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Auditory Experiences in Game Transfer Phenomena: An Empirical Self-report Study

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Abstract

This study investigated gamers' auditory experiences as after effects of playing. This was done by classifying, quantifying, and analysing 192 experiences from 155 gamers collected from online videogame forums. The gamers' experiences were classified as: (i) auditory imagery (e.g., constantly hearing the music from the game), (ii) inner speech (e.g., completing phrases in the mind), (iii) auditory misperceptions (e.g., confusing real life sounds with videogame sounds), and (iv) multisensorial auditory experiences (e.g., hearing music while involuntary moving the fingers). Gamers heard auditory cues from the game in their heads, in their ears, but also coming from external sources. Occasionally, the vividness of the sound evoked thoughts and emotions that resulted in behaviours and copying strategies. The psychosocial implications of the gamers' auditory experiences are discussed. This study contributes to the understanding of the effects of auditory features in videogames, and to the phenomenology of non-volitional experiences (e.g., auditory imagery, auditory hallucinations).

Keywords: Game Transfer Phenomena; Videogame effects; Auditory cues; Auditory imagery; Effects of priming and conditioning; Auditory verbal hallucinations; Self-monitoring failures; Semantic memory

AUDITORY EXPERIENCES IN GAME TRANSFER PHENOMENA

Modern videogames are rich in sensory cues. Auditory effects are crucial for enhancing the playing experience by increasing the awareness of surroundings, capturing the attention, and eliciting emotions in combination to visual cues (Nacke, Grimshaw, & Lindley, 2010). Auditory cues in videogames include theme songs, background sounds, and ambient sounds, spoken narrations and dialogue, and even spectral silence. Furthermore, sounds are used as rewards, punishment, and as feedback in response to gamer actions. The psychological and physiological effects of auditory stimuli and music are well known (Polkosky & Lewis, 2002). In fact, music is one of the most effective ways to induce mood in experimental psychology studies (Kenealy, 1988). A considerable amount of literature has been published on the effects of music (Blood & Zatorre, 2001), as well as the phenomenology of re-experiencing auditory cues in an absence of auditory stimuli in clinical and non-clinical populations (Hyman et al., 2012; Liikkanen, 2012). However, only a few studies have focused on exploring the effects of videogames' auditory cues on gamers during playing (Hebert, Beland, Dionne-Fournelle, Crete, & Lupien, 2005).

In virtual environments, sounds, visual cues, colour, and viewer perspective (e.g., first person, third person) have all been reported to affect presence in the game (Anderson & Casey, 1997; Hendrix & Barfield, 1995). Better simulation of multiple senses results in an increased feeling of presence and immersion (Anderson & Casey, 1997). Furthermore, sensory input can boost memory of objects in the virtual environment (Dinh, Walker, Hodges, Song, & Kobayashi, 1999). Västfjäll (2003) found that emotional reactions to auditory events in the virtual environment were moderated according to the audio channels (mono, stereo, and six-channel reproduction). Stereo and six-channel reproductions were found to be strongly correlated with changes in emotional reactions when compared to the mono condition. Additionally, six-channel reproductions showed the highest ratings of presence and emotional realism.

Hebert, et al., (2005) examined the effect in cortisol secretion triggered by techno music in a violent videogame. They found that the group who played with music showed significantly higher cortisol levels, which suggested the importance of music in inducing stress by playing the game. Eui Jun, Bohil and Biocca (2011) conducted an experiment with violent videogames where the colour of blood (red versus blue) and realistic screams of pain (on versus off) were manipulated. The results showed that realistic blood colour and screams resulted in higher physiological arousal. Similarly, Lauter, Mathukutty, and Scott (2009)

investigated the effects on the nervous system of erratic breathing sounds heard in some videogames while the character is frightened, wounded and running. Their experiment showed that hearing erratic breathing (compared to quiet breathing) affected the human nervous system. According to the researchers, these findings together with studies that show that videogame playing provoke arousal (Hebert, et al., 2005) support the fact that anxiety and panic can be elicited by playing videogames.

To our knowledge, the current study is the first to examine hearing re-plays of auditory cues from videogames after stopping playing. The aim of this study was to investigate gamers' auditory experiences (e.g., hearing music, sound effects, or characters' voices) that occurred directly after stopping playing or sometime after stopping playing via the triggering of automatic associations. This was done by identifying, classifying, quantifying, and analysing gamers' auditory experiences. These experiences will be referred to as Game Transfer Phenomena auditory (GTP-AUD) and contributes to the understanding of the effects of auditory features in videogames, and the phenomenology of non-volitional experiences (e.g., auditory imagery, semantic memories, and hallucinations).

Method

Participants

A total of 2,000 gamers' experiences identified as GTP in one or more modalities (e.g., visual, auditory) were collected from 60 online videogame forums[1] over a seven-month period. This resulted in 192 auditory experiences from 155 gamers collected from 31 different online forums. Only 37 gamers reported their age (ranging from 14 to 30 years; M = 20.03 years, SD = 4.32 years). The majority were male (95%). A few gamers reported more than one videogame-related auditory experience. Therefore, the number of experiences was bigger than the number of participants in the study. A total of 95 different videogame titles were associated with GTP-AUD ranging from tile-matching puzzle games to first-person shooters, in addition to the sound alerts from the consoles themselves (e.g., *Xbox* achievement[2] and alerts from *Steam's* message service[3]).

[1] Online videogame forums include comments to articles on websites, since these are considered discussion platforms.
[2] Xbox-achievement is, in short a pop up that appears on the screen every time you complete something in the game (a challenge, quest or part).

Procedure

Data collection

Online videogame forums were searched with the *Google* search engine using the keywords: “Tetris effect”, “bleeding effect AND videogames”, “hallucinations videogames”, “videogames AND/OR real life/reality”, and "Game Transfer Phenomena". Posts that included explicit information about the gamers' experience were coded along with gamers’ response posts if relevant to auditory GTP.

Data analysis

The data analysis was carried out using thematic analysis and was carried out in a number of stages. First, the gamers' auditory experiences were extracted from the forums and recorded in a table. The experiences were then coded in a database in order to systematically classify and quantify them. Each gamers’ self-report included information about the forum, gamer nickname, demographic information (e.g., age, gender) [if the gamer provided], name of the game, type of GTP (e.g., visual, auditory), nature of the GTP (associative or non-associative), number of occurrences (e.g., once, more than once), duration of the experience (e.g., seconds, minutes), the situation where it occurred (e.g., waking up in bed), perceived location (e.g., head, ears, coming from an external source), the gamers’ physiological conditions while experiencing the GTP (e.g., tired), playing habits (e.g., long sessions), videogame elements mentioned (e.g., explosions), real life elements that worked as a trigger (e.g., vacuuming sound) and gamers’ perception of the experience (e.g., positive, neutral, negative).

The interpretation of the data was informed by literature concerning auditory phenomena, implicit memory, and priming theories. Videos of walkthroughs were watched to examine if auditory cues in the game could explain the gamers' experiences. The main investigator played some of the games associated with the data. In order to the protect gamers' online identity and reduce the possibility of gamers being tracked, the posts used as examples were paraphrased when possible, without decontextualized gamers experiences Paraphrasing consisted in using synonyms, changing tenses, and/or removing irrelevant information. The gamers' pseudonyms were also modified.

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[3] Steam is a platform for purchasing and downloading games and software. The platform is developed by Valve Corporation.

Results

General characteristics of GTP-AUD

Compared to other sensory stimuli (e.g., visual GTP), only a few posts included information about the characteristics of GTP-AUD. Details of the GTP-AUD experiences collected included: (i) gamers' perception about their experiences, (ii) perceived location of the auditory cue, (iii) coping strategies, (iv) duration of the GTP-AUD experiences, (v) frequency of the GTP-AUD occurrence, (vi) hours played per session when having GTP-AUD, (vii) activities associated with GTP-AUD, and (viii) physiological factors associated with GTP-AUD.

Gamers' perception about their experiences (n = 144) – There were a larger number of gamers' posts that explicitly included negative expressions (n = 29) (e.g., "I hope I'm not going crazy", "scary", "annoying", "freak me out", "maddening", disconcerting") than the ones that were neutral (e.g., "it is not unpleasant", "no big deal") (n = 4) or positive (e.g., "entertainment", "fun way of using imagination", "creative") (n = 2).

Perceived location of the auditory cue (n = 47) – A number of gamers experienced auditory cues in their head (n = 37) (e.g., "in my head") while others heard something coming from nowhere or outside their head (n = 11) (e.g., "from the speakers", "the sound is coming from somewhere"); gamers also heard auditory cues in their ears (n = 2) (e.g., "in my ear", " echoing through my ears"). Additionally, some gamers heard auditory cues in their dreams (n = 5).

Coping strategies (n = 7) – A few gamers said they sung along when a song got stuck in their head (n = 4), while other gamers either closed their eyes and tried to focus on something else (n = 2), or reduced their gaming (n = 1).

Duration of the GTP-AUD experiences (n = 75) – Quite a few of the gamers' posts specified that the experiences occurred all the time/lasted a very long time (n = 15) (e.g., "forever", "indefinite earworm") or lasted at least a day (n = 14) (e.g., "about 3 days", "most of the next day", "all day"). Others reported that GTP-AUD lasted for weeks (n = 3) (e.g., "two weeks"), for a while (n = 2), (e.g., "for quite some time"), and seconds/minutes (n = 21) (e.g.,"30 minutes"). Here, some gamers reported experiences that appeared to have occurred episodically and lasted seconds (e.g., "the door shut behind me, I heard the same sound that spiders make", "walking past a construction site and I'll swear I heard someone creating a portal").

Frequency of the GTP-AUD occurrence (n = 191) – The majority of the gamers in the total sample mentioned that the auditory experiences happened only once or they only reported one experience (n = 104). However, there were also some gamers that experienced GTP-AUD more than once (n = 66), anytime/every time (n = 17), and many times (n = 4).

Hours played per session when having GTP-AUD (n = 39) – No gamer indicated that the GTP-AUD experiences occurred when playing short videogame sessions. They all occurred when playing very long sessions (n = 6) (e.g., “4 days straight”, “2 days straight”) or very long session (n = 33) (e.g., “+10hrs straight”, “enough”, “all night”).

Activities associated with GTP-AUD (n = 61) – A larger number of posts mentioned that the experiences happened when they were trying to sleep (n = 21), while dreaming (n = 5), and when just waking up (n = 3). The experiences also occurred while doing daily activities. These activities included: packing (n = 3), in a lecture (n = 3), driving (n = 2), walking (n = 4), hurrying (n = 2), and in a cognitive demanding activity (n = 2). Other auditory experiences occurred while swimming, climbing stairs, and walking through a crowd.

Physiological factors associated with GTP-AUD (n = 7) – Very few gamers mentioned how they were feeling when their auditory experiences occurred. A few said that they were sleep deprived (n = 2), tired (n = 3) or stressful (n = 2).

Types of GTP-AUD

A variety of GTP-AUD experiences were reported. The largest numbers of experiences (90%) were identified as (i) *auditory imagery*. This manifested as hearing music (n = 73), sound (n = 83), or voices from within the game (n = 12). Some experiences were triggered by external cues associated with the game, while others were not. In the other main categories, only a small number of experiences were identified, (ii) *inner speech* (n = 9), (iii) *Auditory misperceptions* (n = 8) and (iv) *multi-sensorial experiences* (n = 1) and a few experiences that were not classified as either hearing music or sound (n = 3). (See Table 1 for a complete quantification of all the subcategories). Only 19% of the GTP-AUD experiences occurred via associations between real life stimuli and videogame elements and experiences, whereas 81% occurred either without an external trigger or without one being identified by the gamers. While the different types of GTP-AUD were imbalanced, the authors’ believed that the categorization made was the most appropriate based on the data collected.

I. Auditory imagery

In this category, gamers re-experienced music, sounds, and/or voices from the game. These experiences manifested either episodically or persistently, were heard in the head, in the ear or appeared as coming from external sources, or from nowhere. They appeared when being exposed to multiple external stimuli in day-to-day settings or to limited stimuli while trying to sleep. These types of experiences were divided in two main sub-categories: (i) Auditory experiences not triggered by an identifiable cue, and (ii) auditory experiences triggered by associations.

Auditory experiences not triggered by an identifiable cue (n = 152)

Some gamers heard something from the videogame when not playing without any apparent external cue as a trigger.

Heard music from the game not triggered by an identifiable cue (n = 70)

These experiences took place while the gamers were performing daily activities, or while trying to sleep or waking up. For instance:

> *"I played The Sims 3 for too long and tried to sleep, I could not get the music out of my head"* (Yoell)

> *"Command & Conquer: Red Alert was an exception. I used to wake up with 'Hell March' in my head for weeks after finishing the game"* (RockerLao)

Heard sounds from the game not triggered by an identifiable cue (n = 67)

Some gamers reported hearing repetitive sound effects or sound from the game console and menus when not playing. These sounds were heard in the head, in the ears, or coming from external sources, episodically or persistently. Some examples included sounds of weapons, explosions, vehicles, groans, screams, breathing, and percussive sounds. Other sounds heard included the sound of lasers, swords, bullets, spreading of a web, creating a portal, beeping, rings, and falling. Also, sounds from the gaming console itself were heard. Some gamers experienced sound effects recurrently. For instance:

> *"When I played Half-Life, sometimes heard exactly the same noises as in the game. I thought they were real. Damaged lights, sparkles, creaking... at that time I was just awaiting a head crab behind the next corner"* (Raven22)

> Other gamers reported experiencing this constantly while trying to sleep. For instance:

> *"After playing 100 hours of Killing Floor, I heard constantly chainsaws and the grunts constantly… Maybe I need a break"* (Xoel)

Furthermore, some gamers reported that they heard sounds from the game coming from external sources. For instance:

> *"After a Team Fortress 2 binge one day, I started hearing Spies decloaking around the house. Would move my head around before I noticed what I was doing"* (Link3000)

Some gamers heard sounds in their dream and thought that it came from external sources in real life. For instance:

> *"I will wake up sometimes and check if my computer is off because I swear I heard videogame music coming out of my speakers. I need help"* (AraRider)

Heard voices from the game not triggered by an identifiable cue (n = 12)

Some gamers heard videogame character voices after playing. On one occasion, a gamer experienced it as background voice:

> *" I constantly heard someone whispering 'Death' in the background. After I played Black and White for a many hours. It lasted a few days"* (Zullo)

Other gamers heard a voice from the game constantly. For instance:

> *"Once after I played Battlefield 2 for long, I kept hearing 'ENEMY BOAT SPOTTED, ENEMY BOAT SPOTTED'"* (Se13)

Some gamers heard voices when trying to sleep. For instance:

> *" I heard when Trying to fall asleep after playing Counterstrike 1.3,"Hold this position, hold this position"* (Nexo7)

Auditory experiences triggered by associations (n = 173)

In this category, gamers heard music, sounds, or voices from the game episodically. These experiences were triggered by external cues associated with the game. The associations could be coming across an object, hearing a sound, engaging in an activity, or experiencing some event.

Music triggered by associations (n = 3)

In some instances, gamers heard music from the game when performing some similar activities as in the game in real life settings. For instance:

> *"Every time I stack a trolley or cab I heard the Tetris theme in my head and try to stack everything without gaps"* (Pepertony)

Sounds triggered by associations (n = 8)

Stimuli or events that have somehow been associated with the game triggered sounds from the game. Sometimes these auditory experiences resulted in gamers doing some action to avoid danger or sometimes they got scared. For instance:

> *"I keep a flashlight next to my bed, and sometimes when I walk in a dark area I hear the sound the radio makes near a monster in Silent Hill, I turn around if I don't see anything in front of me"* (CrownDave)

Sounds triggered by some other sound or music (n = 8)

In this sub-category the auditory experiences involved gamers hearing sounds or music from the game in the presence of other auditory stimuli. For instance, some gamers heard the spiders from Minecraft when a door shut:

> *"I walked into the school as the door shut behind me, I heard the same sound that spiders make when they're attacking in Minecraft, and I ran like hell"* (Jelor)

Another gamer heard the sound from the sword in a *Zelda* game when playing pool. It could perhaps be speculated that the sound produced when hitting the ball may have triggered the auditory imagery. For instance:

> *"At one time, when I was around 13, I had been playing Zelda on Gameboy really a lot…I was playing some pool and started hearing the sound of Link's sword. First I was not sure if I was just thinking about that sound or if I was actually hearing it. I looked around and didn't see anything the sound could be coming from and it didn't change in volume when I moved around. I was sure I wasn't just remembering because I couldn't make it stop and when I was thinking of other things I still heard it. It went on for approx. 30 minutes, and I became a bit concerned I was going insane"* (FlashPlus)

Heard voices triggered by associations (n = 2)

Here the gamers heard voices when they did or saw something that reminded them of the videogame. In these cases, gamers did not clearly indicate the location of the voice but these experiences appeared to be different than inner speech where gamers clearly recognized

that it occurred in their head. Also in these experiences, the gamers felt frightened. For instances:

> *"After playing Clive Barker's [JerichoUndying] for a couple of hours I heard that shivering voice saying "looooooook" when I passed a painting… I scared the hell out of me"* (Radion56)

> *"When I'm home alone at night, sometimes I hear a little girls voice saying, 'Come along now Mr. Bubbles' and she mutters things about chocolate being better than grapes... It's creeping me out. But maybe not exactly in the confusing reality"* (Rollberia)

Undefined sound/music imagery (n = 3)

In this category, auditory experiences were classified if it was not possible to identify if the gamers heard music or sound effects from the game. For instance:

> *"After Devil May Cry 3, all the super modes in all videogames are a 'Devil Trigger'"* (FashionXo)

II. Inner speech

Inner speech occurred when gamers thought with words in their head (McGuire et al., 1995p., 596). Sometimes the voices were regulated by ongoing activities. Some of these were triggered by associations while others were not.

Inner speech triggered by automatic associations (n = 7)

Sometimes gamers thought in voice commands from the game in real life situations. For instance:

> *"Sometimes I think in voice commands from Team Fortress, especially Go Go Go! to make people move in the subway"* (FashionXo)

On other occasions, gamers heard an internal voice with some instruction from the game when they were performing some activity. For instance:

> *"After years of playing Outrun whenever I drive under a sign on the road, I hear in my head "CHECKPOINT!"* (Yates1000)

Other examples included when gamers heard phrases from the game in their head when someone said something in real life as some sort of feedback. For instance:

"*Every time someone welcomes me, , no matter the phrase I hear 'Wind' from Castlevania: Portrait of Ruin in my head saying 'you are back' I have played too much"* (Oregatech)

"The Team Fortress 2 announcer. Every time a football commentator has mentioned that a game might go into overtime, a voice at the back of my mind has yelled 'Overtime! OVERTIME! OVERTIME!'" (Souly)

Inner speech not triggered by automatic associations (n = 2)

In this type of auditory experience, gamers' speech did not occur due to being triggered by automatic associations. Here, inner speech was generalized and it was clear that the inner voice heard by the gamers preserved the perceptual details or the phonetic features from voices heard in the game. This manifested either (i) when voices from someone else were heard preserving the phonological characteristics of the voices in the game, or (ii) when gamers' inner speech preserved the phonological characteristics of the voices in the game. A gamer said that he heard everything as the voice in the game. For instance:

"After a marathon of Portal/Portal 2, I heard everything in GLaDOS's voice for about three days" (Peartech)

In another case, a gamer said that after playing he could hear his inner voice as a game character. For instance:

"Played Metal Gear Solid 4 for 15 hours when it first came out. When I went on MSN afterwards everything was being read aloud in my brain with David Hayter's voice. I always have this :)" (Jackson_m)

III. Misinterpretation of Real life sounds (n = 8)

Here, gamers misinterpreted a real life auditory cue from something in the videogame. For instance:

"*Quite often I mistake sounds in real-life for sounds I hear in videogames"* (Trevor_Class)

One gamer heard that someone mentioned a place from the game instead of a street name:

"I was in London, someone gave me directions, he said Wardour Street, but I swear I heard Ulduar Street" (ManuelXas)

IV. Multisensorial (n = 1)

This category comprised gamers' auditory experiences where they heard music from the game in their heads accompanied by body movement. Gamers also reported seeing videogame elements while hearing the music from the game but these experiences were coded in the visual modality of GTP (See more details in Ortiz de Gortari & Griffiths, 2013a). For instance:

> *"I once played Tetris for so long that when I stopped I could still hear the music in my head for hours and my fingers kept twitching occasionally"* (Pachis)

Discussion

The aim of this study was to investigate how videogames' auditory cues were experienced by gamers after stopping playing. Re-experiencing music, sound effects, and voices were associated with auditory cues in the game, could occur in the absence of an appropriate stimulus, and appeared to be out of the gamers' control. Hearing sounds from the game included consoles sounds such as the *Xbox* achievement "plonk". Gamers perceived the location of the auditory cues in their heads, in their ears, as coming from external or unidentifiable source. These were experienced either continuously or episodically and were sometimes triggered by associations. Sounds that were re-experienced after playing included sounds of weapons, explosions, vehicles, groans, screams, breathing, percussive sounds. It also included the sounds of lasers, swords, bullets, web spreading, creating a portal, beeping, rings falling. Experiences with music included hearing high pitch music in addition to calm and classical music. Music from the videogames was usually experienced persistently, while sound effects from or voices appeared to have occurred more episodically. In many cases, the gamers said that they had been playing intensively (i.e., either playing long sessions or playing frequently). Previous studies have linked hearing music in absence of auditory stimuli with the recent or repeated exposure to music (e.g., Beaman & Williams, 2010; Hyman, et al., 2012; Liikkanen, 2012).

Only a few gamers mentioned under what circumstances their auditory experiences occurred. A large number of gamers heard some auditory cue from the game when trying to sleep, but quite a few gamers experienced GTP-AUD when waking up or in their dreams. Other gamers heard something while doing daily routines such as being in a lecture, packing, walking, driving but also when doing activities that required high cognitive overload such a attending an exam or designing something. These findings are consistent with previous

studies about GTP (Ortiz de Gortari, Aronsson, & Griffiths, 2011; Ortiz de Gortari & Griffiths, 2013a, 2013b), and studies that suggest that intrusive songs arise in periods of low cognitive load when performing automatic activities, but also in high cognitive loads (Hyman, et al., 2012). For this reason, auditory experiences appear to be related to mind wandering (Smallwood & Schooler, 2006). Only a few gamers said that they were sleep deprived, tired or stressed when they occurred. Physiological factors have been previously suggested as contributors for auditory experiences (Louise C. Johns, Hemsley, & Kuipers, 2002) as well as for GTP experiences (Ortiz de Gortari, et al., 2011; Ortiz de Gortari & Griffiths, 2013a, 2013b).

Some gamers reported that they heard the music directly after stopping playing or when triggered by automatic associations. According to Hyman (2012) if the song is re-experienced directly after the exposure it is more likely it returns again later on (e.g., Hyman, et al., 2012). Gamers responded to their experiences in different ways and used different coping mechanisms. Sometimes they looked for videogame elements in real life sceneries until they realized what they were doing or checked if the game was on. Furthermore, some gamers vocalized the songs. Singing, humming, or whistling along with auditory imagery is very common (Hyman, et al., 2012). Other coping mechanisms included trying to think about something else, trying to control the auditory cues, and moving to see if the volume of the sound changed. Other gamers found themselves expecting to experience something that happened as it had done so in the game.

Numerous studies have showed that auditory imagery preserves structural properties of auditory stimuli, including pitch, loudness, distance, timbre, melody, tempo, etc. (e.g., Intons-Peterson, Russell, & Dressel, 1992; Zatorre, Halpern, & Bouffard, 2010). Some gamers said that the auditory cues were heard exactly as in the game (e.g., pitched or loud with such vividness that they thought it was a real sound for at least a moment). Gamers' experiences were classified as: (i) auditory imagery, (ii) inner speech, (iii) auditory misperceptions and, (iv) multi-sensorial auditory experiences. Most of the experiences analysed in this study were classified as *auditory imagery*. Some happened persistently and some episodically occasionally triggered by identifiable external cues.

Several gamers reported experiencing the music from the game that got stuck in their heads. These games were mostly those that used music mainly in the background such as *Pokémon* or *Tetris* but not exclusively. Gamers reported this type of auditory experience

when trying to sleep, waking up, or while sleeping. Mavromatis (2010) reported that during hypnagogic states (the state between awake and falling asleep) or hypnapompic states (the state between sleep and waking up), people have reported hearing their name being called, neologism, irrelevant statements, nonsense, quotations, references to spoken conversations and remarks directed to oneself. Persistent thoughts about the game and visualizations of images from the game while trying to fall asleep have been reported previously (Ortiz de Gortari & Griffiths, 2013a, 2013b). Also, visualizations of videogame images accompanied by music from the game were found while trying to fall asleep or while being awake (Ortiz de Gortari & Griffiths, 2013a).

Furthermore, some gamers woke up because they heard sound effects from the videogame. One gamer said that he heard the sound coming out from the speakers so he stood up to check them. Cases of hearing music that appear to be of external origin (e.g., music coming from a turned off radio or television) had been reported (Sacks, 2010). While awake, the gamers' auditory experiences appear to have been occurring episodically. According to Williamson (2012), it is not clear if sometimes people fail in identifying the external stimuli which triggered their experiences. The auditory replays reported by the gamers were sometimes triggered by automatic associations similarly as when involuntary memories manifested as a response to external stimuli cues (Mace, 2005). The relevance of memory triggers in the experience of auditory imagery is well documented (e.g., Williamson, et al., 2012) and explained by the priming mechanism. For instance, every time one gamer stacked a trolley or cab he heard the *Tetris* theme in his head and tried to stack everything without gaps. Furthermore, gamers heard sounds from the game due to false expectations. Seeing videogame images, experiencing automatic thoughts and behaviours triggered by automatic associations due to false expectations have been found among previous GTP studies (Ortiz de Gortari, et al., 2011; Ortiz de Gortari & Griffiths, 2013a, 2013b).

Examples in the current study included the case of a gamer that sometimes when walking in a dark area heard the sound the radio makes near a monster and he turned around to find nothing was there. The radio is an item found early in *Silent Hill* that emits a 'static-like sound' to warn about the presence of a monster. Another gamer heard someone creating a portal from the game *Portal* when passing by a construction site. The setting of *Portal* is in a large and deserted set of rooms surround by empty walls where portals can be created on white surfaces to complete different puzzles. These experiences are interesting because they

show the relevance of semantic memory in auditory imagery (Liikkanen, 2008), as well as top-down expectations that some researchers argued can explain auditory hallucinations (Aleman, Böcker, Hijman, de Haan, & Kahn, 2003; Louise C Johns et al., 2001; Morrison, Haddock, & Tarrier, 1995). Furthermore, according to Liikkanen (2008), people that experience music imagery also experience a variety of involuntary semantic memories that manifest as images, words, sentence, odours or smells, kinetic patterns, and/or tactile sensations.

Cross-modal experiences have also been observed in GTP when gamers saw images from the game while listening to music (Ortiz de Gortari & Griffiths, 2013a) or when a gamer saw frets from *Guitar Hero* when her teacher said the word guitar (Ortiz de Gortari, et al., 2011). In the present study, it was evident that real life stimuli (e.g., passing by a construction site and hearing a portal, stacking a trolley and hearing music from *Tetris*) triggered auditory experiences in the gamers. The present findings support other studies that have found that visual stimuli can elicit an auditory image of that stimuli if a sound has been previously primed (Schneider, Engel, & Debener, 2008; Stuart & Jones, 1995). The activities that the gamers were engaged in when the GTP-AUD occurred were fairly automatic activities that may have facilitated the experiences.

Furthermore, it appears that in some cases, real life sounds played an important role for evoking the experiences. Some gamers heard something from the game when they were exposed to certain real life sound. However, it is not possible to know to what degree the external auditory cues elicited re-experiencing sound from the game. For instance, one gamer heard the sound the spider make in *Minecraft* when a door closes, another gamer heard the sound of Link's sword from a *Zelda* game when playing pool, another one heard music from *Pokémon* when vacuuming. One gamer heard the sounds when Sonic drops rings from a *Sonic* game when he was in a crowd. It could be argued that in front of an ambiguous auditory stimulus, some gamers' minds tried to make sense of these sounds, similarly to when recognizing shapes in abstract images (i.e., pareidolia). Moreover, some gamers *heard voices* from the game. Some voices appeared to have resembled auditory verbal imagery and inner speech when being experienced in the head, while other voices were experienced as coming from external sources. These experiences were categorized in the present study as auditory verbal imagery. However, these experiences share phenomenological similarities with *auditory verbal hallucinations*. Auditory verbal hallucinations have been understood as "hearing a

voice in the absence of a corresponding external verbal stimulus, with a sufficient sense of reality to resemble a veridical perception" (Jones, Fernyhough, & Larøi, 2010 p., 214). Cognitive models of auditory verbal hallucinations have explained auditory verbal auditory hallucinations as misattributions or errors in recognizing one's own thoughts and inner speech, in other words self-monitoring failures, where the influence of top down expectations on conscious perception appears to be crucial (Aleman, et al., 2003; Louise C Johns, et al., 2001; Morrison, et al., 1995). Interestingly, similar to auditory verbal hallucinations identified in other studies (Jones & Fernyhough, 2007; Jones, et al., 2010), the voices heard by the gamers (either as auditory imagery or inner speech) included commands (e.g., "hold this position"), suggestions for performing actions (e.g., "we must construct additional pylon", "come along now Mr. Bubbles"), and condensed content (e.g., "check point!", "death", "you are back") as these types of verbal stimuli are commonly used in videogames. Sometimes the voices appeared to have regulated the gamers' activities using commands. For instance, one gamer heard a "shivering" voice saying " looooooook" when passing a painting after having played *Clive Barker's Jericho* and got scared, or another one heard a suggestion "not enough time units" when being in a hurry. Hearing voices was mainly experienced in day-to-day settings but some gamers also heard it when falling asleep. For instance, one gamer heard instructions from the game such as "hold position, hold position" while trying to sleep after playing *Counterstrike*. Hearing voices during hypnagogic states include hearing one's name being called, neologism, quotations, and references to spoken conversation (Mavromatis, 2010).

Other experiences with verbal auditory content manifested when the gamers heard voices in their head such as "thinking in words" (McGuire, et al., 1995p., 596). This was usually activated by the presence of an external stimulus. This is known as *inner speech*, which is defined as "subjective phenomenon of talking to oneself, of developing an auditory image of speech without uttering a sound" (Levine, Calvanio, & Popovics, 1982p., 391). These types of experience were acknowledged by gamers as being experienced within themselves. These experiences manifested in different ways. One gamer thought in a voice command "Go Go Go!" when he was in the subway and wanted people to move away or when gamers completed actions alongside verbal thoughts. For instance, one gamer heard the "wind" from *Castlevania* in his head saying "you are back" every time someone welcomed him. In fact, in a previous study about GTP, some gamers reported that they felt compelled to say something as in the game when something happened in real life (Ortiz de Gortari &

Griffiths, 2013b). Although these gamers did not mention if they experienced inner speech, it is speculated that inner speech preceded gamers' verbal outbursts or at least played an important role.

Additionally, in some gamers' experiences of inner speech it was clear that the voices preserved the phonetic features from the game. For instance, one gamer said that he heard everything as the voice in the game, more specifically after a marathon session of *Portal* and *Portal 2,* he heard everything in GLaDOS' voice[4] for a long time. Experiments have demonstrated neural adaptation affects to a speaker's voice and identity (Zäske, Schweinberger, & Kawahara, 2010). Some gamers experienced inner speech while reading a text. Here also, the phonological characteristics from the videogame character's voice were preserved. These findings are in concordance with experiments conducted by Alexander and Nyggard (2008) where participants' reading velocity were dependent on the ownership of the text, either by a slow or fast speaker. When participants read a passage from the slow speaker they read it significantly slower. According to the researchers, this suggests that readers engage in a type of auditory imagery that preserved the perceptual details of the text author's voice.

Misinterpretation of auditory cues in real life. In this type of experience, the gamers' reported that they confused sounds or verbal cues in real life with some auditory cues from the videogame. Also, they thought they had heard something from the videogame. One gamer said that every sound outside sounded like zombies. Another gamer misheard a street name in London for a street name from the videogame he had been playing. Finally, one gamer reported a multi-sensorial experience. After playing *Tetris* he heard the music from the videogame and his finger twitched occasionally. Similar experiences were reported in a previous GTP study focusing on visual experiences. In that study, gamers reported experiencing involuntary movements of fingers or body while seeing the images from the game, as well as seeing images from the game while hearing music from the game (Ortiz de Gortari & Griffiths, 2013a).

[4] GLaDOS is a robotic female voice that has been described as funny and sinister, and it is the narrative voice in the *Portal* games. Usually the players heard monologues with her voice. The developers noticed that testers were more motivated when hearing the voice (Gamasutra, 2008). In fact GLaDOS is one of the six best videogame characters (2000-2009) (Killingsworth, 2009).

Limitations

A number of limitations of the present study need to be acknowledged. First, the experiences were collected from online videogame forums, so in some cases, they were not as detailed as ideally desired. Second, many gamers' demographic and psychological profile were unknown as only a few of them provided information about their age and gender. Third, from all the studies based on gamers' experiences collected from online videogame forums, the auditory modality was the one that contained the least number of reported experiences. This is likely to be due to the type of words used when searching the online videogame forums. However, this does not mean that the experiences are less common than other GTP modalities, just that they were the least reported. This also limited the analysis about GTP-AUD characteristics and perhaps the variation in types of auditory experience. There are also more general limitations. For instance, the study suffers from the same weaknesses as any other self-report study in that there is no way of knowing how accurate the data are and whether the reports collected were honest, accurate and valid. Additionally, it was not known if there was any recall bias or whether comments were biased due to social desirability factors. While there may have been some advantages in using other methods of data collection, the authors believed that the use of online form data would be the most honest and accurate compared to experimental or survey designs.

Conclusions and implications

This study suggests that intense exposure to videogame playing may be accompanied by potentially intrusive auditory experiences in susceptible individuals. Reducing the playing time and being aware of coping strategies may be beneficial. The most novel contribution of this study were data showing that that re-experiencing auditory cues from videogames is not limited to music, but that sound effects and voices were also heard by some gamers. Most importantly is that these experiences were sometimes capable of triggering the mind popping of illogical thoughts, as well as automatic reactions and behaviours. In this way this study distanced itself from other auditory studies that deal exclusively with auditory cues. Additionally, findings from the present study analysing the auditory modality of GTP extend our understanding of gamers' experiences, and it appears to suggest that gamers' thoughts can manifest themselves as auditory experiences, and that such experiences appear to mirror studies showing that gamers' thoughts can also manifest themselves as visual experiences (Ortiz de Gortari & Griffiths, 2013a, 2013b). Cognitive psychological models claim that

hallucinations originate as internal thoughts or images that are misattributed to external sources (Aleman, et al., 2003; Louise C Johns, et al., 2001; Morrison, et al., 1995). This argument appears to be supported by the findings in GTP studies (Ortiz de Gortari & Griffiths, 2013a, 2013b), showing that gamers' thoughts and false expectations have resulted in actually seeing and/or hearing something from the videogames.

Intrusive songs occurred as positive or negative experiences (e.g., Hyman, et al., 2012). Only a few gamers mentioned how they perceived their experiences. A few explicitly said it was positive, whereas more gamers used negative adjectives when referring to their auditory experiences. Intermittent auditory experiences were perceived as annoying, and provoked sleep deprivation in some gamers. Persistent and intrusive experiences were reported previously as visualizations of videogame images in the back of the eyelids (Ortiz de Gortari & Griffiths, 2013a) or as uncontrollable thoughts about the game (Ortiz de Gortari & Griffiths, 2013b). Furthermore, episodic GTP-AUD such as hearing sounds and voices resulted in the gamers getting disconcerted and frightened to the point where in a few cases they questioned their own sanity, even though they were aware that their experiences were explained due to their high engagement in the game. It also appears that distress stemmed in some gamers due to lack of control over the GTP-AUD and surprise relating to the vividness of the sounds that made them look around their immediate environment for the source of the sound.

In this study it was observed that the gamers' auditory experiences – especially the ones triggered by automatic associations and the ones with unknown localization – were accompanied by a sense of threat and confusion. These findings extend previous studies about GTP where gamers built up false expectations based on their game experiences, such as one gamer who thought for a moment that a flipped car would explode after playing *Grand Theft Auto* (Ortiz de Gortari, et al., 2011; Ortiz de Gortari & Griffiths, 2013a, 2013b). Some gamers also interacted with their visual pseudo-hallucinations, such as the gamer who tried to fit furniture in his room according to a grid he was seeing after have played *Minecraft* for 72 hours (Ortiz de Gortari & Griffiths, 2013a). In the present study, only a few gamers experienced such types of experience. More research is needed to understand how common these experiences are and whether there are psychological, social, and/or physiological implications.

Previous research has demonstrated the effects of music on physiological arousal and anxiety in violent videogame while playing (Hebert, et al., 2005; Lauter, et al., 2009). The current study is concerned about the recurrent overreactions due to re-experiencing sound and voices from the videogame that may provoke distress, especially when the auditory cues are associated with aversive or dangerous experiences in the game, at least for a few moments (e.g., groans, screams, explosions). The psychological and physiological implications in case of recurrent GTP-AUD should be investigated. In this sense, re-experiencing the game events appear to be more in line with post-traumatic stress events (Ehlers, Hackmann, & Michael, 2004) than just actually re-experiencing auditory cues. It may to be important to investigate whether the intense exposure to emotional content in videogames enhance the gamers' auditory experiences in relation to the duration and vividness of the experiences. We do not know which gamers are more susceptible to experiencing auditory experiences associated with games but previous studies suggest that music-related activities (Liikkanen, 2012), neuroticism, and obsessive-compulsive disorders are related to intrusive song experiences (Beaman & Williams, 2010).

Furthermore, it is important to consider the consequences of prolonged exposure to constant ambient sounds or intermittent exposure to loud sounds. (Jones, Weiler, Warm, Dember, & Sandman, 2003). The National Health Service (NHS) recommends applying the rule of 60:60 that means a person should use a maximum 60% of the volume for maximum 60 minutes per day[5]. User guide recommendations for the *iPod Shuffle* from *Apple* suggest listening responsibly. Hearing loss can occur due to the repeated exposure to loud sounds over time. The exposure to excessive sound pressure can manifest in symptoms that include distorted or muffled sounds or difficulty to understand speech. Knowing particular videogame features and their effect on gamers during and after playing may contribute to taking more informed decisions regarding the physiological, psychological, cognitive and social effects of videogames and augmented technologies.

[5] http://www.nhs.uk/Livewell/hearing-problems/Pages/tips-to-protect-hearing.aspx

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Table 1. Auditory Game Transfer Phenomena (AUGTP) categories and sub-categories among video game players (n = 155)

Type of AUGTP	Number of Experiences	AUGTP Experiences (%)	AUGTP categories (%)
I. Auditory imagery			
Not triggered by associations			
Music	71	46	
Sounds from game	57	37	
Sounds from console	10	7	
Voice	12	8	
Undefined sound/music	3	2	
Sub-total	153		
Triggered by associations			
Music	3	14	
Sound	8	38	
Sounds triggered by some other sound or music	8	38	
Voice	2	10	
Sub-total	21		
Total	174		91
II. Inner speech			
Not triggered by associations	2	22	
Triggered by associations	7	78	
Total	9		5
III. Auditory misperceptions			
Have confused a real life sound with a sound from the video game	5	62	
Think they have heard a sound from the video game	3	38	
Total	8		4
IV. Multi-sensorial auditory experiences	1		1
Total	192		