Designing Game Audio Based on Avatar-Centred Subjectivity

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Abstract:

This chapter explores a selection of practical approaches for designing video game audio based on the subjective perception of a player avatar. The authors discuss several prototype video game systems developed as part of their practice-led research, which provide interactive audio systems that represent the aural experience of a virtual avatar undergoing an altered state of consciousness. Through the discussion of these prototypes, the authors expose a variety of possible approaches for sound design in order to represent the subjective perceptual experiences of a player avatar. Building upon this work, they argue for 'avatar-centred subjectivity', as a generalised concept applicable for first-person perspective video games and simulations. A hypothetical system for 'avatar-centred subjectivity' is proposed to exemplify the concept, which would allow aspects of an avatar's cognition, emotion and state of consciousness to be parameterised for the purposes of interactive sound design.

Keywords:
Video Games, Virtual Reality, Altered States, Immersion, Subjectivity, Perspective, Simulations, Design, Cognitive Psychology.

1. Introduction

Since the early days of computer games, the graphics, sound and narrative capabilities of the medium have steadily advanced. Sprites and early forms of wireframe 3D with flat shading gave way to accelerated OpenGL 3D in the 1990s, which was soon augmented with various effects such as coloured lighting, bump mapping, fog, transparencies, and lens effects. In game audio, early 'chip sounds' were superseded by digital sampling, eventually leading to multichannel CD-quality sound effects and musical soundtracks that respond dynamically to events in the game (Collins, 2008). In the current state of the art, video games within genres such as the first-person shooter (FPS) are able to depict highly realistic 3D environments, which the user can navigate interactively with an avatar[1]. With the latest virtual reality (VR) equipment, this drive towards realism continues, as designers seek to immerse users in virtual environments that engulf the senses.

In immersive simulations, first-person perspective (FPP) is often used, which provides the user with an 'eye-view' from the subjective perspective of an avatar. FPP video games do this by utilising a virtual camera, which is typically located on the head of an avatar, thereby allowing graphics to be generated based on the virtual perspective of the avatar. In effect, the camera acts as a substitute for the eyes of the avatar, allowing us to view what the avatar would be seeing from its location in the virtual world. Similarly, 3D audio is calculated based on the location of the avatar relative to the virtual sound sources within the level. This allows the amplitude of sound sources to change based on their relative distance from the avatar and for environmental effects such as reverberation to be applied, for instance. Using such techniques provides the user with the illusion of seeing and hearing the virtual environment from the perspective of the avatar, which contributes towards the sense that the user has of embodying it. This sense of embodiment may also lead to a feeling of 'presence', the sensation that the user has when he or she feels that they are really there in the virtual world (Slater and Wilbur, 1997). Following Slater and Wilbur's definition, this sensation can be distinguished from 'immersion', which describes the capabilities of technology to envelop the senses of the user. For video games, this feeling of presence, along with the achievement of flow (Csikszentmihalyi, 1997), may be among those features that make the experience particularly compelling, and perhaps partly explains why genres such as the FPS have gained such popularity since the 1990s.

Immersive technologies, such as the latest VR devices, augment FPP by bringing the user yet closer to the visual and aural perspective of an avatar, by mounting a stereoscopic display on the head of the user, which can be orientated in correspondence with the avatar. This impression is used by VR games and 360 VR videos in various ways. For instance, *Affected the Manor* (Fallen Planet Studios, 2016) places the user within a terrifying haunted house that he or she must navigate through. The 360 VR video *Clouds Over Sidra* (Arora and Pousman, 2015), by contrast, situates the viewer within a refugee camp, with the aim of promoting awareness of the struggles faced by people in the camp. Along similar lines, the *Autism TMI Virtual Reality Experience* (The National Autistic Society, 2016) portrays the experience of a person with autism using FPP, to generate awareness of autism. Meanwhile, *The Machine to Be Another* (BeAnotherLab, 2016) explores the idea of using VR to see through another person's eyes, by switching the viewpoints of two individuals using live cameras. Each of these examples utilises FPP to create the illusion of seeing an environment from the alternate perspective of an avatar, which may be fictitious or based upon a real person. Yet the last three examples also show how VR is not only being used to provide a sense of being *there* within the environment, but also how it is being used to provide a sense of actually being *someone* (the avatar)[2]. This concept — the idea of communicating the experience of a virtual avatar — is a key theme that we shall explore in this chapter.

For media that seeks to convey the experiences of a virtual avatar, we must consider how this can appropriately be achieved through their design. In video games, VR applications and 360 videos that use FPP, there are two distinct approaches that may be used. The first of these is to employ cameras and microphones, or their virtual equivalents, to capture the *objective* patterns of light and sound in the approximate location where the head of the avatar would be[3]. For the user, the approach replicates the incoming patterns of light and sound that would be received by the avatar in the given situation. The second approach must also do this, but takes further steps to represent the *subjective* perception of the avatar, by using various techniques to represent how the visual or auditory information is processed. The key difference between these two approaches can be clearly highlighted if we imagine a hypothetical scenario in which an avatar has consumed a hallucinogenic drug. In this situation, the avatar would be in an altered state of consciousness (ASC), which substantially changes their subjective perception of the world around them (Ludwig, 1969). Using the first *objective* approach to FPP, the patterns of incoming light and sound that are external to the avatar would be represented, thereby giving no indication of the hallucinations or altered perception experienced by the avatar. By contrast, the second *subjective* approach would represent the visual and auditory experience of the avatar including the hallucinations, which might be shown by increasing the intensity of colours or using sound to represent auditory hallucinations. The key difference is that the subjective approach takes into account the perceptual processing of the avatar.

The second of these approaches, in which graphics and sound seek to represent the *subjective* visual and auditory perception of an avatar, is our main focus in this chapter. This approach, which we shall refer to as 'avatar-centred subjectivity', may provide a means through which the user can gain a deeper sense of connection with an avatar, since it communicates more aspects of the avatar's subjective perception[4]. For example, using this approach we may represent how an avatar directs attention towards incoming sensory stimuli; has certain types of emotional reactions; or perceives sensory hallucinations that arise internally within the brain. Such information may allow the user not only to understand what it is like to be *where* the avatar is, but also to understand what it is like *to be* the avatar.

In order to explore the concept of 'avatar-centred subjectivity', in this chapter we first discuss a variety of prototypes that demonstrate approaches to sound design based on subjectivity. These prototypes focus in particular on the concept of ASCs, such as the intoxicated experiences and hallucinations that people may have on psychedelic drugs. Such experiences provide an interesting way to explore notions of subjectivity, because they include experiences of hallucination that are more easily distinguished as 'subjective'. Through our discussion of these projects, we illuminate some approaches for sound design in relation to subjectivity, within the interactive context of video game engines. Following this, we then describe a framework for 'avatar-centred subjectivity', which draws upon various theories of consciousness and cognition, drawing notably on the approaches of information processing[5]. Through this discussion, we aim to define the concept of 'avatar-centred subjectivity' in terms that will point towards its generalised use for a variety of purposes, such as interactive sound design for video games and other networked communication tools that utilise avatars.

2. Prototype Systems for Representing ASCs in Video Games

2.1 Quake Delirium

In order to explore ways in which representations of ASCs could be designed in a video game through practice-led research, our Affective Audio research group (http://www.affectiveaudio.net/) created several prototype systems[6]. The first of these was a development of Weinel's *Quake Delirium* (2011), a modification of the video game *Quake* (id Software, 1996). Using a Max/MSP patch and various scripts, *Quake Delirium* enabled the use of a MIDI mixing device to adjust various graphical and game parameters such as field of vision (FOV), drunk mode (causes the camera to sway drunkenly), fog density/colour, game speed, stereo vision (stereoscopic effect for red and blue 3D glasses), gamma, and red hue. By manipulating these parameters with a haptic device, fluctuations in the appearance and speed of the game could be introduced, reflecting the way in which an ASC may cause visual disruptions and alter perception with regards to the flow of time (Figure 1). The modification allowed the sequence of these changes to be automated, while the same fluctuating parameters were also used to control various sound generating processes in a Max/MSP patch. The latter caused filters and other audio effects to follow the visual changes, thereby producing a corresponding electroacoustic soundtrack. This connection between the soundtrack and the visual distortions was conceived as a way to reflect the synesthetic aspects reported in hallucinatory experiences[7].

Quake Delirium EEG (Weinel et al., 2015a) expanded the system by utilising a consumer-grade EEG headset (a Neurosky Mindwave), as a controller for the fluctuating parameters. Here, the main intention was to explore how a brain-computer interface (BCI) might provide a form of 'passive' control[8], linking the biosignals of the player to the simulation of hallucination, and thereby providing a deeper sense of connection between the player and the avatar. As part of the project, we explored the user experience of the system. Here we found some challenges in providing the user with a meaningful sense of connection and interactivity via the biofeedback, perhaps due to the quality and tangibility of the EEG signals as a controller source. Similar issues were also highlighted in a related study exploring the user experience of *Psych Dome,* an EEG-controlled audio-visualisation based on the visual patterns perceived during hallucinations (Weinel at al., 2015b). Despite these shortcomings, we suggest that future systems could utilise improved biofeedback devices and build upon the basic approach demonstrated by *Quake Delirium EEG*, in order to yield effective results.

[INSERT FIGURE 1 HERE]

Figure 1. Screenshot from *Quake Delirium*. A Max/MSP patch is used to automate distortions to graphics and sound, in order to represent a hallucinatory experience that varies in intensity over time.

2.2 Auditory Hallucinations Project

While some existing representations of ASCs in video games[9] may rely on intuitive notions of what a hallucination might entail, we can argue that if improved accuracy is sought, we should refer to research regarding the experiences people actually describe during ASCs. Towards this aim, we carried out a large-scale analysis of nearly 2000 experience reports gathered from an online database, which described intoxication from a variety of substances such as LSD, MDMA, amphetamines, alcohol and others (Weinel, Cunningham, and Griffiths, 2014). Using these descriptions we were able to isolate key features that people described during intoxicated experiences of auditory hallucination, and assemble a large number of qualitative descriptions to use as a resource for designing audio.

Using the qualitative descriptions, we designed sound materials based on different types of auditory hallucinations, such as auditory-verbal hallucinations, hallucinations of noises, and of music. These sonic materials were categorised in relation to Hobson's (2003) 'AIM' model of consciousness, a three-dimensional model of consciousness, with the axes of 'activation', 'input' and 'modulation'. 'Activation' describes the level of brain activity; 'input' describes the origin of sensory inputs; and 'modulation' describes how events are recorded to memory. The 'input' axis is of particular interest for our purposes here, and ranges from 'external' to 'internal'. 'External' sensory inputs originate in the surrounding environment, whereas 'internal' sensory inputs are generated within the brain. According to this model, dreams and hallucinations can be considered as a predominantly 'internal' form of sensory input[10].

Utilising the concept of the input axis, we designed sounds based on auditory hallucinations that corresponded with 'internal' sensory input, and digitally manipulated sounds based on ‘external’ environmental sensory inputs, allowing us to traverse the 'input' axis of Hobson’s (2003) 'AIM' model of consciousness through sound. Along the mid-point of this axis, where the perception of everyday sounds becomes enhanced or distorted due to intoxication, we used a variety of digital signal processing techniques such as reverb, delay, flanger, EQ, time stretching and spectral processes to give an impression of warped perception. This was undertaken by using the qualitative descriptions as a guide to decide which type of sound manipulation process to use. Developing a trajectory that was explored earlier in Weinel's (2012) PhD work, in which he composed electroacoustic music based on altered states of consciousness (see also Weinel, 2016), several of these demonstration pieces were also assembled into miniature electroacoustic compositions.

Among these, Cunningham's *LSD No.1* (2014) was performed at several international electroacoustic concerts, such as *Étude de l'objet: Bilder und Klangbilder* held at the Kurt-Tucholsky-Literaturmuseum in Rheinsberg, Germany (2017). The piece was produced in response to a specific account of LSD hallucination gathered from our study:

> "I was hearing voices in the wind when I had the window down, and I heard bizarre, distorted, nearly demonic voices coming out of the radio if I turned it on. I had my driver's license and car registration out on the dashboard, and I was ready, if I got pulled over by a cop, to tell him or her that I was way beyond anything that could be tested and to just arrest me and have it finished. But I made it home. I was on the back side of the acid peak by this time, but still really high."[11]

This account features descriptions of both 'external' ('real') and 'internal' (hallucinated, or 'unreal') experiences of sound, which could be designed using corresponding layers of digital audio. An 'external' layer of sound was constructed using a recording made in the interior of a car during a journey. This layer includes engine hum and road noise, interspersed with the sound of gears being shifted and the car turn indicator clicks. Car radio sounds are introduced approximately halfway through the composition, which were made by recording the sound of an analogue radio being tuned, introducing static and occasional clips of radio stations. Band-pass filtering was also applied to these, to reflect the typical frequency response of a car stereo. An 'internal' layer of sound, which describes the subjective aural experience of hallucinations, was also constructed using recordings of male and female voice actors. A degree of artistic licence was also applied to elaborate on the basic description. In this case the word “acid” was recorded several times, to provide the “…voices in the wind…” component of the text. These sounds were processed with a high-pass filter, augmented with short, frequent delays, placed at a low level in the mix, and alternately panned. The “demonic voices” on the radio were recorded by having the actors shout instructions that might be relevant to the situation, such as “wind that window up”, “acid”, “who do you think you are”, and “listen to me”. Multiple sections of these recordings were overlaid to create a sense of confusion and distress. The voices were all band-pass filtered and processed with distortion. Several were pitch shifted into lower registers, to create a slower and more sinister sound. Finally, toward the end of the piece, the radio tuning sound was reintroduced and the sound of the radio being switched off is heard, as the listener is returned to the normality of the car interior. In this way the structure of the piece reflects a transition through external and internal layers of sound.

While *LSD No.1* and the other demonstrative compositions we created as part of this project were fixed-media outputs, the separation of materials into the layers of 'external' and 'internal' sounds allowed us to begin thinking about ways in which a real-time system could be developed, which parameterised sensory ‘input’ as a basis for interactive sound design. For example, an extension of this project could map layers of 'external' and 'internal' sounds to separate channels of audio within a game engine, and mix between these in real-time when a player avatar becomes intoxicated.

2.3 ASC Simulation

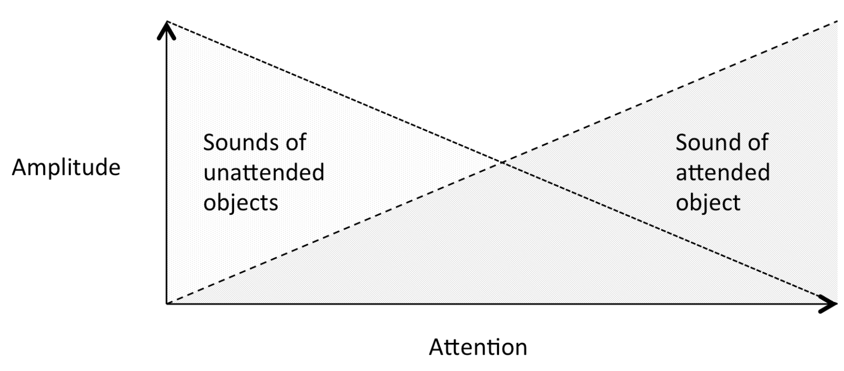
Building upon the previous projects, the first iteration of our *ASC Simulation* demonstration patch was conceived to explore other ways in which an interactive system could represent auditory hallucinations through real-time mechanisms (Weinel and Cunningham, 2017). A prototype was created in the Unity game engine, consisting of a simple 3D game environment with several coloured cubes, each of which emit different sounds such as synthesized tones. This was used as a basis to explore three prototype mechanisms for representing auditory hallucinations using real-time approaches, which were based on ASC features identified from the previous study.

The first of these mechanisms looked at the idea of ‘selective auditory attention’. This concept is often illustrated with the example of the 'cocktail party effect', in which amidst a noisy room of people talking, it is possible to selectively focus on a single conversation. Broadbent (1958) carried out important early work in relation to selective auditory attention, arriving at his ‘filter theory of attention’, which considers how attention directs incoming auditory inputs, promoting some for higher level processing, while others are filtered out. Subsequent theories such as Treisman (1960) developed this idea further, suggesting that unattended sources are ‘attenuated’. More recently Bregman's (1994) theory of 'auditory scene analysis' (ASA) further developed our understanding of how complex aural sources can be separated into different auditory streams, distinguishable from one another as separate objects, though potentially constituted by complex acoustical phenomenon. For some ASC reports we looked at in the previous study, absorbed attention towards certain objects was pronounced, and hence we were interested in modelling this effect for an avatar using a real-time process. Our design selects which of the sound emitting cubes in the demo game is being attended by the avatar, based on which of the cubes the avatar is looking at[12]. When the avatar attends a cube, the amplitude for all other cubes is reduced in accordance with a time-varying envelope, as shown in Figure 2. This mechanism therefore demonstrates an approach for interactive sound design based on the concept of selective attention.

The second mechanism our *ASC Simulation* demonstrates is that of ‘enhanced sounds’. This aims to model a feature described in reports of intoxication, where sounds are perceived as more bright, intricate, detailed, enjoyable or interesting than usual. As illustrated in Figure 3, we split the source material for the sound emitting cubes into three copies, each of which were then processed with EQ to create ‘dull’, ‘medium’ and ‘bright’ versions of the sonic material. This then allowed us to manipulate an ‘enhancement’ parameter, which applied cross-fading playback between the three versions of the material, thereby eliciting sounds from the cubes that became gradually brighter in correspondence with the degree of 'enhancement'. This demonstrated another specific effect that could be used as part of a package for representing intoxicated states using real-time processes.

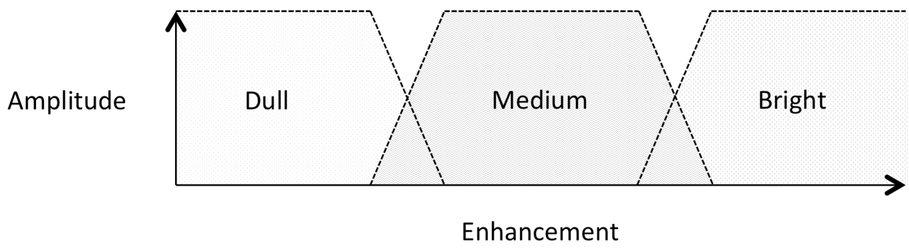
Our third mechanism related to reports from our auditory hallucination study, in which people described disruption to their experience of the spatial location of sounds. As show in Figure 4, we developed a real-time demonstration that caused the sounds being emitted from the cubes to follow oscillating patterns of movement around the actual physical object, which remained stationary. Using this technique, the sounds of the cubes became detached from where they should be in terms of their spatial location, therefore demonstrating one possible real-time approach for representing spatial disruptions due to intoxication.

ASC Simulation is the most recent in a series of prototypes utilising practice-led research as a means to explore ways to represent ASCs using video game development platforms. Through this project we have demonstrated a variety of specific techniques that could be used for representing effects of intoxication described in the experiential reports that we analysed. However, ASCs are a very specific type of subjective experience, and therefore this work could also be considered as a subset of a larger project in the field of 'avatar-centred subjectivity'. With this in mind, in the next section we will seek to define 'avatar-centred subjectivity' as a more general concept that could be utilised for representing ASCs, affective states and others.



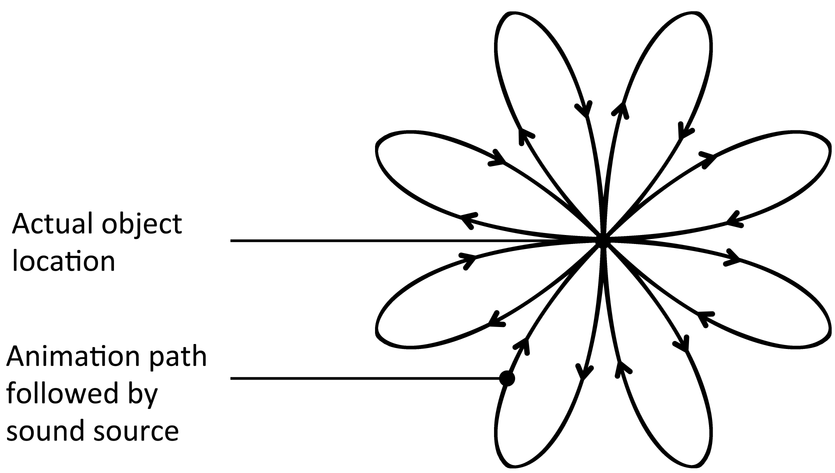
[INSERT FIGURE 2 HERE]

Figure 2. The ‘selective auditory attention’ mechanism of the *ASC Simulation* project changes the amplitude of sound sources based on the ‘attention’ of the avatar. As the avatar looks at a sound source, all others fade out, so that only the object currently within attention is heard.



[INSERT FIGURE 3 HERE]

Figure 3. The ‘enhanced sounds’ mechanism of the *ASC Simulation* adjusts the EQ parameters of all sound sources, by cross-fading between different versions. As the ‘enhancement’ meter increases, the source material mixes between ‘dull’, ‘medium’, and ‘bright’ versions of the source material.



[INSERT FIGURE 4 HERE]

Figure 4. The ‘spatial disruption’ mechanism of the *ASC Simulation* causes sound sources to moves in an oscillating ‘flower’ pattern around the central point where the associated object is located in 3D-space.

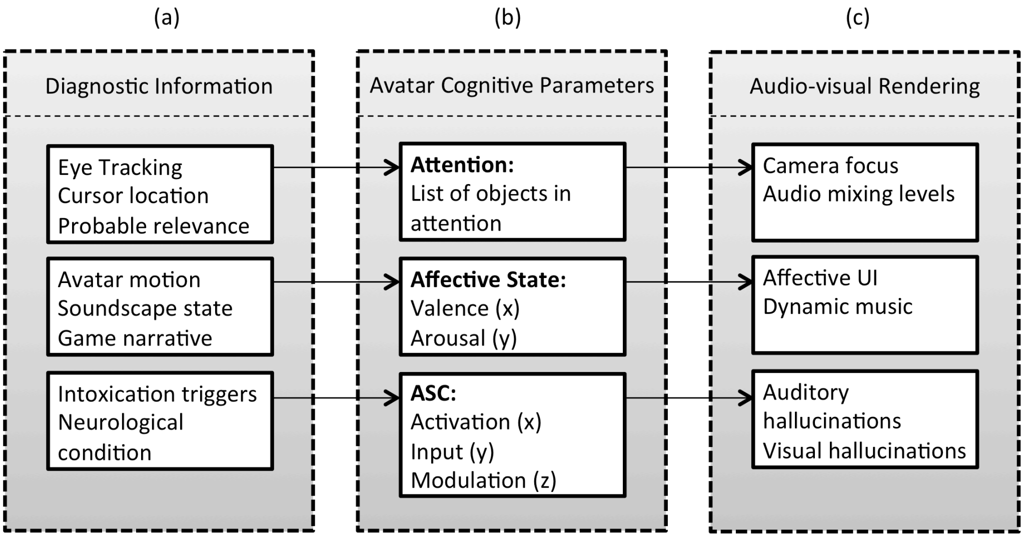
3. Avatar-Centred Subjectivity

3.1 Concept

The concept of ‘avatar-centred subjectivity’ proposes that we can model various features related to the conscious state of a particular avatar, such as may be used in video games or networked communication tools (e.g. those that utilise virtual avatars, such as social media, live chat and Second Life). By parameterising various features of the avatar’s cognitive state, and modelling specific perceptual systems, we can make this information available to inform how graphics and sound are rendered. In doing so, we can aim to communicate various aspects of the avatar’s subjective experience to the user, such as sensory experiences or emotional states.

To develop such systems in ways that meaningfully correspond with human perception, we can inform their design based on research from the domain of cognitive psychology. For example, in this chapter we have already referred to Hobson’s (2003) 'AIM' model of consciousness, and theories of attention such as Broadbent’s (1958) ‘filter theory’ and Bregman's (1994) 'auditory scene analysis'. These and other established theories could be used to develop models of avatar-centred subjectivity with increasing levels of complexity. Eventually, by modelling multiple systems that exchange information collaboratively, we could conceive of designing highly complex VR systems that provide a ‘theatre of consciousness’ (to adopt the metaphor used by Baars, 1997). While such designs are a more long-term goal for this research, here we shall illustrate a more basic system that could be developed and utilised for the purposes of interactive sound design with relative ease.

Our proposed system for ‘avatar-centred subjectivity’ is illustrated in Figure 5. In this figure there are three main groups: ‘Avatar Cognitive Parameters’ (b) store information regarding the attention, affective state and ASC of the avatar, which is acquired via ‘Diagnostic Information’ (a) processes. The ‘avatar cognitive parameters’ then become available to inform various aspects of real-time 'Audio-visual Rendering' (c). In the following sections, each group will be discussed in further detail.



[INSERT FIGURE 5]

Figure 5. Diagram illustrating the proposed concept of ‘avatar-centred subjectivity’ as a system that utilises theories of attention, affective state and ASC. ‘Avatar Cognitive Parameters’ (b) are acquired via ‘Diagnostic Information’ (a) processes, and are used to inform ‘Audio-visual Rendering’ (c) in a video game or VR application.

3.2 Avatar Cognitive Parameters

The core of avatar-centred subjectivity is group (b) labelled ‘Avatar Cognitive Parameters’, which provides a set of attributes that describe the conscious state of the avatar. Here these attributes are limited to the categories of ‘Attention’, ‘Affective State’ and ‘ASC’, though other models or categories could also be used. Following our discussion of Broadbent's (1958) 'filter theory' and Bregman's (1994) 'auditory scene analysis', 'Attention' describes the game objects that are currently within the attention of the avatar; this could be modelled as a list or collection of game objects. 'Affective State' describes the valence and arousal values of the avatar, in accordance with Russell's (1980) circumplex model of affect. Russell's model describes mood and emotion according to a two-dimensional model: valence (x) describes the extent to which emotions are pleasant or unpleasant, while 'arousal' (y) describes the level of energy activation, in correspondence with systems such as the autonomic nervous system (ANS). In our proposed model, valence and arousal can likewise be parameterised as numerical x and y values. Lastly, 'ASC' describes the conscious state of the game character according to Hobson's (2013) AIM model, with x, y, z values.

3.3 Diagnostic Information

The 'Avatar Cognitive Parameters' (b) group provides the main set of attributes that define the conscious state of the avatar with regards to attention, affective state and ASC. This information needs to be acquired through some systematic means, which here we have suggested through group (a) 'Diagnostic Information'. This group provides methods through which the required parametric data can be acquired. Firstly, as demonstrated through our *ASC Simulation* prototype, a simple way to get attention information is by analysing what the avatar is looking at (cursor location). If eye tracking is available, this could also be used to identify which objects the user is actually looking at, as explored by Hua, Krishnaswamy, and Rolland (2006); Sundstedt (2010); and Turner et al. (2014). Additionally, in the context of a game narrative, predictions could be made about which objects are likely to be of most relevance to the avatar; for example, an avatar searching for a door key might be drawn to looking at door key objects more than other items in a scene. Through a combination of methods such as these, it is possible that a list of attended objects can be provided, which is updated on an on-going basis.

For identifying the affective state of the avatar, we propose that the movement of the avatar could be analysed. Where an avatar is moving rapidly, this is likely to produce a high arousal state, due to the interaction between physiological condition and affective state. Conversely, an avatar that is not moving would likely have low arousal. Another approach could be to analyse the surrounding soundscape. For example, we can conceive in a war game that a soundscape filled with explosions may suggest a more fearful affective state for an avatar than one containing calm environmental sounds such as birds singing. We could also examine the narrative of the game, since events in the story of the game could be defining features that suggest what emotional state the avatar would be in. This would provide a useful way to determine the valence state of the avatar and could be accompanied by other in-game variables such as level of health and overall progress on the current task or mission. Using such information can provide ‘Diagnostic Information’ (a) that informs the affective state component of the ‘Avatar Cognitive Parameters’ (b).

Lastly, we need to consider how the ASC state of the avatar can be determined. Where states of intoxication are concerned, this could also be analysed based on events in the game, such as the consumption of substances that cause an altered state of consciousness. Here we might also use time-based envelopes with attack and decay parameters to model how the effects of a drug intensify over time and eventually wear off (for further discussion, see also Weinel, 2016). Once we know what type of ASC a character would be in, we can define values for the AIM values of the ‘Avatar Cognitive Parameters’ (b) accordingly, following Hobson’s (2003) discussion of how these change during different states. Similar approaches could also be used for dream states; for instance, an avatar that remains undirected by the user for a period of time might start to daydream, or possibly fall asleep, precipitating corresponding changes to the AIM values.

3.4 Audio-visual Rendering

Once the ‘Avatar Cognitive Parameters’ (b) are available within the game engine, they can be used to inform ‘Audio-visual rendering’ (c), which defines how various aspects of graphics and sound are rendered in order to communicate the subjective experience of the avatar in real-time.

With regards to graphics, for instance, attention information could be used to focus the camera that represents the avatar’s visual experience on attended objects. In the sound domain, ‘attention’ could be used to adjust the mixing of audio levels for attended objects in real-time, using an approach similar to the one we prototyped in the *ASC Simulation.*

With regards to ‘affective state’, valence and arousal information could be used to inform the design of UI elements such as a visual impression of the avatar’s facial expression, and/or other symbolic information regarding emotional state. In sound, these values could also be used to control parameters of dynamic music, so that the music changes emotion in accordance with the character to follow his or her affective state or to trigger the playback of a character monologue about their situation. In the case of the adaptive music, this would most likely be implemented by using the ‘Avatar Cognitive Parameters’ (b) as controllers for a dynamic music interface, such as those provided by FMOD or Wwise.

The ‘ASC’ values of the ‘Avatar Cognitive Parameters’ (b) could also be used to control aspects of how graphics or sound are rendered. For instance, utilising the ‘input’ (y) parameter of the AIM model, we could design a system that modulates between ‘external’ and ‘internal’ graphical elements and 3D geometry, effectively moving the avatar between real and unreal virtual environments. For the purposes of sound design, this input parameter could be used to gradually distort the ‘external’ sonic materials, and introduce ‘internal’ sonic materials related to auditory hallucinations. This could be achieved using approaches we began to explore through layers of sound in the *ASC Simulation* project, which were discussed earlier in this chapter. Using such techniques, as the avatar enters an ASC, real-time sound design could reflect that state by modifying the presentation of the virtual soundscape, and by introducing unreal sounds that reflect dreamlike or hallucinatory states.

4. Conclusion and Future Work

Through the course of this chapter we have defined the concept of 'avatar-centred subjectivity'. This concept is intended for use in video games, VR applications and networked communication tools, in order to provide a means through which to enhance the communication of information regarding the subjective experiences of avatars. This concept emerged from, and is informed by, our practice-led work developing several prototype systems for representing ASCs. Though our work in this area has focused predominantly on ASCs so far, the concept of 'avatar-centred subjectivity' can be used to explore a whole range of cognitive systems, in order to model the ways in which subjective perception can vary for individuals under different circumstances. Therefore, it may be useful not only for looking at ASCs and states of intoxication, but *any* type of subjective perceptual state.

Working towards this goal, in this chapter we have outlined 'avatar-centred subjectivity' as a general concept, which we propose points towards a system that could be useful for a much broader range of avatar designs. At its core, the concept of 'avatar-centred subjectivity' is a system for communicating information regarding subjective experiences. Although we illustrated this primarily with regards to video games, this capability for communication could be useful for many networked communication tools in order to enhance understanding between individuals. In a world where our interactions are increasingly mediated through digital environments, this capability for enhanced communication of subjectivity could yield more 'human' interactions that recover aspects that become lost in purely text-based forms of communication[13].

As we have explored, the concept of 'avatar-centred subjectivity' can be used to inform various aspects of design including graphics and sound. Using interactive sound design techniques, with relative ease, we can immediately begin to design media that represents subjective experiences of attention or ASC. Communicating affective states may be trickier, but music already has an established use for indicating and stimulating emotion, and thus provides one obvious means through which to develop an affective interface. Using the system we proposed here, it would be relatively easy for a composer and games designer to implement an interactive system where dynamic music responds specifically to the emotional state of an avatar. Therefore, the essential concept of 'avatar-centred subjectivity' can be implemented in the short-term with relative ease. Moving forwards, there is may also be scope for 'avatar-centred subjectivity' to inform other sensory stimuli that might be used in video game and VR scenarios, such as tactile and olfactory representations, as well as elements of gameplay or challenges.

In the long-term we hope to see the basic concept defined here expanded upon. The next steps for researchers will be to design robust systems that implements different approaches to 'avatar-centred subjectivity', and subject these to rigorous user testing[14]. As discussed, these can be devised by drawing upon the wealth of knowledge that is available in fields such as cognitive psychology. Therefore, while we outlined several systems that can be used, there are others we could look at; for example, we could model memory by using Atkinson and Shiffrin's (1971) distinctions of short-term memory (STM) and long-term memory (LTM), and consider how items in short-term memory may move to long-term memory through repetition (for example). Or, we might utilise Baddeley and Hitch's (1974) concept of 'working memory', which describes a temporary memory system used for information currently being processed. It is easy to imagine how these systems could be useful for modelling avatar memories in games that require complex character psychologies, such as *L.A. Noire* (Team Bondi, 2011) or *Max Payne 3* (Rockstar Studios, 2012). By providing multiple systems, we could begin to provide a toolkit for designers, with different modules that can be activated as needed depending on requirements. By developing these we can begin to provide FPP simulations in video games and VR that closely correspond with our subjective human experiences. As the sophistication and pervasiveness of VR and FPP simulations increases, we believe that research into 'avatar-centred subjectivity' is going to be a growth area of critical importance.

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Biographies

Jonathan Weinel is a London based artist, writer, and researcher whose main expertise is in electronic music and audio-visual media. He is the author of: *Inner Sound: Altered States of Consciousness in Electronic Music and Audio-Visual Media* (Oxford University Press, 2018). In 2012 Jon completed his AHRC-funded PhD in Music at Keele University regarding the use of altered states of consciousness as a basis for composing electroacoustic music. His work currently operates within the nexus of sound, psychedelic culture and immersive computer technologies. His creative projects have been presented at a variety of international festivals, while his writings have been published in books, journals and conference proceedings. Jon has held academic posts in the UK at Keele University, Manchester Metropolitan University, Wrexham Glyndŵr University, and Aalborg University, Denmark, where he is currently a Visiting Research Fellow. He is a Full Professional Member of the British Computer Society (MBCS), a member of the Computer Arts Society (CAS) specialist interest group, and serves on the organising committee of the EVA London (Electronic Visualisation and the Arts) conference.

Stuart Cunningham is Reader in Audio and Affective Computing and was formerly Head of the Department of Creative Industries (2010–2014) at Wrexham Glyndŵr University. His background is in computing and audio technologies. He holds a PhD in similarity-based audio compression from the University of Wales, having previously completed a BSc and MSc at the University of Paisley. His research interests cover a range of computing and creative hybrids, including: audio compression; affective technologies; sonic interaction; sound design; and the socio-economic impact of leading-edge technologies. Stuart is a Fellow of the British Computer Society (FBCS), Chartered IT Professional (CITP) and Fellow of the Higher Education Academy. He currently serves on the committee of the BCS Computer Arts Society (CAS) specialist group and the steering committee of the Audio Mostly conference series. Stuart was also a member of the MPEG Music Notation Standards (MPEG-SMR) working group, which developed ISO/IEC 14496-23:2008.

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[1] Throughout this chapter the term 'avatar' is used to refer to both fictional and non-fictional characters or persons depicted either in synthetic 3D worlds, or via cinematography such as first-person perspective (FPP) video footage used in 360 VR videos.

[2] Of relevance to this area of research, is Slater's (2009) work, which seeks to expand the discussion by suggesting the definitions of: 'place illusion' (PI): presence, or the feeling of

‘being there’; and ‘plausibility illusion’ (Psi), the belief that what is occurring is actually happening.

[3] While we refer to this as an *objective* approach to make the distinction clear, it should be acknowledged that locating these patterns in relation to the avatar affords them some basic features of subjectivity. Yet, as will become clear through the course of our discussion, we feel that there is room for these representations to take into account many more aspects of the avatar's subjective experience.

[4] For example, Weinel, Cunningham, and Pickles (2018), argue for the concept of ‘deep subjectivity’, in which the representation of emotions and non-aural or non-visual aspects of sensory experience increases the information available to the user for discerning the subjective state of an individual. In the chapter, they propose ‘deep subjectivity’ as a design approach that may provide the possibility of improved empathy between the user and the avatar.

[5] For a general overview of 'information processing' in relation to other approaches in cognitive psychology, see Galotti (2014). For the purposes of the projects discussed in this chapter, the use of this paradigm is pragmatic since it can readily be used as a basis for design within video game engines.

[6] For each of the projects discussed in this chapter, various materials have been provided in the accompanying package of supporting files. These include: beta source code, example sounds, videos and other related documentation.

[7] For example, the experience of visual hallucinations that respond to auditory stimulation is discussed in Bliss and Clark (1962, p.97).

[8] As discussed in (Zander et al*.,* 2010, p.185), ‘passive’ BCIs utilise brain activity outputs without voluntary control, in order to enrich human-computer interaction through the use of implicit information.

[9] For a comprehensive review of video games and other audio-visual media that represents ASCs, see Weinel (2018).

[10] It should be noted that Hobson's (2003) concept of 'external' and 'internal' inputs certainly allows for the subjective perceptual processing of both types of information within the brain. What is important in this distinction is where the *input* of the information comes from. In cases of dreams or hallucination, sensory information received from the surrounding environment is reduced, and internally generated sensations seem to play a more significant role. Of course, though these sensations seem to be generated within the brain while a dream or hallucination is occurring, they inevitably involve systems such as memory that we may reasonably presume have been shaped by interactions within the surrounding 'external' environment, prior to the event.

[11] This quotation appears in the data collected as part of our study, which is available within the supporting documents (AH_Descriptions_Draft.pdf). The original source can also be found online (https://www.erowid.org/experiences/exp.php?ID=8232).

[12] This is achieved in Unity using 'ray casting', where a line is projected along the avatar's 'line of sight' (represented on-screen with a cross-hair), and the objects that intersect with that line can be identified.

[13] For example, the limitations of digital communication technologies in relation to trust are explored in an episode of Douglas Rushkoff's 'Team Human' podcast series, in an interview with William Softky and Criscilia Benford (Rushkoff, Softky, and Benford, 2017).

[14] For a discussion of approaches for the testing and evaluation, see Cunningham, Weinel and Picking (2016).