Video Game Addiction: What Can We Learn From a Media Neuroscience Perspective?

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Abstract

In recent years, video game addiction has received considerable empirical attention. Unfortunately, this research is stymied by inconsistencies in both conceptual and operational definitions of video game addiction. Moreover, the use of several video game addiction scales makes it difficult to estimate the prevalence and potential effects of video game addiction. While game genre is often treated as a predictor of video game addiction, existing measures often downplay the structural and social characteristics of video games that may contribute to behavioral outcomes such as increased playing time and addiction. In an effort to provide the clarity necessary to overcome these issues, we review research on video game addiction with a focus on the largely ignored unique characteristics of video games that are crucial for a more complete conceptualization of video game addiction. With this review in mind, we offer a conceptual framework for the integration of video game addiction within the broader context of behavioral addictions. Finally, we consider the neurological foundation of addiction and suggest opportunities for media neuroscientists to increase understanding and prediction of video game addiction and explore how game content features interact with reward systems in the brain.

Resumen

Adicción a los Videojuegos: ¿Qué podemos aprender desde la perspectiva de la neurociencia de la comunicación? En los últimos años, la adicción a los videojuegos ha recibido una atención empírica considerable. Desafortunadamente, la investigación en este campo se encuentra obstaculizada por inconsistencias en definiciones conceptuales y operacionales de la adicción a los videojuegos. Por otro lado, el uso de varias escalas de adicción a los videojuegos dificulta la estimación de la prevalencia y los efectos potenciales de la adicción a los videojuegos. Mientras el género del juego es considerado frecuentemente como un predictor de la adicción a los videojuegos, las medidas existentes restan importancia a las características sociales y estructurales de los videojuegos que pueden contribuir a resultados conductuales tales como un incremento en el tiempo de juego y adicción. En un esfuerzo por proveer de claridad necesaria para subsanar estos problemas, se realiza una revisión sobre investigaciones relacionadas a la adicción a los videojuegos con un enfoque en las características de los videojuegos extensamente ignoradas y que son cruciales para una conceptualización más completa acerca de la adicción a los videojuegos. Con esta revisión, ofrecemos un marco conceptual para la integración de la adicción a los videojuegos dentro de un contexto más amplio como el de las adicciones conductuales. Finalmente, consideramos la base neurológica de la adicción y sugerimos oportunidades para los neurocientíficos de la comunicación con el objetivo de incrementar la comprensión y predicción de la adicción a los videojuegos y explorar cómo los elementos de un juego interactúan con los sistemas de recompensa en el cerebro.

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1. Introduction

Video game addiction is a topic of increasing interest for both researchers and the general public. Perhaps one of the best indicators of this increased focus is the recent inclusion of Internet Gaming Disorder (IGD) to Section III of the Diagnostic and Statistical Manual (DSM-V; American Psychological

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Association, 2013) as an issue warranting further study. While IGD is not included in the main DSM book as a formal disorder, this choice demonstrates a specific and somewhat narrowly focused interest in the effects of online games. However, we adopt a more general view and propose that content features in video games, both online and offline, are a crucial and largely overlooked aspect that may contribute to video game addiction. Over the past three decades, research on the topic of video game addiction has increased steadily with the early 2000s marking an important turning point both for the video games industry as well as research on video games and addiction. This last decade was characterized by growth in the number of video game players as well as the expansion of video games into online environments. Research followed suit by investigating how these new avenues for play impacted game addiction (Griffiths, Kuss, & King, 2012). Today, 59% of Americans play video games (Entertainment Software Association, 2014). Western Europe and Singapore show similar rates of play (Quandt, Chen, Mäyrä, & Van Looy, 2014). For millions of people, playing video games is part of everyday life. Therefore, it is crucial that we understand the cause and prevalence of video game addiction.

Broadly speaking, there are two types of addiction: chemical and behavioral. The mesolimbic reward system is a network of brain structures that developed to reinforce survival-relevant behaviors (Di Chiara, 1998). Traditionally, chemical addictions are characterized by a dependence on a substance that pharmacologically hijacks the reward circuitry in the brain (Karim & Chaudhri, 2012). By comparison, behavior is motivated by an interaction between the environment and evolved systems that motivate individuals to engage in rewarding activities while avoiding negative experiences (Lang, 2009). Crucially, even in the absence of drug taking, behaviors can **induce chemical changes in the brain's reward** networks that are similar to those seen in substance addiction (Koepp et al., 1998), transforming naturally occurring rewards into repetitive craving or seeking behaviors (Karim & Chaudhri, 2012). Dopaminergic dysregulation, which may reduce the ability of the prefrontal cortex to regulate behavior, is a common factor in both chemical and behavioral addictions and suggests that both chemical and behavioral addictions share common neuroadaptations. Video

game addiction has been conceptualized as a behavioral addiction (Kuss & Griffiths, 2012; Kuss, Louws, & Wiers, 2012; Ng & Weimer-Hastings, 2005). Apart from video games, the term behavioral addiction has been applied to a variety of behaviors including gambling, media use, eating disorders, physical exercise, and pathological working (Alavi et al., 2012). Importantly, addiction and addiction related disorders appear to fall on a spectrum where individuals may shift from normative behaviors towards pathological behaviors when influenced by environmental factors (Karim & Chandhuri, 2012).

Unfortunately, as this paper will discuss, video game addiction research suffers from both theoretical and operational ambiguities. For instance, a variety of terms including video game addiction, excessive game use, problematic game use, and Internet gaming disorder (among others) are used within the literature, yet they appear to be different terminology for similar phenomenon and outcomes (Griffiths et al., 2012). For the sake of clarity and consistency, we will use the term video game addiction to describe this phenomenon throughout the paper.

Researchers have used a variety of scales to measure video game addiction, most of which are adapted from criteria for gambling disorders. While parallels have been drawn between gambling disorders and video game addiction (Griffiths & Wood, 2000), there are important differences between video games and casino games. Reward structures in video games and casino games share many similarities, however one key difference between gambling and gaming is that video games do not typically feature monetary rewards.[2] Moreover, one of the latest trends in video game development is the inclusion of social features as an integral aspect of gameplay. Gambling sometimes involves multiple participants or includes social features, yet, in video game play, the social features themselves are often highly rewarding. Furthermore, gambling does not involve narratives and stories as many video games do and it is well known that humans are inherently attracted to stories as a form of survival relevant information exchange (Ohler & Nieding 2005).

Video game addiction has emerged as a topic of

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[2] There is a wide array of video game genres and some video games or game genres may feature reward schedules that resemble gambling more closely than others. While this makes heuristic sense, the truth of this is an untested empirical question.

multidisciplinary research. Our goal in this review is to synthesize current research on the topic of video game addiction and to illuminate areas where a deeper understanding is needed in order to promote progress on this topic. Therefore, we: (1) provide a review of research on video game addiction, (2) discuss the unique characteristics of video games that are crucial for any conceptualization of video game addiction, (3) integrate this research within the broader context of behavioral addictions and their neurological foundation, and (4) suggest avenues for media neuroscientists to increase the understanding and prediction of video game addiction by exploring how game content features interact with reward systems in the brain. This includes suggestions for sound neuroscientific investigations of video game addiction, even as scholars work to develop a formalized and widely agreed upon definition of video game addiction.

1.1. Defining and Diagnosing Video Game Addiction

Video game addiction has been the subject of cross-disciplinary research, capturing the attention of scholars in communication, psychology, psychiatry, and neuroscience. This is unsurprising since gaming is a prevalent form of entertainment around the world. However, inconsistencies in the definition of video game addiction make it problematic to compare the prevalence of this phenomenon across studies. Indeed, researchers have yet to establish a clear definition of what it means to be a gamer making it difficult to measure and compare the prevalence of gameplay, let alone pathological gameplay, between studies and across countries. This point is well demonstrated in a recent investigation of the prevalence of video game play in Germany, Belgium (Flanders), Finland, and Singapore (Quandt et al., 2014). This study compared existing studies of gameplay prevalence in these four countries. Since there is no established definition of what it means to be a gamer, each study used different criteria to classify individuals as gamers. Quandt et al. (2014) found that in Finland, Flanders, and Singapore, 40-50% of the population are gamers while in Germany, 25% of the population are gamers. Unfortunately, it is difficult to assess if these values reflect actual differences in prevalence or if they are the result of **differing definitions of "gamer" across all four studies.**

Unfortunately, this all too common issue may be partially to blame for the wide variation in estimates of video game addiction. Studies from various Western countries indicate that addiction affects between 1.5% and 11.6% of gamers (Kuss, van Rooij, Shorter, Griffiths, & van de Mheen, 2013). A more recent representative study in Germany indicated that 0.2% of individuals across all age groups are addicted and 3.7% are problematic users (Festl, Scharkow, & Quandt, 2013), whereas a study in the Netherlands focusing on game usage in adolescents between the ages of 13 and 16 found that 3% of adolescent online gamers are addicted (van Rooij, Schoenmakers, Vermulst, van den Eijnden, & van de Mheen, 2011). A representative sample of high school students in Connecticut (United States of America) found that 5.9% of boys and 3% of girls were classified as problematic gamers (Desai, Krishnan-Sarin, Cavallo, & Potenza, 2010). A meta-analysis of the prevalence of video game addiction found that the most precise measures indicate that 3.1% of gamers are problematic gamers (Ferguson, Coulson, & Barnett, 2011). These results suggest that there is a problem: inconsistent definitions of addiction and gamer, coupled with different sampling strategies, make it difficult to grasp the true extent of video game addiction around the world.

1.2. Diagnosing Video Game Addiction

A potential explanation for differing results is the use of multiple measurement scales. The problem video game playing (PVP) short scale (Tejeiro Salguero & Bersabé Morán, 2002) was adapted from DSM criteria for substance dependency and focuses on seven dimensions of problematic game use (preoccupation, loss of control, withdrawal, escape, lies and deception, disregard for physical and psychological consequences, and family and school related disruptions). The game addiction scale (GAS; Lemmens, Valkenberg, & Peter, 2009) is modified from the DSM criteria for gambling disorders and it focuses on seven somewhat different dimensions of problematic use (salience, tolerance, mood modification, withdrawal, relapse, conflict, and problems). Gentile (2009) utilized an 11-item pathological gaming scale based on the DSM-IV criteria for pathological gambling and included somewhat similar dimensions (salience, euphoria or relief, withdrawal, relapse and reinstatement). Critically, these scales employ different cut-off points for quantifying normal, problematic, and addictive

gameplay, which may lead to different estimations of the prevalence of video game addiction and problematic game use. For example, Gentile (2009) classified gamers as addicted if they selected 6 of 11 items on the scale. The GAS short scale (Lemmens et al., 2009) classifies individuals as addicted users if they demonstrate strong agreement with each of the 7 scale items. And Tejeiro Salguero and Bersabé Morán (2002) indicated that further research should be conducted to determine the appropriate cut-off point for their scale.

Video game addiction scales such as the GAS comprise two distinct factors: high engagement and problems related to video game play (Brunborg, Hanss, Mentzoni, & Pallesen, 2015). Scales that diagnose gamers as addicted if they demonstrate agreement with only a portion of the scale items (e.g., Gentile, 2009) may be classifying highly engaged gamers as problematic gamers. Brunborg et al. (2015) demonstrated that the GAS is a two-dimensional scale with four core criteria that relate to video game addiction (withdrawal, relapse, conflict, and problems) and three peripheral criteria (salience, tolerance, and mood modification) that relate to high engagement. Some researchers have considered using only the four core criteria to diagnose video game addiction. Importantly, when using only the four core criteria (rather than the full seven-item scale), more individuals are classified as addicted (Brungborg et al., 2015). It is unclear if individuals classified as addicted using only the four core features should be classified as addicted or if high engagement is a necessary component of video game addiction.

These findings highlight the importance of creating an agreed upon definition and measure of video game addiction. Utilizing scales that categorize highly engaged players as addicted, or scales that ignore high engagement may lead to an overestimation of the prevalence of video game addiction. Video game research, including research on the topic of pathological gaming, is susceptible to moral panic (Barnett & Coulson, 2010; Ferguson et al., 2011). Ferguson et al. (2011) suggest that, "moral panics result in crises being manufacture by well-meaning but ideologically biased scholars and **advocates, regardless of evidence to the contrary"** (p. 1577). A number of individuals undoubtedly suffer from video game addiction, but until the criteria for assessing video game addiction are firmly established, it is difficult to justify appropriate levels of concern.

Encouragingly, longitudinal studies suggest that for many gamers, video game addiction is not a long-term problem (Scharkow, Festl, & Quandt, 2014; King, Defabbro, & Griffiiths, 2013; van Rooij et al., 2011). Scharkow et al. (2014) found that among addicted gamers, 75% ceased to exhibit symptoms of addiction two years later. King et al. (2013) found that for both normal gamers and problematic gamers, scores on the problematic video game playing test decreased over an 18-month period. By comparison, van Rooij et al. (2011) found that after 1 year, half of the addicted gamers in their sample still showed signs of game addiction. Gentile et al. (2011) suggest that pathological gaming is not a passing phase of adolescence and found a higher retention rate of addictive gameplay behavior indicating that 84% of pathological gamers continued to show signs of pathological gaming 2 years later. Unfortunately, each study utilized a different measurement scale to access addiction. Scharkow et al. (2014) used the GAS short scale, King et al. (2013) asked participants to self-identify as problematic users in addition to using the problematic video game playing test, van Rooij et al. (2011) used a compulsive Internet use scale and measured video game playing time, and Gentile et al. (2011) utilized a scale based on the DSM criteria for problematic gambling. Perhaps the variation in results found in these four studies is an indication that some scales are more sensitive to problematic behaviors than other, or that some problematic behaviors are more likely to persist over time.

A related issue is that these scales do not necessarily measure an important component of video game addiction; that is, the negative consequences and conflict experienced by individuals as a result of video game addiction. Griffiths (2009) argues that, while some gamers do experience negative outcomes as a result of excessive game use, other excessive gamers may be using gameplay to add structure to their lives or to socialize when their social groups are disrupted (e.g., after graduating from college or moving to a new location). For this second group of excessive gamers, new activities (such as starting a full-time job or entering a new relationship) begin to displace gameplay to the point where playtime is reduced and is no longer assessed as problematic. Unlike substance addictions, video

game addiction may be a temporary condition used to fill time or to add structure to an individual's life in the absence of other activities. Taken together, inconsistent and incomplete measurement may explain the variation in addiction retention rates observed in longitudinal studies. While pinpointing exact retention rates is still problematic, it is clear that for many individuals, video game addiction is not a long-term problem.

1.3. Predictors and Consequences of Video Game Addiction

Several researchers have focused on finding personality, biological, and environmental factors that predict or are associated with video game addiction. While many studies have indicated that male gender predicts or is associated with video game addiction (Rehbein & Baier, 2013; Zanetta Dauriat et al., 2011; Ko, Yen, Chen, Chen, & Yen, 2005), Festl et al. (2013) found that 4.1% of males and 3.2% of females are problematic gamers. This finding suggests that the absolute differences in rates of addiction between males and females are rather small. While several studies have indicated that video game addiction is more prevalent in adolescent and young-adult males, sampling bias may play a role in these findings since many of these studies rely on self-selected samples and males are over-represented in these samples (Griffiths et al., 2012). Other potential predictors of video game addiction for adolescents include: living in single-parent households, gaming time, and the use of violent games (Rehbein & Baier, 2013). Children who demonstrate impulsive behavior, who have lower social competence and empathy, or who have poor emotion regulation are also more likely to develop a game addiction (Gentile et al., 2011).

In addition to looking for predictors, researchers have examined negative consequences and outcomes related to video game addiction. Spending excessive amounts of time gaming can lead to a variety of negative consequences such as forfeiting time for family, friends, work, education, and sleep, and it can increase stress and lower psychological well being (Griffiths et al., 2012). Pathological gaming in children is associated with lower grades and poorer parent-child relationships (Gentile et al., 2011). Video game addiction is also associated with negative physiological consequences such as epileptic seizures, obesity, wrist and neck pain, sore tendons, numbness of extremities, and sleep abnormalities (Griffiths et al., 2012).

While previous research suggests that video game addiction is a problem—at least for some individuals—there is disagreement about how to define and measure this phenomenon. The variety of measurement instruments used to classify video game addiction may explain the wide range of estimates for game addiction. This is a serious issue for addiction research since indecision about the cut-off points in these measures may lead to an inaccurate diagnosis of video game addiction. These issues are further confounded as game addiction scales frequently use outcomes (e.g., playing time) to define addiction, are modified from scales created to diagnose other addiction phenomenon, and ignore the very characteristics of video games that may cause addiction in the first place. As the next section will demonstrate, video games contain unique content features and mechanisms that, for some individuals, may contribute to video game addiction.

1.4. The Characteristics of Video Games that Contribute to Addiction

Game genre has been implicated as a predictor of addiction and some genres of games are more strongly associated with addiction than others. For instance, massively multiplayer online role playing games (MMORPGs) are associated with increased playing time and gaming addiction (Berle, Starcevic, Porter, & Fenech, 2014; Zagalo & Gonçalves, 2014; van Rooij et al., 2011; Ng & Wiemer-Hastings, 2005). MMORPG design encourages social interaction and interdependence between players since each player has access to only a limited number of in-game skills. Thus, in order to progress and achieve game goals, players must collaborate (Zagalo & Gonçalves, 2014). Other game genres associated with addiction include first-person shooter, action-adventure, and gambling games (Elliott, Golub, Ream, & Dunlap, 2012). While game genre may be an important component of video game addiction, communication scholars can lend their knowledge of game content features to the study of video game addiction in order to gain a deeper understanding of which specific mechanisms within games lead to different behavioral outcomes.

In the area of problematic gambling, researchers have recognized that the structural characteristics of slot machine programs contribute to continued use of slot machines (Griffiths & Wood, 2000). Various structural characteristics of gambling machines,

including the probability of winning, light and sound effects, and event frequency, have the potential to promote excessive gambling and can produce psychologically rewarding experiences, even while players are losing (Griffiths, 1993). Drawing on this body of research, video game addiction researchers have begun to explore the relationship between specific video game features and excessive use of video games. As a starting point, early work in this area identified content features that are important to players. Wood, Griffiths, Chappell, and Davies (2004) surveyed a self-selected sample of gamers and identified 12 content features that are important to all players including: sound, graphics, background and setting, duration of game, rate of play, advancement rate, use of humor, control options, game dynamics, winning and losing features, character development, brand assurance, and multiplayer features. King, Delfabbro, and Griffiths (2010a) identified psycho-structural elements that may be related to problematic game play. They proposed a taxonomy of features that contribute to video game enjoyment including social, manipulation and control, narrative and identity, reward and punishment, and presentation. These features and their relevant theoretical foundations provide a catalyst for research in the area of video game addiction. An empirical follow-up study (King, Delfabbro, & Griffiths, 2010b) demonstrated that reward and punishment features (i.e., earning points, finding rare items) were rated as the most important and enjoyable aspects of gameplay. However, determining which features of gameplay are important to players does not necessarily explain why players engage in specific behaviors, or what game features contribute to addiction.

While much of the research on game content and enjoyment has been descriptive, nascent experimental research is beginning to test associations between game features and individual differences in playing behavior. Chumbley and Griffiths (2006) examined the effects of reward and reinforcement features (along with the level of trait impulsivity, gender, and player experience) on self-reported affective response and willingness to continue gameplay. They found that trait impulsivity was not a significant predictor of propensity to play. However, an increase in the ratio of positive reinforcement to negative reinforcement features

increased self-reported propensity to continue playing and to return to gameplay in the future. This provides evidence that manipulating content features, such as reward structures, in games may lead to an increase in playing time that works independently of self-regulation mechanisms.

Reward and punishment features in games are informed by theories of reward schedules in behavioral psychology. Operant conditioning theory indicates that the reward schedule (e.g., the distribution of rewards) is more important than the rewards themselves for determining behavior (Ferster & Skinner, 1957). Variable reinforcement, versus continuous reinforcement, sustains behavior (Fester & Skinner, 1957) and it has been widely demonstrated that partial reinforcement is more effective at maintaining behavior than continuous reinforcement (Jenkins, 1962; Theios, 1962). It is common for video games to provide players with rewards, such as points, in-game items, or character experience, for little effort early on in gameplay. As players progress through a game, the reward structure often becomes less predictable and rewards more difficult to achieve. While an increase in positive reinforcement characteristics (in relation to negative reinforcement characteristics) increases the likelihood that players will continue to play a game and return to gameplay in the future (Chumbley & Griffiths, 2006), game designers may also adopt a sporadic reward structure by programing payouts that only occur a small number of times for a given action. These findings are consistent with operant conditioning theory. When playing games with intermittent rewards (e.g., partial reinforcement effects), players are less likely to quit gameplay in comparison to games featuring predictable rewards (King et al., 2010a). Behavioral research often used highly controlled environments, such as the Skinner Boxes that used just one stimulus to test operant conditioning and reward sensitivity. Video games provide players with multiple short and long term goals, allow players to choose which goals to peruse, and allow players to simultaneously work towards multiple goals. Reward schedules in games are likely to fall along a continuum with some video games resembling a partial reinforcement schedule and others resembling a continuous reinforcement schedule. Since video games employ a variety of rewards, it is likely that games feature a complex mix of both reward schedules where perhaps larger

rewards (e.g., completing quests, acquiring rare in-game items) follow a sporadic partial reinforcement schedule and smaller rewards (e.g., in-game money or points) are awarded to players continuously.

As the next section will demonstrate, combining knowledge of specific content features with a neurophysiological understanding of human behavior can help to determine how game mechanisms lead to excessive playing time or addiction for some players. Conceptualizing video game addiction as a behavioral addiction driven by variable reward payout structures is a first step toward overcoming existing conceptual and operational ambiguities. Current conceptualizations and measures of addiction have been derived from other problematic and addictive behaviors. Incorporating the content features that are unique to video games into the definition of video game addiction may help to resolve conceptual ambiguities. One avenue for accomplishing this objective considers how reward structures in games contribute to addiction. This also provides a foundation for integrating research on video game addiction within a broader body of neuroscientific research attempting to identify the neural substrates of addiction. In the next sections, we will review the neuroscientific literature on behavioral addiction and discuss what can be gained from the integration of neuroscience and more traditional behavioral investigations into video game addiction.

1.5. The Neuroscience of Behavioral Addiction

Whereas chemical addiction research focuses on the pharmacological effects of exogenous drugs on reward networks in the brain (Karim & Chaudhri, 2012), behavioral addiction research investigates how behavior modulates brain chemistry in these same neural networks. The current section has two main goals: (1) to broadly explore neuroscientific research on behavioral addictions including Internet addiction and video game addiction and (2) to explore how game content features might stimulate the reward system in the brain.

Dopamine is a neurotransmitter involved in processes such as learning, behavior reinforcement, attention, and sensorimotor integration (Schultz, Apicella, & Ljungberg, 1993; Robbins & Everitt, 1992). In animal studies, dopaminergic neurotransmission has been associated with sensorimotor function related to rewarding, aversive, and stressful stimuli (Robbins & Everitt, 1992). Dopamine is also thought to

be a crucial link between reward and addiction. Indeed, dopamine is one of the most commonly investigated neurotransmitters studied in neuroscientific investigations of gameplay behavior and video game addiction. For instance, Koepp et al. (1998) used positron emission tomography (PET) to demonstrate that dopamine is released in the human striatum during video game play. Importantly, this showed for the first time the behavioral conditions under which dopamine is released in humans and demonstrated that a behavior, in this case playing a video game, can lead to changes in brain chemistry that are similar to pharmacologically induced changes. Since then, an abundance of evidence has implicated the dopaminergic system in the regulation of rewarding behaviors as well as behavioral addictions (Karim & Chaudhri, 2012).

Investigations of the dopaminergic system have shed light on the neurobiological mechanisms of Internet gaming disorder (IGD). Tian et al. (2014) used PET to assess dopamine and serotonin receptors in the brain and found that dopamine is associated with glucose metabolism in individuals with IGD. This suggests that dopamine receptors may play an important role in the mechanism for loss of control and compulsive behavior associated with IGD. Compared to the control group, participants with IGD demonstrated dysregulation of dopamine receptors in the orbitofrontal cortex, suggesting a loss of control over compulsive behavior. Related research has used electroencephalography (EEG) to examine the cognitive effects of Internet addiction disorder (IAD). Participants with IAD demonstrate lower impulse control and less efficiency in information processing (Dong, Lu, Zhou, & Zhao, 2010) and male participants with IAD demonstrate impaired executive control (Dong, Zhou, & Zhao, 2011). A study utilizing an event related fMRI Stroop test demonstrated that participants in the IAD group exhibited less efficiency of response inhibition processes and demonstrated greater neural activity in the anterior cingulate cortex (a structure which is integral to cognitive control) compared to the non-IAD group (Dong, DeVito, Du, & Cui, 2012).

Self-regulation is an important aspect of behavioral control and has important implications for behavioral addiction research, including video game addiction. Differences in self-regulation and impulse control may help predict susceptibility to video game

addiction. Neuroimaging research investigating the neural correlates of self-regulation suggest that self-regulation of behavior is dependent on a balance between activation in the prefrontal cortex and subcortical regions in the brain (Heatherton & Wagner, 2011) where the self-regulation of behavior requires top-down control from the prefrontal cortex. The prefrontal cortex exerts control over the subcortical regions of the brain involved in the regulation of reward and emotion. Some stimuli may evoke a strong impulse, which then tips the balance in favor of bottom-up control from the subcortical regions. This increases the likelihood that an individual will fail to self-regulate behavior (Heatherton & Wagner, 2011). In previous studies, trait impulsivity has not been implicated as a predictor of video game addiction (Chumbley & Griffiths, 2006). This may suggest that momentary changes in self-regulation are a crucial component of behavioral control. As we will discuss, video game content features may play a role in altering this balance between the prefrontal cortex and subcortical regions.

Indeed, behavioral research suggests that the reward schedule in a video game (actual versus predicted rewards) plays an important role in motivating gameplay behavior. Mathiak et al. (2011) used fMRI to investigate the role of the reward system in the affective evaluation of playing a violent first-person shooter video game. Specifically, they looked at negative reward prediction error (the decrease in neural activity that is observed when outcomes are more negative than expected). Deactivations in the caudate nucleus, a subcortical structure involved in learning processes when comparing actual versus predicted rewards, occurred when players did not receive an expected reward. Violent events were not found to be directly rewarding for the players—rather gamers played to avoid failure. More recent results further expand on these findings by demonstrating that the neural structures associated with positive and negative affect correspond to distinct neural patterns (Mathiak, Klasen, Zvyagintsev, Weber, & Mathiak, 2013). Taken together, these studies demonstrate that game outcomes (and not necessarily content) are linked with reward network activation, and that the reward network is differentially engaged depending on the valence of in-game events.

Flow, a positively valenced affective experience resulting from a balance between task challenge and individual skill (Csíkszentmihályi, 1990), is commonly offered as an explanation for why video games are enjoyable to play. Indeed, players often report that the play experience closely matches the subjective experience of flow; that is, the sensation of losing track of time, a disappearance of self-consciousness, intense concentration, and a pleasant experience that is not perceived as taxing (Sherry, 2004). While these characteristics are central to the flow experience, they **may also play a role in an individuals' inability to self**-regulate gameplay behavior (Wood & Griffith, 2007; Gentile, 2009). The rewarding nature of flow might also be implicated in video game addiction. While there still is not much empirical work in this area, a study of Taiwanese gamers found that players who have experienced flow in the past are more likely to be addicted to video games (Chou & Ting, 2003). Indeed, neural activity associated with free play in a video game environment has been shown to result in activation in reward networks (Klasen, Weber, Kircher, Mathiak, & Mathiak, 2011). However, there are several key distinctions between flow and addiction that are important to tease apart. First, flow is characterized by a positive experience whereas addiction is associated with negative outcomes such as social and psychological conflict. Secondly, having experienced flow in the past and being addicted to video games in the present is not necessarily the same thing as flow causing addiction. In the case of the Chou and Ting (2003) paper, the flow construct included a number of measures that may be both antecedents of flow or addiction (e.g., exploratory behavior, telepresence).

Neurologically, flow is thought to occur as a result of a synchronization of attentional and reward networks under conditions of a balance between task challenge and individual skill (Weber, Tamborini, Westcott-Baker, & Kantor, 2009). It may very well be that, while there is descriptive overlap in the subjective experiences that characterize flow and addictive behavior, the neural antecedents of each diverge considerably. Moreover, if flow is thought to be a cause of addiction, then we should expect much **higher rates of video game addiction as "[g]ames are** obvious flow activities and play is the flow experience par excellence" (Csíkszentmihályi, 1975, p. 36-37).

Nevertheless, there are several interesting opportunities for research in this area. The first is establishing the extent to which playing video games

results in flow for behaviorally addicted individuals as the psychological conflict associated with addiction may have a dampening effect on the flow experience. Relatedly, psychological conflict in addicted players may result in weaker functional connectivity (a measure of neural synchronization) between attentional and reward networks during video game play that balances challenge and skill. Under such circumstances, we should expect these players to report dampened flow experiences. Finally, balance theories (e.g., Heatherton & Wagner, 2011) suggest that addiction occurs when reward networks exert a bottom-up dominance over prefrontal executive control networks. Conversely, flow is thought to occur when these two networks operate simultaneously and in synchronization (Weber et al., 2009). Admittedly, the synchronization theory of flow explicitly discusses alerting and orienting attentional networks; however, more top-down executive attention networks are also thought to be relevant. While these theories specify different neural mechanisms and suggest that flow and addiction represent two distinct higher-order processes, to our knowledge, no study has directly tested these predictions.

Finally, time spent playing video games is often treated as either a predictor of or consequence of video game addiction. However, mounting evidence points to the inadequacy of simplified conceptualizations of time as an antecedent or outcome of video game addiction. For instance, a recent study investigated anatomical differences between individuals with IGD, professional gamers, and a normal control group (Han, Lyoo, & Renshaw, 2012). While the pro-gamers in this study practiced 7-10 hours each day, they did not meet the criteria for addiction. Interestingly, participants in the IGD group had increased gray matter volume in the left thalamus, a structure in the reward network, compared to the professional gamer and control groups. The authors suggested that this anatomical difference might contribute to behavioral distinctions between pro-gamers and addicted players. The same study also found significant differences in gray matter volume in the left anterior cingulate gyrus, a structure associated with executive function and self-regulation, in the addicted players when compared to the pro-gamers. Consistent with previously discussed research, a disruption of executive function in the anterior cingulate in addicted players may prevent individuals from monitoring and inhibiting inappropriate playing behaviors. These results support the argument that playing time alone is not a good indicator of game addiction, and instead suggest that video game addiction is rooted in maladaptive reward and executive processing.

These neuroscientific findings compliment more traditional investigations into media use and addiction. Understanding how rewards are processed in the brain may help us recognize how the unique content features in video games, including reward schedules, affect player behavior. For instance, previous research has demonstrated that some stimuli trigger bottom-up processing of information making self-regulation failures more likely (Heatherton & Wagner, 2011). Perhaps specific content features within video games (such as reward schedules) tip the balance towards bottom-up processing, reducing top-down control of behavior and making self-regulation failures more likely for some individuals. Understanding the role content features play in video game addiction may allow us to identify specific features that increase vulnerability to self-regulation failures for some players.

It has been suggested that trait impulsivity is not a significant predictor of self-reported propensity to play video games (Chumbley & Griffith, 2006). However, this view is difficult to reconcile with findings suggesting that self-regulation is disrupted among addicted players, but not among players who play for extended periods of time (e.g., Han et al., 2012). It may be that there are yet to be discovered conditions under which individuals are particularly vulnerable to lapses in impulse control, which may ultimately contribute to video game addiction. Perhaps specific content features of video games, such as the reward schedule or social features, affect the dopaminergic reward system or leave some individuals more vulnerable to lapses in impulse control. Studies that compare addicted users to other heavy users (e.g., pro-gamers) as well as control groups will be crucial for understanding the psychophysiological differences between heavy users and addicted users. There is considerable opportunity for empirical investigation in this domain. To date, no study has investigated the complex relationship between game content, reward structures, neural activation, and addiction. This is a crucial next-step in

disentangling video game addiction from other types of video game play. And, as our review demonstrates, a rich empirical tradition of research on video game addiction in communication and neuroscientific traditions sets the foundation for this next generation of research.

1.6. Media Neuroscience: A Neurophysiological Perspective of Video Game Addiction

Exciting research is emerging on the topic of video game addiction. Within this paper, we presented three unresolved issues in the video game addiction literature: (1) the lack of theoretical and conceptual clarity among scholars as to what the phenomenon of video game addiction is and how it should be measured, (2) that research in this area largely ignores the unique content features of video games that may contribute to video game addiction, and (3) that emerging findings in neuroscientific research suggest reward regulation and impulse control interact in important ways that shape addiction. While communication scholars have been slow to embrace neuroscientific research (Weber, Mangus, & Huskey, 2015), a growing group of media neuroscientists are working at the intersection of these two disciplines. Media neuroscience is a field of research that recognizes the brain as the center of cognition; this includes the processing of media messages (Mangus, Adams, & Weber, 2015). Media neuroscientists develop explanations for media selection, processes, and effects that account for the interaction between evolved psychological mechanisms and socio-environmental inputs (Weber, Sherry, & Mathiak, 2008). A media neuroscience perspective informs the study of video game addiction by merging the tools of neuroscience with an understanding of video game content features in order to understand how evolved psychological capacities (such as reward structures in the brain) combine with environmental inputs (such as video game content features) in order to produce effects (such as video game addiction) for some individuals.

As Han et al. (2012) demonstrated, there are clear anatomical differences between heavy game users, such as pro-gamers, and addicted users. Exploring these differences may lead to better criteria for measuring addiction. However, a sound and universally agreed upon conceptualization of video game addiction is necessary in order to conduct classical brain imaging investigations such as identifying the neural correlates of addiction. Unfortunately, as we have discussed, existing measures are insufficient. In the absence of consensus about the conceptualization of behavioral measures for video game addiction, we propose that one way to approach this topic is to utilize well-defined concepts related to addiction in the neuroscientific investigation of video game addiction. Specifically, previous research has identified several cognitive-behavioral concepts related to both chemical and behavioral addiction including: impulse control (Dong et al., 2010), response inhibition (Dong et al., 2011), cognitive control (Dong et al., 2012), and self-regulation (Heatherton & Wagner, 2011). By relying on processes that are thought to apply to addiction more generally, it is possible to approach research on video game addiction from a different angle. For instance, are there specific content features that disrupt self-regulation, cognitive control, and response inhibition? As implied by limited capacity models (e.g., Lang, 2009), are these disruptions more likely to occur when cognitive processing load is moderate (motivating approach) but not overly high (motivating avoidance)? Do dynamic changes in video game reward structures tip the balance of self-regulation from top-down executive processing to more bottom-up automatic processing, and if so, how?

Importantly, we are not proposing that exploring the link between these concepts and video game addiction replaces the need for a clear conceptualization of video game addiction. Instead, we are working towards an intermediate approach that is not hindered by a poorly specified definition of video game addiction. In fact, a benefit of this approach is that it has the potential to inform the future conceptualization of video game addiction. In this paper, we put forth the empirically testable idea that content features unique to video games can contribute to addiction. The systematic confirmation or falsification of this view will inform any eventual definition of video game addiction. This type of investigation may be the crucial next-step that moves the field beyond a reliance on playing time as a measure of addictive behavior and allows for the differentiation between those who are addicted to playing video games and those who simply spend considerable time playing video games.

As progress is made towards the conceptual refinement of video game addiction, it will be useful

to consider measures that predict video game addiction. Media neuroscientists are at the forefront of recent advances that use neural activity in relatively small samples to make accurate predictions about larger samples. This brain-as-predictor approach (Berkman & Falk, 2013; Falk, Cascio, & Coronel, 2015) has demonstrated its utility in increasing prediction accuracy above and beyond self-report measures. Several recent studies related to addiction hint at the utility of this approach. For instance, neural activation while watching anti-smoking public service announcements (PSAs) predicted smoking cessation behavior (Falk, Berkman, Whalen, & Lieberman, 2011) and smoking cessation hotline call volume (Falk, Berkman, & Lieberman, 2012) better than self-report data alone. The brain-as-predictor approach has also been applied to investigate message effectiveness in antidrug PSA campaigns (Weber, Huskey, Mangus, Westcott-Baker, & Turner, 2014). While these studies are focused on preventing chemical addictions, they hint at a possible direction for video game addiction research. By drawing on a growing corpus of brain imaging studies investigating the neural basis of video game addiction (Han et al., 2012), it may be possible to use neural activity in networks associated with reward and self-regulation to predict video game addiction. Immediate applications might draw comparisons between addicted and non-addicted video game players. However, the brain-as-predictor approach may be particularly fruitful for experimental research investigating the addictive potential of various content features. For instance, does reward network activation in response to experimentally manipulated content features predict addiction? Given that video game addiction afflicts a relatively small portion of total players, a related question would address the boundary conditions under which activation in reward networks does and does not predict addiction. Drawing on balance theories of addiction, neural activation in reward networks may only predict addiction when there is comparatively weak activation in prefrontal structures, or in instances when there is limited functional connectivity between these networks.

In addition to helping resolve current issues within the addiction literature, applying a media neuroscience perspective to video game addiction allows us to pose a variety of new questions about addiction. Gameplay is a popular form of entertainment but only a small percent of players exhibit signs of game addiction and even fewer players experience prolonged symptoms of game addiction. Moreover, video game addiction is correlated with many factors such as being male, adolescence, coming from a single-parent family, and the use of violent games (Rehbein & Baier, 2013). Are those susceptible to video game addiction wired somewhat differently from the general population? Or, as suggested by Han et al. (2012), is video game addiction associated with anatomical changes to the brain? Do these changes have long-term and self-reinforcing effects? Can neural data in response to playing video games be used to understand how content shapes addiction and to even predict addiction in independent samples? What distinguishes addiction from other higher-order psychological processes related to video game play like flow? Addressing these questions may have real-world relevance for patients, practitioners, parents, and politicians; all groups concerned about or impacted by video game addiction.

Importantly, we do not see neuroscience as a magic bullet that will resolve all conceptual ambiguities associated with video game addiction research (cf. Weber, Mangus, & Huskey, 2015). Instead, coming to an agreed upon set of criteria for what constitutes video game addiction—criteria which recognize the importance of video game content features—will allow us to begin the laborious task of understanding the neurological basis of video game addiction. In the absence of these criteria, demonstrating the role of related concepts (impulse control, response inhibition, cognitive control, self-regulation) in the development and progression of video game addiction may provide us with insight into this phenomenon and assist with developing substantive criteria for video game addiction. Finally, just as poorly operationalized measures may inflate rates of video game addiction, flawed statistical analyses of fMRI data may also result in artificially inflated outcomes (Vul, Harris, Winkielman, & Pashler 2009a, 2009b). This could fuel yet another round of moral panic as both lay and specialist audiences are apt to treat neuroscientific data as more persuasive than other empirical results (McCabe & Castel, 2008; Weisberg, Keil, Goodstein, Rawson, & Gray, 2008; but see Farah & Hook, 2013). Therefore, it is crucial that researchers apply caution in their data analysis,

reporting, and interpretation.

The success of this endeavor will require statistical precision, conceptual clarity, methodological innovation, and cross-disciplinary collaboration. Our hope is that the ideas presented in this paper will provide an important step towards advancing these objectives.

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