What can Game Transfer Phenomena tell us about the impact of highly immersive gaming technologies?

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***Abstract*— The imminent introduction of highly immersive technologies for entertainment that bring exciting possibilities for the users also raises important questions regarding the impact on their well-being. Game Transfer Phenomena (GTP), a research approach focusing on understanding the psychosocial effects of video game playing by examining non-volitional phenomena (e.g., altered sensorial perceptions, automatic mental processes, involuntary motoric activations and behaviours related to playing video games), suggests similarities between gamers' experiences reported after playing on conventional devices and side effects of highly immersive technologies (e.g., head-up displays, highly realistic virtual environments). The aim of this paper is to discuss the challenges highly immersive technologies posit to the malleable human mind, taking into account not only the side-effects of the virtual immersion manifesting as physical symptoms, but also the psychosocial implications.**

Keywords*— *Virtual reality, head-up displays, Game Transfer Phenomena, effects of video game playing, impact of VR

I. INTRODUCTION

The imminent introduction of highly immersive technologies for entertainment that bring exciting possibilities for the users also raises important questions regarding the impact on their well-being. Virtual reality devices such as head-mounted displays have been used with specific purposes under regulated settings, offering effective solutions in therapy and training [1, 2]. However, the use of highly immersive technologies (e.g., Oculus rift, Morpheus, Vive, etc.) for entertaining purposes at home takes us to a new era of possibilities and wonders.

A large variety of accessories are being developed for use together with head-mounted displays, including a multisensory virtual reality mask that simulates effects of wind, heat, water, mist, vibration and smell (e.g., Feelreal) [3], and some head-mounted displays even include eye tracking (e.g., FOVE).

Virtual reality related devices for gaming dates from the time of arcade-based gaming machines in the early '90s (e.g., *Virtuality*'s products) [4]. One of the few that was released for home use was *Virtual Boy* by *Nintendo* [5, 6]. Some of the reasons why these devices were discontinued were the technological limitations of that time and the discomfort they provoked [6]. Stanney and Kennedy [7] in an experiment reported that one hour after the exposure to a virtual environment using a head-mounted display the total severity of the symptoms (e.g., nausea, disorientation) were 12 times higher than the levels previous to the exposure. However, contemporary, highly immersive technologies promise to reduce the physical side effects by providing a more integrative sensorial virtual experience.

The side effects of virtual immersion can take place at tissue level (e.g., photic seizures, migraines, damage of visual or auditory system, and injuries), but also at high functional levels (e.g., modification of behaviour, eyestrain, modification of stereoscopic vision, visual acuity, modification of perception, motion sickness, and psychological implications) [2].

The aim of this paper is to discuss the challenges highly immersive gaming technologies posit to the malleable human mind, taking into account not only the side-effects of the virtual immersion manifesting as physical symptoms, but also the psychosocial implications. This will be done based on findings on research conducted using the Game Transfer Phenomena (GTP) research approach. GTP focuses on understanding the psychosocial effects of video game playing by examining non-volitional phenomena (e.g., altered sensorial perceptions, automatic mental processes, involuntary motoric activations and behaviours) manifesting mainly after playing video games.

II. GAME TRANSFER PHENOMENA AND HIGHLY IMMERSIVE GAMING TECHNOLOGIES

To date over 1,600 gamers' experiences have been analysed qualitatively, and 97% of participants in a survey with a self-selected sample had experienced GTP at least once (n=2,362) (see Table 1 for a summary of the main GTP identified) [8-13]). The findings of these studies related with the use of highly immersive gaming technologies are discussed in the following sections of the paper in terms of altered visual, body and auditory perceptions and automatic mental process and behaviour.

Table 1: *Summary of main GTP types*

GTP (sub) modalities	GTP types
Visual	Distorted perception of objects/ environments Recurrent after-images with closed eyes Seeing images with open eyes Misperceiving real for virtual objects

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Auditory	Distorted perception of sounds Hearing replays of music, sound effects or voices Misperceiving real for virtual sounds
Body	Tactile sensations Sensation of body movements Uncoordinated movements/stiffness Stereotypical body movements Out of body experiences
Automatic mental processes /automatic mental actions	Spontaneous or recurrent thoughts or urges Cognitive bias (e.g., reasoning bias, attention bias) Source monitoring errors Lack of cognitive flexibility (e.g., perseverative mental actions) Subjective experiences of unreality/ Detachment of objective reality
Behaviours and actions	Change of behaviour/behaviour influenced by the game Slips of action/oral slips Involuntary motoric activations and behaviours

A. Visual related experiences

Epileptogenic precipitators (e.g., flashing lights, figure patterns) have been identified in video games [14] and most games and even some consoles include warnings about epileptic seizures. However, unintended altered sensorial perceptions can easily be induced, particularly since playing video games involves the exposure to repetitive stimuli for extended periods of times. For instance, in an experiment with a music/dance game, participants saw the text on the screen sliding upwards as motion after-effects after playing [15]. The *Rock Band* user manual included warnings about motion sickness [16]. LaViola [17] described the case of a pilot who after using a flight simulator saw the world completely inverted while driving afterwards. A user of a virtual reality head-up display reported seeing pixel grids "burned" into his retinas after using a test version of the display for five hours [18]. Seeing everything pixelated, wavy, in slow motion or coloured has been reported after playing a variety of video games on typical screens [9].

Most intrusive experiences reported by gamers in the GTP studies include constantly seeing after-images in movement in the back of the eyelids, seeing icons on the highway, menus in the corner of the eye or icons above people's heads [9, 11]. For instance, in a survey about GTP almost a third reported having seen video game images with open eyes (e.g., maps, power bars) and a little more than a third reported having seen objects and environments distorted after playing [12].

In most of the cases it appears that these experiences did not cause serious discomfort, but some gamers have reported annoyance and sleep deprivation [9, 10]. Moreover, while reality checking appears to be intact in most of the cases, automatic actions reported when seeing video game images in a social context (e.g., seeing video game images on the road while driving) raise questions about potential risks.

B. Body related experiences

One of the more well-known side effects of exposure to virtual environments is cybersickness (subset of motion sickness), which implies the disruption of sensorial systems. Related symptoms include: postural instability, kinaesthetic sensations, proprioceptive errors, lack of motor flexibility, uncoordinated movements [19, 20]. In an experiment conducted by Lawson and Mead [21], approximately 60% of the users of virtual environments (VE) reported symptoms during the first exposure, 5% could not tolerate the exposure, and another 5% did not present symptoms. The immersion in a VR environment for 3 hours or more has been found to reduce postural control at a psychological and physiological level [22]. Moreover, case studies of accidents after the use of virtual reality devices related to proprioceptive disarrangements and hand–eye coordination problems have been reported. These include: a woman trying to drink though her eye, and a child who poked his eye with a cue stick when playing billiards after using a virtual environment home system for a long time [23]. Also, an experiment using Oculus Rift found that a roller coaster that was more realistic and with better optical flow provoked greater levels of cybersickness symptoms [24].

Interestingly, it is suggested that precursors of out-of-body experiences and autoscopy involve the disruption of multisensory integration, particularly the proprioceptive, tactile and visual systems [25]. In the studies about GTP, gamers have reported feeling their mind disconnect from the body, as well as feeling the movement of the game when not playing, similar to cybersickness [13]. Also, gamers have reported uncoordinated movements of arms and finding themselves moving as in the game (e.g., "strafing" as in First Person Shooters) [9]. These experiences are particularly interesting when it comes to the use of virtual reality treadmills (e.g., Omni, Cyberith Virtualizer, PrioVR) since these devices allow users to walk and in general control the game with more natural body movements. Also, rotating platforms or chairs (e.g., Roto, FeelTree) allow the user to rotate his physical body according to the movements in the game, which potentially can reduce cybersickness symptoms by avoiding the sensory discrepancies when perceiving movement when being static.

Moreover, gamers have reported feeling their body stiffen while perceiving the time slowing down (chronoceptive altered perception) after playing video games with slow-motion or high-speed effects on conventional screens [9]. Additionally, gamers have reported tactile sensations of game controls when not playing (e.g., pushing buttons or force feedback) [9, 11]. This is particularly pertinent in relation to haptic devices (e.g., gaming vest such as KOR-FX, Control VR), although even users of mobile phones have reported ghost vibrations [26].

C. Auditory related experiences

Prolonged exposure to certain sounds can exceed the recommended limits and provoke hearing loss, similar to exposure to repetitive high intensity pulsatile sound [2]. Noise exposure (which are well within safety regulations) is capable to provoke cortisol secretion, subjective stress levels and exacerbate tinnitus symptoms [27]. According to research, playing First Person Shooters games with techno music result in higher levels of cortisol which suggest stress provoked by the game [28]. Also, realistic screams of pain lead to increased arousal [29], and hearing erratic breathing in comparison to quiet breathing can potentially lead to panic attacks in susceptible individuals [30]. Particularly, hearing through headphones allows the greatest control over the auditory cues [31] and novel wearable haptic audio accessories enables "feeling" the sound rather than just hearing it. Some claim that the body turns into a sub-woofer (e.g., KOR-FX, Woojer).

In the studies about GTP, many gamers have reported hearing music, sounds or voices (e.g., explosions, coins falling, whisperings) from the game when not playing. The auditory cues have been heard in the head, ears or coming from outside [10, 11, 33]. Some gamers have even checked if they left the console on.

Although, hearing recurrent replays of music and ringing from mobile phones is a common phenomenon [26, 32], interacting rather than listening to sounds may have further implications. Auditory cues provide vital information to the gamer to make them aware of the surroundings, captivate their attention and elicit emotions [34]. Experiencing involuntary auditory replays of cues from the game when not playing can elicit thoughts, emotions and impulsive actions learned in the game [12]. Intermittent replays of music or hearing sounds associated with dangerous situations after playing can provoke stress [10, 12]. Also, evidence of neural adaptation to voices has been found when gamers' inner speech or external voices preserved phonological characteristics from voices in the game [10].

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D. Automatic mental processes and behaviours related experiences

Research suggests that higher graphic quality, and playing in a highly immersive virtual environment, lead to a heightened sense of presence, which in turn strengthens some of the effects of the video games' contents [35, 36]. For instance studies have reported that realistic cues are associated with physiological arousal [29, 37], and emotional content has been associated with short and/or long term recalls of this content (e.g., images, scenes, brand logos) [29, 38, 39]. Memories from both the virtual world and the physical world contain information about perceptions (e.g., visual, aural), emotions, and time and space, which may facilitate mix-ups such as source monitoring errors between the "worlds" [40, 41]. Sensory realistic cues such as simulation of physical objects are typically embedded in video games [35] and perceived realism [42] would be enhanced with immersive technologies.

For instance, in an experiment a participant spent 24 hours wearing a head-up display, only taking short breaks. On several occasions the participant confused being in the VE or in the physical world, and made mix-ups between artefacts and events in both contexts [43].

Research about GTP suggests that transfers of effects depends directly on the contents of the game that in many cases are activated by automatic associations between physical and virtual objects [12]. Gamers have reported making mishaps when wanting to use video game elements that either pop up just as thoughts or manifest as automatic movements of arms, like the gamer who tried to use a grappling hook to swing under a bridge [44]. Also, gamers have reported feeling strange for not having video game elements (e.g., bionic arm) after playing [11, 33, 45]. Moreover, automatic responses to physical cues related to the game have resulted in some gamers being close to doing something as in the game, but in most of the cases they have held back their impulses [8, 11]. In a survey about GTP, the majority of the participants reported having wanted or felt the urge to do something as in the game triggered by a stimulus associated with the game, and almost half reported having acted unintentionally in a real life situation due to their gaming experiences at some point [13].

III. Discussion and conclusion

Playing video games requires high cognitive loads, it hyper stimulates the senses, induces "false" sensations and can unintentionally provoke neural adaptations that can temporarily compromise the individual's ability to interact in the real world. Particularly, engaging in repetitive activities for prolonged periods of time as playing video games can lead to mental fatigue and contribute to failures in executive control [46] triggering GTP [47]. The length of the playing session has been significantly associated with GTP [47], and according to research about virtual simulators the recovery from the effects of neural adaptations tends to depend on the time of the exposure [22, 48]. This suggests that attention should be paid to the length of the sessions.

The biggest challenge in terms of the occurrence of GTP is that even though GTP are more likely to take place shortly after playing [13], as is the case with the side effects of highly immersive technologies, the effects can be activated a long time afterwards, when triggered by automatic associations between physical stimuli and stimuli simulated in the game [12].

Some GTP may be reduced or disappear after repetitive exposure as happens with symptoms of cybersickness [23], while others may be strengthened due to the repetitive exposure and some gamers may even become hypersensitive to certain stimuli (e.g., visual, aural).

Many post-effects may depend not only on the medium, that among other things would enhance the degree of presence in the virtual world by stimulating more sensorial channels, but mostly on the content of the games. Individual susceptibility plays a crucial role since to start with the sense

of presence is mediated by individual characteristics (e.g., age, users' abilities to allocate attention or focus on a stimuli) [49], and some individuals may respond to one or other stimuli.

Only a small minority appears to have experienced GTP as a negative post-effect of playing video games and some even wanted them to occur again [13], although one in five of the participants in a survey with 2,362 gamers reported distress or were affected socially, occupationally or in other areas of their day-to-day functioning due to experiencing GTP [12].

It is important to point out that engaging in repetitive activities may elicit similar experiences as those reported by gamers. For example, working on an assembly line, playing a card game for prolonged periods of time, or driving using holographic head-up displays to improve performance [50] may result in seeing objects [51] or the head-up display in the periphery. However, one of the peculiarities about the post-effects of video game playing is that seeing or hearing something from the game elicits responses, naturally manifesting as in-game actions (e.g., hit, move, push, jump), and on many occasions engaging in activities that exceed human physical capacities (e.g., flying). Repetitive activities in real life contexts typically do not involve actions that can compromise the individual at this level, but can very well act as potential distractors.

To embrace the upcoming highly immersive gaming technologies their safe and healthy use should be ensured. Strategies of monitoring or self-monitoring when using the devices to avoid injury to self or others, and implementation of re-adaptation strategies when coming back to the real world – which would not necessarily be the same for different products – are recommended. In terms of GTP remarkable similarities have been observed among GTP experiences reported in the same games, suggesting the relevance of video games' structural characteristics [8-13].

When the technological improvements actually reduce the side effects provoked by sensorial disarrangements (e.g., cybersickness) then the next challenge will be to reduce the impact the contents can have on susceptible individuals.

Immersing in virtual reality does not impair our ability to distinguish reality, but permeates the way we define reality and mishaps after the exposure can come along. The positive or negative implications of those mishaps may depend on the appraisal users do of their non-volitional experiences, the individual executive control when not performing automatic actions, and the circumstances where these occur; therefore, investigating, informing and demystifying post-play phenomena are essential.

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