Biofeedback And Virtual Environments
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Abstract

This paper explains potential benefits of indirect biofeedback used within interactive virtual environments, and reflects on an earlier study that allowed for the dynamic modification of a virtual environment’s graphic shaders, music and artificial intelligence, based on the biofeedback of the player. The aim was to determine which augmented effects aided or discouraged engagement in the game. Conversely, biofeedback can help calm down rather than stress participants, and attune them to different ways of interacting within a virtual environment. Other advantages of indirect biofeedback might include increased personalization, thematic object creation, atmospheric augmentation, filtering of information, and tracking of participants’ understanding and engagement. Such features may help designers create more intuitive virtual environments with more thematically appropriate interaction while reducing cognitive loading on the participants. Another benefit would be more engaged clients with a better understanding of the richness and complexity of a digital environment.
1. INTRODUCTION

This article argues the converse to the ‘liquid architecture’ theory of digital worlds posted a decade ago by Novak [1]. Rather than a liquid realm, we may wish for vague digital media boundaries that congeal or even solidify on interaction, in order to direct people into different cognitive realms, and through their more indeterminate nature afford a wider and richer range of interactive modes and contextual information. Unfortunately, architecture (as a built place) has too often been viewed as an art form that relies on its aesthetic value in terms of being an immovable and immutable object.

For example, in the nineteenth and twentieth century, empathy theorists viewed architecture as little more than sculptural objects that we can create associations for, according to Malgrave and Ikonomou [2], Leech [3], Neumann [4] and Morgan [5]. In a similar manner but much more recently, the philosopher Anthony Savile [6] attacked Richard Foster’s work: treating the essence of architecture as sculptural form.

For Savile, architecture also involves interior spaces, the linking of spaces (e.g., from inner to outer and the converse), and the placing or locating, using and imagining of symbolic objects (as well as the self and other people) in order to create a significant sense of place. Whether Savile was or was not correct in his criticism of a modernist architect, it is clear that many famous architectural critics [7] [8] [9] believe the experiencing of architecture involves an understanding of how environments affect the psychology and physiology of the inhabitant, visitor and the passerby.

Even though there is undoubtedly a great deal of literature concerning how architectural form is experienced, and a substantial body of research and debate into the experience of presence in virtual environments, this research does not appear to have found its way into the design of virtual environments for architectural visualization.

For if it had found its way into the design of virtual environments for architectural visualization then surely critics would not describe virtual environments as sterile or boring. In his inaugural address Richard Coyne [10] stated “It is a common lament against contemporary architecture that it has lost touch with the body…Some see the incursion of the computer, computer-aided design and the invention of digital architecture, as the last step in this transformation. The computer also takes us away from engagement with each other at a bodily level…”

The experiencing of architecture in a virtual environment typically lacks the richly embodied and visceral experience of visiting and moving through real world architecture situated on changing terrain and visited during changes of light, heat, atmosphere, and sound. Technical limitations may be part of the issue, but a further factor is the inability of current virtual environments to adapt meaningfully to the participants. Could biofeedback help address this lack of rich embodiment in digital environments?
2. DEFINITION OF BIOFEEDBACK

We use the term biofeedback to represent a real-time two-way feedback loop between the machine and the user: the user reacts to an action initiated by the system, and the system can then react based on the participants’ physical/emotional reaction (and so forth). Biofeedback interaction does not necessarily form the primary mode of interaction, but augments existing interaction. This is an important point: HCI researchers have warned us that direct biofeedback control is difficult and variable for many users, but they do not seem to have fully scoped the potential of indirect biofeedback to avoid these issues.

In the following case study we focus on the use of simple devices within gaming environments to create indirect biofeedback. While the initial implications are for games [11] there is also widespread potential for many forms of digital interaction [12].

We suggest that this is a new and emerging field for architectural computing. A search for “biofeedback” on the 3rd of November 2011 in the online ACM Digital Library [13] retrieved 528 papers and proceedings; IEEE Xplore Digital Library [14] retrieved 317. Even granted many false positives, these results far surpass the same search in the Cumulative Index of Computer Aided Architectural Design [15]; a search in CUMINCD of “biofeedback” finds one conference paper (the paper on which this article is based); and while searches for “physiological” and “architecture” returns 18 results, only 6 were in the last ten years.

3. BIOFEEDBACK IN COMPUTER GAMES

For First Person Shooter (FPS) computer games, biofeedback can help in the visual and audio adjustments of the avatar and HUD (Heads Up Display). Manipulation of the game environment and events, and enhancement of generalised gameplay can be affected (player speed, strength and avatar abilities). Low galvanic skin response helps with the aiming of weapons. High heart rate might assist with agility and movement. Please note we are not saying these are useful attributes for architectural visualization, they are however of interest to game designers.

There are also stealth games, which could require the player to remain calm while walking through the city, avoiding suspicion, and monitor their breathing and heart rate when using a weapon to perform, say, an assassination. They may have to raise their heart rate to move faster during an escape, but also keep their skin response low in order to remain focussed. Similarly, for jail breaking: when speaking with Non Playing Characters, or when hiding objects, the player must remain calm to be inconspicuous. Traditional game interfaces designed to accomplish these kinds of interaction do not help break down the barrier between the player and their avatar.
In the developing world of social player games, biofeedback can also help provide other players with information on the trustworthiness of the player. After all, the lie detector is a simple form of biofeedback. Biofeedback can also be used to trigger automatic facial behaviours or physical gestures in the avatar.

Boredom could trigger certain avatar characteristics so that other players realise this player is not fully engaged, but this could also be accomplished with eye tracking, which is part of the CALLAS research project [16], but does not appear to be complete (the project deliverables page does not appear to be online). Eye tracking is however of interest to architectural visualization, for it can help clients understand which features and spaces people are interested in, where they tarry, and (with biofeedback results) which spaces they find more comfortable and inviting. These evaluation results could in turn change the design or presentation of the digital environment: attractive features could have higher resolution or more enticing lighting of sound effects; less desirable features could be hidden entirely or appear at lower resolution.

4. PAST WORK: CASE STUDY

In the following case study [17] we investigated how commercial biofeedback devices could be integrated with existing computer game environment. Iancovici et al [18] described this paper as “The most comprehensive research done on the feasibility of GSR and HRV biofeedback in gaming” but in despite the kind words we suggest our study was only one of many new papers in this field but may still be of interest to those who wish to create evaluations of the more “designerly” aspects and potential of indirect biofeedback.

The audience for the project was derived from data drawn from the then existing audience for PC first person shooters, in particular players who had previously played Half-Life 2. See for further reference, the demographics study conducted on the Half-Life 2 audience:

“When we look at the composition of personal computer game players in the December 2008 data, the single largest group of personal computer video game players is females ages 25 to 54, accounting for approximately 29 percent of total personal computer game players. Males ages 25 to 54 account for the next largest block at roughly 20 percent of all personal computer game players.” [19]

We hoped to address the following questions. By augmenting existing gaming environments with biofeedback, can the system be aware of users reaction to game content? Can we successfully tailor game content to create a more engaging experience than with traditional environments?

The process that was followed required finding an appropriate existing gaming environment that would have a high chance of eliciting emotional
reactions from the player throughout the gaming experience. A variety of
game engines and game environments were examined informally and
through literature in order to choose an appropriate setting. We decided
that First Person Shooters were the most likely to provide a visceral
emotional reaction (tension, action etc) - Role Playing Games did appear to
provide more of an emotional change over time, but it was more at the
reflective level (visceral, behavioral and reflective stages being part of
Norman’s theory of Emotional Design [20]). Horror was chosen as the
theme of the game because it provides a physical reaction that is relatively
easy to measure (stress and tension) and something that is controllable.

The design, development and evaluation was conducted throughout an
iterative design processes. Scenarios and events drew inspiration from various
entertainment mediums. The event (or ability) was designed and developed in
the game engine. The event was tested, to examine two things: (a) what
sensory readings were appropriate to trigger the event and (b) how did the
event change the users’ sensory readings? The study evaluation was a qualitative
process, not quantitative. Interviews and observations of the fourteen
participants were used to determine the success or failure of each event.

4.1. Test Equipment

This study utilized the Wild Divine sensor technology, which includes a
device that clips onto the fingers. The Lightstone measures the ECG HRV
(Electrocardiogram Heartrate Variability) and the GSR (Galvanic Skin
Response) of the user in real-time. While these measurements do not give
enough information to make a complete Biometric Analysis [21], they
provide insight into participants’ reactions to specific game events.

![Figure 1: Wild Divine Lightstone biofeedback sensor.](Image)

The Lightstone device (Figure 1) has the potential to measure: anxiety and
stress, relaxation and meditation, tension, sudden changes in mood, and
breathing variability. EEG was not used due to ethical considerations.

We developed sockets for the Wild Divine biosensor, enabling us to use
them for commercial games and for virtual environments.
4.2. Software Design

For our experimental design we modified an existing zombie horror level developed in the Half-life 2 Source game engine by connecting wild divine sensors. Invisible boxes in the game level detected the biofeedback, and depending on the biofeedback registered whether the user was calm or excited, creating changes in apparent time (bullet time effects), music, and visibility (a calmer participant could see through walls or their avatar could even become invisible to their enemies).

Filters (Figure 2) were also applied to the game if the player’s heartbeat was faster or slower than average. If the user’s heartbeat and galvanic skin response was over 3 times their average, the screen became bright red, the field of view of the avatar would change to 130 degrees and the speed of the avatar would dramatically increase (to simulate a ‘berserker’). A calmer heartbeat turned the display black and white or faded it to white, while an excited heartbeat caused the display to fade to red or further, to shake, to represent a lack of control.

4.3. The Users

The qualitative evaluation of the prototype was performed with 14 participants.

They were aged between 15 and 50; and 25% were female, 75% male. They were both experienced and not experienced in first person shooters and Half-Life. They had not been previously involved in the project or participated in earlier informal evaluations.

Participants both enjoyed and didn’t enjoy horror computer games, movies and books and had various levels of computer game experience (from users who rarely played computer games to users who played games as a hobby).
4.4. The Study

To compensate for possible problems associated with this method of analysis, readings were averaged at two-second intervals. The current average of the participants’ biometrics were compared against the calibration average, to create a multiplier. The three multipliers (heart rate variability, skin response and heartbeat) dynamically changed the game environment.

Users were required to read the information sheet supplied and give consent to be evaluated and have their experiences video-recorded. First the user plays a level (either the standard or enhanced level) for 5 minutes, and then the participant plays the alternate level (the level that was not previously played) for 5 minutes. After the levels there followed a short interview, where they answered questions about the game and discussed their experiences.

The prototype was designed to support the structure of the evaluation. Two game levels (named Level A and Level B) were developed for the evaluation. Level A recreated a level from the first person shooter Half-Life 2 (Valve, 2004). Level B was created as an extension to Level A, where added game events were triggered from biometric information.

It was important to identify and eliminate where possible variables that may influence results. Both levels were created to limit the amount of variables within the evaluation. The variables that were anticipated, which could influence the evaluation results were:

- User preference of game genre, theme and style of game.
- Learning curve of the interaction method.

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Table 1: User Background.
• Human computer interaction (HCI) problems associated with the Lightstone device.
• Preconceptions of the prototype with influence from commercial computer games.
• Issues with the design and pace of the enhanced game.
• Learning curve of the level structure (e.g.: where to go).
• Dynamic events within the environment.
• Being killed and other immersion breaking events.
• Hawthorne Effect (placating the interview).
• Placebo Effect (with wearing the biometric device).
• External environment and technical inconsistencies.

These variables were either controlled and removed for the evaluation or taken into consideration when analyzing evaluation results. We also suggest changing and/or randomizing the sequence order of the environments visited, as the order in which they are experienced may affect the results.

The most apparent variable within the evaluation process was the learning curve associated with the game level. Aspects to the gameplay including exploration and triggering objects within the world were influenced by users playing through the base game level twice (once in Level A, once in Level B). Due to the nature of the evaluation structure, this variable cannot be removed, but can be taken into account when analyzing evaluation results.

Events that affected gameplay in the prototype were considered to be a variable that should be taken into account during evaluation. Generic game events such as being killed or escaping to the game menu have the ability to break the users’ sense of immersion. The evaluation analysis also considered the Hawthorne Effect (where users are inclined to agree with the interviewer) by structuring interview questions in a way that creates a discussion. The biometric device was required wearing in both the standard (A) and enhanced level (B) to avoid any influence based on the interaction influence of the Lightstone. Also, the external environment (such as lighting and seating) remained constant throughout the evaluation. Any technical issues discovered during the evaluation were also taken into account during the evaluation.

4.5. The Play Testing

Each user was required to play both the standard level (Level A) and the biometric enhanced level (Level B). 6 users were required to play Level A and then Level B, while the other users were required to play Level B and then Level A. At the conclusion of playing both levels, users were required to be interviewed on their experiences they had during the course of the evaluation. The interview questions were targeted to start an informal discussion about the prototype and biometric enhancement. The questions that were asked during the interviews were:
• Do you consider yourself a gamer?
• Do you enjoy, or have you played First Person Shooter games?
• Have you played Half-Life 2?
• Do you enjoy horror games, films or books? What do you enjoy about them?
• Did you enjoy the first level you played, or the second level?
• Why did you enjoy one level over the other?
• Did you realize which level was incorporation your biometric information?
• Did you like or dislike the visualization effects that were present in the enhanced level, what did you like or not like about them?
• What other game elements did you find different between the two levels, did they aid or hinder the game experience?
• What other game elements do you think may be enhanced through incorporating biometric information?
• From your experiences in the prototype, do you feel that biometric information can assist in creating a more engaging experience?

4.6. Results

After the interview, users were allowed to view their video footage, and discuss which game elements they found helped or hindered gameplay.

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<tr>
<th>User</th>
<th>Prefer enhanced version?</th>
<th>Noticed enhanced version?</th>
<th>Correct?</th>
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The above table shows that nine preferred the enhanced (biometric-driven) level. Eight said they noticed one level was driven by their biometric
data, although two chose the wrong level. Four participants did not notice at all that one level was biometric-driven.

Secondly, the below table (Table 3) is a summary of participant responses as to whether they noticed the visualizations, and, if they did notice them, if they liked them. It also recorded if they noticed other (non-visualization) game events (driven by their biometric data), and if they thought biometric data-driven games have potential.

<table>
<thead>
<tr>
<th>User</th>
<th>Noticed effect?</th>
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\*Please note that user 14 thought they noticed biometric-driven events but they ascribed it to the standard level when it was actually part of the enhanced level so there were 12 correct "yes" answers not 13.

Players 1 and 8 did not like the visualization effects, but neither had played Half Life 2 before. Eleven of the fourteen thought biometric information could assist engaging game experiences. Two of them also suggested that it could measure retinas twitching, or be related to the type of weaponry carried.

Apart from users 6, 8, 10, 11 and 12, all participants had suggestions. User 1 suggested more ammunition and a larger area to explore. User 2 suggested health should be based on heartbeat. User 3 asked for more dynamic audio effects. User 4 suggested accentuated colors and more dynamic visualizations. User 5 preferred a less limited area. User 7 suggested that when the participant experienced more stress the game could create fewer enemies. User 9 suggested the interaction device (sensors) and out of synch audio could be improved. User 13 also said that the audio was out of synch and the external environment could improve. User 14 suggested better game balancing of the learning curve.
We noted that the participants’ changes in facial expressions were easily comparable to the change in biometric information (we also used video cameras to track the players and the onscreen action). Audio effects had a considerable effect on participants’ biometric information and reactions. The dynamic shaders clearly affected the users. Black and white visualisation calmed users. The red filter visualisation did not affect biometric information significantly. The white screen visualisation confused users. Users seemed more engaged in the enhanced biofeedback version (over the control environment) especially when sounds were played. Users also reacted strongly when the screen shook. Participants realised there was biofeedback but did not try to adjust their breathing or heart rate to see how it affected game-play. In short, indirect biofeedback seemed effective and more engaging than the control (a game level with no biofeedback).

4.7. Design Implications of Study Results

Overall participants appeared to appreciate the addition of biofeedback. However we are reluctant to recommend further use of the Wild Divine technology. The sensors interfered with hand control, required continual recalibration and occasionally gave unreliable data. While for our research these limitations were acceptable (although some might disagree, such as Kuikkaniemi et al., [22]), more recent developments such as Neurosky [23] and Emotiv [24] offer more promise in terms of stability and ease of use. We note in passing that the Half-Life 2/ Source game engine also had implementation issues, but one advantage of using the Source game engine is that the parent company Valve also researches the use of biofeedback in their games [25].

In the light of the above study we have created middleware that will allow the evaluator to attach commercial biofeedback devices to commercial or self-created game engines and virtual environments, but we are yet to fully test the software. We are also interested in better systems of correlating video and eye tracking with biofeedback. We note there have also been suggestions by researchers that postural changes could be related to engagement in virtual environments [26].

5. BIOFEEDBACK AND ARCHITECTURE

There are various papers and projects on using biofeedback or phobic triggers in virtual environments to either expose (and cure) phobias, or to develop understanding of oneself, or of others, and biofeedback seems to be of increasing concern at Human Computer Interaction conferences [22] [27] [28] [29]; but we have not encountered discussion on how biofeedback can be used to enhance (digital) architectural appreciation and understanding.

One potential use is for personalization. We noted at the outset of this article that digital environments have been criticized for being sterile, and
empty, lacking personality, individuality or warmth [30][31]. Biofeedback could augment and provide individual personalization, adding in unique lighting affects, sounds, or other details relating directly and dynamically to the participant’s physiological states.

Biofeedback could also personalize social virtual environments, where multiple people (such as stakeholders in urban design projects) are simultaneously immersed in a virtual environment. They could view or hear how others are reacting to the virtual space. Or perhaps where the virtual world is based on a real-world place, biofeedback from real world passers by and inhabitants could be fed in real-time into the virtual world.

If walking through a virtual environment triggers participants’ memories or emotional attachments of the real-world place being simulated, it may be possible to colour or otherwise tag these locations in the virtual environment in relation to the biofeedback being generated. However, this does not seem accurate or reliable. Bored mental states that arise independently of the virtual environment may affect results. Non-visual (not tactile or olfactory or audio) sensations aren’t likely to be available via digital media. There may be useful applications in the evaluation of engagement via virtual environments being automatically tagged by the biofeedback of visitors (chairs, rooms or graspable objects could retain a metaphorical aura, for example), but this would be hard to evaluate in small experiments.

There is also the notion of architectural empathy. In a book entitled *Empathy and Its Development* [32] a clear distinction is made between empathy and sympathy (concern for people). Despite various definitions of empathy there is a tendency for empathy to be divided into empirical empathy (by association) or empathy through feeling (also called personal empathy). Empirical or aesthetic empathy involves attributing personal qualities to people and to objects, such as columns etc. So one may be able to create differing architectural spaces and evaluate with biofeedback whether they elicit certain responses, but this at least initially appears a highly involved and complex situation to evaluate.

Atmospheric augmentation was carried out in the Ravensholm Wild Divine-Half Life 2 study; uniquely personalized and augmented environments could be created from varying rates of biofeedback. However, how the environment is modified might not necessarily augment the experience during play, and may not even be recognizable (let alone be considered evocative) by the participants. Another problem is that this may gamify and adrenalize the architectural experience. In other words, enjoyment comes from visceral augmentation, and a rewards system, which does not necessarily relate to the architecture as designed, nor help any meaningful experience of the surroundings themselves apart from as backdrop or as ludic affordances.
Perhaps more effectively, biofeedback may be used to augment the overall atmosphere, or even climate. Recent technology has seen the development of real-time interactive weather simulation, and they could also be controlled by biofeedback (Figure 3). However although this external environmental data may add to user engagement, this information is not necessarily relevant to the individuals’ goals and emotional state. A more architecturally appropriate interaction metaphor might be linking visual signs of pollution and decay to the overly excited biofeedback; the more excited the player the more quickly the building decays.

Extrapolating from game mechanics, we could leverage biofeedback states that are generated from excitement (or boredom) in games to colour or otherwise alter digital spaces as a reward and feedback system. Architecture can be seen as a complex symbolic relationship of path and centre, of detail at places of rest (such as in formal seating areas), and subdued detail where circulation is important (such as corridors and staircases). If the participant understood a space was designed more for rest than for activity and acted accordingly (such as slowed down their heartbeat and GSR to appropriate levels) the environment could change to reflect their physiological harmony with their surrounds.

Such a scenario might not work so well in a game environment where it would not be clear how activity based biofeedback would give either the participant or the viewer a better idea of how the participant is affected by the architectural quality of the space itself and not just by responses to located events. However it may be appropriate for sacred or mythical spaces, where the calmer the participant is, the richer the interaction afforded, increased environmental details, avatars develop supernatural or mystic powers, or religious beliefs take virtual form.

It is also possible to use biofeedback as an evaluation mechanism, such as evaluating spatial awareness, and detecting potential differences between spatial designers and the public. This technology might be able to detect developing spatial awareness in student designers, and where and when spatial awareness impinges on general awareness in virtual environments.

Biofed architecture could track phobias (also known as negative engagement in virtual reality literature). Where people encounter phobias
near architectural points in time and space, their negative phobias can be visibly recorded and aggregated. The digital model could be ‘sprayed’ with an aggregated spray of phobia colour. We note here it may be difficult to aggregate phobic areas or even locate the spatial or symbolic phobic triggers. Furthermore, trained psychological help may be required to create, calibrate and adjust the environments as well as ensure that the test environments pass ethical and medical clearance and are used safely and effectively.

Conversely, positive engagement could also be tracked: significant points of interest (indicated by pauses, and by heightened or lowered rates of biofeedback, and perhaps camera tracking of postural change, or tracking of eye gaze) could be recorded.

Finally, filtering environmental detail through biofeedback may aid both virtual reality and augmented reality projects, such as lifeClipper [33].

Through the head mounted display, participants saw vague and coloured video characters as they walked through Basel, but through oddly shaped stencils. Biofeedback could affect the perimeter and clarity of the augmented reality objects, the calmer the walker; the higher the resolution clarity or viewing window of the augmented display object or video. This project also featured pressure sensors incorporated in soles to wear in one’s own shoes for tracking walking behaviour, but it could also be used to augment the excitement level in the augmented environment. For example, the more excited the participant is, less or more detail could be added to the augmented projection, or shader effects could be triggered.

At a simpler level, biofeedback can be used to affect territorial awareness, for example, more excited states could increase or diminish the
field of view, and this could have significant benefits for large-scale projected environments such as CAVE UT [34].

6. METHODOLOGICAL ISSUES

Are there currently accessible, effective and accurate devices to measure biofeedback? What can we measure, react to, and creatively leverage when implementing individual and group biofeedback, which are appropriate to the architectural domain? Are there any advantages or disadvantages to the use of biofeedback and can we ascertain them by trial evaluations?

The following products, Neurosky, Emotiv, and Wild Divine have been selected as the most accessible and widely used biofeedback devices for recent virtual environments. For the sake of simple architectural experience tests, we argue that biofeedback can be applied in terms of understanding the self, the environment, or other (fictional or real) participants’ reactions to the environment. Clients could graphically see how different market segments experience and react to biofeedback-augmented digital visualizations. However, the variety of responses possible, the lag, the calibration required, and the indirect and vague nature of the biofeedback have convinced us that for architectural testing purposes it would be difficult to conduct tests using biofeedback to ascertain architectural empathy of form or material.

Secondly, we suggest that indirect biofeedback used to increase the sense of trepidation or excitement of the environment is best employed in games (or perhaps in social worlds), however there is potential to assess serenity and contemplation in sacred spaces such as digital simulations of churches and meditation spaces. Thirdly, using indirect biofeedback to personalize the environment and recognize the attitude through physiological state of others is interesting, but difficult to evaluate in smaller test environments of shorter duration. For measuring subjective responses, using a control group to test comparative results in task performance does not seem appropriate.

Architects may be more interested in whether participants find the modified environment is more responsive (in a positive way), with more character, more appropriate to what is simulated, and more interesting. They may also be interested in whether the modified environment has a more engaging sense of territoriality. Do certain seated views or standing positions create a sense of unease?

For example, changes between calm and excited biofeedback states could affect the field of vision and the lighting condition. Finally, the participants could also be asked which of these biofeedback-influenced factors have the most natural mappings (i.e. the interaction metaphors are most appropriate).
7. CONCLUSION

What is innovative about biofeedback applied to digital modeling of architecture and architectural settings, and why is it significant? As far as we know, there is so far no convincing and through review of how biofeedback, and indirect biofeedback in particular, can be usefully applied to architecture. While there are increasing numbers of papers on biofeedback applied to games, such research must be critically reviewed before being applied to digital simulations of architecture, for the two fields differ so greatly.

This paper explored the imaginative and atmospheric use of real time biometric feedback within interactive digital environments but particularly for architecture. We suggest five main areas of applications for the above type of biofeedback (indirect biofeedback based on changes in physiological states) for digital visualizations of urban settings and the built environment in general. Participants could indirectly colour their surroundings, which may afford them more insight into the world around them, their interactions with it, or the progress and experience of other participants. In terms of object creation, more uniquely personalized and engaging environment elements (also known as externs) could be directly or indirectly created from biofeedback. Atmospheric-affecting biofeedback may augment and enhance a sense of inhabitation. Biofeedback could also be used to contextually filter and display information so that a user is not overloaded with extraneous information, or, conversely, observant and more empathic participants could be rewarded with more information. Indirect biofeedback could also help tracking of participants (of phobias – also called negative engagement – and positive engagement).

These ideas may be of interest to those keen on creating more engaging virtual worlds, those interested in whether digital simulations can better approach the experiential richness of real world places, and those curious in indirect interaction metaphors for experiencing places. Biofeedback may help those who wish to create not just simulations of religious, revered and historic architectural sites, but also those who also wish to convey a sense of the experience of various audiences who have visited them.

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References


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