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ORIGINAL ARTICLE

The Potential Interaction Between Time Perception and Gaming: A Narrative Review

Filip M. Nuyens[1] · Daria J. Kuss[1] · Olatz Lopez-Fernandez[2] · Mark D. Griffiths[1]

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Abstract

Compromised time control is a variable of interest among disordered gamers because time spent on videogames can directly affect individuals' lives. Although time perception appears to be closely associated with this phenomenon, previous studies have not systematically found a relationship between time perception and gaming. Therefore, the purpose of this narrative review is to explore how gaming disorder may be associated with time perception. It has been found that gamers exhibit a stronger attentional focus as well as an improved working memory compared with non-gamers. However, gamers (and especially disordered gamers) exhibit a stronger reaction to gaming cues which—coupled with an altered emotion regulation observed among disordered gamers—could directly affect their time perception. Finally, "'flow states'" direct most of the attentional resources to the ongoing activity, leading to a lack of resources allocated to the time perception. Therefore, entering a flow state will result in an altered time perception, most likely an underestimation of duration. The paper concludes that the time loss effect observed among disordered gamers can be explained via enhanced emotional reactivity (facilitated by impaired emotion regulation).

Keywords Time perception · Gaming · Gaming disorder · Gaming addiction · Time loss · Impaired time control

In recent years, videogame playing has become one of the major leisure activities with more than two billion people playing at differing levels of involvement (Statista 2018a). However, although almost all researchers agree on the fact that most of the time, gaming is non-problematic and associated with positive outcomes (e.g., Colder Carras et al. 2017; Granic et al. 2014; Nuyens et al. 2018), it is also recognized that, for a minority, excessive videogame playing can result in a number of problems. Indeed, disordered gaming has been associated with deficits affecting specific cognitive processes (e.g., decision-making and inhibitory

✉ Filip M. Nuyens
filip.nuyens2016@my.ntu.ac.uk

[1] International Gaming Research Unit, Psychology Department, Nottingham Trent University, 50 Shakespeare Street, Nottingham NG1 4FQ, UK

[2] Turning Point, Eastern Health Clinical School, Monash University, Richmond, Victoria, Australia

control; see Nuyens et al. 2017, for a systematic review) and to various psychological and health-related negative outcomes (e.g., Achab et al. 2011; Gentile 2009; Hellström et al. 2012; Männikkö et al. 2017).

Negative consequences of videogame overuse have become a health concern because a small percentage of gamers are impacted by problems emerging as a consequence of disordered gaming (e.g., Gentile 2009; Rumpf et al. 2018; Taechoyotin et al. 2018; Yen et al. 2008). This concern led to the inclusion of Internet Gaming Disorder (IGD), in Section 3 (i.e., disorders requiring further research) in the latest (fifth) edition *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; American Psychiatric Association 2013), and Gaming Disorder in the eleventh revision of the International Classification of Diseases (ICD; World Health Organization 2018). Based on these recent developments, the present paper uses the terms "gaming disorder" and "disordered gaming" for the sake of consistency.

One factor of interest existing in both disordered and healthy gaming is compromised time control (i.e., time loss) which can be defined as the underestimation of time spent in a gaming session (e.g., Chou and Ting 2003; Meerkerk et al. 2009). Empirical research has shown that spending a lot of time gaming is not necessarily associated with gaming disorder and can simply be a sign of high non-problematic engagement (Billieux et al. 2013, 2017; Griffiths 2010). Furthermore, several studies have shown that high engagement in videogames is inherently different from gaming disorder and have differentiated the concepts of passion and addiction (Charlton and Danforth 2007; Deleuze et al. 2018). However, this phenomenon is clinically relevant because time spent playing videogames can directly affect an individual's life if not controlled properly (e.g., compromising sleep quality, occupation and/or education, and/or relationships) (Griffiths et al. 2012).

Compromised time control is also frequently encountered by clinicians dealing with patients suffering from gaming disorder (Torres-Rodríguez et al. 2019). However, little is known concerning the psychological mechanisms underlying compromised time control. Time loss may potentially be explained by impaired time perception, resulting in difficulty in keeping track of within-session gaming duration. Although the present paper focuses on gaming disorder, it is worth noting that impaired time control has been related to a wide range of psychopathological disorders, including attention deficit and hyperactivity disorder (e.g., Bielefeld et al. 2017), bipolar disorder (e.g., Bolbecker et al. 2014), schizophrenia (e.g., Ciullo et al. 2018), and substance use disorder (e.g., Wittmann et al. 2007). Consequently, compromised time control constitutes a trans-diagnostic etiopathological process (e.g., Dudley et al. 2011). Therefore, the purpose of this narrative review is to explore the common mechanisms between gaming disorder and time perception in order to explain the observed time loss. However, as the literature examining the relationship between disordered gaming and time perception is scarce, research on healthy gaming will also be explored to delineate the possible associations between time perception and disordered gaming.

Time Perception

According to influential models, time perception depends on two separate processes: a conscious and ad hoc process where attention is directed towards time (i.e., prospective time perception, PTP), and an unconscious and post hoc process where attention is diverted from time (i.e., retrospective time perception, RTP) (Levin and Zakay 1989). The prospective process is conceptualized in the scalar expectancy theory (SET) model (Gibbon et al. 1984), which postulates that time perception depends on the processing of pulses through the action of three specific mechanisms, namely a pacemaker, an accumulator, and a comparator. The more pulses that are recorded during a specific time interval, the longer the time will be estimated. The retrospective process is mainly conceptualized within the contextual change model (CCM, Block and Reed 1978). The CCM is memory-based and posits the more that single events are memorized in relation to a specific time interval, the longer the interval will be perceived. Although obvious from a clinical perspective (i.e., compromised time control is often observed in gaming disorder), to date, only four studies have explored impaired time perception among disordered gamers, leading to mixed results (i.e., Rau et al. 2006; Rivero et al. 2012; Tobin and Grondin 2009; Wood and Griffiths 2007).

Utilizing *Diablo II* (a dungeon crawler real-time role-playing game), Rau et al. (2006) recruited 26 expert players and 38 novice players and asked them to play this game in three conditions corresponding to different time intervals (i.e., 30, 60, and 90 min) before asking them to retrospectively estimate the duration of the gaming sessions. Although the difference between the two groups was non-significant ($p = 0.059$), the expert gamers underestimated the 60-min duration while the novice gamers overestimated it. An important limitation to the study is the fact that the participants were aware of the total duration of the testing session (90 min). Another limitation is that a significant part of the novice players presented with "internet addiction" symptoms, which potentially influenced the results.

In order to compare the impact of different activities on both PTP and RTP, Tobin and Grondin (2009) recruited 116 adolescents and asked them to perform three consecutive activities (i.e., playing a game for 8 and 24 min, and reading a text for 8 min). The 24-min session of videogaming was underestimated, but as no control condition was used, the reason for the underestimation remains uncertain. Furthermore, the 8-min gaming session was more frequently underestimated than the reading session. The authors also compared time perception among disordered gamers ($n = 14$, according to the scale developed by Griffiths and Hunt 1998) to the rest of the sample ($n = 102$), and showed that disordered gamers tended to underestimate the duration of the session compared with other participants in the 24-min session. When comparing participants playing more than 7 h per week ($n = 27$) with participants playing between 1 and 6 h a week ($n = 58$), the authors replicated these results.

In another experiment, Wood and Griffiths (2007) asked 40 participants to play one of two videogames (i.e., participants could choose whether they wanted to play a console or computer game) for 45 min and were interrupted at three pre-determined moments (i.e., after 13, 37, and 45 min) where they were asked to report how long they had played. Results showed that there was no significant association between videogame play and temporal estimation after each pause. However, a methodological issue arose because the authors did not inform the participants about time estimation before the experiment. Indeed, while the first temporal estimation would be defined as retrospective, the two subsequent evaluations would arguably be considered as prospective according to Grondin and Plourde (2007). When a participant is asked to estimate a time span, the following estimation(s) will systematically become prospective because participants begin to become cognizant of what they are being asked for.

The final study exploring time perception among gamers was conducted by Rivero et al. (2012) who examined both sub-second and multi-second time perception. The first one was relative to reflexes and action planning rather than duration estimation, and is therefore not discussed here. Compared with the other three studies outlined, this final study recruited a small sample of participants comprising nine frequent gamers (i.e., 30 h per week playing videogames during the past month) and nine occasional players (less than 5 h per week playing videogames during the past month). Participants were asked to perform a time estimation task (i.e., estimating three different durations of 10, 30, and 60 s) and a time production task (i.e., pressing a button for 5 or 45 s). No significant differences between the occasional and frequent gamers were found which may have been due to the small sample used.

The research on time perception and gaming (i.e., whether disordered or healthy) currently suffers from a lack of cohesion, as the aforementioned studies produced very different findings. From a clinical perspective, understanding the underlying mechanisms of compromised time control is important in order to improve and tailor treatment interventions. Accordingly, the purpose of this narrative review is to elaborate on the psychological processes and mechanisms susceptible to cause compromised time control while gaming. Two different pathways will be considered, underlain by either cognitive or emotional processes. Indeed, past research has emphasized that disordered gaming is associated with specific cognitive (e.g., executive functions) and emotional factors (e.g., emotion regulation strategies) that are postulated to play a pivotal role in time perception (e.g., Baudouin et al. 2006a; Cain et al. 2014; Colzato et al. 2013; Fayolle et al. 2014).

Cognitive Processes in Time Perception and Gaming

Attentional Processes

Attention processes play a crucial role in time perception, even if it is postulated that they affect RTP and PTP in opposite ways (Block and Zakay 1997). In RTP, performing a task which elicits more selective attention lengthens the perceived duration via the larger number of events happening during the interval (Block and Reed 1978). In PTP, performing a more cognitively demanding task shortens its perceived duration because participants pay less attention to time (Zakay and Block 1995). In experimental situations, the first way to assess how attention affects PTP is to divert the participant's attention away from time by using a dual-task paradigm. In doing so, researchers have observed a systematic underestimation of time when participants have had to perform a non-temporal concurrent task while estimating time duration (e.g., Burle and Casini 2001; Chinchanachokchai et al. 2015). Brown and West (1990) explored how two concurrent temporal tasks interfered with each other. In the first experiment, 80 participants observed four stimuli simultaneously at various time intervals. Participants were divided into four groups, depending upon the number of stimuli they had to observe (i.e., one, two, three, or four). Results demonstrated that the more stimuli participants were asked to attend to, the more errors there were in their time estimation judgment. In another attempt to manipulate attention demand, it has been shown that it is possible to consciously divert an individual's attention from time to a different increment (Casini and Macar 1997; Kladopoulos et al. 2004; Macar et al. 1994). For example, Macar et al. (1994) asked participants to perform both a word categorization task (i.e., counting animals' names) and a temporal task (i.e., estimating a word series duration). The participants were also told to split their attention, either entirely on one of the two tasks (i.e., 100%/0%), mainly on one of the two tasks (i.e., 75%/25%), or equally between the two tasks (i.e., 50%/50%). Results showed that the more attention was directed to the categorization task, the more errors were made in the temporal task and the fewer errors were made in the categorization task. A final way of testing the attentional effect is by using cues to explore attention orientation. Here, participants receive a cue regarding the stimulus that has to be followed (e.g., its duration, location, modality), which helps participants to focus on it because they are prepared. As the participants were more focused on the stimulus, and therefore less on time perception, an underestimation of time was observed (Mattes and Ulrich 1998; Osugi et al. 2016). Furthermore, these results have been replicated for transient attention (i.e., attention driven by a sudden change in the visual field) which operates over very short durations (i.e., around 100 ms) (Yeshurun and Marom 2008). In the experiment, 15 participants performed a temporal comparison task (23–94 ms) on two circles on the screen, the first one being cued on both when and where it would appear, while the second was only cued on when it would appear. The results showed that the disc cued on its location was perceived as longer than the other disc, but only for durations shorter than 94 ms.

Many videogames (especially action videogames such as first-person shooters, FPSs) require continuous and flexible attention from players, and even the slightest lapse in attention can lead to losing the game. Attention can be divided into two separate processes, namely top-down attention (i.e., when individuals consciously direct their attention towards a specific stimulus) and bottom-up attention (i.e., when individuals' attention is attracted towards a prominent stimulus). Furthermore, top-down attention can be "activated" by either normal cues (i.e., warning the participant that a stimulus is about to appear) or a spatial cue (i.e., directing participants' attention towards a specific spatial area). Therefore, it is expected that videogame players exhibit better top-down attention, winning a game requiring inhibiting distractors, and to focus on the relevant stimuli (e.g., to focus an individual's attention on important objective-related stimuli without being distracted). However, because important stimuli can appear in games requiring a fast relocation of attention, bottom-up selection can also be at stake during the playing of action videogames. The current literature demonstrates that videogame players appear to exhibit better top-down control (e.g., Cain et al. 2014; Chisholm and Kingstone 2015; Irons et al. 2011), although some studies have shown improved bottom-up processing (e.g., Castel et al. 2005; Mishra et al. 2011; Schubert et al. 2015). However, these studies used different tasks and paradigms to measure attention (e.g., theory of visual attention tests, anti-cueing task, and compound search task) and recruited gamers playing different games genres, which complicates their comparison. Another way to explore attentional processes among gamers is to utilize attentional biases. Although the tasks used to explore these biases differ between studies, the basic principle is to include game-related stimuli (i.e., either words or pictures) in a previously validated task. The studies using this paradigm among disordered gamers have systematically demonstrated that gamers unintentionally direct their attention towards the gaming stimuli and have difficulty in disengaging from these stimuli (Jeromin et al. 2016; Lorenz et al. 2013; Metcalf and Pammer 2011; van Holst et al. 2012).

Interestingly, a study by Krishnan et al. (2013) compared players of two different videogame genres (i.e., role-playing game (RPG) and FPS game players) to assess whether game genre impacts the performance on attentional tasks. The participants were all tested on an identical task requiring them to press a button every time a preselected stimulus appeared in a given zone of the screen. Depending upon the types of trial, participants had to attend to one, two, or four regions of the screen, thus increasing the difficulty of the task and the spatial distribution of attention. The findings demonstrated an overall better performance by the FPS players, the largest difference being when the participants had to attend to four simultaneous locations. However, because there was no control group (i.e., participants who did not play any videogames), the only conclusion that can be drawn from this study was that FPS players have better attentional processes than RPG players. Consequently, nothing can be concluded on the direct contribution of playing RPGs on time perception compared with non-players.

Working Memory

Another important process in prospective time perception is working memory, especially when an individual has to compare two different time durations. According to Baddeley (1992), working memory comprises three components (i.e., visuospatial sketchpad, phonological loop, and central executive). The visuospatial sketchpad plays a central role in retaining and manipulating the visuospatial imagery while the phonological loop has the same role concerning auditory information. The central executive facilitates controlled and proactive cognitive processes and coordinates the visuospatial sketchpad and the phonological loop. According to the SET model of PTP (Gibbon et al. 1984), working memory plays a central role in the decision-making process. First, pulses are gathered in an accumulator in working memory, allowing an individual to make a time duration estimation. After the estimation is made, the response is stored in a reference memory which is more durable. This storage allows the comparison of a newly observed time duration estimation with a previous experienced time duration via working memory. Research on the relationship between time perception and working memory has mainly—if not entirely—been conducted in prospective settings, confirming the SET model theory. Indeed, studies have shown that PTP is predicted by both the storage components (i.e., visuospatial sketchpad and phonological loop) of working memory (Baudouin et al. 2006b; Bi et al. 2013; Perbal et al. 2002). Furthermore, numerous studies have shown that when performing dual tasks, participants tend to underestimate time (e.g., Brown and Merchant 2007; Brown and Smith-Petersen 2014), which is of interest given that divided attention is part of the four executive functions comprising the central executive component of the working memory (Baddeley 1992).

A study conducted among elderly participants showed that poorer temporal performance (i.e., lack of precision when estimating a time duration) was associated with working memory deficits (Baudouin et al. 2006a). However, when exploring the development of time perception skills among children, Zélanti and Droit-Volet (2011) observed that while short-term memory and attention predicted temporal sensitivity development in the different age groups, working memory did not show such an effect. Additionally, while attentional processes predicted the difference in temporal performance between single and dual tasks among children, working memory did not play such a role (Hallez and Droit-Volet 2017). To date, the only study showing an effect of working memory on time perception among children did not show any developmental effect, but an overall positive correlation between the two variables (Droit-Volet et al. 2015).

Most of the available research concerning videogame players emphasizes that regular gamers have an improved working memory (e.g., Colzato et al. 2013; McDermott et al. 2014; Mishra et al. 2011), although some studies have shown that these improvements only occur with regard to the visuospatial sketchpad (e.g., Posner letter identity task, visual working memory task) (Lau-Zhu et al. 2017; Mishra et al. 2011; Seya and Shinoda 2016). Although this latter finding is theoretically coherent because gaming is mainly associated with improved visuospatial skills (Bavelier et al. 2012), studies still demonstrate that healthy gamers do not exhibit any impaired working memory component (e.g., Colzato et al. 2013; Lau-Zhu et al. 2017). Furthermore, although most studies have explored console gaming, Huang et al. (2017) compared the effects of the console and mobile gaming on cognition, including a measure of working memory. Although their results supported previous research (i.e., regular console gaming improves working memory), they also found that playing casual games on a mobile device led to similar effects. This study is noteworthy given that increasing numbers of people now own a smartphone (Statista 2018b), granting them free and easy access to multiple videogames.

Emotional Processes in Time Perception and Gaming

Emotion

Time is subjective because it appears to drag out when engaged in a boring activity (e.g., waiting for an appointment or queuing in a shop), but to pass by very quickly when engaged in an appealing or joyful activity (e.g., partying or watching a good film). When researchers have tried to explore the effect of emotions on time perception in a laboratory setting, results have not systematically supported the idiom that "time flies when you are having fun." However, it does not necessarily mean that the idiom is wrong. Indeed, most of the research on emotions in time perception has used emotional stimuli (i.e., videos, music, pictures, and odors) and assessed whether being exposed to such stimuli influences time perception. Surprisingly, the results mainly showed an overestimation of time irrespective of whether the task was prospective or retrospective (e.g., Bisson, Tobin and Grondin 2009; Cassidy and Macdonald 2010; Kellaris and Kent 1992).

However, whether music affects time perception and whether listening to music while performing a laboratory task can be considered as "fun" are two separate issues. For example, a few studies have explored "fun" in other ways, showing different results. For instance, one study explored time perception among 76 novice tandem skydivers (Campbell and Bryant 2007). Although this is a very different experience from gaming, the way the researchers investigated this may be helpful in understanding how gaming enjoyment could affect time perception. The study assessed participants' levels of excitement and fearfulness before the jump and after landing, and (retrospectively) asked participants how long the skydive had lasted. The results showed that although the level of fear positively predicted their time estimation (i.e., time slowing down), their level of excitement showed the opposite (i.e., time passing faster).

Another study explored the motivational intensity of the positive state effect on time perception by comparing a low-approach motivation positive state (i.e., feeling calm or peaceful) and a high-approach motivation positive state (i.e., feeling desire) to a neutral state (Gable and Poole 2012). In this study, participants could either look at pictures of flowers (low-approach), dessert pictures (high-approach), or geometric shapes (neutral). The results showed that there was no difference between the low-approach motivation positive state and the neutral state. However, the high-approach motivation positive state was significantly underestimated compared with the other two groups. Furthermore, by telling half the participants that they would receive a dessert at the end of the experiment, the authors showed that expectancy was able to strengthen the previous results because the participants expecting to actually eat a dessert ended up underestimating time more than other participants not expecting to eat a dessert.

The impact of gaming on emotion has been investigated via neuropsychological studies. These studies demonstrate stronger brain reactivity for disordered gamers compared with control participants when confronted with gaming cues, meaning that disordered gamers are more aroused by gaming stimuli (Ahn et al. 2015; Ko et al. 2013; L. Liu et al. 2017; Zhang et al. 2016). Although stronger reactivity has mainly been observed within the prefrontal cortex (i.e., both ventrolateral and dorsolateral; Ahn et al. 2015; Ko et al. 2013), other areas of the brain have shown similar results (e.g., precuneus, posterior cingulate, striatum; Ko et al. 2013; L. Liu et al. 2017). For instance, two studies using the same paradigm showed that disordered gamers exhibited stronger brain reactions than healthy gamers when confronted with gaming-related cues (Ko et al. 2013; Thalemann et al. 2007; Wang et al. 2017), and that these activations were associated with their urge to play videogames (Ko et al. 2013; Wang et al. 2017). These two studies imply that not only are disordered gamers more sensitive to gaming cues than non-gamers (which would be normal because non-gamers are not familiar with these), but they are also more sensitive than healthy gamers.

Three other studies have explored in-game reactions with either neural activation through an electroencephalogram (EEG, Shin et al. 2012) or physiological activation through an electrocardiogram (ECG), facial electromyography (EMG), and skin conductance (Ravaja et al. 2006; Salminen and Ravaja 2007). The EEG study showed that although healthy gamers can experience negative emotions during a gaming session (e.g., their character getting shot or dying), they reported only positive subjective emotions after the gaming session. The physiological activation studies showed that some game events elicited arousal (Salminen and Ravaja 2007) and that not only positive events elicited positively valenced arousal but also some negative ones among healthy gamers (Ravaja et al. 2006). Taken together, the findings of these studies tend to support the emotional explanation for compromised time control. Indeed, behavioral and EEG studies have demonstrated that disordered gamers tend to show stronger brain reactivity when confronted with gaming-related stimuli than non-gamers and also exhibit stronger neural activity than non-disordered gamers while playing. These findings demonstrate that disordered gamers experience stronger arousal, which can lead to increased time distortion and in turn to experiencing greater compromised time control. Furthermore, the in-game studies demonstrate that healthy gamers experience positive arousal during their gameplay, whether they are achieving something good or bad in-game.

Emotion Regulation

Although emotion regulation plays a crucial role in the interaction between cognitive skills and emotion (e.g., working memory; Malagoli and Usai 2018; executive functions; Marceau et al. 2018), this has rarely been studied in the field of time perception. According to Eisenberg and Spinrad's (2004, p. 338) comments on a paper by Cole et al. (2004), emotion regulation can be defined as "the process of initiating, avoiding, inhibiting, maintaining, or modulating the occurrence, form, intensity, or duration of internal feeling states, emotion-related physiological, attentional processes, motivational states, and/or the behavioral concomitants of emotion in the service of accomplishing affect-related biological or social adaptation or achieving individual goals." The studies on this topic show that good emotion regulation leads to a lower (almost non-existent) interference of emotion on time perception (Tian et al. 2018; Wittmann et al. 2015).

However, as emotional regulation can be defined as the reduction of an individual's reaction to an arousing stimulus (e.g., Evren et al. 2018), two studies can be included in this section because they explored the different ways to reduce a stimulus-arousing effect on an individual. The first way to reduce reaction to an arousing stimulus is to divert attention from it. Using this method with aversive sounds, Mella et al. (2011) showed that when their participants had to focus on the sounds, there was a clear effect of the stimulus on their time estimation (i.e., overestimation). However, when participants were asked to focus equally on the task and the sound, or exclusively on the task, this effect was disrupted, supporting previous findings. Using the perceived level of control as a mediating variable, Buetti and Lleras (2012) recruited arachnophobe and non-arachnophobe participants and confronted them with spider pictures. In order to fluctuate their level of perceived control of the situation, and therefore the arousing effect of the pictures, the participants either were told that pressing a button would make less spider pictures appear or did not receive such instruction. The results showed that under a higher perceived control of the situation, the effect of the very arousing pictures was completely nullified and this was independent of the percentage of spider pictures presented. These results were further replicated in another study using a similar design (Mereu and Lleras 2013). Therefore, it can arguably be concluded that emotion regulation would diminish (if not entirely inhibit) the interference of emotional stimuli on time perception. If this was verified, it would mean that better emotion regulation would lead to a lesser impact of emotion on time perception, and therefore a lesser underestimation of duration.

This fact is of interest given that several studies have shown clear associations between videogame play and emotion regulation. Although Villani et al. (2018) showed that regular videogame play can be a useful tool in regulating emotion (e.g., to relax during a stressful time), and is even used in therapy, it would appear that this is different among disordered gamers. For instance, Seo et al. (2012) compared regular and disordered gamers on various emotional variables (i.e., emotional competence, positive emotion, emotional expression, and emotional intelligence) and showed that disordered gamers exhibited lower scores on the emotional variables compared with healthy gamers. These results are further supported by studies showing that disordered gamers have impaired emotion regulation (Evren et al. 2018; Wichstrøm et al. 2018) as well as abnormal activation in brain areas responsible for emotion regulation (i.e., orbitofrontal cortex, Du et al. 2016; dorsal anterior cingulate cortex, Lee et al. 2015; subcortical and cortical regions, Yip et al. 2018). Based on this literature, it would appear that although an efficient emotion regulation ability would alter (if not prevent) any emotional interference on time perception, the fact that the disordered gamers exhibit an impaired regulation of their emotion may explain why they cannot control the emotional affect coming from their gaming sessions. Indeed, while a healthy gamer could "inhibit" or at least reduce the arousal arising from their gaming session (and thus diminish the impact on their time perception), disordered gamers would not be able to (or would have more difficulties to) do so, resulting in observed compromised time control.

Flow

Flow has been defined as a total involvement in a task where the level of the individual's skill is matched by the level of challenge the task poses leading to experiencing a loss of self-consciousness (Csíkszentmihályi 1975). According to Csíkszentmihályi (1993), it includes four main components (i.e., control, attention, curiosity, and intrinsic interest) and eight elements (i.e., clear goals and immediate feedback, balance between skills and challenge, concentration, sense of control, loss of self-consciousness, awareness and action merging, reward, and time distortion). When an individual experiences a flow state, all attention is focused on the task itself (e.g., playing videogames) to the point of possibly experiencing a momentary self-awareness loss. Csíkszentmihályi pointed out that one of the flow elements is time distortion, where individuals experience either lengthening or shortening of time duration while in a flow state (i.e., overestimation or underestimation of lapsed time during the activity). In an opinion paper on the possible effect of boredom on time perception, Zakay (2014) based part of his argument on Csíkszentmihályi's (1990) definition of flow, asserting that boredom was the other end of a pole on the enjoyment continuum.

Therefore, according to Zakay (2014), while boredom leads to an overestimation of duration, flow experience leads to the opposite effect (i.e., a significant underestimation of time due to the almost entire attentional pool resources being allocated to the activity, inducing the flow state). The case of boredom tends to be supported when comparing participants with a high level of boredom-proneness to participants with low levels. Indeed, Watt (1991) and Danckert and Allman (2005) showed that individuals with more boredom-prone tendencies judge time to be longer during a boring task than participants with lower levels of boredom-proneness. Although this is not a direct measure of flow, the findings indicate a possible fluctuation of time depending on flow experience–proneness.

However, although numerous studies on attention (i.e., see the "Attentional Processes" section) also tend to support the direct relationship between flow and time perception because they show that increased attention on non-temporal activity systematically leads to an underestimation of time, few studies have explored the direct effect of flow on time perception. By solely exploring the effect of immersion in a videogame, Sanders and Cairns (2010) showed that in a prospective setting, the more a videogame player was immersed in a game (through the inclusion or not of music within a short videogame session), the more they underestimated the time spent playing it. This matched the reports of the participants stating that they felt more immersed when they heard in-game music. This result, among other things, may explain the different results obtained in the previously described experiment on compromised time control among disordered gamers because different games include different background music which may constitute a confounding variable.

The results of studies exploring the effect of flow experience on playing videogames have been inconsistent and could be due to the varying measures used in the different studies (e.g., Game Engagement Questionnaire, Brockmyer et al. 2009; the Flow State Scale-2, Jackson and Eklund 2002). For example, some studies have found a clear association between flow experience and disordered gaming (Chou and Ting 2003; Hull et al. 2013; Khang et al. 2013), while others have not (Wan and Chiou 2006). However, when exploring time spent gaming among healthy gamers, studies showed that the gamers experiencing flow states spent more time gaming (Johnson et al. 2016; Khang et al. 2013). Finally, it has been pointed out that the structural characteristics of videogames (e.g., negative rewards features, narrative), as well as the players' motives (e.g., playing alone or with other gamers, online or offline), can affect how likely gamers are to experience a flow state (Kaye 2016; Laffan, Greaney, Barton, & Kaye 2016; Liu and Chang 2016). A common denominator between the three papers is the importance of social interaction. While Laffan et al. (2016) and Liu and Chang (2016) only reported that the result on a subscale exploring social interaction correlated significantly with the experienced level of flow, Kaye (2016) put this variable to the forefront in her study. It was demonstrated that knowing teammates' skill levels and having efficient communication and teamwork with teammates significantly predicted the level of experienced flow.

The study by Kaye showed that in online cooperative games (e.g., massively multiplayer online role-playing games (MMORPG) and multiplayer online battle arena (MOBA) games), not only are the gameplay and the players themselves important to achieve a flow experience, but the way the players interact with their teammates plays an important role. These studies also imply that some game genres (e.g., first-person shooter games and real-time strategy games) can facilitate the experience of a flow state. Although this is speculative, it needs to be explored in future studies because the finding implies that different types of games have different indirect impacts on time perception via the level of flow they induce.

Another way to explore the potential association between time perception, gaming, and flow is through the concept of enjoyment. In a study by Christandl et al. (2018), participants engaged in a task for 10 min, and half of them were told that the task lasted 5 min (time-dragging condition), while the other half was told it lasted 15 min (time-flying by condition). The participants who were told that the task lasted longer than what they had thought evaluated their recalled level of flow as higher than the participants who were told the task was shorter. This study shares similar results to another study on time perception and task enjoyment (i.e., Sackett, Meyvis, Nelson, Converse, & Sackett et al. 2010). They showed that by making participants feel like time passed faster (i.e., by deceiving them about the total duration of the task), participants judged the task as more enjoyable. The study also replicated the results with irritating sounds (i.e., using an "underestimation" condition, leading to a lower irritating rating) and music (i.e., using an "underestimation" condition, leading to a higher rating of the song played). These two studies suggest that time perception and flow are highly associated because they both showed a bidirectional association with enjoyment.

Interestingly, by incorporating the results of research on the interaction of emotion and time perception in the research explored in this section, it may provide a possible explanation of how retrospective time perception of gamers can be affected. Although none of the studies reported in the "Emotion" section recruited gamers, the studies showed that emotions, and especially "having fun," can induce an underestimation of time duration. Therefore, it could be argued that gamers will experience arousal when confronted with gaming stimuli, which would lead to an emotional response which would not be present among non-gamers, even if they were to play once (as there would not be such an association due to the lack of repetitive gameplay). Furthermore, as disordered gamers exhibit hypersensitivity to gaming stimuli, this would lead to a stronger emotional effect compared with healthy gamers. This stronger effect may then result in a stronger underestimation of time during the gaming session, leading to the observed compromised time control effect. This hypothesis is once again supported by flow theory because enjoying a game helps in experiencing a flow state while playing, strengthening the aforementioned effect. Furthermore, the difficulty to inhibit one's arousal while playing (i.e., emotion dysregulation observed among disordered gamers) could prevent disordered gamers from attenuating this effect compared with healthy gamers. Finally, the presence of an impaired delay of gratification among disordered gamers supports the potential association between gaming and time perception via impaired emotional processes because the delay of gratification is highly associated with time perception.

Discussion

This narrative review aimed to collate previously published data on the compromised time control effect and relate it to disordered gaming. The compromised time control effect is a possible direct consequence of impaired time perception, which leads to an underestimation of the time spent gaming. Although this may appear harmless at first sight, underestimating gaming session length significantly can lead to detrimental consequences due to little time remaining for other important activities (e.g., education and/or occupation, spending time with loved ones, sleep). Although it would appear that compromised time control is a direct consequence from an impaired time perception, the studies on this topic did not show consistent results, implying that this may not be the case (Rau et al. 2006; Tobin and Grondin 2009; Wood and Griffiths 2007). Therefore, the present paper sought to understand how time perception and videogame use can be associated in order to explain the compromised time control effect.

The first explanation provided for this relates to cognitive processes because cognition can be both impaired by disordered gaming (Nuyens et al. 2017) and improved by regular (non-disordered) gaming (Nuyens et al. 2018). When examining cognitive factors relevant in time perception, two common processes with gaming are attention and working memory (Gibbon et al. 1984; Zakay and Block 1995). When evaluating these two processes among non-disordered gamers, it has been shown that they were both improved, although it specifically applied to visual working memory (e.g., Colzato et al. 2013; McDermott et al. 2014) and top-down attention (e.g., Cain and Mitroff 2011; Chisholm et al. 2010). Therefore, from a cognitive perspective, it would appear that non-disordered gamers are more likely to have a more accurate time perception than non-gamers, whereas this is not a common observation among gamers. However, the studies on the associations between working memory and attention with time perception solely used prospective experimental settings. Therefore, it is possible that the compromised time perception among gamers is not prospective but retrospective, which fits gaming reality because gamers rarely consciously monitor time while engaging in the activity they enjoy. This is supported by the concept of flow according to Zakay (2014), who posited that flow and boredom represent opposite ends of the same continuum. While being bored lengthens time duration (i.e., overestimation of time), experiencing flow leads to the opposite effect (i.e., underestimation of time), thus explaining the compromised time control effect. Although this has not been thoroughly researched, the studies on the association between attention and time perception tend to support this because the less attention is focused on time, the shorter the time duration is perceived to be.

Another possible explanation relates to emotional factors rather than cognitive ones. However, the laboratory studies to date mainly showed an overestimation of time when adding emotional stimuli to the experimental task (e.g., Bisson et al. 2009; Cassidy and Macdonald 2010), thus contradicting the idea developed by Zakay (2014). However, there is a difference between observing emotional stimuli in a laboratory setting and actually having fun to the point of forgetting about time. This fact is underlined by the study among novice skydivers, showing that their level of excitement during their very first jump was negatively associated to their duration estimation (i.e., the more they were excited, the shorter they estimated the jump; Campbell and Bryant 2007). Interestingly, the opposite trend was also observed, with participants estimating a task as more enjoyable when they were tricked into believing that a task lasted longer than they thought (Sackett et al. 2010). Furthermore, the studies reviewed in the present paper showed that disordered gamers tend to show more intense reactivity to gaming cues and to exhibit greater physiological reactions during a gaming session than healthy gamers and control participants (e.g., Ko et al. 2013; Ravaja et al. 2006; Salminen and Ravaja 2007; Thalemann et al. 2007). They not only showed higher reactivity, but studies also showed that even "bad" in-game events could lead to positive arousal reactions (e.g., character getting shot or dying in the game; Ravaja et al. 2006). Again, flow can play a determining role in the relationship between gaming, emotion, and time perception. Using Zakay's definition of boredom as the opposite to flow on the enjoyment continuum, research has demonstrated that boredom-prone participants tend to overestimate the duration of a boring task more than less boredom-prone participants (Danckert & Allman, 2005; Watt, 1991). Furthermore, when participants were more immersed in a game, they estimated the duration of their gaming session as shorter than when they were less immersed, although this was only true in a prospective setting (Sanders and Cairns 2010).

Although there is a lack of studies examining the causal link between enjoyment and time perception, it appears plausible that having fun leads to underestimating time duration. Furthermore, since disordered gamers exhibit difficulties regulating their emotions, it is possible that it would affect the emotional interference of gaming on time perception. Indeed, it has been shown that an efficient emotion regulation can reduce (if not nullify) the emotional interference on time perception. Therefore, it is expected that a deficient emotion regulation will lead to a stronger effect of emotion.

From the literature, it would appear that both attentional and emotional processes could be contributors in the emergence of compromised time control among gamers. It has been repeatedly shown that having fun and enjoying an activity helps individuals experiencing a flow state (e.g., Brailovskaia et al. 2018; Corcos 2018; Limperos et al. 2011). Therefore, it could be hypothesized that since disordered gamers react more strongly to gaming stimuli, and can associate negative outcomes with pleasure, not only will it be easier for them to underestimate time, but they will also tend to experience flow states more easily than healthy gamers (e.g., Ko et al. 2013; Ravaja et al. 2006). Because experiencing flow directs the whole attentional pool towards the game, emotion can have both a direct impact on time perception (i.e., enjoyment leading to an underestimation of time) and an indirect one (i.e., enjoyment inducing flow leading to an underestimation). Therefore, this would indicate that gaming disorder can be related to an interaction of cognition (i.e., attentional processes) and emotions, which fits the framework offered by dual-process models (D'Hondt and Maurage 2017; Mukherjee 2010). Indeed, According to Noël et al. (2013), addiction would result from an imbalance between three main systems: (i) an impulsive system dependent upon the amygdala-striatum network which promotes automatic actions, (ii) a reflective system dependent upon the prefrontal cortex important in decision-making, and (iii) a system dependent upon the insula, which would turn bottom-up information into subjective output.

Finally, there are two constructs that may have a strong impact on the interaction between time perception and gaming, namely the structural characteristics of videogames and the motivations of the gamers. Since the present review only evaluated the common variables between gaming and time perception, these constructs were not developed due to the lack of studies examining their association with time perception. However, as aforementioned, the structural characteristics of an online videogame can directly affect the level of flow experience of the gamers (Kaye 2016; Laffan et al. 2016; Liu and Chang 2016), which in turn may impact how time perception is affected by this level of flow. In relation to motivations, it has been shown in studies that some specific motivations have been significantly associated with the time spent gaming (e.g., Billieux et al. 2013; Myrseth et al. 2017). For example, in the study by Billieux et al. (2013), while several gaming motivations correlated significantly with the time spent gaming weekly (i.e., advancement, mechanics, competition, relationship, customization, and escapism), other motivations did not show such associations (i.e., role-play, teamwork, and socializing). Therefore, it could be hypothesized that those some motives may also influence the gamers' time perception but this is little more than speculation at the present time.

Conclusion

Interestingly, several of the potential associations between time perception and disordered gaming explored in this paper are included in the Interaction of Person-Affect-Cognition-Execution (I-PACE) model (Brand et al. 2016). According to this model, the development and maintenance of addictive behaviors (including disordered gaming) would rely upon common underlying mechanisms. Each category of process affecting the development is represented by a letter of the model: (p) represents the core characteristics of the *p*erson (e.g., the biopsychosocial constitution, the personality, the motives), (a) and (c) are the *a*ffective and *c*ognitive responses to stimuli (e.g., cognitive biases, cue-reactivity, emotion regulation), and (e) represents the *e*xecutive functions (e.g., inhibition, decision-making). Concerning this paper, the (a), (c), and (e) sections of this model are of particular interest because they integrate the emotional and cognitive processes explored in the present paper (e.g., attention, working memory).

Consequently, based on the literature, it would appear that it is not time perception itself which is impaired among disordered gamers, but the joint impact of two exacerbated processes. This is important because this has yet to be tested in studies exploring time perception among gamers, which may affect the results to date and explain the relative lack of significant findings. Therefore, the following studies on this topic should include flow measurement, as it appears to be a promising tool in order to explore this interaction as has been highlighted throughout this paper. Furthermore, studying the interaction between time perception and gaming via a dual-process perspective may help to reach a better understanding of the processes at stake in this interaction. For example, according to Noël et al.'s (2013) model, it could be possible that a third system (i.e., the insula-based system) has a role in the interaction. Therefore, exploring other processes in interaction with such a system (e.g., craving) may reveal more underlying processes explaining why disordered gamers exhibit such a compromised time control.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they do not have any interests that could constitute a real, potential or apparent conflict of interest with respect to their involvement in the publication. The authors also declare that they do not have any financial or other relations (e.g. directorship, consultancy or speaker fee) with companies, trade associations, unions or groups (including civic associations and public interest groups) that may gain or lose financially from the results or conclusions in the study. Sources of funding are acknowledged.

Ethical Approval N.A. (Narrative review)

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References

Achab, S., Nicolier, M., Mauny, F., Monnin, J., Trojak, B., Vandel, P., Sechter, D., Gorwood, P., & Haffen, E. (2011). Massively multiplayer online role-playing games: Comparing characteristics of addict vs non-addict online recruited gamers in a French adult population. *BMC Psychiatry, 11*, 144. https://doi.org/10.1186/1471-244X-11-144 .

Ahn, H. M., Chung, H. J., & Kim, S. H. (2015). Altered brain reactivity to game cues after gaming experience. *Cyberpsychology, Behavior and Social Networking, 18*(8), 474–479. https://doi.org/10.1089/cyber.2015.0185.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Baddeley, A. (1992). Working memory. Science (New York, N.Y.), *255*(5044), 556–559. https://doi.org/10.1126/science.1736359

Baudouin, A., Vanneste, S., Isingrini, M., & Pouthas, V. (2006a). Differential involvement of internal clock and working memory in the production and reproduction of duration: A study on older adults. *Acta Psychologica, 121*(3), 285–296. https://doi.org/10.1016/j.actpsy.2005.07.004.

Baudouin, A., Vanneste, S., Pouthas, V., & Isingrini, M. (2006b). Age-related changes in duration reproduction: involvement of working memory processes. *Brain and Cognition, 62*(1), 17–23. https://doi.org/10.1016/j.bandc.2006.03.003.

Bavelier, D., Green, C. S., Pouget, A., & Schrater, P. (2012). Brain plasticity through the life span: learning to learn and action video games. *Annual Review of Neuroscience, 35*(1), 391–416. https://doi.org/10.1146/annurev-neuro-060909-152832.

Bi, C., Yuan, X., & Huang, X. (2013). The impact of object working memory on timing. *Journal of Cognitive Psychology, 25*(4), 390–399. https://doi.org/10.1080/20445911.2013.777071.

Bielefeld, M., Drews, M., Putzig, I., Bottel, L., Steinbüchel, T., Dieris-Hirche, J., Szycik, G. R., Müller, A., Roy, M., Ohlmeier, M., & Theodor te Wildt, B. (2017). Comorbidity of Internet use disorder and attention deficit hyperactivity disorder: Two adult case–control studies. *Journal of Behavioral Addictions, 6*(4), 490–504. https://doi.org/10.1556/2006.6.2017.073 .

Billieux, J., Van der Linden, M., Achab, S., Khazaal, Y., Paraskevopoulos, L., Zullino, D., & Thorens, G. (2013). Why do you play World of Warcraft? An in-depth exploration of self-reported motivations to play online and in-game behaviours in the virtual world of Azeroth. *Computers in Human Behavior, 29*(1), 103–109. https://doi.org/10.1016/j.chb.2012.07.021.

Billieux, J., van Rooij, A. J., Heeren, A., Schimmenti, A., Maurage, P., Edman, J., Blaszczynski, A., Khazaal, Y., & Kardefelt-Winther, D. (2017). Behavioural Addiction Open Definition 2.0-using the Open Science Framework for collaborative and transparent theoretical development: commentaries. *Addiction, 112*(10), 1723–1724. https://doi.org/10.1111/add.13938.

Bisson, N., Tobin, S., & Grondin, S. (2009). Remembering the duration of joyful and sad musical excerpts: Assessment with three estimation methods. *NeuroQuantology, 7*(1), 46–57. https://doi.org/10.14704/nq.2009.7.1.206 .

Block, R. A., & Reed, M. A. (1978). Remembered duration: Evidence for a contextual-change hypothesis. *Journal of Experimental Psychology: Human Learning and Memory, 4*(6), 656–665. https://doi.org/10.1037/0278-7393.4.6.656 .

Block, R. A., & Zakay, D. (1997). Prospective and retrospective duration judgments: A meta-analytic review. *Psychonomic Bulletin & Review, 4*(2), 184–197. https://doi.org/10.3758/BF03209393 .

Bolbecker, A. R., Westfall, D. R., Howell, J. M., Lackner, R. J., Carroll, C. A., O'Donnell, B. F., & Hetrick, W. P. (2014). Increased timing variability in schizophrenia and bipolar disorder. *PLoS One, 9*(5), e97964. https://doi.org/10.1371/journal.pone.0097964.

Brailovskaia, J., Rohmann, E., Bierhoff, H.-W., & Margraf, J. (2018). The brave blue world: Facebook flow and Facebook addiction disorder (FAD). *PLoS One, 13*(7), e0201484. https://doi.org/10.1371/journal.pone.0201484.

Brand, M., Young, K. S., Laier, C., Wölfling, K., & Potenza, M. N. (2016). Integrating psychological and neurobiological considerations regarding the development and maintenance of specific Internet-use disorders: An Interaction of Person-Affect-Cognition-Execution (I-PACE) model. *Neuroscience & Biobehavioral Reviews, 71*, 252–266. https://doi.org/10.1016/j.neubiorev.2016.08.033.

Brockmyer, J. H., Fox, C. M., Curtiss, K. A., McBroom, E., Burkhart, K. M., & Pidruzny, J. N. (2009). The development of the Game Engagement Questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology, 45*(4), 624–634. https://doi.org/10.1016/j.jesp.2009.02.016 .

Brown, S. W., & Merchant, S. M. (2007). Processing resources in timing and sequencing tasks. *Attention, Perception, & Psychophysics, 69*(3), 439–449. https://doi.org/10.3758/BF03193764.

Brown, S. W., & Smith-Petersen, G. A. (2014). Time perception and temporal order memory. *Acta Psychologica, 148*, 173–180. https://doi.org/10.1016/j.actpsy.2014.02.003.

Brown, S. W., & West, A. N. (1990). Multiple timing and the allocation of attention. *Acta Psychologica, 75*(2), 103–121. https://doi.org/10.1016/0001-6918(90)90081-P.

Buetti, S., & Lleras, A. (2012). Perceiving control over aversive and fearful events can alter how we experience those events: An investigation of time perception in spider-fearful individuals. *Frontiers in Psychology, 3, 337.* https://doi.org/10.3389/fpsyg.2012.00337 .

Burle, B., & Casini, L. (2001). Dissociation between activation and attention effects in time estimation: Implications for internal clock models. *Journal of Experimental Psychology: Human Perception and Performance, 27*(1), 195–205. https://doi.org/10.1037/0096-1523.27.1.195 .

Cain, M. S., & Mitroff, S. R. (2011). Distractor filtering in media multitaskers. *Perception, 40*(10), 1183–1192. https://doi.org/10.1068/p7017.
Cain, M. S., Prinzmetal, W., Shimamura, A. P., & Landau, A. N. (2014). Improved control of exogenous attention in action video game players. *Frontiers in Psychology, 5*, 69. https://doi.org/10.3389/fpsyg.2014.00069.
Campbell, L. A., & Bryant, R. A. (2007). How time flies: a study of novice skydivers. *Behaviour Research and Therapy, 45*(6), 1389–1392. https://doi.org/10.1016/j.brat.2006.05.011.
Casini, L., & Macar, F. (1997). Effects of attention manipulation on judgments of duration and of intensity in the visual modality. *Memory & Cognition, 25*(6), 812–818. https://doi.org/10.3758/BF03211325.
Cassidy, G. G., & Macdonald, R. A. R. (2010). The effects of music on time perception and performance of a driving game: effects of music on time perception. *Scandinavian Journal of Psychology, 51*(6), 455–464. https://doi.org/10.1111/j.1467-9450.2010.00830.x.
Castel, A. D., Pratt, J., & Drummond, E. (2005). The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search. *Acta Psychologica, 119*(2), 217–230. https://doi.org/10.1016/j.actpsy.2005.02.004.
Charlton, J. P., & Danforth, I. D. (2007). Distinguishing addiction and high engagement in the context of online game playing. *Computers in Human Behavior, 23*(3), 1531–1548.
Chinchanachokchai, S., Duff, B. R. L., & Sar, S. (2015). The effect of multitasking on time perception, enjoyment, and ad evaluation. *Computers in Human Behavior, 45*, 185–191. https://doi.org/10.1016/j.chb.2014.11.087.
Chisholm, J. D., Hickey, C., Theeuwes, J., & Kingstone, A. (2010). Reduced attentional capture in action video game players. *Attention, Perception, & Psychophysics, 72*(3), 667–671. https://doi.org/10.3758/APP.72.3.667.
Chisholm, J. D., & Kingstone, A. (2015). Action video games and improved attentional control: Disentangling selection- and response-based processes. *Psychonomic Bulletin & Review, 22*(5), 1430–1436. https://doi.org/10.3758/s13423-015-0818-3 .
Chou, T.-J., & Ting, C.-C. (2003). The role of flow experience in cyber-game addiction. *Cyberpsychology & Behavior, 6*(6), 663–675. https://doi.org/10.1089/109493103322725469.
Christandl, F., Mierke, K., & Peifer, C. (2018). Time flows: Manipulations of subjective time progression affect recalled flow and performance in a subsequent task. *Journal of Experimental Social Psychology, 74*, 246–256. https://doi.org/10.1016/j.jesp.2017.09.015 .
Ciullo, V., Piras, F., Vecchio, D., Banaj, N., Coull, J. T., & Spalletta, G. (2018). Predictive timing disturbance is a precise marker of schizophrenia. *Schizophrenia Research. Cognition, 12*, 42–49. https://doi.org/10.1016/j.scog.2018.04.001.
Colder Carras, M., Van Rooij, A. J., Spruijt-Metz, D., Kvedar, J., Griffiths, M. D., Carabas, Y., & Labrique, A. (2017). Commercial video games as therapy: A new research agenda to unlock the potential of a global pastime. *Frontiers in Psychiatry, 8*, 300. https://doi.org/10.3389/fpsyt.2017.00300 .
Cole, P. M., Martin, S. E., & Dennis, T. A. (2004). Emotion regulation as a scientific construct: Methodological challenges and directions for child development research. *Child Development, 75*(2), 317–333. https://doi.org/10.1111/j.1467-8624.2004.00673.x .
Colzato, L. S., van den Wildenberg, W. P. M., Zmigrod, S., & Hommel, B. (2013). Action video gaming and cognitive control: Playing first person shooter games is associated with improvement in working memory but not action inhibition. *Psychological Research, 77*(2), 234–239. https://doi.org/10.1007/s00426-012-0415-2 .
Corcos, A. (2018). Being enjoyably challenged is the key to an enjoyable gaming experience: An experimental approach in a first-person shooter game. *Socioaffective Neuroscience & Psychology, 8*(1), 1474668. https://doi.org/10.1080/20009011.2018.1474668 .
Csíkszentmihályi, M. (1975). *Beyond boredom and anxiety.* San Francisco: Jossey-Bass.
Csíkszentmihályi, M. (1990). *Flow: The psychology of optimal experience.* New York: Harper and Row.
Csíkszentmihályi, M. (1993). *The evolving self: a psychology for the third millenium*. New York: Harper Perennial.
Danckert, J. A., & Allman, A.-A. A. (2005). Time flies when you're having fun: Temporal estimation and the experience of boredom. *Brain and Cognition, 59*(3), 236–245. https://doi.org/10.1016/j.bandc.2005.07.002
Deleuze, J., Long, J., Liu, T.-Q., Maurage, P., & Billieux, J. (2018). Passion or addiction? Correlates of healthy versus problematic use of videogames in a sample of French-speaking regular players. *Addictive Behaviors, 82*, 114–121. https://doi.org/10.1016/j.addbeh.2018.02.031.
D'Hondt, F., & Maurage, P. (2017). Electrophysiological studies in Internet addiction: A review within the dual-process framework. *Addictive Behaviors, 64*, 321–327. https://doi.org/10.1016/j.addbeh.2015.10.012 .

Droit-Volet, S., Wearden, J. H., & Zélanti, P. S. (2015). Cognitive abilities required in time judgment depending on the temporal tasks used: A comparison of children and adults. *Quarterly Journal of Experimental Psychology, 68*(11), 2216–2242. https://doi.org/10.1080/17470218.2015.1012087 .

Du, X., Qi, X., Yang, Y., Du, G., Gao, P., Zhang, Y., … Zhang, Q. (2016). Altered structural correlates of impulsivity in adolescents with internet gaming disorder. *Frontiers in Human Neuroscience*, *10,* 4. https://doi.org/10.3389/fnhum.2016.00004 .

Dudley, R., Kuyken, W., & Padesky, C. A. (2011). Disorder specific and trans-diagnostic case conceptualisation. *Clinical Psychology Review, 31*(2), 213–224. https://doi.org/10.1016/j.cpr.2010.07.005.

Eisenberg, N., & Spinrad, T. L. (2004). Emotion-related regulation: Sharpening the definition. *Child Development, 75*(2), 334–339. https://doi.org/10.1111/j.1467-8624.2004.00674.x .

Evren, B., Evren, C., Dalbudak, E., Topcu, M., & Kutlu, N. (2018). Relationship of internet addiction severity with probable ADHD and difficulties in emotion regulation among young adults. *Psychiatry Research, 269*, 494–500. https://doi.org/10.1016/j.psychres.2018.08.112.

Fayolle, S., Droit-Volet, S., & Gil, S. (2014). Emotion and time perception: Effects of film-induced m4ood. *Procedia - Social and Behavioral Sciences, 126*, 251–252. https://doi.org/10.1016/j.sbspro.2014.02.399 .

Gable, P. A., & Poole, B. D. (2012). Time flies when you're having approach-motivated fun: Effects of motivational intensity on time perception. *Psychological Science, 23*(8), 879–886. https://doi.org/10.1177/0956797611435817 .

Gentile, D. A. (2009). Pathological video-game use among youth ages 8 to 18: A national study. *Psychological Science, 20*(5), 594–602. https://doi.org/10.1111/j.1467-9280.2009.02340.x .

Gibbon, J., Church, R. M., & Meck, W. H. (1984). Scalar timing in memory. *Annals of the New York Academy of Sciences, 423*, 52–77. https://doi.org/10.1111/j.1749-6632.1984.tb23417.x.

Granic, I., Lobel, A., & Engels, R. C. M. E. (2014). The benefits of playing video games. *American Psychologist, 69*(1), 66–78. https://doi.org/10.1037/a0034857.

Griffiths, M. D. (2010). The role of context in online gaming excess and addiction: Some case study evidence. *International Journal of Mental Health and Addiction, 8*, 119–125. https://doi.org/10.1007/s11469-009-9229-x .

Griffiths, M. D., & Hunt, N. (1998). Dependence on computer games by adolescents. *Psychological Reports, 82*(2), 475–480. https://doi.org/10.2466/pr0.1998.82.2.475.

Griffiths, M. D., Kuss, D. J., & King, D. L. (2012). Video game addiction: Past, present and future. *Current Psychiatry Reviews, 8*(4), 308–318. https://doi.org/10.2174/157340012803520414 .

Grondin, S., & Plourde, M. (2007). Judging multi-minute intervals retrospectively. *Quarterly Journal of Experimental Psychology, 60*(9), 1303–1312. https://doi.org/10.1080/17470210600988976.

Hallez, Q., & Droit-Volet, S. (2017). High levels of time contraction in young children in dual tasks are related to their limited attention capacities. *Journal of Experimental Child Psychology, 161*, 148–160. https://doi.org/10.1016/j.jecp.2017.04.013.

Hellström, C., Nilsson, K. W., Leppert, J., & Åslund, C. (2012). Influences of motives to play and time spent gaming on the negative consequences of adolescent online computer gaming. *Computers in Human Behavior, 28*(4), 1379–1387. https://doi.org/10.1016/j.chb.2012.02.023.

Huang, V., Young, M., & Fiocco, A. J. (2017). The association between video game play and cognitive function: does gaming platform matter? *Cyberpsychology, Behavior and Social Networking, 20*(11), 689–694. https://doi.org/10.1089/cyber.2017.0241.

Hull, D. C., Williams, G. A., & Griffiths, M. D. (2013). Video game characteristics, happiness and flow as predictors of addiction among video game players: A pilot study. *Journal of Behavioral Addictions, 2*(3), 145–152. https://doi.org/10.1556/JBA.2.2013.005 .

Irons, J. L., Remington, R. W., & McLean, J. P. (2011). Not so fast: Rethinking the effects of action video games on attentional capacity. *Australian Journal of Psychology, 63*(4), 224–231. https://doi.org/10.1111/j.1742-9536.2011.00001.x .

Jackson, S. A., & Eklund, R. C. (2002). Assessing flow in physical activity: The Flow State Scale–2 and Dispositional Flow Scale–2. *Journal of Sport and Exercise Psychology, 24*(2), 133–150. https://doi.org/10.1123/jsep.24.2.133 .

Jeromin, F., Rief, W., & Barke, A. (2016). Using two web-based addiction Stroops to measure the attentional bias in adults with Internet gaming disorder. *Journal of Behavioral Addictions, 5*(4), 666–673. https://doi.org/10.1556/2006.5.2016.075.

Johnson, D., Gardner, J., & Sweetser, P. (2016). Motivations for videogame play: Predictors of time spent playing. *Computers in Human Behavior, 63*, 805–812. https://doi.org/10.1016/j.chb.2016.06.028 .

Kaye, L. K. (2016). Exploring flow experiences in cooperative digital gaming contexts. *Computers in Human Behavior, 55*, 286–291. https://doi.org/10.1016/j.chb.2015.09.023.

Kellaris, J. J., & Kent, R. J. (1992). The influence of music on consumers' temporal perceptions: does time fly when you're having fun? *Journal of Consumer Psychology, 1*(4), 365–376. https://doi.org/10.1016/S1057-7408(08)80060-5.

Khang, H., Kim, J. K., & Kim, Y. (2013). Self-traits and motivations as antecedents of digital media flow and addiction: The Internet, mobile phones, and video games. *Computers in Human Behavior, 29*(6), 2416–2424. https://doi.org/10.1016/j.chb.2013.05.027.

Kladopoulos, C. N., Hemmes, N. S., & Brown, B. L. (2004). Prospective timing under dual-task paradigms: Attentional and contextual-change mechanisms. *Behavioural Processes, 67*(2), 221–233. https://doi.org/10.1016/j.beproc.2003.12.004 .

Ko, C.-H., Liu, G.-C., Yen, J.-Y., Chen, C.-Y., Yen, C.-F., & Chen, C.-S. (2013). Brain correlates of craving for online gaming under cue exposure in subjects with Internet gaming addiction and in remitted subjects: Online gaming craving. *Addiction Biology, 18*(3), 559–569. https://doi.org/10.1111/j.1369-1600.2011.00405.x .

Krishnan, L., Kang, A., Sperling, G., & Srinivasan, R. (2013). Neural strategies for selective attention distinguish fast-action video game players. *Brain Topography, 26*(1), 83–97. https://doi.org/10.1007/s10548-012-0232-3.

Laffan, D. A., Greaney, J., Barton, H., & Kaye, L. K. (2016). The relationships between the structural video game characteristics, video game engagement and happiness among individuals who play video games. *Computers in Human Behavior, 65*, 544–549. https://doi.org/10.1016/j.chb.2016.09.004.

Lau-Zhu, A., Holmes, E. A., Butterfield, S., & Holmes, J. (2017). Selective association between Tetris game play and visuospatial working memory: A preliminary investigation. *Applied Cognitive Psychology, 31*(4), 438–445. https://doi.org/10.1002/acp.3339 .

Lee, J., Lee, S., Chun, J. W., Cho, H., Kim, D., & Jung, Y.-C. (2015). Compromised prefrontal cognitive control over emotional interference in adolescents with internet gaming disorder. *Cyberpsychology, Behavior and Social Networking, 18*(11), 661–668. https://doi.org/10.1089/cyber.2015.0231.

Levin, I., & Zakay, D. (1989). Advances in psychology. In *Time and human cognition: a life-span perspective* (p. 59). Oxford: North-Holland.

Limperos, A. M., Schmierbach, M. G., Kegerise, A. D., & Dardis, F. E. (2011). Gaming across different consoles: Exploring the influence of control scheme on game-player enjoyment. *Cyberpsychology, Behavior and Social Networking, 14*(6), 345–350. https://doi.org/10.1089/cyber.2010.0146 .

Liu, C.-C., & Chang, I.-C. (2016). Model of online game addiction: The role of computer-mediated communication motives. *Telematics and Informatics, 33*, 904–915. https://doi.org/10.1016/j.tele.2016.02.002 .

Liu, L., Yip, S. W., Zhang, J.-T., Wang, L.-J., Shen, Z.-J., Liu, B., Ma, S. S., Yao, Y. W., & Fang, X.-Y. (2017). Activation of the ventral and dorsal striatum during cue reactivity in Internet gaming disorder: Activation of the ventral and dorsal striatum. *Addiction Biology, 22*(3), 791–801. https://doi.org/10.1111/adb.12338 .

Lorenz, R. C., Krüger, J.-K., Neumann, B., Schott, B. H., Kaufmann, C., Heinz, A., & Wüstenberg, T. (2013). Cue reactivity and its inhibition in pathological computer game players: Cue reactivity and inhibition. *Addiction Biology, 18*(1), 134–146. https://doi.org/10.1111/j.1369-1600.2012.00491.x .

Macar, F., Grondin, S., & Casini, L. (1994). Controlled attention sharing influences time estimation. *Memory & Cognition, 22*(6), 673–686. https://doi.org/10.3758/BF03209252.

Malagoli, C., & Usai, M. C. (2018). WM in adolescence: What is the relationship with emotional regulation and behavioral outcomes? *Frontiers in Psychology, 9*, 844. https://doi.org/10.3389/fpsyg.2018.00844 .

Männikkö, N., Ruotsalainen, H., Miettunen, J., Pontes, H. M., & Kääriäinen, M. (2017). Problematic gaming behaviour and health-related outcomes: a systematic review and meta-analysis. *Journal of Health Psychology*, 135910531774041. https://doi.org/10.1177/1359105317740414.

Marceau, E. M., Kelly, P. J., & Solowij, N. (2018). The relationship between executive functions and emotion regulation in females attending therapeutic community treatment for substance use disorder. *Drug and Alcohol Dependence, 182*, 58–66. https://doi.org/10.1016/j.drugalcdep.2017.10.008.

Mattes, S., & Ulrich, R. (1998). Directed attention prolongs the perceived duration of a brief stimulus. *Attention, Perception, & Psychophysics, 60*(8), 1305–1317. https://doi.org/10.3758/BF03207993.

McDermott, A. F., Bavelier, D., & Green, C. S. (2014). Memory abilities in action video game players. *Computers in Human Behavior, 34*, 69–78. https://doi.org/10.1016/j.chb.2014.01.018.

Meerkerk, G.-J., Van Den Eijnden, R. J. J. M., Vermulst, A. A., & Garretsen, H. F. L. (2009). The Compulsive Internet Use Scale (CIUS): Some psychometric properties. *Cyberpsychology & Behavior, 12*(1), 1–6. https://doi.org/10.1089/cpb.2008.0181 .

Mella, N., Conty, L., & Pouthas, V. (2011). The role of physiological arousal in time perception: psychophysiological evidence from an emotion regulation paradigm. *Brain and Cognition, 75*(2), 182–187. https://doi.org/10.1016/j.bandc.2010.11.012 .

Mereu, S., & Lleras, A. (2013). Feelings of control restore distorted time perception of emotionally charged events. *Consciousness and Cognition, 22*(1), 306–314. https://doi.org/10.1016/j.concog.2012.08.004.

Metcalf, O., & Pammer, K. (2011). Attentional bias in excessive massively multiplayer online role-playing gamers using a modified Stroop task. *Computers in Human Behavior, 27*(5), 1942–1947. https://doi.org/10.1016/j.chb.2011.05.001.

Mishra, J., Zinni, M., Bavelier, D., & Hillyard, S. A. (2011). Neural basis of superior performance of action videogame players in an attention-demanding task. *Journal of Neuroscience, 31*(3), 992–998. https://doi.org/10.1523/JNEUROSCI.4834-10.2011.

Mukherjee, K. (2010). A dual system model of preferences under risk. *Psychological Review, 117*(1), 243–255. https://doi.org/10.1037/a0017884.

Myrseth, H., Notelaers, G., Strand, L. Å., Borud, E. K., & Olsen, O. K. (2017). Introduction of a new instrument to measure motivation for gaming: The electronic gaming motives questionnaire: the electronic gaming motives questionnaire. *Addiction, 112*(9), 1658–1668. https://doi.org/10.1111/add.13874 .

Noël, X., Brevers, D., & Bechara, A. (2013). A neurocognitive approach to understanding the neurobiology of addiction. *Current Opinion in Neurobiology, 23*(4), 632–638. https://doi.org/10.1016/j.conb.2013.01.018.

Nuyens, F., Kuss, D. J., Lopez-Fernandez, O., & Griffiths, M. D. (2017). The experimental analysis of problematic video gaming and cognitive skills: A systematic review. *Journal de Thérapie Comportementale et Cognitive, 27*(3), 110–117. https://doi.org/10.1016/j.jtcc.2017.05.001 .

Nuyens, F., Kuss, D. J., Lopez-Fernandez, O., & Griffiths, M. D. (2018). The empirical analysis of non-problematic video gaming and cognitive skills: A systematic review. *International Journal of Mental Health and Addiction, 17*, 389–414. https://doi.org/10.1007/s11469-018-9946-0 .

Osugi, T., Takeda, Y., & Murakami, I. (2016). Inhibition of return shortens perceived duration of a brief visual event. *Vision Research, 128*, 39–44. https://doi.org/10.1016/j.visres.2016.08.007.

Perbal, S., Droit-Volet, S., Isingrini, M., & Pouthas, V. (2002). Relationships between age-related changes in time estimation and age-related changes in processing speed, attention, and memory. *Aging, Neuropsychology, and Cognition (Neuropsychology, Development and Cognition: Section B), 9*(3), 201–216. https://doi.org/10.1076/anec.9.3.201.9609.

Rau, P.-L. P., Peng, S.-Y., & Yang, C.-C. (2006). Time distortion for expert and novice online game players. *CyberPsychology & Behavior, 9*(4), 396–403. https://doi.org/10.1089/cpb.2006.9.396 .

Ravaja, N., Saari, T., Salminen, M., Laarni, J., & Kallinen, K. (2006). Phasic emotional reactions to video game events: A psychophysiological investigation. *Media Psychology, 8*(4), 343–367. https://doi.org/10.1207/s1532785xmep0804_2 .

Rivero, T. S., Covre, P., Reyes, M. B., & Bueno, O. F. A. (2012). Effects of chronic video game use on time perception: Differences between sub- and multi-second intervals. *Cyberpsychology, Behavior and Social Networking, 16*(2), 140–144. https://doi.org/10.1089/cyber.2012.0103 .

Rumpf, H.-J., Achab, S., Billieux, J., Bowden-Jones, H., Carragher, N., Demetrovics, Z., Higuchi, S., King, D. L., Mann, K., Potenza, M., Saunders, J. B., Abbott, M., Ambekar, A., Aricak, O. T., Assanangkornchai, S., Bahar, N., Borges, G., Brand, M., Chan, E. M. L., Chung, T., Derevensky, J., Kashef, A. E., Farrell, M., Fineberg, N. A., Gandin, C., Gentile, D. A., Griffiths, M. D., Goudriaan, A. E., Grall-Bronnec, M., Hao, W., Hodgins, D. C., Ip, P., Király, O., Lee, H. K., Kuss, D., Lemmens, J. S., Long, J., Lopez-Fernandez, O., Mihara, S., Petry, N. M., Pontes, H. M., Rahimi-Movaghar, A., Rehbein, F., Rehm, J., Scafato, E., Sharma, M., Spritzer, D., Stein, D. J., Tam, P., Weinstein, A., Wittchen, H. U., Wölfling, K., Zullino, D., & Poznyak, V. (2018). Including gaming disorder in the ICD-11: the need to do so from a clinical and public health perspective. *Journal of Behavioral Addictions, 7*(3), 556–561. https://doi.org/10.1556/2006.7.2018.59.

Sackett, A. M., Meyvis, T., Nelson, L. D., Converse, B. A., & Sackett, A. L. (2010). You're having fun when time flies: the hedonic consequences of subjective time progression. *Psychological Science, 21*(1), 111–117. https://doi.org/10.1177/0956797609354832.

Salminen, M., & Ravaja, N. (2007). Oscillatory brain responses evoked by video game events: The case of Super Monkey Ball 2. *Cyberpsychology & Behavior, 10*(3), 330–338. https://doi.org/10.1089/cpb.2006.9947 .

Sanders, T., & Cairns, P. (2010). Time perception, immersion and music in videogames. *Proceedings of the 2010 British Computer Society Conference on Human-Computer Interaction, BCS-HCI 2010,* Dundee, United Kingdom, 6-10 September 2010, 160–167.

Schubert, T., Finke, K., Redel, P., Kluckow, S., Müller, H., & Strobach, T. (2015). Video game experience and its influence on visual attention parameters: An investigation using the framework of the theory of visual attention (TVA). *Acta Psychologica, 157*, 200–214. https://doi.org/10.1016/j.actpsy.2015.03.005 .

Seo, M., Kang, H. S., & Chae, S.-M. (2012). Emotional competence and online game use in adolescents. *Computers, Informatics, Nursing, 30*(12), 640–646. https://doi.org/10.1097/NXN.0b013e318261f1a6.

Seya, Y., & Shinoda, H. (2016). Experience and training of a first person shooter (FPS) game can enhance useful field of view, working memory, and reaction time. *International Journal of Affective Engineering, 15*(3), 213–222. https://doi.org/10.5057/ijae.IJAE-D-15-00014.

Shin, M., Heard, R., Suo, C., & Chow, C. M. (2012). Positive emotions associated with "Counter-Strike" game playing. *Games for Health Journal, 1*(5), 342–347. https://doi.org/10.1089/g4h.2012.0010.

Statista (2018a). Number of active video gamers worldwide from 2014 to 2021 (in millions). Retrieved August 13, 2019, from: https://www.statista.com/statistics/748044/number-video-gamers-world/ . Accessed 13 Aug 2019

Statista (2018b). Number of mobile phone users worldwide from 2015 to 2020 (in billions). Retrieved August 13, 2019, from: https://www.statista.com/statistics/274774/forecast-of-mobile-phone-users-worldwide/

Taechoyotin, P., Tongro, P., & Piyaraj, P. (2018). Prevalence and associated factors of Internet gaming disorder among secondary school students in Chachoengsao Province, Thailand. *Revue d'Épidémiologie et de Santé Publique, 66*, S419. https://doi.org/10.1016/j.respe.2018.05.498.

Thalemann, R., Wölfling, K., & Grüsser, S. M. (2007). Specific cue reactivity on computer game-related cues in excessive gamers. *Behavioral Neuroscience, 121*(3), 614–618. https://doi.org/10.1037/0735-7044.121.3.614.

Tian, Y., Liu, P., & Huang, X. (2018). The role of emotion regulation in reducing emotional distortions of duration perception. *Frontiers in Psychology, 9*, 347. https://doi.org/10.3389/fpsyg.2018.00347.

Tobin, S., & Grondin, S. (2009). Video games and the perception of very long durations by adolescents. *Computers in Human Behavior, 25*(2), 554–559. https://doi.org/10.1016/j.chb.2008.12.002.

Torres-Rodríguez, A., Griffiths, M. D., Carbonell, X., Farriols-Hernando, N., & Torres-Jimenez, E. (2019). Internet gaming disorder treatment: A case study evaluation of four different types of adolescent problematic gamers. *International Journal of Mental Health and Addiction, 17*, 1–12. https://doi.org/10.1007/s11469-017-9845-9 .

van Holst, R. J., Lemmens, J. S., Valkenburg, P. M., Peter, J., Veltman, D. J., & Goudriaan, A. E. (2012). Attentional bias and disinhibition toward gaming cues are related to problem gaming in male adolescents. *Journal of Adolescent Health, 50*(6), 541–546. https://doi.org/10.1016/j.jadohealth.2011.07.006.

Villani, D., Carissoli, C., Triberti, S., Marchetti, A., Gilli, G., & Riva, G. (2018). Videogames for emotion regulation: A systematic review. *Games for Health Journal, 7*(2), 85–99. https://doi.org/10.1089/g4h.2017.0108 .

Wan, C.-S., & Chiou, W.-B. (2006). Psychological motives and online games addiction: A test of flow theory and humanistic needs theory for Taiwanese adolescents. *Cyberpsychology & Behavior, 9*(3), 317–324. https://doi.org/10.1089/cpb.2006.9.317 .

Wang, L., Wu, L., Wang, Y., Li, H., Liu, X., Du, X., & Dong, G. (2017). Altered brain activities associated with craving and cue reactivity in people with internet gaming disorder: Evidence from the comparison with recreational internet game users. *Frontiers in Psychology, 8*, 1150. https://doi.org/10.3389/fpsyg.2017.01150 .

Watt, J.D., (1991). Effect of boredom proneness on time perception. *Psychological Reports, 69,* 323-327.

Wichstrøm, L., Stenseng, F., Belsky, J., von Soest, T., & Hygen, B. W. (2018). Symptoms of internet gaming disorder in youth: Predictors and comorbidity. *Journal of Abnormal Child Psychology, 47*, 71–83. https://doi.org/10.1007/s10802-018-0422-x .

Wittmann, M., Leland, D. S., Churan, J., & Paulus, M. P. (2007). Impaired time perception and motor timing in stimulant-dependent subjects. *Drug and Alcohol Dependence, 90*(2–3), 183–192. https://doi.org/10.1016/j.drugalcdep.2007.03.005.

Wittmann, M., Rudolph, T., Linares Gutierrez, D., & Winkler, I. (2015). Time perspective and emotion regulation as predictors of age-related subjective passage of time. *International Journal of Environmental Research and Public Health, 12*(12), 16027–16042. https://doi.org/10.3390/ijerph121215034.

Wood, R. T. A., & Griffiths, M. D. (2007). Time loss whilst playing video games: Is there a relationship to addictive behaviours? *International Journal of Mental Health and Addiction, 5*(2), 141–149. https://doi.org/10.1007/s11469-006-9048-2 .

World Health Organization (2018). Gaming disorder. Retrieved August 14, 2019, from: https://www.who.int/features/qa/gaming-disorder/en/. Accessed 13 Aug 2019

Yen, J.-Y., Ko, C.-H., Yen, C.-F., Chen, S.-H., Chung, W.-L., & Chen, C.-C. (2008). Psychiatric symptoms in adolescents with Internet addiction: Comparison with substance use. *Psychiatry and Clinical Neurosciences, 62*(1), 9–16. https://doi.org/10.1111/j.1440-1819.2007.01770.x .

Yeshurun, Y., & Marom, G. (2008). Transient spatial attention and the perceived duration of brief visual events. *Visual Cognition, 16*(6), 826–848. https://doi.org/10.1080/13506280701588022.

Yip, S. W., Gross, J. J., Chawla, M., Ma, S.-S., Shi, X.-H., Liu, L., Yao, Y. W., Zhu, L., Worhunsky, P. D., & Zhang, J. (2018). Is neural processing of negative stimuli altered in addiction independent of drug effects? Findings from drug-naïve youth with internet gaming disorder. *Neuropsychopharmacology, 43*(6), 1364–1372. https://doi.org/10.1038/npp.2017.283.

Zakay, D. (2014). Psychological time as information: The case of boredom. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.00917 .

Zakay, D., & Block, R. A. (1995). An attentional-gate model of prospective time estimation. In M. Richelle, V. D. Keyser, G. D. Ydeualle, & A. Vandierendonck (Eds.), *Time and the dynamic control of behavior* (pp. 167–178). Liege: University of Liege Press.

Zélanti, P. S., & Droit-Volet, S. (2011). Cognitive abilities explaining age-related changes in time perception of short and long durations. *Journal of Experimental Child Psychology, 109*(2), 143–157. https://doi.org/10.1016/j.jecp.2011.01.003.

Zhang, Y., Ndasauka, Y., Hou, J., Chen, J., Yang, L., Zhuang, Wang, Y., et al. (2016). Cue-induced behavioral and neural changes among excessive internet gamers and possible application of cue exposure therapy to internet gaming disorder. *Frontiers in Psychology, 7*, 675. https://doi.org/10.3389/fpsyg.2016.00675.