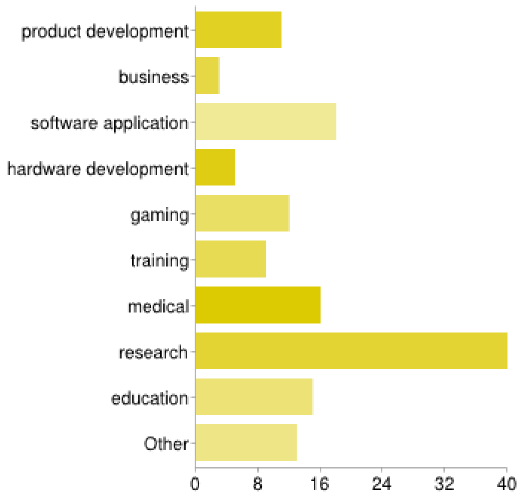
What do you want to accomplish with BCI technology?



product development	**25**	35%
business	**12**	17%
software application	**35**	49%
hardware development	**15**	21%
gaming	**13**	18%
training	**14**	20%
medical	**23**	32%
research	**42**	59%
education	**21**	30%
Other	**14**	20%

People may select more than one checkbox, so percentages may add up to more than 100%.

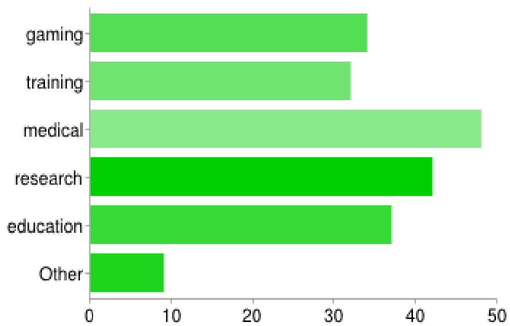
How have you used BCI technology?



product development	**11**	17%
business	**3**	5%
software application	**18**	28%
hardware development	**5**	8%
gaming	**12**	19%
training	**9**	14%
medical	**16**	25%
research	**40**	63%
education	**15**	23%
Other	**13**	20%

People may select more than one checkbox, so percentages may add up to more than 100%.

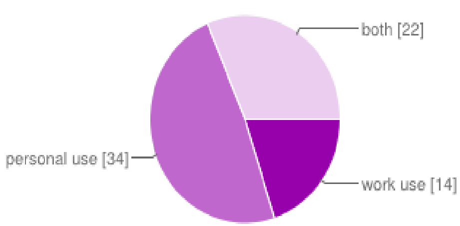
In what areas do you think this BCI technology can be used/developed most successfully?



gaming	**34**	49%
training	**32**	46%
medical	**48**	69%
research	**42**	60%
education	**37**	53%
Other	**9**	13%

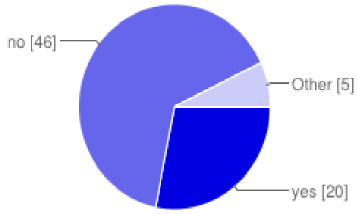
People may select more than one checkbox, so percentages may add up to more than 100%.

Is your project/use for work or personal?



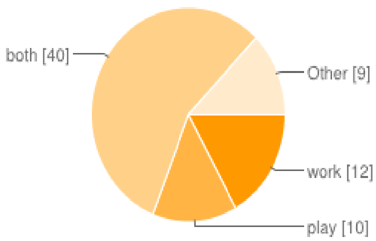
work use	**14**	20%
personal use	**34**	48%
both	**22**	31%

Have BCI company administrators/representatives contributed or aided with your project or interests?



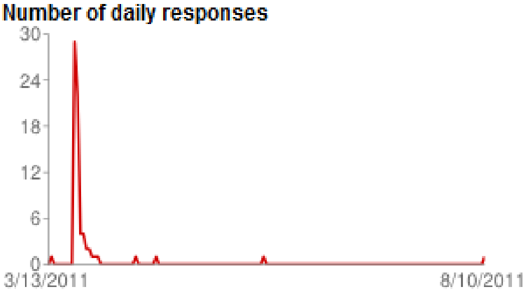
yes	**20**	28%
no	**46**	65%
Other	**5**	7%

Do you consider your interest and interaction with BCI technology as work or play? Both?



work	**12**	17%
play	**10**	14%
both	**40**	56%
Other	**9**	13%

Number of daily responses



Appendix F: NeuroSky Interview (Tansy Brooks)

Neurosky: Ask me and I'll…and I'll…I'll answer your questions.

Cloyd: Yeah 'cause I mean it seems like a lot of questions here. So…okay…so um….you know… I…I apologize some of these probably seem uh redundant…..

Neurosky: That's okay.

Cloyd: …and they might overlap….so. Okay…again thanks for participating in this. So, I guess generally what is your technology or how would you describe your technology?

Neurosky: Um…kind of the…the short of it is what we usually say is our technology is a simplified EEG. Um….basically we have a technology that's been around for over 60 years and we reengineered it from the ground up to be cost effective and user friendly, because we were interested in taking the proven technology from the lab environment and taking it into the consumer realm(?). So…traditionally this technology's really only been used for people who are sick or people who have…um…you know…physical disadvantages and uh we really see that there is a lot of benefit for the technology for…you know…for just the consumer in general. (Pause) Do you want me to go more detail about what…all…what our technology is?

Cloyd: Um…I…yeah, I was actually gonna ask like…well…how many different technologies have you developed…um…and what are they, why and for whom? I guess…um….um….seems like…like based off your website there's multiple….um markets which I have a question later about, but...

Neurosky: Well…well let's take it in pieces and then if I'm missing something bring it up again because I wanna make sure….there's a lot of information so let's make sure we cover all of it. So um basically what our technology is, is we're a platform technology. We have an A6 chip that we've created so we've taken all of the…you know data collection, amplification, filtering and put it on a chip form. In the past you would have to have like a big computer to have been able to do all the processing. But, what we've done is we've distilled it down into a microchip so that um, you know, first of all it makes it much more powerful second of all it makes it much cheaper. So, for example when you're dealing like with Mattel, you know they are very cost conscious and so we had to engineer down the cost…the cost down to the penny to try to make their margins. Um…so traditionally what we have been has been a business to business company. We sale those chips and other people build their hardware around it. However, um, we've found that um there were a lot of groups that wanted to use the technology but they wanted to make their own software they didn't want to have to deal with hardware and so we cut our (?) with our model to a certain extent to make a consumer product and with that um what we did was we released the mindset about a year and a half ago. And the mindset has like…it…we consider it like a multimedia headset 'cause it has a speaker and it has a…um…a microphone. Um…because we're trying to make…uh you know end all solution for everyone um that needed a hardware solution. Um…and…uh the mindset….um actually has the…the…the chip in it and we call chip technology sync gear. And sync gear um right now off puts…out puts three different types of data. The first one is the algorithms that we created the intention and the meditation. The second is the brain wave power spectrum bands which are alpha, beta, zeta, delta and gamma. And those are the various hertz ranges…um that they can be calculated a little bit differently, but they're pretty much the standard when you look at EEG. Um…and then the last one is the raw brain wave so it's basically, you know, just kind of a wave of data um that has, you know, different….different peaks and different ranges and, you know. Typically it's the researchers who take that technology who have familiarity with EEG's and they look at that brain wave data and they can read much more into it than, you know, people who don't have a lot of background in it. So one of the things that we've um done is we've decided to make these algorithms. We picked intention and mediation because they were the easiest for people to do most people wouldn't know what it feels like to concentrate over the lax. Um, so first of all from a user interface point of view it was…um…it's easier when people first start to be able to start using the technology usually say within 15 minutes of practicing, you know, in worst case scenario I would say people tend to get the hang of it. So they can, you know, try a number of different tactics to try to get a response from the technology until they figure out which one works best for them and then they can repeat it more easily. So, you know, that was important for us to try to make it easy, as easy as possible. Um…the other thing is…um…about making these algorithms is it helps us to bridge the gaps into industries who don't have any background in neuro feedback….so…um…or EEG in general. Um…you know when we're working with the game developer or working the toy companies like Mattel, they can just take the value that comes from the algorithm which is, its analog data and we released it in a range of um zero to 100. So, you know, it's important to point out that the technology is analog it's not digital so it's not ones and zeros. So if someone is interested in using one of the algorithms they would set a threshold. For example with the toys, I don't know what the exact value is but, say for Mattel's toys they set the threshold much lower, say they set it at a 30 before the ball starts going up. They concentrate it at least…at a 30….um you know before, you know, the ball starts moving and then maybe at a 60 it goes higher and higher. You can set….a response within a devise on these different thresholds and if you wanna make it more difficult you can do that as well. I'll break down one of the……

Cloyd: Are the thresholds the amplitudes of the wave or the overall wave or….

Neurosky: Um…no…it's not…hmmm.

Cloyd: Like you said one to…one to a hundred or something…so there's a threshold meaning that it's…the output of the actual…frequency…that…so it's like…

Neurosky: A sufficient output, so it's like you have to have enough of this frequency to get to a 30. You have to have more of that frequency to get to a higher number.

Cloyd: Okay.

Neurosky: So…exactly…it's not a one or a zero…which is…sometimes you'll be like well…you can use it as a button but basically what it is, is you're just setting the button where you would want the threshold to be.

Cloyd: Okay…so…really you've taken care of kind of that…the hardware, analog stuff…so like computer science people…people who just wanna write code, can then write some sort of computer software application for this in some sense.

Neurosky: Exactly

Cloyd: Okay…I think that kind of…let's see question two…I guess you kind of answered that in the previous. It says, how is this technology different from previous existing neuro feedback or EEG technologies…I guess you kind of answered that in some sense.

Neurosky: Well…a big thing for us though is also the dry(?) sensor. So, first of all the ASICS chip…we have it in embedded solutions and also the fact that…like I said we have a dry sensor. So, the way I explain it, especially when I'm talking to PR is…a lot of groups have taken the medical technology and tried to…engineer it down…tried to strip it down and…make it easier to use or less expensive…but we've reengineered it from the ground up which involves…creating that dry(?) sensor. So again, focusing on the usability aspect…if you want somebody to use the technology for entertainment purposes not because they are desperate to communicate with their loved ones, as is the case with most of these devices…you have to make it as easy as possible and so we created that dry(?) sensor to help with that.

Cloyd: Something else I also noticed too was that…the traditional or what previous EEG stuff there was the 10-20 international system had multiple…electrode sites where you just have one…and that seems to be a major difference. I don't know…I guess…later on I was going to ask questions related to…design and some of the obstacles to achieve that, the technical problems, but…I don't know what those were or if…it seems like….with the monopolar(?) and the bipolar you had to do some referential(?)…adjustments like you have to measure one in terms of another and then…take the value and use that one so…

Neurosky: Yeah…and that's one of the ways that…not one of the ways…I mean, I would say that's, to an extent, an accepted limitation. So…it's funny within technology especially when you're…(inaudible)…a lot of it is what's good enough and for us…we really think that one sensor is good enough for getting this technology started. In the future if you wanna get more complicated and actually have a new chip that we're releasing that can do kind of a daisy chain thing where you have multiple sensors…you're gonna wanna have this…and we have people who want to do more serious applications or more complex applications coming to us and saying we want multiple sensors and so we are creating systems that can do that but, to just try to get this technology into the market we sacrificed some of the things that you would need for…from having multiple sensors and just went with the single sensor. Which is one of the reasons why…right now we have intention and meditation, because those in addition are also things that are measurable on the frontal lobe. It's like you can get the…forehead…to be in a different location then you would be able to have different algorithms and things like that.

Cloyd: So, I guess really fundamental difference here is kind of like those…when you talked about those two branches it's…rather than just like diagnostic and therapeutic approaches its just the one sensor can give you enough to register frequencies that then have uses for control and interventions which don't have anything to do with diagnostic aspects…

Neurosky: And that's…that's a really, really important discussion because if you read into the neuro feedback stuff you'll find that there's all these…there's a lot of safety steps…everybody is like oh my god you're changing the brain…what if you misdiagnose some people and I know that from being in the neuro feedback community that there is a lot of concern about inaccurately diagnosing somebody because you're changing someone's brain and so…and it's a legitimate concern. It's an absolute legitimate concern but, when you're dealing with neuro feedback, and I shy away from saying that we're really neuro feedback…(inaudible)…is because they…the goal is to change the brain and exactly like you said it's like you identify the condition or the problem the person has and try to…basically reengineer them to get them back to what's considered normal. So, exactly what you're saying…and to do that there is a couple of things. First of all you have to asses them…at a deep enough level to be able to know what's wrong with them or what they would need to be modified and then you have to be able to tweak the treatments in the system. So…(inaudible)…because that's what I'm used to but it sounds like you kind of have the technical terms for it as well but….yeah exactly what we're looking at right now especially for the toys and games is…what I call transitory….information…it's like…can you control your ability to concentrate and relax. I'm not trying to change the structure of your brain. I'm just trying to make you more self aware of…of things that occur in your brain naturally…and consciously be able to control them. Now…long term and working with (inaudible) partners there is interest in more of the serious applications, more of the diagnostic, more of the…trying to…recondition people's brains. But…we acknowledge that you want to have a clinician or you want to have an expert who is helping you with that.

Cloyd: Yeah, I did some reading saying that…sometimes…depending on your filtering I guess they called it or your quantitative database that one person's…measurement of fade away can be another person's delta or something like that. Depending on the…

Neurosky: It can be tricky. And the thing is that even like ADHD…one example that I have heard about is…there are multiple different…patterns…exactly what you are saying….ranges which can be ADHD…and for one type…there's one way you treat…one type of ADHD but if you have the other type of ADHD it can actually be negative and they can have negative repercussions and so again with that the diagnosis is pretty important.

Cloyd: …since we're on the subject, but this one question I have, was at the very end of the interview. But since we're kind of talking about…implications…I said: the medical uses of quantitative EEG and neuro feedback often focus on changing the mental states of subjects and ADHD to reduce data waves…autism, epilepsy, etc., what experts call operative conditioning. So if general users of BCI technologies…have no preexisting conditions and are not using BCI technologies…for treatments…what are the implications of using BCI technologies…I guess, and this is what we are discussing…is it training people to think in particular ways? If BCI technologies become kind of defused in society(?) such that they become part of our social…in networks and things of…such like texting and cell phones. I was just thinking. This is more kind of speculative kind of…but, it's more on the subject of…I know a lot of…with some of these performance…therapies…they talk about how it's like…they compare it to exercise. If you just exercise your mind just like exercising your body then you get into these certain mental states. So, I guess, what are the implications of that in some sense…and if…do your technologies often times focus on the beta or the alpha…or … guess it could be multiple things?

Neurosky: Okay, you asked me a ton of different questions there. Let me…give me a second to write…

Cloyd: Well I guess just…

Neurosky: …give me one second to write a couple of the notes…

Cloyd: Sorry…it was just…just relevant to what we were discussing about the differences…

Neurosky: Okay…so…let me go through a couple of different points…and we can skip back again. First of all you said a phrase I think is important to point out and…just identify. You said something about the general uses of BCI…I think what you meant is: in the future what will be the…uses of the BCI. I think that it's important to note that currently the uses of BCI are for people who are disadvantaged. So, I mean, that is why this whole industry was created originally. And…especially when you're looking at the marketer you're looking at trying to compare what our technology is to kind of more the hardcore serious stuff, is I guess is the other way to put it…we are not after that. I mean (inaudible) 'cause you said "the general uses of BCI". I just want to reiterate the general uses of BCI right now are not what we do. In the future we hope that that becomes the standard that…you're using this technology as more (inaudible) and that's our goal…but as of right now…this is not the general use of BCI.

Cloyd: Yeah…this kind of…the project…we are kind of working on…in the future. I'm sorry…hold on a sec.

Neurosky: It's okay…no worries. And I know you're still working that but I just wanted to make that point because you referenced something…just know that that matters.

Cloyd: Yeah, and I know it's not diffused popularly yet…it's kind of a nebulous…kind of ambivalent technology that people are still trying to...see the benefits and…and how can we fit this in. Okay that's fine…I'll just go back…

Neurosky: Let me…can I add a couple more points?

Cloyd Yes

Neurosky: The other thing you asked…was what frequencies do we primarily focus on…alpha and beta is correct. Alpha…well for our algorithms…our intention algorithm…which is like focused attention is primarily beta wave and our meditation algorithm is primarily alpha. I mean, they're in algorithms so it's a combination and we don't disclose what the exact combination is but that is primarily what the hertz ranges are just so you know.

Cloyd: Oh okay…

Neurosky: And then do you…do we want to go into the…to talk about future stuff or did you want to circle back with that?

Cloyd: Uh…yeah…I did have a question. What potential do you see for the widespread use of BCI technology…which is question nine. 'Cause you said now it's sort of disadvantaged like the focus…initially I thought they were thinking you would have a smart house or like a…for the disabled and things like that.
Neurosky: There's a lot of different things and actually…I should…let me tell you this. There's actually a chart that I created recently. Let me grab it because I think it really gives you a good broad prospective. It's basically the five different benefits of the technology, is how I phrased it because I've been trying to figure out the best way to explain to people what you can do with the technology. So the first one…is what I would call control and basically this is the one that's the traditional BCI. This is the telekinesis this is I concentrate and something happens…moving like a mouse or moving an object where you're actually trying to intentionally focus on something in order to make a reaction happen in device. Right?

Cloyd: Uh-huh

Neurosky: The next one is…monitoring. So…data collection and this is…kind of falls in the realm of assessment and diagnosis. So…this could be things like in the future….say in a Doctor's office…you get your blood pressure done, you have your weight taken and you know maybe we check your EEG. I mean right now…because of the technical limitations and the pricing even within a medical environment it's pretty limited to what…where you can use an EEG and so…if you could do some sort of an assessment with people…we see the technology becoming as prevalent as…a heart rate monitor or a scale.
So…that's another one…the next one is…what I call change and that's kind of the category that holds brain

plasticity. This is where we're actually trying to change the brain. This is where you're trying to condition your brain to be more healthy. And I think that …it's kind of funny when people talk about ADHD, I mean what person doesn't sometimes fell like they have ADHD? … and it's a spectrum(?) of like you could have a little bit or not at all but….even healthy people feel like….there's this benefit to being able to condition yourself…condition your mind the way that you've been able to condition your body in the past. And so…that's…on the lighter side of that you're talking about…entertainment based applications that…help people increase brain plasticity. So…we want to help you not get Alzheimer's. So you play these games that are like…Sudoku or crosswords puzzles that help kind of…build brain plasticity. Or….like I said more on the serious side you're talking about a clinician environment where it gets the full diagnosis and you're actually trying to do long term change for the structure of the brain…on that more serious level.
The next one is…I call it adapt and I also consider this machine empathy. So… this is the ability of…technological devices to adapt to a person's mind. And a good example of that is…I was given…say you're driving home late at night and you start falling asleep at the wheel. What if your car could detect that and pull you off to the side of the road? And that's the same thing like you're saying with the smart homes. What if your environment…what if the technology that surrounds you could adapt to your mind…so that's…that's another important one.
And then…the last one which is a little bit similar to one of the previous ones but it's important enough to separate it out. I call it evolve and I…

Cloyd: You call it the what?

Neurosky: I call it the evolve. Marketing speak, what can I say.

Cloyd: The volve?

Neurosky: Evolve.

Cloyd: Oh evolve. Okay, sorry.

Neurosky: Evolution. And I reference the quantitative self. I don't know if you're familiar with that term. It's something that Kevin Kelly, who I think is one of the founders of Wired magazine came up with. And it's this…obsession…recent obsession that people have with charting data about themselves and making behavioral changes. So…say I…count… my workouts, I count my calories, I count the food that I eat and then I look at it and then I make behavioral changes depending on the outcome of what my body is doing.

Cloyd: And that was called what? What was the term? I didn't…

Neurosky: It's called…quantified self.

Cloyd: Oh quantified self, okay.

Neurosky: Yeah, and it's pretty interesting. It's kind of an up and coming thing but, it's becoming more popular because you have all these different types of technology now that are mobile, that are inexpensive and so people are using…are leveraging technology in a way…to asses themselves in which they never have before. So…and of course there's a lot of potential for our technology in that, in things like sleep therapy…say you collect data while you're sleeping and then you can reflect and say "oh you know obviously I shouldn't have had that margarita before I went to bed because even though I thought I slept the quality of my sleep wasn't that good". Or…in sports training you…for some reason you have a mental block that you can't overcome but you're not even aware of it until you can look at the brain wave data and say "ah, okay I see that I'm kind of choking at this point what exactly is…what's going on in my mind?" So…and also things like education….we have…an announcement that we just did at the demo conference was about a new product where you can do things like play a math game that charts your level of concentration while you're answering these math problems and you have a readout afterwards that shows how many you got correct and then also what your level of focus was. The idea is that you can identify how the mind is reacting to the contents. So, say you're supposed to memorize all of your multiplication tables. Well, if…obviously you had to do a lot of cognitive processing in order to remember this multiplication table….even though you may have got it correct it's not memorized. Or…being able to adjust content to the person depending on how difficult it is for them…so maybe you take a test…not take a test but, you do an assignment or something like that and then….you can see that…you can see whether the person was paying attention, you can see if the person was a little more bored and then potentially even be able to adjust the subject matter accordingly.

Cloyd: So the recent five…potential…uses or areas of domains in which this can be used.

Neurosky: Yeah that's kind of how I classify them. Pretty much everything you can think of falls into those. I mean as far as industries, and I think you mentioned this earlier, industries that we're focusing on toys and games are one. First of all because…from a toy perspective…the people who we first worked with is Mattel and they were really creative, they got it right away, the liked the idea, they liked the magic behind it, this idea of simulating telekinesis. Also, from the money point of view…they could create a product relatively quickly, we don't have to get all the medical validation and you can get a product into the market and have revenue coming in. So that was really intelligent, I think, on our part as far as a strategic…approach.
The other one we're really focusing on is video games. And part of that is again kind of that whimsical aspect of the technology and part of is that the industry is just huge…there's so much money and so many different types of applications that….that makes sense…

Cloyd: Yeah, that kinda over laps with…I'm trying to….I was looking at BCI Technology…but…in general but also was trying to narrow my project to gaming….technologies in some sense and…I guess this is also related to the potentials and…what limitations or obstacles do you see in the widespread diffusion of this technology in general and also in relation to gaming? Do you see any obstacles socially or…

Neurosky: …So, I think that the good thing is that people are excited about it. And….but the challenge is…and I'd say with this technology in general is the misconception and…let me make a quick note….

Cloyd: So you think there's like…would you say there is some preexisting values and expectations of the technology that don't meet…

Neurosky: Exactly. So, it's like people will contact me and they'll say "oh I heard you have this technology that reads your thoughts" and it's like "no we do not" and that's a really big challenge for us. Especially because…and I'll tell you for two reasons. It's a really big challenge for us because we have to educate them…and then…in a way, I shouldn't say this but, bash their hopes, but in the beginning you have to give someone a realistic explanation of the possibilities of the technology. However…the good thing about that is once they understand that, you can show them…realistic scenarios in which the technology can be used. So, the technology has incredible potential but you…people have to kind of reframe…their perspectives on it.

Cloyd: Would you say…

Neurosky: The good thing from a marketing point of view is it really catches people's attention but on the other hand…you have to make sure that they understand accurately what is going on.

Cloyd: Would you say the novelty of it and some sort of the foreignness of it….isn't necessarily mapping onto their normal social practices and behaviors in some sense, does that…is that…would you think that's a potential obstacle? I mean…for instance for gaming…there's an expectation of like they want quick responses to….if they're fighting a zombie or whatever. And there's a big difference between not being aware that you're exhibiting an alpha wave or a beta wave and then knowing that you can press your thumb down. Which the knowledge…the body knowledge is a lot different and the intuitive knowledge is different…so I guess that's what I'm kind of getting at…

Neurosky: Yeah and I agree with that. That's absolutely a big challenge. When we talk to people they're like "well can"….the first question I have….is "can it replace handheld controllers" no it can't. And…a big thing about…adapting new technologies is why use something….that works less well just because it's new for something that works perfectly well as it is. And that's kind of the approach of the controllers. It's like no it doesn't make sense to use this technology as a controller because yes people who are handicapped do and should, but when you're talking about a healthy person who can push buttons it doesn't make any sense. And so from a gaming perspective again we're kind of relooking at…changing the paradigm. We're looking at this and saying "okay this is more of…something that changes the experience rather than something that replaces the technology that already exists"…and so….we look at it as an enhancement. And actually could do some pretty powerful things, but again like we were saying before the challenges to get people educated about the technology and understanding…what it can do and can't do.

Cloyd: So yeah, so the end users on some of the forms I see in the gaming stuff in relation to some of these BCI technologies is that there is this assumption that it will get more advanced where it could just read your mind and they say things like "I'll wait until the next generation". Actually I've found some…examples in the past like in…I think in…of some of these…it's not necessarily BCI's but they're EEG related stuff like the Nintendo entertainment system had a bio sensor for I think to…I don't know if it was for Tetris or not…but it worked off your…your heart rate. There was another one that Atari never released called Mind link and it worked off your…facial muscle movements…but some of the things that I saw in that was just people were giving themselves like headaches. So, it was never really released.

Neurosky: Yeah so, there's a couple different things. When we're talking about…the technology…in general first of all is additional sensors. So like I said before we're going with the algorithms we have now for a number of different reasons and the single sensor for a number of different reasons. But as you have more sensors…you will have more capabilities. There'll be more things that you can do and…as far as…I don't like to discourage people when they say "oh well is it going to be possible to read your mind?" and all this like crazy science fiction stuff. You know a lot of that is possible but it's in the invasive BCI realm. I mean…its being done by like Miguel Nichlaylus at Duke University or Phillip Kennedy who's working on things like telepathic speech. And a lot of that stuff is being done but again it still falls into that lab realm where people who are desperate for solutions…if it's being used on people at all…are willing to go that invasive route where as when you're talking about taking a product and making and consumerizing it there's a lot more challenges to it. So…the kind of (inaudible) that people are excited about is possible but it's just…it's pretty far off. I'd say at least ten years off…because it's in the lab. It's still very much in the lab environment.

Cloyd: In reading the mind….

Neurosky: But…I think it gives people some perspective on…where some of the stuff can go in the future.

Cloyd: …oh I was just thinking the reading the mind, you said the stuff at Duke is more you said invasive in the sense that it's more…reading minds means what exactly?

Neurosky: It means they drill a hole in your head and stick a chip in your brain.

Cloyd: Oh.

Neurosky: Like invasive in that you literally your brain is being opened up and they're sticking a chip, the chip in the brain matter.

Cloyd: So like a truly a hybrid really.

Neurosky: Truly, truly a hybrid. And the reason they do that is because…the closer you get to the brain the better the data is. So right now we have to…I'm trying to remember what the term is, it's something called…something smear...where basically since you have this liquid between your brain and your skull…you get distorted signals. So, the farther away you get from the brain the more difficult it is to get information. And there's this…example that people love to get…they love to say like "EEG is like listening to a symphony…outside across the street" like you can kind of hear pieces of it but you can't…you don't really have…you can't really clearly hear what's going on inside and that's a good allegory that people have for EEG.

Cloyd: Yeah, I mean that's one of the problems I saw on some of your…on your website…and on all the EEG literature is distinguishing signal from noise…and also artifact…I guess interference they call it…for muscle ticks or…other, you know electrical…

Neurosky: And that's…yeah that's a really big problem and that's one of the things that again as a big technology advancement…something that we've focused on…

Cloyd: So…

Neurosky: …is people identify those artifacts and remove them. So we take them out, we filter it.

Cloyd: So in what sense…what information could you give me about overcoming those…obstacles and then…and then actually coming up with, on your website you have these technology principles like portability and ease of…use accuracy and lower cost…by matching those, having those criteria how easy…what was easy to overcome the other problem of distinguishing noise from a signal and…blocking out artifacts?

Neurosky: Um, specifically…taking the perspective of how we approached that in the beginning I'm not sure 'cause I wasn't here at the time, but I might be able to get more perspective. But I know that, a couple of different things. First of all, we were taking the technology from a different direction and like I said this is back to the, to the kind of the good enough principle. You know, we're taking a technology that in the past has had to be very exact and we've put it in a consumer realm where it's much more forgivable and it's also used for a different purpose. So, things that would be considered unacceptable in a medical environment are considered okay in a consumer environment. So, part of that is just saying…the technology wouldn't have been okay for this but its fine for what we're trying to do with it. Um, and even like for example with our algorithms…they're not…I mean I would say that they're more kind of toy and game algorithms to a certain extent. It's like they're…they do some averaging so that they work for everybody and then there's filtering because we're taking out noise and things like that. And so they're not as exact as it would be for somebody who is doing kind of a clinical system with the neuro feedback where they're…identifying a specific range and drilling that range for that individual.

Cloyd: Okay…

Neurosky: Um…uh…okay. Does that answer your question?

Cloyd: Yeah and then…so I guess this kind of this notion of good enough helped…so there was nothing like…I was thinking what factors helped in the production of this, like…was there any new plastics, new software, new things available to help achieve this or was it just kind of…

Neurosky: You know what, let me write that down. I'm gonna talk to my team and I'll ask them about that.

Cloyd: I mean is it…'cause I'm trying to look at contextualized…going back to some earlier questions like…given the fact that EEG…

Neurosky: What changed to make this possible right?

Cloyd: Yeah and then EEG has been around so why now…why…what are the factors that are allowing this now? Is there something unique…going on with software…are the…

Neurosky: I would say…two things that I can tell you and then like I said let me talk to my team to see if they have anything else they want to add to it. First of all…processing power is getting smaller. I think it's more (inaudible) it's like the processing that you can do is doubling. So, just the fact that we can use this teeny tiny chip to be able to do the stuff in the past that you had to have a really expensive system for…that's impacting all the technology around us. So that's a really big deal. The other thing is…the fact that we're very much an engineering company, I would say we…we are very heavy on the hardware engineering side even. So…there are advancements that our team specifically did with…the algorithm development but also with the hardware with the type of sensor that we did with the way that we engineered it down so that you could actually get it onto a chip. And so…if you're talking about an internal thing, those are things that within our company we have overcome and that as…as a company…part of our (inaudible)…and part of our contribution comes from…solving those problems. But, as far as environmental stuff, materials, et cetera I can talk to the team because they may know that better than I do. 36:13

Cloyd: And did those things help establish these technology principles you call them? Like portability, lower costs. You just figured that these were things that needed to happen to overcome some of the…why EEG in the past was not so widespread that…

Neurosky: Yeah

Cloyd: Okay

Neurosky: Exactly, exactly. And it's funny cause….on one hand if you're trying to use the technology for medical systems you have a different set of criteria. Whereas if you're trying to use it in a consumer space you still have criteria they're just different criteria. So, it's like maybe we don't have the…technology's not exact…as exact as it is in a medical environment which is…not okay in a medical environment but on the other hand the medical stuff doesn't work well in the consumer environment. So it's, part of it is…I think being clear on what's your market, who are you trying to go after, what are you trying to do with the technology and setting your goals from that….saying okay what do we have to do as a company in order to be successful. Well, try a consumer product…it's gotta be inexpensive and it's gotta be…gotta be easy for people to use. And we're seeing that a lot with even some of the…there are trends in the medical industry now where in the past if you had a medical technology your audience was not the consumers your audience was the insurance companies and the providers. You were selling to doctors because the consumers weren't gonna pay for it their insurance companies were gonna pay for it. So that's…it's a completely different market. Now, there's a lot of focus on kind of the shift toward the consumers taking more active interest in their…in their medical…in their medical care and so there's a big focus on okay we're no longer trying to sell to these insurance providers, we're trying to sell to the consumer. Which means…maybe the quality isn't as high to a certain extent. I don't want to say the quality I would just say the requirements in certain areas aren't as high….but then you have to satisfy what the consumers want which is inexpensive and easy to use.

Cloyd: So, okay…so this is kind of related. So…these factors you're talking about focus on consumers is this…a little bit how your company came up with the idea for…developing this technology or focusing this company around this technology…I mean how did…what are the factors that allowed you to perceive a need for this technology or are you creating a need, do you think?

Neurosky: I think that's partially what's gonna help us. I think we're gonna ride kind of that…wave of where things are going but that's pretty recent. I would say that's probably within the last…five to ten years that this shift is really, really starting to happen. And…it's interesting 'cause I was at a conference a while ago where I think it was Tim O'Riely was talking about it. And he was saying "you know where innovation comes from, it comes from people who like to have fun. It comes from people who tinker and enjoy the technology". And actually…our corporate story is something like that where we, one of our founders was…creating a toy and he was just playing with it in his garage 'cause he meant it for entertainment purposes…and it wasn't 'til….other people more on the business side and less on the….research and…development side came on board and said "okay now this is a cool technology but…where it's gonna be really powerful is how we apply it to these different markets". So…there are…key people our CEO included that came on board…with the request of the founders to…take this technology that seems like a neat little technology and make it…a much more substantial technology and that's where they implemented things like…the cost engineering and….the platform making it into a chip solution…we have a lot of people that have…experience working with chips, both our CEO and our Vice President of sales. Both have really, really strong backgrounds working with embedded systems and so that was a big contribution in…why we went that direction and why it was successful. And probably why they saw potential in it, it's because they saw it and said "this makes sense if we make this an embedded system then…we can make this technology instead of just being a flash in the pan and kind of making it entertaining we can make it into something a lot more substantial".

Cloyd: Embedded system you mean…something embedded into society or…

Neurosky: Working with chips…yeah. Like people who work with chip companies.

Cloyd: Oh, okay that's what embedded…okay.

Neurosky: That's what…yeah. In this instance that's what I'm referring to is…people who are used to working on a microchip level….or VP sales as a background. And he was…I almost consider him one of the, kind of one of the company founders because he was really…key in this. But…NRC (? 40:54) as well…both of them had previously worked…a lot of their careers were…working with companies that created microchips.

Cloyd: So I guess in some sense there is, it wasn't just necessarily perceived need…but (inaudible) I guess the idea kind of came out of a playfulness…about the potential and then part of it's also in some sense also creating not necessarily a need but….a place in society in some sense is kind of….

Neurosky: Yeah, I mean…and that's one of the things that, that happened with us and I see that happen a lot….in Silicon Valley where it's like okay you have this cool technology, well where's your market. And that's where a lot of the challenge comes in, is taking the technology and lining it up with a potential market. Like, alright that's cool how are you actually gonna use it?

Cloyd: Yeah and then I had one question…how did you identify the needs of the market place…when there's…when you say there's not…is there really a need…of matching with existing social groups…that may…where it may enhance their work or their play…I guess is what your kind of saying in some sense.

Neurosky: Yeah…yeah. Well…and actually to go back to what we were talking about a little bit before there are a couple of key areas that we are working…working on…I told you about toys, I told you about games…education is a relatively natural one…just because of the potential for the technology…education…automotive and…oh what's the last one I'm thinking of…education, automotive…health and wellness. So those are kind of the markets, the general markets that are, that are our biggest focuses. Um…you can…the toys and the games ones are the ones we've focused on the most so far and that we've…had a lot of success in and so there's more information on those but we can, you look at the education market and the potential of the technology (inaudible) education market and also…for health and wellness. There's a lot of focus on…health in general like how do you…how are you more mentally healthy, how are you more physically healthy and so that's another trend that…benefits us…that's happening right now…and the fact that brain is really hot right now. I mean…the…I'm trying to remember who said it, on the radio the other day but they were saying "this is the…this is the time of the brain". I mean within the last ten years they've kind of started this, this thing were people are really excited about the brain and part of it is because…we're getting to the point where technology is progressing enough that…we actually can learn something about the brain because for a long time it was such a big mystery. And part of it is…you have these aging baby boomers who don't want to necessarily let go of their reins of power…I mean don't quote me on the way I'm saying that…(laughing) but…they want…people want to maintain their health. And it's like they want to keep their mental health and there's…there's all these other conditions in the past that would kill people off sooner but these days…one of the biggest fears is that you're gonna get Alzheimer's and live to a ripe old age…slowly losing your mind.

Cloyd: Increasing longevity you know.

Neurosky: Exactly, so you have…this whole generation of people that are now…looking at…mental health and mental fitness. And so the timing…and again that's the big thing timing is…for us is pretty important.

Cloyd: So I guess in some sense it's locating, locating nonusers of this technology and trying to make them users…or potential users in some sense…so it seems like a two tiered system where you're focusing on people that develop industrial consumer based applications that can go into these end user applications like…where it's personal readouts of things…in some sense I guess 'cause. So, I guess nonusers in some sense are kind of like your markets, you try to construct a market to see where you can potentially put those technologies?

Neurosky: Yeah it's, it's like…how do I say this…um. We're looking for markets who can benefit from the technology…you're looking, you're looking at okay what do these different groups of people value and what can we provide them that's a benefit for them.

Cloyd: It's interesting that the technology, it is so…yeah I mean I'm just trying to see, how would you…what sort of values would you attach to the BCI technologies if you could any, given the fact that there's such a range that this could be used for? This was just kind of off the cuff kind of question too. So…

Neurosky: I mean, I think a lot of it is the self awareness component…I think a lot of it boils down to getting to know yourself. Whether it's…consciously controlling something with your mind, whether it's trying to learn more about your mental fitness…I think there's two things that are fundamental. I think one is just this idea of kind of unlocking the mind and unlocking the…well three actually…so first of all getting to know yourself, second of all unlocking the potential of your mind…people want to read better, they want to be stronger, they want to be faster, they wanna…they're always trying, I think fundamentally push to improve themselves and this is probably seen as one of the most powerful ways you could improve yourself. You can get smarter, you can make your brain better than….it almost seems like the sky's the limit. And the other, the last one I would say is again, the whimsical thing of controlling things with your mind. I mean the telekinesis idea is so powerful…people…it's almost this weird emotional thing. Like this idea that they can move something with their mind…and I think part of it is that we have this expectation of technology where…you have these shows of suggestions or…we all thought we'd be driving flying cars by now and so…you have technology trying to catch up with people's imaginations. And I think in a lot of ways people thought we'd be farther along by now and so when they find out that there's a technology that maybe can satisfy some of that they're just like emotionally ecstatic…it can almost be strange the way that people react to it.

Cloyd: Yeah and this goes back to your…to saying everything's timing and I guess just the environment of.

Neurosky: Yeah…a lot of things definitely have to come together for…for it to be successful, I think.

Cloyd: Yeah, and we've talked…several of those….I guess one would be the kind of marketing, identifying certain…well I guess you've done that social…social values you could then put in the market…so you think part of it is also too just the…certain historical place where there's baby boomers and…this kind of focus on longevity perhaps creating a potential…ok

Neurosky: I think the focus on longevity, I think the shifting healthcare…people starting to take better care of themselves…in the past it wasn't so popular but now green technology is getting popular and taking care of yourself is getting popular. And if you want to talk about…frankly if you want to talk about things like…money…if you look at the venture capitalist groups…they're really, really interested in things like gaming technology. It's like…gaming technology has made so much money that…there's a really big….there's a lot of interest within the venture community.

Cloyd: So I guess…it just seems like the potential obstacles are, it seems like there may be industries where…you kind of have to like have a honey moon period with the technology to then…for it to become a domesticated or appropriated into people's behaviors to then where you can, maybe there's like more transformative things where people just start using things for medical uses and monitoring their own…I guess technologies…or monitoring their own…frequencies…like their health and things like you were saying. Yeah I guess…I was just focusing on…it just seem the difficulty in getting that into just everybody's normal behavior. I talked to someone they said "you know maybe it just seems like I'll use it then there's a cool factor but then they may not appropriate it or utilize it in their everyday…behavior or something."

Neurosky: Yeah I mean and that's…that's different levels of problem solving…entertainment is one thing and you'll…and you can kind of play with it. But long term if you wanna…if it's not just a gimmick it's gonna have to be something that's more serious.

Cloyd: Substantial. Would you say that the focusing…cause…I've kind of looked at your website and kind of analyzed like the full range of potential users is quite avast that you've uh…seemed to articulate in your website…but it seems like, would you say that…you're trying to get these first end applications like for gaming I guess? Do you think there are certain domains that will help domesticate the technology more than others or…

Neurosky: Yeah I mean I think…I think entertainments a big one…

Cloyd: Entertainment.

Neurosky: Like everybody wants to do stuff that is fun and so…I think introducing the technology in an entertainment environment weather its toys and games or something else…is really going to be helpful because it's like if its enjoyable then people are going to be more likely to do it.

Cloyd: Alright…thanks. I was gonna also ask about, and you said you can't reveal names but I said well who helped in development and you can ask generally like what disciplines, what background or disciplines of the designers or founders were there that since…neuro feedback is such a…it is a hybrid kind of technology…so what would you say, who…

Neurosky: Our founders…psychologists…ergonomic specialists so people who are used to dealing with human machine interface and I can…I can probably send you…I can send you the bio of our primary…founder if you'd like. And that hardware focus like I said…it's…heavy heavy engineering so it kinda, it kinda started off with…with a little more kind of playing around with the technology and then it's almost like to a certain extent we brought in the heavy duty engineers and they did a more solid solution.

Cloyd: With the…like kind of the microchip kind of fabrication…

Neurosky: With all the microchip guys yeah…

Cloyd: …and design.

Neurosky: …with the business guys. I mean they're business, but they're engineering heavy guys.

Cloyd: Like design…oh yeah designing the circuitry of the chips in some sense?

Neurosky: Exactly.

Cloyd: Which I was always…interested in cause I worked for a company that cleaned the radicals or the photo masks of a company and then we'd always look at…we'd clean them to make sure there was nothing on them and then we'd look at the architecture, I'm like "what designates the design you know there's all these t-bones and things like that." I could never get an answer but they said it had to do with algorithms and how the electricity or electrons moved across the chip but…I don't know I just thought it was fascinating. It's unrelated but…

Neurosky: That is interesting.

Cloyd: Let me see…

Neurosky: I had another thing I was going to throw in here too actually.

Cloyd: Okay.

Neurosky: I think it's important when we're talking about the industry…and this is from both BCI industry and the neuro feedback industry. So the BCI industry and the neuro feedback industry are kind of interesting places. So, first of all…

Cloyd: So there's a…go ahead

Neurosky: Sorry?

Cloyd: Is there a substantial difference I guess in those two?

Neurosky: Yeah, I think there is…because BCI like I said is more of a control thing. I mean…I think that other things could be put under the BCI umbrella, but if you're playing purely academically the BCI component is the telekinesis component. It's the, it's the moving something with your mind. Right?

Cloyd: Uh huh.

Neurosky: And it's an emerging industry so…it's considered relatively new and…it has, they have center for concern so for example…what is considered BCI, what is considered not BCI. Like when they're establishing a new industry you're trying to clarify…your own identity by establishing what you are and what you're not so that's a big challenge and interest for them. Um another one is being able to set expectations…for the technology because I know actually for both the neuro feedback and for the BCI industry they're really concerned about companies like us actually in general…I would say at the particular we have a pretty good relationship with both industries, but with people making claims about the technology that are unfounded and then people have a bad experience with technology and then they're…it stifles adoption. And…a lot of times people will reference like the 1980's with artificial intelligence. It's like people had all these…ideas of how amazing it was going to be and what the technology was going to be and then they were disappointed and it really stifled the development. And so there is definitely a lot of concern about…different companies and research groups with companies…more taking…taking on…to educate the public about the technology but not doing a good job. And we fight to actually try to be, and here's my…my marketing hat, we fight to be pretty good stewards of that…we try to be as clear as possible about the reality of what the technology can do and what it can't do…but it is a serious concern. And we even face it. Like we have to deal with it when people are like "Well I thought this was possible" and it's like…uh no, you're being mislead. So…industry wise that's pretty important…for BCI. For the neuro feedback industry like we said before they're dealing with, they've been around for a while…they don't necessarily have the best brain reputation although…they are very legitimate…if you look at the success they've had and the type of people that are involved, there are some really, really amazing people and the industry is pretty respectable. But their concern is…will people take this technology and think it can do one thing and if it doesn't actually do it will it reflect bad on their industry. So they have kind of the same concern as the BCI industry. Another concern that they have is what happens if…you misdiagnose somebody or…your changing people's brains and you don't change it positively, what if you have a negative impact instead of a positive impact? Which again is legitimate and when you're getting into the realm of…using the technology for…more of that long term change or the…dealing with changing the brain, that's kind of more of a concern.

Cloyd: Okay…so I guess…so really it's an important distinction to make the…neuro feedback versus the BCI technology. Even though BCI's are kind of built off EEG stuff…

Neurosky: You know I don't…I don't know if it is…I…like there is a difference. If you're really getting in to…the differences in the industries then yeah I would, but I mean I'm kind of telling you this just so that you understand sort of the political landscape and things like that, but you know for most people I don't know that…when you get into the academic realm it's like you can draw lines in so many different directions…there are so many categories within BCI there are so many different types of neuro feedback, there's additional groups that you would add into it. So, I think it's worth noting but I wouldn't dwell too much on it.

Cloyd: Okay, but you said there are BCI technologies that are hindering the diffusion of it by their misrepresentation of things?

Neurosky: Yeah, I would just say that…that for both neuro feedback or…it seems like people saying…"oh you know this group is making these games that they claim make you smarter" but it hasn't been proven so it makes the rest of us look bad or things like that.

Cloyd: And so are these…would these be in a league with…I figured like…companies like Emotiv, Neurosky and you…are kind of like these lead BCI technology people…so there are others that are more kind of not as I guess developed or productive in some sense?

Neurosky: Yeah…there's…we've actually…between the two of us, us and the Emotiv do I think get quite a bit of attention, but there is a lot of…I wouldn't say they're doing the same thing as us but there's other smaller groups. And then…I…I'm not going on the record to dig Emotiv but I would.

Cloyd: Say what?

Neurosky: So…I think sometimes they can be misleading.

Cloyd: Oh okay, yeah.

Neurosky: I mean…they're good for us. It's good to have them around. I'm actually glad that they're around to a certain extent but there are times that they're misleading and it's not…it's…it can be troublesome.

Cloyd: Well how many other BCI technologies…cause I seem…I tried to identify four…ones that I…OCZ Technology.

Neurosky: Yeah. OCZ, Emotiv and Neurosky are kind of the acknowledged consumer leaders. There's a ton of other groups that are not consumer focused or maybe they want to be but they…they're not that far along yet they're still using a lab environment.

Cloyd: Or in someone's garage or something (laughing)

Neurosky: Yeah. A big one that does really cool stuff is really kind of still pretty heavily…research, is Guger Tec, g.tec and they're based in Germany and they use like…a gel and they use electro tap but their interfaces are pretty cool. Like they have videos that they show…where you can type with your brain and some of that's neat…some of their stuff is really cool, it's pretty slick. Whereas a lot of the lab…their stuff looks kind of rudimentary and it's not too slick but...Guger Tec is respected I would say.

Cloyd: This kind of leads me to other aspects of identifying…cause sometimes. I'm trying to focus on the relationship between not just industry developers but also…like kind of hobby developers. How important are users in developing this technology or for you has there been feedback from users…utilizing forums…things like that? Has there been more of a one way relationship or kind of a two way relationship…in developing…

Neurosky: You know…I would almost call it like the Steve Jobs' question where…Apple never listens to consumers and Google always does is kind of argument right? And the thing is, how, and I think even Steve Jobs said this at one point. He said…"consumers can't know what they want because I haven't given it to them yet." And as (inaudible) as that is when you're talking about a new technology you kind of have to have that approach to a certain point. It's got…how can you…how can you explain water to someone…an ocean to somebody who's spent their life in a desert? So, part of it I think is the company itself has to have a vision…and I think we have.

Cloyd: So, what is that vision?

Neurosky: Um, I would just say making…hmm. I would say making this a platform technology where you can put this technology into any industry.

Cloyd: Okay

Neurosky: There are a lot of way you can answer that question, but I would just say being able to put BCI technology into any industry, into any product.

Cloyd: And then go back to those users it's that…seemed to…the Jobs quote…it seems to focus on consumer based uses, but so much of…seems like with your website…is contingent on or it's based off people that are very knowledgeable about software and writing code…who are very knowledgeable…so there is kind of like a lead user in some sense cause they're also helping to develop a product in some sense and not just, it's not a ready made product to go out into the public. I mean how much have those people…those lead users been in developing the technology?

Neurosky: Pretty important to us and I would say especially because we are a platform technology which means we enable other groups to make their own stuff. So, for example one of the reasons that our SVK is free is because we want to encourage developers to create applications. First of all, of course, because it helps us sell hardware but on the other hand because they come up with ideas and they have areas of expertise that we don't have and we won't ever have and don't plan to. So…it is important for us to get feedback and say "okay what do you need" and of course…depending on who it is that carries more weight. So, when Mattel comes to us to say "hey we thing we need this" or another partner an industrial partner says "we need this" we're gonna give more weight to that obviously. Um…I think it is important for us…to get individual feedback from consumers. I don't know that we're enough far along that we're…we've got other challenges to deal with…some of the. It's kinda like don't sweat the small stuff because on one hand…we need to tackle the big problems…you're launching a new product, you're launching a new industry and so those are kind of your highest priority. I mean, I think there are consumer things but…maybe the interface could be a little bit different, maybe things like that, that when you're trying to fill different usability…maybe there are things that we could do better and we do take those into consideration, but you have to kind of prioritize. I don't know if that answers your question at all

Cloyd: I guess, 'cause I mean really we're trying to do a taxonomy of users. Especially with software and platform stuff 'cause there's like the platform, a developer that built something and then that goes out into someone who uses it. Right?

Neurosky: Right.

Cloyd: So, I guess there's the hierarchy of…of…I guess you're saying that users have been helpful in the developing section like people that build platforms…that use your platform to then build another thing. So…so that relationship, you said there's been feedback between you…those…those developers?

Neurosky: Yeah…I think developers and I say developers in the sense that I'm talking about like software developers, application developers. I…I think that's been important for us…partially with them we're just trying to get the word out and trying to educate them. So, yes we…of course their feedback is really valuable to us, but we're still kind of at a stage where we're just trying to get the word out. Um, when we're talking about like business to business like partners…on one hand…it's…I guess it's…you might describe it as a low hanging fruit approach. You know, somebody's like "hey I'm interested in…buying this technology and making a product off it". If they're gonna to commit to that then…we'll do more development or we'll look into to the more, give them more of what they want compared to somebody whose just like "hey I think this is kind of neat can you guys go…spend a ton of research and time and dollars on building this thing, but I don't know if I'm really even interested" and it's like "yeah I don't know about that". I mean, we do things where we work with partners and if they want us to do research and development they pay for it. In some instances it's just things that make sense we think across the board. So, it's like "okay that's a good refinement for a technology and kind of the general product road map that we're working on", but…if they want to work on things that maybe aren't what our primary focus is then we can do that but (inaudible) 01:05:10

Cloyd: So…the online forms…they're kind of useful or not useful? So, really the main…

Neurosky: Those are definitely, those are definitely useful. Those are really useful because…for me, in particular, it's good because I get an idea of…is there enough (inaudible) working, are people understanding the technology properly are they interested in the technology. So I would say yeah, I do think those really, really important because they give us feedback…and in most cases non biased feedback on the technology and kind of the different things that we need to work on…but…again you have to prioritize…you have to be like "okay well this person has an interesting thing, but it's not realistic to say that we would do that feature for a long time because the market in general doesn't demand it or it's…it's technically so difficult that it doesn't make sense for us to try it. I mean…so yeah…I think that information is really valuable…I think at this point in our development though we know some of the challenges that we need to overcome and so it's kinda like focus on those first, but also…keep in mind the feedback that you get from all of these various places whether its online or whether it's from partners and things like that.

Cloyd: Yeah, I may not…because I'm thinking specifically too, video game controls or…some of the…have there been criticisms in regard to that? Like how difficult it is…I know you had something with Square Enix. Right? With that Judecca…

Neurosky: Yep, Judecca, uh huh.

Cloyd: Have there been criticisms…about how difficult it is to kill the zombies or (laughing) with your mind or…

Neurosky: No, I don't think so.

Cloyd: …or the interfacing or such…

Neurosky: The one thing I would also say about the forms is very rarely will anybody write on the form something that we don't already know.

Cloyd: Yeah.

Neurosky: I mean…people can be more or less there or more or less informed, but I would say most of the time…we probably know. So…so…and if it's not fixed or it's not being fixed there's probably reasons why it is or it is not being fixed. You know what I mean?

Cloyd: Mm hmm

Neurosky: And people think "oh well it's not a replacement for a controller". Well I'll tell you that. Anybody in our company will tell you it's not a replacement for a hand held controller. Um, so part of that is the education process and having people really understand the realistic…capabilities of the technology.

Cloyd: Oh okay.

Neurosky: So if anything that would be feedback on a messaging level. It's like "okay are we properly communicating to people the benefits of the technology?" Because if they think that…the benefit is that it's a replacement for a controller then…we need to either work on our messaging or work on getting it out more.

Cloyd: …I guess I'm trying to think too of like how…yeah okay. I've got a lot of thoughts and stuff…okay…it's funny like you always start with…like a very…a linear kind of outline (laughing) and it goes all over. But that's usually how it goes, right?

Neurosky: Yeah.

Cloyd: …so I think…okay. I think that's kind of most of, I think everything we've covered…everything I can think of at the moment.

Neurosky: Let me…let me give you another challenge by the way.

Cloyd: Okay

Neurosky: The challenge is that we've overcome, of course, noise reduction…engineering it down to be inexpensive…an ongoing challenge I would say is things like algorithm development. So…

Cloyd: And when you say algorithm…what exactly do you mean? 'Cause I know that as like a logical sequence of steps. That's how I understand it and when you use it, you mean what exactly?

Neurosky: …so the algorithms that we've created basically the process is…and rough, I would say this is roughly, you measure a ton of people when they're doing a specific thing and you average it and over time you see the pattern and you can use that pattern within the technology. So, if people are paying attention we know that this patter is they're paying attention therefore it is a device we can…control something because somebody's paying attention. That's…that's the thing…but algorithms are usually made to standardize things. And most of the people who have strongest expertise in this industry I would say…well two groups. One is clinicians that do biofeedback, do neurofeedback…they're seeing patients all the time, they're making customized things…on a regular basis. Although…they may customize a protocol…instead of steps for an individual patient, but they're not averaging they're doing everything pretty custom…however, the groups that do tend to make algorithms are universities. Because a lot of the times they'll be…they'll be doing a study where they want to test a lot of people…on a specific thing. They're like "okay I'm making this algorithm because I wanna make, I wanna see…the consistencies between people, does this consistency actually exist. Does that make sense?

Cloyd: Mm hmm

Neurosky: Now the problem is, is that…since our technology is really new and because we (inaudible) and the algorithms…have to be different using a single sensor than a multi sensor…we have the one's that we've created in house and we have one's that we're working on in house and with university partners, but a big challenge is finding people who have expertise in developing algorithms.

Cloyd: Oh. That's a company challenge is what you're saying?

Neurosky: Yeah, that's a company challenge. We have things that we're working on, but I would say…that is something that is difficult because…you're launching a new platform…you have to educate people in terms of finding people with expertise. You know its one thing to give, to take the algorithms we have and let game developers build stuff off it. It's another thing to say "okay, now we want more algorithms and how do we find the people who have really in depth backgrounds in them to build them. And it takes time. Sometimes…we work with…researchers and universities where they have a ton of experience and the already have algorithms…but then you still have to test them or you might have to modify them for a single sensor system…it's just it's a whole world of potential complications. So I would say company challenges, that's an important one.

Cloyd: So…these algorithms is kind of the same thing, what I see in the neuro feedback literature they call it qualitative EEG databases in some sense…

Neurosky: Yeah.

Cloyd …is that the same thing?

Neurosky: Yeah, same kind of thing.

Cloyd: So you're kind of creating your own database in some sense…for your technology, right?

Neurosky: Mm hmm

Cloyd: Uh, okay. And then uh…

Neurosky: Oh, another challenge is when you're developing things like that is IP issues because…if you're a company and you wanna work with say, and I talked about this before. I've worked with different doctors and they may be developing an algorithm, but people are nervous about telling you what they're working on because nobody wants anybody stealing their other ideas. So you have to…go into kind of the legal realm of okay so now we have to like…find confidentiality agreements and…once you get into that realm it gets tricky because…you, on one hand you want to move forward with business, but on the other hand you have to protect your intellectual properties. So…typical business stuff (laughing) when you're dealing with that sort of thing.

Cloyd: Yeah, patents and I guess knowledge.

Neurosky: Exactly.

Cloyd: Protection…I saw some other things here…it's kind of related to, well there's…kind of not related…I thought. What other ways do, what ways dose your company promote this technology or market it? Like do you do magazines? Do you do…you do these conferences I guess?

Neurosky: We do a handful of conferences and we do PR

Cloyd: PR. So…do you like…just the…in what sense?

Neurosky: In the sense that we have…one of my biggest focuses is on PR, although I work with a lot of other departments internally, but just public relations…just trying to get reporters to write articles on the technology.

Cloyd: Okay, okay gotcha.

Neurosky: So (inaudible) we'll present at certain universities especially the local ones. Like we go to Stamford and talk every couple of months and other places that are local, but…and then we do a handful of…shows. Like we did the game developer conference this year, we did this demo conference…we've done the Tokyo game show before.

But we do very, very few…conferences because they're expensive and because it's hard to pick and choose because our technology can be used in almost any industry. So why go to a toy conference or a game developer conference over a research conference or an automotive conference…you have to kind of just narrow down what you can do…we're still a relatively small company and we really don't have much marketing budget.

Cloyd: Hmm…okay that makes sense. So how did they come up with the name Neurosky?

Neurosky: …our founders were Korean and I don't know the specifics but I know that…it was considered a really…I can ask.

Cloyd: (laughing) It was just a…

Neurosky: That's always a joke, oh yeah they're Korean. I mean that in a positive way because you know in Korea there's a lot of things like the (inaudible) and the ocean. They're very, I think, environment focused on a, not on a…an actual environment level, but more I don't know…spiritual level, I don't know. I'll ask if there was an interesting story or somebody just kind of decided on a name.

Cloyd: Well I can…obviously there's symbols related to mind and to the heavens and things like that. So, I can see the connection I just thought I would ask and then, and I thought you had other projects. Like project Millennium and this thing called Mind Ball. Are those…still going on or…

Neurosky: So, the other big focus that we have right now…we have a number of different things that are happening, but probably the next really big one, there's well actually there's two. One is the non contact sensor. So right now…we've developed a dry sensor, we put it on your forehead but it's got to make skin contact…however we've actually created a capacitive sensor where it can either, you can put it on clothing. So, you could embed it into a car seat or…

Cloyd: Wow

Neurosky: …it goes through hair. So, that also…makes things, opens up the possibilities because you can have sensors without a gel on multiple locations on the…you can embed it like I said into a car seat. So that's a pretty big deal too that we're working right now is that not only just having it not…not need to have a gel, but now you can not necessarily have to have it making skin contact. So, it has to be close but it's not like "oh you're a foot away". You still have to be up against it, but you don't have to have it like directly on your skin.

Cloyd: Yeah…

Neurosky: That's a big…

Cloyd: Yeah that is. Especially…if you see some of the critiques of previous technologies. When they talked about bio sensor like the clip on the ear, they said it like pinched really hard. Like when Nintendo made one. I see another helmet you have has the clip on ears…that definitely opens up possibilities…I'm trying…

Neurosky: The other one is called SSVEP, Steady State Visually Evoked Potential and…it's been around for a while. The technology's been around for a while in a lab environment but basically what it is, is we can detect, how do I say this? We can detect…what you're looking at to a certain extent. So, we have a sensor that goes on your occipital lobe which is the back of the head and which is where sight, all the processing is done for sight. And we have a thing we call the light box. I think you saw the picture was probably on the website. And you can look and each of those little lights is flashing at a different hertz range…ones 9, ones 10, ones 11, ones 12 something like that. And depending on which light you look at…we can have it register, it registers in your brain….it can…I'm trying to figure out a way to…basically it's like we can look for those spikes that come from looking at a specific thing. Like we can generate…an artifact if we know what it looks like. So for example you look at…the upper left light and…on the little light box and on the computer screen the upper…the upper left circle…flicks. So we can what you're looking at basically.

Cloyd: Wow

Neurosky: And that's really valuable for things like potentially for directional control because…you can do things with like (inaudible) and stuff like that and you have to really train yourself to do it. Whereas if you can just look somewhere or look at something and have it have the technology to know that's what you're looking at or what you're concentrating on then…it opens up a lot of other possibilities.

Cloyd: So, what do you think…I'm just trying to perceive, it's kind of hard for me to get my…

Neurosky: Well right now what it's used for…in kind of a lab environment…option is. I don't know if you're familiar with P300, but it's a spike in the brain when you basically recognize something. And so a lot of the systems that use typing they want you…if you're a disabled person and you're going to type out something they use P300 and what it does is it flashes different letters on the screen and when you see the letter that you're looking for…there's a little brain wave that shows that you recognize it, it's like….it's that ah ha brain artifact, it's like "oh that's it" and so they can identify it and then know that that's what you were looking for. So, its things like.

Cloyd: I saw something…I don't know what forum I was looking on…I don't know what…I don't know if it was Carnegie Mellon or Stamford. They were using a Smartphone for…recognition of a phone number and it would dial it. Is that the same kind of or similar?

Neurosky: Yeah, same kind of thing probably. It's where they're like that's the number.

Cloyd: Like it was sight and then it would give a certain frequency and then it would dial that number based off "oh there's a peak".

Neurosky: Right.

Cloyd: Oh okay

Neurosky: You can identify the peak.

Cloyd: Wow…it just seems like all kinds of type's potential…

Neurosky: Yeah. And a big thing for us is that we wanna work with different universities who want to take IP that they have and consumerize it. I mean we're in kind of this sweet spot where we have a ton of…companies coming to us and we have…we work a lot with research groups…so it's like we would like to help bridge the gap in areas that are relevant to us, of course. To kind of help…get that technology out of the lab environment and get into the hands of more corporate partners so that they'll actually be able to develop it more.

Cloyd: Okay…I think…I'm trying to go over all these questions. I think we've covered most of them in one form or another. So, I think this is good…and it would be okay in the future I guess to maybe do a follow up in a couple months or something?

Neurosky: Yeah. Why don't you just kind of take a look at it, process whatever you need to. I've two questions from you I think I need to look up. Talking about new material, what kind of things made the technology possible, why now and then…oh and where did our name come from…and then there was one more but I think we already answered. So, yeah think about it and then if you have other questions, it doesn't have to be in a couple months, if you wanna talk next week or something after you've had a chance do digest let me know and we can talk again.

Cloyd: ….oh I know there was one other one. There was something like what key developments in your company...were there that…I was thinking like contracts. I saw…I found things like your contract with Titan. Was it Titan?

Neurosky: Oh two developments…yeah. I mean that's kind of like a timeline, right?

Cloyd: Yeah

Neurosky: Like our first really big client was Mattel….they bought our technology…released the Mind Flex…the Mind Flex Dual was just announced in January at CES, no at the New York toy show, no CES. Now they're making their next round of technology, of toys with our technology. Uncle Milton also around the same time…around two years ago, two Christmas' ago…launched the Star Wars Force Trainer…and then around the same time we launch the Mindset. And then the Mind Wave is specifically consumer priced headset which is going to be $99.00, which is $99.00 that we launched…at the beginning of March…there's kind of like a timeline. I guess there's strategic partnerships and things like that, like have relationships with Toshiba, having relationships with Square Enix…yeah there's a lot of different ways you can go with that.

Cloyd: Okay. Just thought there may be something, some significant moment or something where things were…like there was a momentum in some sense with the tech…with the company or something you could identify…

Neurosky: I say one of the biggest ones is Mattel. Mattel was, Mattel or Uncle Melton I guess they came out at the same time so it's debatable which was first, but Mattel was probably our first really, really big client. So that's a pretty big deal and then I think when we first launched the Mindset which was the $199.00 headset…not last year but the year before, that was a pretty big deal because….we took the technology from being $9,000.00 if you wanted a headset or $5,000.00 if you're lucky into being $200.00…so that was a pretty big step.

Cloyd: And then putting in the hands of just regular software developers.

Neurosky: Regular folks, exactly. And then also I would say…getting the technology onto an ASICS chip…I can, I've got this funny little manikin head that shows our original…let me see if I can send you a picture …it shows you our original…demo headset, like what it looked when they were first playing around with (inaudible) trying to get money. It just looks ridiculous, it's huge and bulky, it's got all these Radio Shack parts hanging off of it (laughing)

Cloyd: (laughing) I would love that picture actually.

Neurosky: Okay (laughing) I'll send it to you. We call him Diver Dan, but yeah it became the first iteration of the headset way back when. And I'll…

Cloyd: I love the…

Neurosky: I'll…

Cloyd: I love the joke…go ahead

Neurosky: I was just saying yeah I'll show you and then you can see the pictures of our current stuff and it's come a long way.

Cloyd: (laughing) This is great…I really appreciate all of your doing and helping with, I know there's no reward other than (laughing) just my thanks and praise…

Neurosky: No, no, no, I'm excited about what you're working on. And I, in particular, but everyone in the company…we want to create, create. Not create, I would say provide a better understanding for the industry. Not only are we trying to grow things in our company, but we benefit from…the industry itself growing. So the more we can kind of tell people about it the better off we all are I say.

Cloyd: Yeah…my area is just a lot different. It's not marketing and it's just kind of trying to understand the trajectory of technology and…some of the values and social values that are going to the appropriation of it, the resistance to technology, the domestication of it and things like that…really the relation between subjects and the technologies themselves. So…

Neurosky: I'm definitely a student of that in my spare time. I love Silicon Valley. They moved here from Colorado…this was a little before that. I'm really fascinated by both technology in general and also the impact it has on society. Which is pretty amazing in my…

Cloyd: Yeah, it's amazing and often times there's always these…these…it impacts in ways we don't often times intend or realize…

Neurosky: Yeah.

Cloyd: …and it often times shapes us in ways that we don't even realize until it's actually happening or happened or. So, it's kind of seeing that trajectory that's fascinating.

Neurosky: That's funny because I…I actually originally study social marketing, which is like marketing for causes…

Cloyd: So is that your background?

Neurosky: Yeah, yeah. Social marketing and psychology, 'cause I was really interested in like how do you change human behavior, how do you make people be better, how do you change them for the better? And I thought…go through marketing, go through advertising for causes right? And what I realized is…if you want to change behavior, first of all I'm a big proponent of doing it with business…if you want to change something make it profitable. And technology's amazing because it's like…it can take you ten years to change human behavior, ten year plus because you're basically raising a whole new generation…it's interesting if you see the comparison between the United States and like Spain, which is where I moved for a little while…they smoke all over the place, they smoke in front of their kids…

Cloyd: No, I know. I was on a train in the no fumar section and this guy comes in and just lights up a cigar right next to me.

Neurosky: Yeah they don't think twice about it. It's like culture it's not considered a big deal, but the reason that American's feel so different about it is because we've had ten, twenty years of telling us that drinking and driving and smoking is bad. And so you've basically raised a whole new generation with different values. So, it's kind of like well that kind of stinks that it takes so long to change behavior. But I realized how it was different with technology…five years is a lifetime in technology and if you create a technology product that catches on you can…you can just revolutionize human behavior and I say in most cases for the better.

Cloyd: Yeah…yeah…it's interesting…getting people to chang ewhen they don't want to is kind of hard. (laughing)

Neurosky: It's really hard…

Cloyd: Yeah and like you were saying it's generational…the public policies and education or social policies of educating people like…cigarettes are bad and I mean my full time job is going to be with…it's Temporary Assistance for Needy Families, so it's Social Services. So, you're talking about people that have kind of been socialized where they don't change their behaviors? You know, if they don't get Food Stamps they're like "well how am I gonna get food?" they don't think of a job or anything like that they just…you always wonder how you can change and …it's true that once you…introduce technologies they end up shaping you in ways that you may not intend to like it's not really sometimes a choice…often times there's…like I resisted texting for so long, but then it was actually affecting my social interaction. 'Cause people come to expect that that's how you communicate with each other.

Neurosky: Right and so if you don't text then it's like…what's wrong with you or you're not socially behaving properly.

Cloyd: Or that or I wouldn't really know what was going on. There's this text, what is this thing…like people, they would send it and expect you to get it and respond and I wasn't used to doing that.

Neurosky: Right.

Cloyd: So I had…so that's what I mean by you put it out in society and it starts altering whether you want to or not…your behaviors. So, I guess you're right that there's a…that's one way you can alter behavior.

Neurosky: Well you know, something that's really interesting to me is there's a philosophical debate over who's done more good for the world Mother Teresa or Bill Gates? It's like think what you will about Bill Gates…he has made it possible for people to make their own livelihoods, to…bring computers into the home…revolutionize our society, our world. And….it's an enabling technology…people can do things that they could never do in the past and all of the other benefits you can kind of extol about it, but…it's interesting because it's like the way that we look at…the people who benefit our society.

Cloyd: The thing is, there's always duality…there's this promotion of these things…like communication has increased, but you can go back to even Thoreau talked about "you might have a faster way to communicate, but then the substance of it, is the substance more qualitative?

Neurosky: Right.

Cloyd: Just because we can instant message does that mean that the substance of the message changed? I mean substance, is it more substantial?

Neurosky: Yeah it's funny 'cause I had that debate with, I was having dinner with my cousins, they are really young like they're in their teens, and….my aunt asked me, she's like "oh are you a big texter?" and I'm like "no, I'll send a couple texts like I'm on my way or something like that, but I'm like most of the conversations I would have can't be held in a text". But that's not the type of communication I have with people. So, it's like I'm going to be on the phone or I'm going to be in person because the types of discussions I want to have are going to be too in depth for text messaging. So, but I think it's interesting.

Cloyd: Well, I really appreciate it and I could go on about the impact….

Neurosky: I know (laughing) we've been here for hours…process it and I'll follow up on the questions that I've got and then anything else that you think of we can either talk or you can email me or whatever works. Okay?

Cloyd: And just be…you know if you're like I only got a couple questionnaires back, I just did that because I thought maybe user's feedback about the technology would be helpful.

Neurosky: I really want to do it and I think it would be cool and I'd be interested in getting the feedback, frankly.

Cloyd: Okay

Neurosky: And we have in done as internally and we should and so I'm like ooh dual purpose, but I do have to run it by different people in different departments and I want to push it.

Cloyd: Yeah, definitely do that. I've posted it if you, if there's changes you want me to make whatever and I could do, I could amend that on the IRB and then…make it compatible with your needs or whatever.

Neurosky: Okay

Cloyd: Because…I would like to get that and to…but if…I'll look forward to that. And yeah if could follow up with the possibility of getting anonymous responses to some of these questions that I sent you from the researchers the more technical things and then have researcher A or B so I don't the identity, that would be great too.

Neurosky: Okay
Cloyd: Okay. Well thanks so much.
Neurosky: It was good to chat. I will talk to you a little bit later and have a good evening.
Cloyd: Okay, you too.
Neurosky: Okay, bye.
Cloyd: Bye

Appendix G: Acronyms

ANS: Autonomic Nervous System
ADHD: Attention Deficit Disorder
BCI: Brain-Computer Interface
CAD: Computer Aided Design
CBF: Cerebral Blood Flow
CNS: Central Nervous System
DARPA: Defense Advanced Research Projects Agency
DOD: Department of Defense
ECG: Electrocardiography
ECoG: Electrocorticography
EEG: Electroencephalography
EOG: Electrooculography
EMG: Electromyography
EPSP: Excitatory Postsynaptic Potential
ERP: Event Related Potential
ESA: Entertainment Software Association
fMRI: Functional Magnetic Resonance Imaging
GUI: Graphic User Interface
HCI: Human-Computer Interaction
IPSP: Inhibitory Postsynaptic Potential
ITR: Information Transfer Rate
MMORPG: Multi-Massive-Online-Role-Playing Game
NES: Nintendo Entertainment System
OCD: Obsessive Compulsive Disorder
PET: Positron Emitted Tomogram
PNS: Peripheral Nervous System
QEEG: Quantitative Electroencephalography
SCOT: Social Construction of Technology
SMR: Sensorimotor Rhythm
SNS: Somatic Nervous System
STS: Science and Technology Studies
TCR: Techno-Cultural Resonance
UI: User Interface

Appendix H: Permissions

Hello Tristan,
Please consider this my formal approval to use the information from our interviews and all of the content I provided regarding NeuroSky. As a marketing director for the company as well as approval from the Marketing VP of the interviews, I was qualified to provide the information and approval for this project.

Please feel free to contact me with any questions.

Best wishes,
Tansy Brook

Sent from my iPhone

On Dec 17, 2013, at 1:19 PM, Tristan Cloyd <tcloyd@vt.edu> wrote:

Dear Tansy,

I am writing to request permission to publish the transcribed interview and or excerpts in my dissertation from our telephone interview conducted in 2011, as well as the images of the headsets you sent me via email.

I cannot thank you enough for your cooperation and help in this project. I would have had to change the project without it.

Best Regards,

Tristan D. Cloyd
Science and Technology Studies

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