

# **The Development of Biofeedback Interfaces and their effect on Social Interaction in Virtual Environments**



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Social Interaction in Virtual Environments**

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## **Abstract**

Social interaction within virtual environments is on the increase, in accordance with both the rising prevalence of personal computer technology and the numerous forms of traditional communication being converted to formats suitable for the digital era. This is evidenced firstly by the growing popularity of various virtual social communication activities such as online social networking, and secondly the increasing sophistication and depth of interaction these services provide.

Consequently, there is a continual demand for the improvement of the interface through which these interactions can take place. Current interfaces are highly limited as to the depth and type of information they can respond to from their user. The field of biofeedback contributes aspects that could be crucial to the development of improved interfaces. Although its original purpose was to be a form of medical treatment, the field readily overlaps with the fields in human-computer interface design. The acquisition of physiological data that was originally only intended for use as a feedback loop for patients can actually be used for a much wider variety of purposes as an interface to virtual reality.

With the introduction of biofeedback technology as an interface, there will be a profound change in the means and methodology with which humans can interact with their virtual environments, and subsequently socially within them. Its gradual adoption is enabling the production of interfaces that are both more intuitive to their users and capable of garnering a wider variety of input relevant to particular activities, for instance prospective virtual social environments of the future.

This dissertation examines how the adoption of biofeedback technology into the interfaces for virtual environments will affect social interaction within them by exploring the way that the technology can be adapted to meet the already recognisable requirements for this interaction.

## Introduction

Since the late half of the 20th Century there has been an unmistakable growth in human interaction within virtual environments. Many activities that were considered exclusive to physical reality have either been experimented with as an alternative virtual format or have been outdated by their virtual successor completely.

Most of these activities have been forms of social interaction, regardless of whether they are conducted as people meeting within a three-dimensional virtual space such as a simulation or game, or in the form of media produced in a blog or social networking site. Even where social aspects are not a significant part of an activity, it can be considered in the same context as an individual's interaction with the virtual space and the objects and properties within.

With the improvement of computer technology both in terms of software and hardware, and with the increasingly widespread availability of personal computing products, such interactions are becoming ever more significant and perhaps essential to a growing number of peoples' lives. The personal computer has become an interface for all forms of communication in the same way that it became a meta-medium encompassing all previous forms of media. In *The Language of New Media* (2002), Lev Manovich discusses the importance of the interface as a carrier for cultural media objects but in doing so also reveals why the interface of the system is fundamental to the growth in use. Unlike any form of media that has come before where the relationship between authoring information and consuming it has been a one-to-many model, 'all computer users can "speak" the language of the interface' (2002: 87) and are given equal ability to produce their own personal content.

Additionally, as these interactions become ever more prevalent, it would seem that people wish to express an increasing amount of their personal being. Users will interact with virtual environments from every imaginable type of social website through to persistent virtual worlds such as *Second Life*<sup>1</sup>. While these two environments place emphasis on very different requirements for user interaction, they both push the limitations of current interfaces and the quantity and variety of information they can capture about their user. Social networking sites provide plenty of space for user generated content, storing intimately personal details on a 'profile' page, encouraging users to share essentially as much detail as they can with each other. A good example would be the website *Twitter.com*<sup>2</sup> that is designed to allow its users to make very frequent and small updates detailing their every movement.

Alternatively the example of *Second Life* emphasises the ability of the user to customise every tiny detail of their virtual avatar. However because of its appearance as entertainment software and obvious parallels with 3D computer games many of its users choose to indulge in fantasy lives rather than mirror physical reality.

In both cases the user's involvement with their virtual presence is influenced by the interface. However with both of these examples the fundamental purpose for interaction is the ability to share an experience with a human orientated community. Hence while the development of these interfaces can be attributed to this growth they can also be considered as an inhibiting factor. Currently they are largely unintelligent in terms of their ability to respond to the needs of their user and the physical aspects of computer interfaces have seen little change since the modern home PC was introduced as a widespread product. The connection between humans and

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<sup>1</sup> Second Life is a 3D virtual world developed by Linden Labs and the client application is freely available to download. (<http://www.secondlife.com/>)

<sup>2</sup> Twitter is a free social micro-blogging/messaging service that allows users to post frequent and very short updates. (<http://twitter.com/>)

their digital representation is mediated through an aging interface that still lacks real intuition.

*The Art of Human-Computer Interface Design* (Laurel 2002) seeks to dispel the notion of traditional interfaces of this very type. In particular, Scott Fisher describes virtual environments with very different interfaces to the current paradigm that employ a multitude of alternative inputs to the system giving its users unparalleled interaction capability. The eventual goal of such a system is to 'provide a human interface that disappears' (Fisher in Laurel 2002: 438) and hence totally immerses its user within the virtual world. There is a need for improvement of the interface in accordance with the improvement of computer processing capability and the subsequent richness or realism of virtual environments.

For my purposes the term interaction has the dualistic meaning of both interaction with other individuals within a virtual environment and interaction with the environment's interface itself, since the latter facilitates the first.

Interface as a term should encompass the entire mechanism with which the user of a system can interact with it, from the physical inputs through to the virtual representation of themselves. This is inclusive of the relationship between the hardware, operating system and software, and of course the output that is typically a graphical representation. Usually this would take the form of a personal computer system that follows the *OSI Reference Model*<sup>3</sup> for interconnectivity, but of particular interest are the highest layers where the software that the user interacts with is.

The term biofeedback is explored in greater detail in the second chapter, but summarily the term is focusing on the technology being used in a virtual reality or digital art application rather than its original medical application for clinical treatment. Similarly the use of the term cybernetics is orientated

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<sup>3</sup> The Open Systems Interconnection Reference Model is a means of describing the various layers (seven in total) involved with computer network designs.

around its application as a bridge between human biological functions and virtual reality.

Finally, a virtual environment can be considered as any space created by computer hardware within which these interactions can take place. This can range from the original analogy of a desktop and folders through to complicated persistent 3D virtual worlds. It is an environment that does not exist in physical reality, but 'having the form or effect of that which [does]' (Bartle 2004: 1) and hence often the consequences of actions in the virtual space are actuated in the real world.

There has been a certain degree of overlap between the fields of biofeedback and human-computer interface design, where the methods of interaction with the system involved in the former are applicable to the latter. In the terms of the original field of biofeedback, the computer or equivalent technology would have simply been a medium for displaying a user's physiological data, but this data would have no influence on the system itself. Since however, using physiological data input has been experimented with and is gradually becoming a more accessible and viable means of interaction with a computer system.

With an introduction of biofeedback-based interfaces it is possible to hypothesise that future computer software and operating systems will be able to adjust themselves according to the emotional state of its human user, and simultaneously it will be possible to convey far more of our self virtually. As a result social interaction will be mediated through more sophisticated interfaces that can respond and adapt to their user.

There have already been interfaces developed for situations where the alertness of the human user cannot be compromised for critical safety reasons, and hence the system has been given the ability to monitor its user for signs of stress or tiredness and take appropriate actions. But examples of biofeedback technology for personal home computing use have yet to really take off, with a

limited number of products exploring it. Integration into the core of a commercial operating system for a computer is not yet a reality either.

For example, the game *Journey to the Wild Divine*<sup>4</sup> makes use of biofeedback as part of a well-established form of therapy. However its use is unsophisticated in the sense that the program itself only acts as a monitor of the user's physiological state and while the software aims to guide the user to change their own physiological state, it does not change its own behaviour in response. The activity in this case is far from being passive.

The first chapter examines the topic of social interaction in virtual environments, beginning with a broadly historical overview of the personal computer as a communication tool, with the intention of outlining the key characteristics and ultimately the requirements of virtual social interaction. It also explores the relationship between human and computer interface and the way that the user is mediated through the interfaces to form a virtual presence or avatar, contemporary to the start of the 21<sup>st</sup> century.

It is important to establish these requirements for the occurrence of social interaction in order to examine how changes to an interface may affect it. But it is also important to make a distinction between the availability for social interaction and how it really occurs. As Howard Rheingold explains in his decisions for choosing the title of the online book *The Virtual Community* (1998), while the technology and functionality may be available 'you have to be careful to not mistake the tool for the task' (1998: Chapter 2).

It will also analyze the development of virtual environments from textual based social communication such as the very early examples of *WELL*<sup>5</sup> and *Habitat*<sup>6</sup> through to the way social interaction has proliferated throughout

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<sup>4</sup> The Passage: Journey to the Wild Divine is a type of game that is intended to promote health and wellbeing through guided meditation/relaxation exercises. (<http://www.wilddivine.com/>)

<sup>5</sup> WELL or Whole Earth 'Lectronic Link is one of the oldest virtual communities on the internet. (<http://www.well.com/>)

<sup>6</sup> Habitat is an online multiplayer game developed by Lucasfilm Games from 1985 and one of the first online environments to incorporate avatars, though no 3D technology was involved.

online three-dimensional virtual worlds such as *Second Life* and various multiplayer game worlds.

The second chapter introduces the subject of biofeedback technology by starting with already established uses of the technology, particularly within its traditional medical context, with a view to analysing their significance as an interface to virtual reality. It also discusses the appropriateness of the use of the term biofeedback when compared to other related or contributory fields, and in the context of determining the types of interaction with a digital system it can provide. It continues by analyzing a variety, but certainly not an exhaustive selection of different feedback mechanisms in contrast to their suitability as a personal user interface. Additionally it looks at existing art that explores biofeedback interfaces, such as the musical neurofeedback art of composer David Rosenboom or *Mind Cupola* by Brigitte Zics, and compares them with developing personal computing products that use biofeedback as a form of computer interface for avatar control in virtual environments.

The final chapter investigates the way that biofeedback can be introduced to interfaces to help further the level of interaction between the user and their virtual environment, before progressing to examining specifically the social impacts. It considers why it is a natural progression in interfaces to be able to read more from its user by using the requirements of social interaction discussed in the first chapter. It also compares biofeedback against progress in other types of interface and why biofeedback has yet to be readily adopted by examining the issues revealed in the second chapter. Finally, it forms the basis of the conclusion which summarises the potential way that biofeedback technology adapted for use as an interface into virtual environments will affect human social interaction within them.

## **Chapter 1: Social Interaction in Virtual Environments**

Communication is possibly the single most important factor in the development of the modern computer system. As a meta-medium it inherited the fundamental purpose of all prior forms of media, to be a carrier for human communications. Hence the first and most essential requirement of social interaction in cyberspace is the ability to connect with others. On the one hand there is a reliance on the availability of network connectivity and growing bandwidth across the internet, and on the other the willingness of users to participate. But the boom in social activities and virtual worlds and consequent demand for expansion of the underlying technology evidences in itself the readiness of users to involve virtual activity in everyday life. Since the advent of the internet and growing development of online social activities, the boundaries of virtual reality and physical reality are becoming increasingly blurred. The computer is permanently changing the nature of the way its users communicate.

The next requirement is to explore the suitability of the medium as a social communication tool. While there are many forms of communication that cannot be described as social interaction, the majority of previous forms have had social implications. The model most appropriate to old media forms such as cinema, music or publishing is one-to-many, where a single or small group of creators produce media that is to be consumed by many. This allows for a clear distinction between other forms of communication such as a telephone call, letter correspondence or a conversation held between numerous people, all of which can be described as dialogue. Essentially, social communication fell into the one-to-one or many-to-many models.

Therefore within the parameters of old media and mediums, the defining feature of social interaction could be the form of communication's ability to sustain a dialogue between individuals or groups of people. But this does not exclude the one-to-many medias as being social, they readily filter into popular culture and influence the way in which people interact. Media is rarely produced that finds itself without social feedback.

However in a virtual environment the boundary between what can be considered social communication and what can't is even less clear. It would simply be incorrect to state that one-to-many models do not exist in virtual environments, but media published in virtual reality is subject to a multitude of responses that previous forms would never have been.

For example, producing an article for a printed newspaper does not have the same two-way participation characteristics of holding a conversation whereas publishing an article on a blog can create an instant response in the form of comments or a counter-post. A strong example of this could be the blog of BBC journalist Robert Peston, and the argument that ensued over its involvement with the collapse of bank shares within minutes of the publishing of a post. While it is possible that an identical article written in an older medium such as a newspaper column could have had the same effect, it would lack the immediacy and hence the essential appearance of being a dialogue.

Additionally a blog might be connected to a social networking site, therefore becoming part of the same channels of social interaction the website was intended for. The concept of the meta-medium can be translated to communication where all forms of media have become involved in social interaction in a way that could never have been sustained before the computer. Similarly, the nature of virtual environments is that they encompass all previous forms of media as a non linear hypermedia.

Consequently virtual environments are inherently social environments, built on a technology created to improve communication. When they are

formed, usually their purpose is not only to be interacted with, but more importantly within and between multiple users. Unsurprisingly there are a large number of exceptions, usually when considering the number of tasks that require the interaction of only a single computer user, but while these situations may appear less relevant to social activities there is no reason why they cannot be expressed in the same terms of a user interacting with their virtual presence.

Just as the previous one-to-many models of media applied to social interaction indirectly, so does media published for the individual computer user. Even the software interface itself, whether it be the operating system or a specific program will form one of the greatest influences on virtual communications. The designer of the software will have attempted to draw upon extrinsic knowledge of their user, often through the use of metaphors. Thomas D. Erickson demonstrates how metaphors are 'an integral part of our language and thought' (Laurel 2002: 65) and act as a means of describing the abstract and intangible concepts that underpin the true mechanisms of a computer system. Hence the metaphors used in the design of interfaces will be ubiquitous in the communications of social interaction. The formation of these metaphors will '[become] universal conventions and thus [slip] into invisibility' (Manovich 2002: 33) until they form the foundation of a new language that will perpetuate the ability to communicate in virtual environments.

Additionally media produced for the computer is often for more interactive than the previous forms. For example where interaction with the cast of a movie is impossible, players of single campaign or non-multiplayer computer games will often interact with 'non-player characters', effectively actors that have been designed to behave realistically in response to the player.

Essentially, interaction with the system learnt here is applicable to forms of interaction between two real users of a social virtual environment. Users are

not interacting directly but rather some part of our intentions, personality and actions are being mediated through the interface, and through the terminology or language of the interface.

But the requirements for social interaction do not end with the suitability of the medium for providing a carrier of human communication. Howard Rheingold discusses in *The Virtual Community* (1998) the importance of distinguishing between the technology of virtual reality being a dangerous substitute for face-to-face interaction and it being a 'medium for genuine human interaction' (1998: Chapter 1) by recounting his own experiences with one of the oldest bulletin-board based communities, *WELL*.

Newer virtual environments are most predisposed to be expressed in game terminology for a number of reasons. Games find themselves at the forefront of 3D development and 'operate in a more demanding user-interface universe' (Laurel 2002: 103), meaning that advancements in virtual worlds and their interfaces will most likely be found in entertainment products before anything else. However a simulated world created for non-entertainment can be discussed using the same terminology as a computer game in the same way that Manovich explains that his term of 'new media object' can be described using universal terminology. The characteristics of virtual environments will 'hold true across all media types' (2002: 39) regardless of whether it is purely browsing the web or a large simulated 3D world. Similarly, Bartle begins by explaining that largely due to massive financial encouragement, virtual world development is being led by the gaming industry, so accordingly 'much of the vocabulary commonly used to describe virtual worlds is game-based' (2004: 2).

However it would be unhelpful to describe users of all types of virtual environment as 'players', even if 3D socialising tools like *Second Life* refers to its users as such. To use this term would certainly be inappropriate for less graphically orientated software and social tasks. Instead a word such as 'avatar' is more appropriate to describe the user's virtual presence since it

translates well across all the forms of social media. For example, the word has been used by social networking websites to label the image users upload to represent themselves, but moreover it encapsulates and embodies the user on the site in the same way that an icon on a computer system represents a particular program or file.

In a virtual world that has all the features expected in a 3D computer game such as *Second Life*, the user's avatar is far more complicated, but performs exactly the same role of virtual embodiment none-the-less. Likewise in terms of games this would usually be manifested as the human assuming the role of a predefined character. The standard practice for *Massively-Multiplayer-Online-Role-Playing* (MMORPG) genre games would be to give new players a limited choice of character types meaning that all its users fall into a particular number of categories and therefore social interaction in this type of simulation is very artificial. The users behave socially as they believe that they should behave in accordance with the concept of the role-play. In the example of *Second Life* however, social interaction is not constrained by the same artifice that typical game worlds present.

The 3D virtual worlds find their roots placed firmly within the old forms of media. Bartle lists among the types of virtual game world early textual examples of multiplayer online games. The transition between graphical, three-dimensional virtual worlds and textual environments is a process that hasn't been limited to the sudden expansion of internet services and graphical processing capabilities of hardware since the late 1990s. In particular Bartle introduces *Habitat* from 1986 as 'one of the earliest systems to use a primarily graphical interface' (2004: 148), which was essentially a chat room using avatars. This environment would eventually become the basis for *America Online*<sup>7</sup>.

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<sup>7</sup> AOL or America Online is one of the largest American internet service providers (peaking in the late 1990's) which also provides an eponymous online community.

Another important consideration for social interaction is the user's embodiment within the environment. Early enthusiasm for 3D virtual worlds like *Second Life* included anticipating liberation from physicality and the inhibitions imposed by physical reality.

However research has shown that there is evidence that the users of *Second Life* exhibit non-verbal social communication behaviours via their virtual avatars that are the same as those observed in physical reality. For example, it was observed that the distance from which male and female avatars stood from each other mimicked real life scenarios. Based on such results, Nick Yee discusses how it is possible to conduct a series of behavioural science experiments within *Second Life* on the basis that there are 'similarities between user [behaviour] in online environments and typical [behaviour] in physical environments' (Yee 2007: 3).

When building an interface to a virtual environment, it is possible to consider that existing sociology and non-verbal forms of communication from physical reality need not apply, but the evidence shows that neglecting such interaction would be a mistake. Even though *Second Life* does not necessarily mirror physical reality for its users, they communicate non-verbally as if it did. Because there is a natural desire for embodiment and a sense of realism to the user's virtual existence, there is also an additional demand for changes in the interface to allow the user to become more connected with their virtual presence.

## **Chapter 2: The Journey of Biofeedback to Becoming a Virtual Interface**

The field of biofeedback was originally developed as a medical discipline, starting in the 1950's, where various methods of input are used to measure subtle but quantifiable physiological changes in a patient in order to collect meaningful data for treatment. The book *Biofeedback: A Practitioner's Guide* (1987) describes the term biofeedback as being 'shorthand... for external psychophysiological feedback, physiological feedback, or augmented proprioception.' (1987: 11) But furthermore it extended the purpose of measuring physiological information far beyond the simple function of providing feedback. Not only was it intended as a means of analysing a patient but also formed the basis of treatment for the patients themselves, where they are made aware through the feedback of their own physiological state and responses. The purpose of this was to provide a mechanism through which they could learn to manipulate and manage certain physiological reactions, which are most likely to be undesirable symptoms of conditions the patient is seeking to eradicate. Usually, these reactions or symptoms begin as being primarily autonomous and beyond the patient's control, but through biofeedback they can learn to manage them. Previously only the voluntary functions of the Central Nervous System were thought to be responsive to learning and conditioning, and the Autonomous Nervous system was considered to be not so.

In the medical community there was initial scepticism of its value as a method of treatment, and adoption of the techniques into other clinical practices was not straightforward. This was largely due to reservations about the speed of its development, and the fact that it challenged previously

established views. Nevertheless biofeedback became a serious area of study for a variety of reasons, not least of all because of the cultural interest in it as a form of alternative medicine. This fundamental purpose of biofeedback as a form of holistic treatment is still evident from personal computing products available today such the *Journey to the Wild Divine*, a stress management game which describes itself as ‘an aid to learn guided meditation, healthy breathing, and relaxation techniques’ (Wild Divine 2009), the intention being to teach the game’s user methods of controlling physiological responses. However the very nature of this fundamental purpose has implications for its application as an interface which will be discussed in greater detail in the third chapter.

Since the initial inception of the field, the development of biofeedback and development of the modern computer system have been closely related, since biofeedback was built upon technology that required the analysis and processing of electrical signals, and there is no more appropriate solution than the modern computer system. This is not to suggest that the overlap in fields was all-encompassing, since the measurement of various physiological inputs required the production of highly specialised hardware which certainly hasn’t been a result of the improvement in computer technology. Instead research and production of the methods of measurement or input have become an integral part of biomedical engineering, which in itself is a very broad field that interweaves with numerous other disciplines. Unambiguously however, for the purposes of biofeedback it has essentially been tasked with producing non-invasive and increasingly sophisticated hardware for which to take biofeedback measurements.

Yet where the fields do overlap most prominently is in the processing of the information once a method of obtaining it via this specialised hardware has been created. Since the introduction of the modern computer system, the potential of using biofeedback beyond its medical purposes has been open to

exploration, and hence the field has expanded significantly. Reflective of this, *Biofeedback: A Practitioner's Guide* outlines from the beginning that it is largely intended as a reference for clinical practice and hence begins by explaining the strong links of biofeedback to a clinical basis. But then it continues by describing the field as being 'heterogeneous in terms of the types of persons in the field and the types of applications' (1987: 17), essentially acknowledging that the field has extended into a multitude of other areas.

One area that biofeedback is especially closely related to is that of cybernetics, which is of particular significance to the study of using biofeedback as a form of human-computer interface. Cybernetics can be described as the field 'that deals most directly with information processing and feedback' (1987: 11) between biological and computer systems, hence focusing on the actual mechanics of providing an interface with a computer system rather than being a process of medical treatment. Cybernetics implies intentional control over the computer system, which of course is one of the primary purposes of any computer interface. But as a term it does not specifically encompass methods of biofeedback, or even the interaction between biological and computer systems in general.

Therefore a better term to be used instead of cybernetics and perhaps even biofeedback as an overall expression is biocybernetics since this focuses more specifically on the use of the interfaces provided for biofeedback measurements as a method of useful, controlled input into a computer system. In an interview, Dave Warner describes the distinction as being between which adapts to the other, where in 'biocybernetics ... the machines adapt to the body' (ARS Electronica 1994) as opposed to the user adapting their behaviour as a result of the biofeedback. It combines the aspects of biofeedback and cybernetics that are most relevant to the study of physiological input as an interface.

But while my use of the term biofeedback is diverting from the constraints of the medical definition, and is more closely related to biocybernetics, it is still a more appropriate term to encapsulate the field as. Since biocybernetics deals with intentional methods of control via biofeedback it is essentially ruling out the potential use of measuring passive information. This dissertation is purposely exploring both aspects of biofeedback measurement, the voluntary form of interface control and the involuntary monitoring of responses. While acknowledging that there is a distinction between both, it is not distinguishing one form as more prevalent or appropriate than the other for application as a human-computer interface.

Therefore the term biofeedback is used to encompass both types of interaction, although it is clear that the term itself is still heavily related with its medical origins. For the purposes of studying forms of future interfaces it is mostly it is being used to describe the means of capturing and then processing physiological information from the user of a virtual interface rather than being a form of medical treatment. This is similar to composer and neurofeedback pioneer David Rosenboom's definition being that biofeedback should refer to the general response of a system presenting the 'biological process in [an] organism, for the purpose of achieving some measure of regulation or performance control over that process' (Diebner: no date) through the measurement of biological processes, but not necessarily requiring the input to be either deliberate voluntary control or a passive response.

Hence biofeedback arrives from being a medical treatment to being a potential interface into any number of possible virtual environments. But while the processing of biofeedback information has improved with the progression of modern computer technology, biofeedback has necessitated the development of several specialised methods of measuring physiological responses or biological mechanisms as described earlier from the field of biomedical engineering. This information can come from a multitude of sources, examples

including measurements of a person's cardiovascular activity such as heart beats per minute or blood pressure, variance in their body temperature, the observation of physical muscle activity including the detection of posture or facial recognition and a variety of electrical signals such as measuring brainwaves or the conductivity of the skin. There have been a number of pieces of specialised hardware developed for the purpose of capturing this information from a user. But despite the interest in biofeedback, the desire for the improvement of human-computer interfaces and advances in computer technology, the production of accessible hardware for consumers has not been seen in the same way that for instance over a comparable timescale the modern personal computer has developed from specialised room-filling equipment.

Beginning with arguably the most desirable form of interaction, it is possible to provide an interface with a virtual environment that directly translates brain activity into feedback without necessitating a physical manipulation of the interface at all. This form of interaction can be enabled through the use of electroencephalography (EEG) technology, which often requires the user wear, or be in contact with a multitude of electrodes in different locations around the brain. The electrodes are sensitive to the electrical activity of neuron cells which are responsible for performing the various functions of the brain and can determine patterns in brainwaves and categorise them into one of five types of frequency. The electrodes also enable the measurement of event-related potentials (ERP) which are meant to signal a direct response of a particular thought or perception from the user.

But naturally the equipment for measuring EEG is particularly complicated and especially until more recently it the equipment for measuring the brain's electrical activity has been particularly large and inaccessible. David Rosenboom describes exactly this issue in his journal piece *The Performing Brain* (1990) where he expresses how his work used the 'analysis of electroencephalogram (EEG) signals, previously achievable only with

cumbersome, non-real-time, laboratory-bound methods' (1990: 48), but made newly possible by advances in the technology providing subsequent accessibility and accuracy. His performances used EEG equipment to produce music by evaluating the user's brainwaves, in particular the alpha rhythms. A straightforward example of the use of EEG to produce sound and therefore music is the electroencephalophone which represents the brainwaves measured as audible sound.

But while the audible representation of brainwave frequencies demonstrated the progression of biofeedback processes diverting from its original medical purpose, the work did not provide an example of the technology being used as an interface to virtual environments by keeping interaction firmly within the realms of physical reality. Instead it is only in very recent years that the technology has started to be used as an interface between the user of a computer system and virtual reality. The *Neural Impulse Actuator*<sup>8</sup> is an example of a recent product that has been made available that allows for EEG input straight into a virtual environment. It also appears to be specifically targeted at the gaming market, allowing control of an in-game avatar's movement be actuated by the use of thought. As described in the first chapter, this is another example of where the financial encouragement of the games industry has pushed ahead the development of much more compact and accessible personal products.

However while the issues of portability and accessibility may be improving for EEG equipment, there is a more significant issue preventing its mainstream adoption as a human-computer interface. Firstly, the collection of information is subjected to a serious level of interference or noise which needs to be effectively filtered before any useful information, such as the detection of ERPs

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<sup>8</sup> The Neural Impulse Actuator or 'Brain Mouse' is a personal computer peripheral device produced by OCZ Technology designed to allow input from brain activity, specifically for the use in 3D virtual environments such as games.  
([http://www.ocztechnology.com/products/ocz\\_peripherals/nia-neural\\_impulse\\_actuator](http://www.ocztechnology.com/products/ocz_peripherals/nia-neural_impulse_actuator))

can be garnered. But even once the data can be filtered and obtained, making sense of the information can vary vastly from individual to individual, which has proven to be one of the most hindering factors in the progress of adoption all forms of biofeedback as a virtual environment interface. It has serious implications for both voluntary and involuntary forms of interaction. In involuntary terms the difficulty stems from this inconsistency of reactions between individuals. However arguably the adoption of voluntary biofeedback into interfaces has a worse issue where methods of control and interaction are difficult to learn and adapt to for the user. In the specific case of EEG, devices such as the *Neural Impulse Actuator* require the user learn to use specific thoughts to get a response but this process seems neither intuitive nor easy.

In comparison to EEG, other forms of biofeedback measurement are even less likely to be consistent between different individuals, and information obtained is consequently greatly ambiguous. Measurement of more external biological values such as temperature, heart rate and even Galvanic Skin Response (GSR) are subjected to a far greater degree of external influences and therefore less substantial meaning and context can be correlated with events.

In examples such as Rosenboom's work, these other forms of physiological information are used in conjunction with EEG as a supplementary source of data. Similarly the *Amigdalae* project by Massimiliano Peretti uses a variety of biofeedback measurements taken from the project's spectators in order to form a feedback loop. It also uses EEG as a primary form of input, and then increases the usefulness of the information with alternative forms of biofeedback including temperature and heart beat frequency. The information is then visualised back to the audience as a form of feedback loop.

But a good example of a modern home-use product that has used purely a combination of Skin Conductivity Level (SCL) and heart rate measurement as a method of input into its software is the *Journey to the Wild Divine* game. SCL is another term for Galvanic Skin Response and is essentially a means of

monitoring electrodermal activity, or specifically the subtle changes in resistance to a current through the skin. But the use of the biofeedback information obtained from these two sources is quite limited since the software is trying to make its user change their own physiological behaviour to conform with pre-set ideals, rather than have the software adapt to the information it is receiving. The reason for this is that while obtaining the information is relatively straightforward, giving it context, for instance to a particular emotional response, has proven effectively impossible.

The piece *Mind Cupola* is one of numerous art installation projects undertaken by artist Brigitte Zics and has a similar purpose whereby visitors interact with the piece and are guided 'to a state of mind entitled "equilibrium"' (2004). Unlike the game however, instead of using methods of data capture that require direct contact, the piece tracks facial and head motion as well as monitoring temperatures remotely. The information is then used to produce a graphical visualisation with which the user can interact with through the mechanism of the feedback loop. But while this piece attempts to give the information emotional context, it still demonstrates similar issues to the *Wild Divine* game in the sense that the experience encourages the user to adapt their own behaviour to the piece.

The best method of using only biofeedback as an interface is to utilize a varied combination of input sources to gain a more complete picture, rather than relying on a few. However these examples do not attempt to give the biofeedback a context from additional interfaces or sources, for instance the traditional interfaces of a computer system, understanding the current activity of the user or being part of an immersive augmented reality environment. If biofeedback is to be used as an interface to virtual environments it is most likely going to be used as a combination of methods of interaction, similar to the direction that the *Neural Impulse Actuator* has taken.

## Chapter 3: Biofeedback and Virtual Social Interaction

Existing interfaces are not capable of truly capturing the interaction between users that would be present with face-to-face communication. Current virtual social interaction has to be conducted through mediums and media that prioritise vision and to a certain extent sound above other senses and interactions. Instead they have traditionally replaced the missing modes of interaction with virtual substitutes, for instance the use of *emoticons*<sup>9</sup> in text to symbolise moods succinctly as a replacement for conversational expressions. In contrast, people adapt their existing behaviour to communicate more effectively using whatever is available in the interface. When a particular part of direct interaction is removed, they will focus on what is available, for example the pitch and tone of voice in a telephone conversation. As concluded in the first chapter, the development of these substitutes indicates that there is a strong underlying psychological desire for embodiment of users in their virtual environment. For example in the case of a 3D online world, as observed in *Second Life*, male and female characters typically position themselves as they would in a physical environment, evidence of non-verbal communications surviving the mediation of a computer interface into a virtual environment.

Areas of biofeedback have naturally overlapped with human-computer interface design. At the simplest level, it can be described as technology that converts analogue physiological data from the human body into a digital format, ready for use in numerous applications, which are traditionally nearly always performed using a computer. The adoption of biofeedback into interfaces adds a new potential for interaction where before there was never really the opportunity with traditional hardware. It is likely that future

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<sup>9</sup> Emoticons or emotes can vary from using purely symbols from the ASCII table of characters through to inline graphical replacements.

methods of controlling an interface will be taken from the field of biocybernetics in order to produce more intuitive and direct methods of controlling a computer system. But in addition to intentional control, it can allow for the use of passive user input. Many of the art installations that explore biofeedback rely on passive audience reaction as part of a feedback loop in the expression of the piece. Hence there is no reason why passive biofeedback measurements cannot be used as part of a computer system interface also. For example, while existing interfaces to 3D virtual worlds can provide incredible flexibility in the aesthetic detail of a user's avatar, biofeedback information could be used to add and enhance the realism much further. Where the user's physiological data becomes part of the process of forming a virtual presence, this will likely create a stronger connection between it and the user, which will have direct implications for social communication.

But despite the scientific and cultural interest in them and the potential for making such interfaces reality, new hardware and software enabling their creation is taking a longer time to replace the old forms than it has taken comparative technologies to develop, for instance the modern computer system. The reason could purely be split twofold, one being that creating hardware that is much more accessible and less-invasive is proving difficult to produce, the other being that while gaining accurate information from a user is possible, it is in the interpretation of the information that the difficulty lies.

Nevertheless it is likely that these issues will eventually be solved, and interfaces that use advanced methods of control, similar to the *Neural Impulse Actuator's* use of EEG to create input from thought will proliferate throughout computer technology. Similarly, it will be possible to give systems or software the ability to collect information passively about its user. But as described in the second chapter, biofeedback was originally intended to give a patient or user an awareness of their physiological state and eventually the ability to

control or manipulate these autonomous responses. This has clear implications if a system of interaction is meant to be measuring involuntary responses. However it is unlikely that a mechanism of biofeedback would stringently require passive, reflexive or impulsive physiological information, especially in a social context. Hypothetically, in a situation where a user's avatar is responding to their physiological input, should the user try and manipulate this feedback it would be no less a valid form of communication than involuntary responses. In this sense it is still a very much justifiable reflection of physical reality.

Another serious concern for the use of such data socially is privacy, and the transmission of essentially personal information to others. Similarly there is the issue raised in the first chapter of users perhaps wanting to completely detach themselves from physical reality, as seen in the fantasy lives of some *Second Life* users. But in either case there is no reason why a software developer would not include the ability to opt out of transmitting personal data in this way.

With the advancement of biofeedback as an interface to virtual social interaction it is unlikely that the crucial driving force for progress will be the desire to communicate as it has done for the development of the modern personal computer. Instead it will probably rely on other influences such as the games industry, much in the same way that graphical computational power in modern computers has vastly increased due to demands from gaming. Specifically in the case of interface design, "games operate in a much more demanding user-interface universe" (Laurel 2002: 103) and the advancements here have subsequently enabled the improvement of other forms of software adopting the same technology such as operating systems, various non-entertainment products and social communications tools. Therefore, the likely trend is that communications technology will improve due to the adoption of specialised interfaces developed first for entertainment purposes.

But moreover for biofeedback technology, there is still a large medical pressure towards the development of the technology, as research continues into how biocybernetics can be used as a treatment for a variety of medical conditions. Therefore it is likely that changes in the way humans interact within virtual environments will be as a result of advances in these other fields rather than being the most important purpose for advancement. Biofeedback will likely become one of essentially a multitude of technologies that enable the interfaces of the future. That is to say that biofeedback will not be an exclusive influence, but because the cultural interest, it is likely to play a major role.

## **Conclusion**

The third chapter identifies the current issues which have held back the adoption of biofeedback technology into human-computer interfaces, and essentially they can be mostly broken into two major categories. Firstly, the collection of physiological data has been difficult since progress with producing non-invasive physical interfaces has been slower than comparable technologies, such as the development of the modern computer system. Secondly the data that is captured needs to be analysed in a meaningful manner, which has proven difficult because of numerous factors including the high level of noise and external interference and the huge variance in responses between individuals.

However given the potential extent of contribution biofeedback has to offer to human-computer interfaces of the future, and interest both cultural and scientific in methods of control that remove the necessity of current physical interfaces, it is highly unlikely that it will disappear. There has been progression in the field beyond the limitations found, and interfaces that provide both passive input and active control over a system have been developed. It is possible to create a virtual presence from more than the simple information that current interfaces will mediate, achieving a greater connection between the user and their virtual presence. But most importantly, because of this biofeedback can be usefully applied to virtual environments as a medium for social communications that are currently missing from present interfaces.

Where these interfaces are mostly likely to make the largest impact is in 3D immersive environments where part of the objective is to create a sense of realism. Social interaction can be mediated by means of avatars that are more

accurate representations of the user they embody. Combined with other forms of interface, it can provide a medium for communicating non-verbal information.

Of course, there is less scope for impact on more traditional means of communication that are less immediate than direct communication. Examples like blogging or email that do not have the same immediacy of a dialogue in other forms are less likely to benefit. But of course, this is within the constraints of the present definitions of such activities; there is no reason why blogging of the future will not change according to the availability of new interfaces.

The potential applications of biofeedback interfaces are numerous, and certainly beyond hypothesising every possible outcome. However it is most likely that the first personal use will be seen in entertainment products, due to their proliferation and financial encouragement that this sector provides. This will then be followed by entertainment products that have evolved from social networking concepts, such as MMORPGs and 3D virtual worlds. Often new forms of computer communications are marketed in the same manner as entertainment products, emphasising the desirability of these activities. Finally, purely social virtual activities will follow such as blogging, messaging and email, most likely as part of changes to the computer's operating system interface itself, for instance when human-computer interfaces have taken advantage of biocybernetic methods of control.

Biofeedback could potentially have a lot to offer social interaction, even if the only purpose for including the technology is to enhance the emotional attachment and sense of embodiment with a user's virtual presence.

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