A multi-modal investigation of reward-based mechanisms underlying excessive and problematic social networking site use

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Thesis Abstract

The use of social networking sites (SNSs) has become a universally popular activity, but there also exists widespread concerns regarding the harmful consequences associated with SNS overuse, including the potential for addiction. Nonetheless, the extent to which a 'SNS addiction' represents a valid psychiatric disorder is still controversially discussed in the scientific literature. The present thesis sought to better understand excessive and problematic SNS use behaviours by assessing the underlying reward-based mechanisms using a range of measurement modalities (i.e., self-report, implicit behavioural, psychophysiological, and neural). Chapter two demonstrated the utility of reward-related motives in predicting problematic SNS use behaviours, with motives related to social reward (e.g., obtaining 'likes') being the strongest predictor of more harmful use. Chapter three assessed explicit and implicit motivational responses to SNS stimuli but found no clear evidence of altered explicit cue reactivity or automatic action tendencies in more problematic SNS users. Chapter four tracked changes in affective and motivational responses during a week of restricted SNS use, however findings revealed no substantial impact on mood or cravings in both regular and problematic users. Chapter five investigated the effect of brief periods of SNS use and subsequent use cessation on heart rate and skin conductance. While SNS use and cessation were associated with distinct physiological changes, these effects were experienced ubiquitously and could not differentiate problematic users from regular users. Chapter 6 systematically reviewed the MRI literature for evidence of neural abnormalities associated with SNS use. Some neural similarities with substance use addictions were identified, but existing research was scarce and findings across studies were largely inconsistent. Taken together, we did not find convincing evidence of a distinct cognitive, behavioural, or physiological profile in problematic SNS users. Therefore, the present thesis argues that conceptualising excessive or problematic SNS use as a new behavioural addiction would be premature. It is clear that SNS use is a highly rewarding and engaging activity that can be overused with negative effects, but equating this behaviour to conditions such as alcohol, cocaine, and heroin disorders risks trivialising the field of addiction research.

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Statement of Copyright

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Chapter 1

Introduction

What are social networking sites and why are they so popular: Conceptual clarification and use statistics

Human beings have been described as 'the ultra-social animal' (Tomasello, 2014). While most mammals belong to social groups, humans have developed an unparalleled ability to interact cooperatively, particularly with nonrelatives (Tomasello et al., 2012). From an evolutionary perspective, the success of our species will have undoubtably been influenced by our capacity to form social bonds, establish group norms, and communicate effectively. Evidently, social networking sites (SNSs) appeal to this fundamental and deep-rooted human desire for social interaction (Baumeister & Leary, 1995). SNSs have made the prospect of social connection more accessible by allowing us to conduct our social interactions from anywhere in the world with the press of a button, opening up channels of communication inconceivable to previous generations. By permitting users to portray only what they wish others to see, SNSs also offer an alluring sense of control over our self-image and the way we are perceived.

The first true SNS is considered to have been *SixDegrees.com*, a website created in 1997 by Andrew Weinreich (Boyd & Ellison, 2007). Its concept was based on the 'six degrees of separation' theory, which suggests that everyone is only ever six or fewer connections away from any other person. The website allowed users to create a public profile where they could list their friends and family members and browse the friend lists of other users. While limited in its scope, this idea of forming a network of personal connections through the internet certainly paved the way for SNSs as we know them today. In the early 2000's SNSs started to become mainstream, with websites including *Friendster*, *MySpace*, and *Hi5* rapidly gaining popularity. However, most of these early SNSs were eventually outcompeted by

Mark Zuckerberg's *Facebook*, which launched in 2004 (becoming public in 2006), and remains one of the most popular SNSs today (DataReportal, 2023). The later introductions of *YouTube* (2005), *Twitter* (2006) and *Instagram* (2010) also quickly grew in popularity and by 2012 it was estimated that there were 1.5 billion active SNS users worldwide (DataReportal, 2012). Now in 2023 the number of global users is estimated to have reached 4.76 billion (DataReportal, 2023)[1], representing a global penetration rate of 59.4% and an increase in users of more than 200% over the last decade. As well as a surge in the number of SNS users, people are also spending an increasing amount of time on these sites each day. The daily average time spent using SNSs has risen from 90 minutes in 2012 to 147 minutes in 2022 (Statista, 2022). Indeed, for many individuals the use of SNSs has now become so ingrained into their daily routine that it forms an integral part of their life.

The rapid increase in the popularity of SNSs has also been met with fears of the potential harms associated with the overuse of this technology. We are only just beginning to understand the impact that SNS use has on our health and wellbeing, but one widely held concern is that some individuals may have become *addicted* to using SNSs. Excessive SNS use is frequently portrayed as an addiction in mass media and public discussions (BBC News, 2021), and numerous books have been published that warn of the addictive properties of SNSs, and which encourage users to delete their SNS accounts (e.g., Alter, 2017; Lanier, 2018). Yet, the concept of a 'SNS addiction' is still a contentious issue in the scientific literature (Billieux et al., 2015; Brand et al., 2022; Carbonell & Panova, 2017; Griffiths, 2017; Kardefelt-Winther et al., 2017), and to date no formal diagnosis of 'SNS addiction' exists.

[1] It should be noted that SNS users might not represent unique individuals and thus these data may not be a true reflection of the current number of global users.

Thus, whether excessive/problematic patterns of SNS use are best conceptualised as representing an addictive disorder is a question that remains up for debate. It is precisely this debate that the present thesis set out to contribute to.

An important first consideration for this thesis is how we are to define SNSs as this will have implications for the design of the studies presented herein. Despite an already large and ever-expanding body of literature examining SNS use behaviours and their psychological, physiological and societal impact – the term 'SNS' remains rather ambiguous. For example, the terms 'social media' and 'social networking site' are often used interchangeably in the literature but can also be understood differently. Social media is a more general term that refers to "*a group of internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content*" (Kaplan & Haenlein, 2010, p. 61). This includes blogs (e.g., *Blogger*), collaborative projects (e.g., *Wikipedia*), content communities (e.g., *BookCrossing*) social networking sites (e.g., *Facebook*), virtual social worlds (e.g., *Second Life*), and virtual gaming worlds (e.g., *World of Warcraft*). Therefore, SNSs can be understood as a specific type of social media. However, the current literature still suffers from some amount of confusion and a lack of clarity regarding precisely what is and what is not considered a SNS. This is perhaps understandable given the overlap between SNSs and other forms of social media, as well as the diverse range of functionalities provided by individual SNSs that are also constantly evolving and occupying new market niches. In this sense drawing clear boundaries for what should constitute a SNS may not be possible. Nonetheless, broadly speaking SNSs can be defined as "*virtual communities where users can create individual public profiles, interact with real-life friends, and meet other people based on shared interests*" (Kuss & Griffiths,

2011, p. 3529). Another helpful distinguishing feature of modern SNSs (compared to other forms of social media) is that they typically contain a 'homepage' or 'newsfeed' feature where algorithm generated content can be viewed based on the users' preferences or past activity. Examples of some popular SNSs include *Facebook*, *Twitter*, *Instagram*, *Snapchat*, *YouTube*, *Weibo*, *TikTok*, and *BeReal*.

Some authors have also argued that instant messaging apps (e.g., *WhatsApp* and *Facebook Messenger*), online dating apps (e.g., *Tinder*) and online gaming sites (e.g., *World of Warcraft*) involve social networking and can therefore be considered SNSs (Kuss & Griffiths, 2017). However, given that the motives underlying the use of these platforms likely differ from that of the SNSs outlined above, we chose not to define such platforms as SNSs in this thesis. A large amount of previous research also investigates the problematic use of modern technologies such as the internet (Cash et al., 2012) or smartphones (Panova & Carbonell, 2018) more generally. While the use of these technologies undoubtedly encompasses the use of SNSs, internet and smartphone use also includes a broad range of other activities that are qualitatively different from SNS use (e.g., online gaming, online shopping, cybersex, online gambling). It is therefore important that research delineates between unspecific internet/smartphone use and the use of specific applications (e.g., SNSs) to avoid muddying the waters with regards to the addictive potential of different online activities. To that end, the present thesis will specifically focus on assessing the addictive potential of SNS use, rather than internet or modern technology use more broadly.

Can social networking sites be considered addictive: Diagnostic approaches to behavioural addictions and current controversies

Addiction is widely considered to be a disease that results in changes to underlying brain circuits (Volkow et al., 2016; but see also Heather et al., 2018). These neurophysiological changes lead to a loss of control over drug use and make the repeat occurrence of relapse more likely. The most recent edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) describes substance use addictions as being characterised by "*a cluster of cognitive, behavioural, and physiological symptoms indicating that the individual continues using the substance despite significant substance-related problems*" (APA, 2013b, p. 483). In addition to 10 separate classes of drugs that may cause addiction, the DSM-5 also included 'gambling disorder' as a behavioural addiction (i.e., an addiction that does not involve the ingestion of a chemical substance). While also describing 'internet gaming disorder' as a condition warranting further research, it was ultimately decided that there was insufficient evidence to classify other problematic behaviours (e.g., 'sex addiction', 'exercise addiction', 'shopping addiction') as mental disorders. However, research has progressed since the publication of the DSM-5 and in 2018 the World Health Organisation's (WHO) 11th edition of the International Classification of Diseases (ICD-11) classified gaming disorder, alongside gambling disorder, as a 'condition due to addictive behaviours' (Saunders et al., 2017; WHO, 2020). Yet, other potential behavioural addictions, including problematic SNS use, have still not been officially recognised as such.

There can be no doubt that some individuals use SNSs in a way that causes them problems. The use of SNSs can interfere with, for example: academic performance (Junco, 2012; Whelan et al., 2020), productivity at work (Moqbel &

Kock, 2018), romantic relationships (Muise et al., 2009), and self-esteem (Vogel et al., 2014), among other things. There also exists a large body of literature documenting a significant (but small) association between SNS use and depressive symptoms (Cunningham et al., 2021; Ivie et al., 2020; McCrae et al., 2017). What remains controversial is whether this interference with normal functioning is substantial enough to meet criteria for addiction. Indeed, repeated engagement with an activity despite it resulting in harmful consequences is a key defining characteristic of addictive disorders, but the extent to which problematic SNS use meets other important addiction criteria is also debateable. The DSM-5 describes 4 groupings of criteria that can be used to diagnose substance use disorders: impaired control over substance use, social impairment, risky use, and pharmacological criteria (i.e., developing tolerance to the substance and the experience of a withdrawal syndrome when use is stopped abruptly). However, some of these criteria (e.g., tolerance and withdrawal) have since been shown to have less clinical validity in diagnosing gaming disorder (Castro-Calvo et al., 2021), which may also hold true for the diagnoses of other potential behavioural addictions.

Some researchers have warned that we might be over-pathologizing excessive, but otherwise normal behaviours as addictions (Billieux et al., 2015). It is feared that such an approach could lead to the undue stigmatisation of innocuous every-day activities and may also damage the relevance and credibility of 'behavioural addictions' as a diagnostic category. There is the potential for almost any behaviour or leisure activity to be pursued to excess, and in this sense the field of behavioural addictions runs the risk of becoming so expansive that it becomes somewhat frivolous (Kardefelt-Winther et al., 2017). Amongst other behaviours, excessive tanning (Kourosh et al., 2010), cosmetic surgery (Suissa, 2008), hair

pulling (Grant et al., 2007), skin picking (Odlaug & Grant, 2010), working (Robinson, 1999), joyriding (Kellett & Gross, 2006), music consumption (Cockrill et al., 2011) and even tango dancing (Targhetta et al., 2013) have all been put forward as potential behavioural addictions. Some researchers have proposed exclusion criteria in order to prevent the field becoming inundated with new behavioural addictions, suggesting that behaviours should not be classed as an addiction when they are better explained by an underlying disorder (e.g., depressive, or impulse control disorder) or as the result of a coping strategy (e.g., as a distraction from negative emotion; Kardefelt-Winther et al., 2017). Yet, as Griffiths (2017) points out, most substance use addictions would also fail to meet these criteria, and drug abuse is not discounted as an addiction if it presents (as it frequently does) with a comorbid psychiatric condition. Given the controversy regarding the creation of new behavioural addictions, previous research has used the term 'problematic SNS use' to describe compulsive/addiction-like SNS use behaviours without assuming the presence of an addiction. In the same vein we use the term 'problematic SNS use' herein to refer to SNS behaviours that might be considered indicative of an addiction. Problematic SNS use can be defined as "*excessive use of social media platforms with detrimental consequences on the user's personal, professional, or social functioning, who experiences adverse outcomes at a psychological and social level*" (Cataldo et al., 2022, p. 1).

Another factor to consider when evaluating the addictive potential of SNS use relates to its capacity to produce sustained functional impairment. As previously discussed, there is plenty of indication that SNS use can cause problems and interfere with other activities. However, addictions are known to have severe effects on physical and psychological health. While there is clear evidence that drugs such as

alcohol and tobacco cause physical harm to the user and result in millions of premature deaths each year (WHO, 2022a, 2022b), it is debateable whether the harms attributable to SNS use alone are substantial enough to warrant a classification as a mental disorder. Despite a wealth of research associating digital technology use with increased mental health problems and poorer wellbeing (Kelly et al., 2018; Twenge, Joiner, et al., 2018; Twenge, Martin, et al., 2018), there is also an opposition to this view which argues that the harmful effects associated with SNS use are often so small as to be trivial, with many individuals also experiencing positive outcomes from their SNS use (Orben, 2020b; Orben & Przybylski, 2019; Vuorre et al., 2021). In their influential research which analysed data from more than 350,000 adolescents, Orben and Przybylski (2019) observed a small negative association between digital technology use and wellbeing, with digital screen time explaining only 0.4% of the variance in wellbeing. In line with this, it is argued that the societal fears surrounding the use of new media may reflect a 'moral panic' to this emergent technology. Originally coined by Cohen (1972), the term 'moral panic' refers to a widespread, exaggerated or unjustified fear that something immoral threatens the values and well-being of society. As Orben (2020a) points out, moral panics often occur in response to the arrival of new technologies that rapidly gain popularity. Just as concerns regarding the harmful consequences of the radio and television were once widely expressed (Dennis, 1998), today fears that SNSs may be damaging society are rife. Equally, just because worries surrounding previous technological innovations are no longer as prevalent does not mean that the putative SNS-related harms do not warrant our attention. Thus, research attempting to understand SNS behaviours and the potential for addiction is certainly needed, as the proper categorisation of mental disorders will have important implications for the

development of efficacious prevention and intervention strategies (Grant et al., 2010).

One way that research attempts to validate the construct of new behavioural addictions is to develop diagnostic tools that borrow criteria from established addictions listed in the DSM or ICD. Indeed, numerous scales purporting to assess 'SNS addiction' now exist, with a recent review identifying as many as 37 different instruments (Varona et al., 2022). Some popular examples include (but are not limited to): *Bergen Facebook Addiction Scale* (Andreassen, Torsheim, et al., 2012) or *Bergen Social Media Addiction Scale* (Andreassen et al., 2017), *Social Media Disorder Scale* (Van den Eijnden et al., 2016), *Facebook Addiction Scale* (Koc & Gulyagci, 2013), *Facebook Intrusion Questionnaire* (Elphinston & Noller, 2011) and *Assessment Criteria for Specific Internet-Use Disorders* (Müller et al., 2022). Other research has adapted the wording of scales originally designed to assess unspecific internet addiction or gaming addiction such as: *Young's Internet Addiction Test* (Young, 1998), *Compulsive Internet Use Scale* (Meerkerk et al., 2009), *Video Game Addiction Test* (van Rooij et al., 2012), *Game Addiction Scale* (Lemmens et al., 2009), and *Generalized Problematic Internet Use Scale 2* (Caplan, 2010). However, the plethora of different instruments that are available to assess 'SNS addiction' complicates our ability to compare findings between studies that employ inconsistent diagnostic criteria. In addition, the inclusion of certain criteria in some of these scales (e.g., escape/mood management criterion) have been criticised for lacking diagnostic validity and pathologizing normal use motives (Brand et al., 2020; Kuss et al., 2017). For instance, some research indicates that as many as 85% of individuals report using the internet to regulate mood/escape (Besser et al., 2019), suggesting that this criterion lacks specificity in distinguishing problematic users

from normal users. Generating consensus regarding the symptomatology of problematic SNS use remains a significant challenge for future research to help establish.

A recent meta-analysis of research employing either the Bergen Facebook or Bergen Social Media Addiction Scale (Andreassen et al., 2017; Andreassen, Torsheim, et al., 2012) has indicated that between 5-25% of the population can be classed as having a 'social media addiction' (Cheng et al., 2021). However, such a prevalence seems inordinately high considering that the global prevalence of addiction to one of the most widely consumed drugs – alcohol, is estimated to be only 1.4% (Ritchie & Roser, 2018). An important point to acknowledge is that scales employing criteria borrowed from diagnostic tools for substance use addiction cannot be assumed to capture a clinically relevant pathology when applied to SNS use behaviours. No clearer has this point been demonstrated than in a recent study assessing 'offline-friend addiction' (Satchell et al., 2021). By adapting criteria used in popular 'SNS addiction' scales, Satchell et al. (2021) devised the 'Offline-Friend Addiction Questionnaire' and found that 69% of individuals could be diagnosed as addicted to spending time with their friends. While the authors do not propose that an 'offline-friend addiction' should be taken seriously as a mental disorder, the research does illustrate why the existence of a 'SNS addiction' should be treated with a similar degree of scepticism when diagnoses are based solely on criteria adapted from substance use disorders, without proper validation. It is for this reason that previous research relying on modified diagnostic instruments to assert the existence of a 'SNS addiction' has been criticised for its atheoretical and confirmatory approach (Billieux et al., 2015; Cataldo et al., 2022; Kardefelt-Winther et al., 2017). Thus, more theory driven, empirical research is urgently required in order to

establish whether excessive/problematic SNS use is best conceptualised as reflecting a behavioural addiction.

A reward and incentive sensitisation perspective

One theoretical approach to assessing the addictive potential of SNS use is provided by the incentive sensitisation theory of addiction (Robinson & Berridge, 1993). This theory posits that repeated drug use gradually causes the neural systems involved in motivating drug consumption to become sensitised to the rewarding effects of the drug (i.e., the drug 'high'). Once sensitisation occurs the brain's motivational circuits become activated more readily in response to drug-related cues due to the expectation of reward that has now become associated with these cues. As such, the 'incentive salience' (i.e., motivational properties) of these cues becomes intensified, and exposure to drug-related cues will result in the experience of cravings and an uncontrollable desire for drug use. For example, the smell of a cigarette would not be expected to elicit any strong motivational response in non-smokers. However, as addiction develops, this cue (i.e., smell of tobacco), now imbued with incentive salience, may trigger an intense desire to smoke.

Important for the theory of incentive sensitisation is a dissociation between the concepts of drug 'wanting' (i.e., cravings/urges) and drug 'liking' (i.e., pleasure/enjoyment). While wanting is typically caused by an initial liking, they are not the same process and become decoupled from each other in addiction (Robinson & Berridge, 1993). During incentive sensitisation, it is the neural systems responsible for the experience of drug wanting that are rendered hyper-reactive (i.e., sensitised) to drug stimuli and which consequently assign incentive salience to these stimuli. Importantly, this occurs without a concurrent amplification of the neural

systems responsible for the experience of pleasure (i.e., liking systems). In fact, with repeated exposure to the rewarding effects of a drug, liking often diminishes over time. In this sense, the brain's liking systems can become desensitised to the drug's effect (i.e., tolerance), which results in the user needing to consume larger quantities of the drug in order to experience the same 'high'. Desensitisation of the brains reward centres can also dampen the ability to experience pleasure from everyday activities that may have previously been motivating and rewarding (e.g., work, hobbies, relationships; Hägele et al., 2015; Volkow et al., 2016). Furthermore, these neural changes can persist for years after drug use is ceased, making the occurrence of relapse more likely even when an individual has no desire to resume use or no longer expects the effects to be pleasant (Berridge & Robinson, 2016).

While this theory was initially developed to explain substance use addictions, there is now also evidence that neural sensitisation of wanting mechanisms may occur during certain problematic behaviours (Berridge & Robinson, 2016; Linnet et al., 2012; Voon et al., 2014). In recent work we have advocated for the utility of a reward and incentive sensitisation approach to assessing the addictive potential of SNS use (Ihssen & Wadsley, 2021). In a proof-of-concept study we found that cue-elicited SNS urges (i.e., cravings in response to viewing SNS app icons) were associated with both excessive and problematic SNS use. Furthermore, explicit ratings of SNS wanting vs. liking could be reliably dissociated from each other, with wanting explaining a greater proportion of the variance in excessive and problematic use, above and beyond what could be explained by liking. Similar dissociations of wanting vs. liking have also recently been shown to predict the severity, frequency, and intensity of engagement with a range of other potentially problematic behaviours (e.g., gambling, overeating, gaming, shopping; File et al., 2022; Polk et al., 2017).

However, while these cross-sectional findings are useful in demonstrating that a decoupling of explicit wanting vs. liking is present in more problematic SNS users, incentive sensitisation predicts that this process occurs gradually over time as addiction progresses. As such, longitudinal research would be required in order to demonstrate that incentive sensitisation is actually taking place during SNS use.

As well as changes in explicit (subjective) motivation, incentive sensitisation can also be expected to result in increased implicit (unconscious) motivation for the drug/behaviour. Such a prediction is also made by a conceptually similar model of addiction, namely the dual-process model (Deutsch & Strack, 2006; Noël et al., 2010; Wiers et al., 2007; Wiers & Stacy, 2006). This model proposes that addictions arise due do an imbalance between an over-reactive impulsive system (implicit cognitions) and a deficient self-regulatory control system (explicit cognitions). The underactive self-regulatory control system (or reflective system) leads to a reduced ability to voluntarily inhibit drug consumption through deliberative processes, whereas the overactive impulsive system (or reflexive system) leads to an automatic positive evaluation of the drug and spontaneous motivational reactions to drug cues. As addiction develops this imbalance between the two systems leads to the behaviour becoming more 'stimulus driven' rather than being under conscious control (Wiers & Stacy, 2006). While reflective-impulsive models of addiction are rooted in cognitive and social psychology, incentive sensitisation models provide a neurobiological framework. Within incentive sensitisation theory, the analogue of the impulsive (automatic) system can be viewed as the level of cue-triggered 'incentive salience', which is amplified by drug-induced sensitisation and often unconscious. In contrast to the dual-process model, incentive sensitisation theory outlines a clear neural mechanism on how heightened wanting/impulses emerge. But crucially, both

perspectives converge in asserting that repeated exposure to a drug's rewarding effects results in appetitive responses to drug-related cues becoming more automatic, facilitating more compulsive drug consumption (Lindgren et al., 2019). The present thesis draws on both of these complementary theoretical frameworks to investigate the addictive potential of SNSs.

As described above, explicit cognitions can be assessed straightforwardly by asking individuals to self-report their motivation/cravings for the drug/behaviour, and such measures are known to be strongly correlated with addiction (Goldman et al., 1999). On the other hand, addiction-related implicit cognitions have been assessed by adapting established behavioural tasks to measure automatic reactions to addiction-related cues. Examples of implicit cognitions and their measurements include: *attentional bias* which can be assessed using the Stroop test (Stroop, 1935), dot probe task (MacLeod et al., 1986) and visual search task (Wolfe, 1998); *implicit associations* assessed using the Implicit Association Test (Greenwald et al., 1998) and Go/No-Go Association Task (Nosek & Banaji, 2001); *approach-avoidance tendencies* assessed using the approach-avoidance task (Rinck & Becker, 2007) and stimulus response compatibility task (De Houwer et al., 2001); *semantic memory associations* assessed using word association (Stacy, 1995) and semantic priming (Hill & Paynter, 1992).

Substance-related implicit cognitions have been reliably associated with the use of a range of different substances (Rooke et al., 2008), and predict a unique proportion of the variance in drug consumption above what can be accounted for by explicit cognitions alone (Reich et al., 2010). There is also evidence that alterations in implicit cognitions may explain behavioural addictions (e.g., gambling disorder; Boffo et al., 2018; Brevers et al., 2013; Flórez et al., 2016). Recent theoretical

models such as the Interaction of Person-Affect-Cognition-Execution (I-PACE) model (Brand et al., 2019; Brand et al., 2016), also consider implicit cognitions important for the development of specific internet addictions, including problematic SNS use. The I-PACE model posits that specific internet use disorders occur when predisposing variables (e.g., genetic factors, early childhood experiences) interact with affective and cognitive responses to situational triggers (e.g., automatic reactions to behaviour-related cues), in addition to reduced executive functioning. Yet, despite the importance of implicit cognitions for theoretical models of addiction, as highlighted by a recent systematic review (Kessling et al., 2023), to date very few studies have utilised such an approach to help explain problematic SNS use behaviours. Therefore, the present thesis will employ concepts central to the aforementioned theories of addiction (i.e., 'wanting' vs. 'liking', cue reactivity, explicit and implicit motivation) in order to better assess the addictive potential of SNS use.

Thesis overview

The present thesis sought to better understand excessive and problematic SNS use by assessing the underlying reward-based mechanisms using a range of measurement modalities (i.e., self-report, implicit behavioural, psychophysiological, and neural). The objectives of this thesis can be broken down into four key questions: 1) can reward-related motives explain problematic SNS use and differences in use intensity? 2) is problematic SNS use related to alterations in explicit and implicit cognitions? 3) do problematic SNS users experience withdrawal-like effects when SNS use is restricted? 4) are there physiological markers of problematic SNS use? If successful in answering each of these questions,

then a much clearer picture regarding the addictive potential of SNS use can be established. Below a brief overview of the upcoming chapters is presented that will address each of these questions.

Can reward-related motives explain problematic SNS use and differences in use intensity? (Chapter 2)

An addictive substance must have the capacity to elicit reward. The importance of reward for substance use addictions is emphasised by the DSM's approach to classifying such disorders: "*All drugs that are taken in excess have in common direct activation of the brain reward system, which is involved in the reinforcement of behaviors and the production of memories*" (APA, 2013b, p. 481). Similarly, addictive behaviours are assumed to produce the same intense activation of the reward system and comparable behavioural symptoms. This has now been compellingly documented for pathological gambling, for which a clear set of behavioural symptoms, neural abnormalities, and genetic factors have emerged (Potenza et al., 2019).

However, while the reward that motivates gambling is obvious and tangible (i.e., the prospect of winning money or valuable goods), the rewarding elements of SNS use (and how they relate to problematic use) are less clearly established and individuals may possess multiple different motives for their use. While there is evidence that social rewards activate similar brain areas as other primary rewards (e.g., food and sexual stimuli; Bhanji & Delgado, 2014), individuals could be motivated to use SNSs for other reasons. For example, SNSs can be used for positive reciprocal interactions between friends, but they can also be used to engage in negative interactions such as 'cyberbullying' and 'trolling'. Furthermore, while some

people may use SNSs as a means to obtain feedback from peers or as a way to feel connected, others could be motivated to use SNSs for more personal reasons such as for entertainment or as a convenient way to document memories/life events. The focus of chapter two will be to understand how different motives for SNS use might elicit reward and to assess which of these motives best explains excessive and problematic SNS use, as in order to better understand the addictive potential of SNSs, we must first be able to identify the hedonic incentives underlying their use.

To address this question, chapter two presents findings from a study in which an international sample of 411 young adults completed an online survey regarding their SNS use motives. Prior to data collection, ten potential use motives were identified in an in-depth review of the existing literature. Participants then evaluated each motive in terms of its capacity to elicit a reward response. However, we suspected that some of these motives might be closely associated with each other, and this prediction was confirmed by a factor analysis that reduced our initial use motives to 5 factors. These factors included *social reward* (i.e., using to gain social approval, feel included or to make comparisons with others), *enjoyment reward* (i.e., using for entertainment purposes or as a way to pass time), *personal utility* (i.e., using to provide personal updates or document life), *relationship maintenance* (i.e., using as a method to interact with friends/maintain relationships), and *negative social potency* (i.e., using to engage in negative interactions, e.g., 'trolling'). These motives were entered into regression models to predict problematic SNS use, excessive SNS checking and duration of daily SNS use. We found that different motives predicted each of our three outcome measures, with the motive 'social reward' explaining the greatest proportion of the variance in problematic use and excessive checking. This finding is important for the conceptualisation of a 'SNS

addiction' as it suggests that a 'social reward' motivation is the most important contributor in driving problematic SNS use behaviours and in increasing intensity of SNS use.

Is problematic SNS use related to alterations in explicit and implicit cognitions? (Chapter 3)

As previously discussed, incentive sensitisation and other prominent models of addiction predict that alterations of both explicit and implicit cognitions contribute to the development of addiction. We can therefore expect 'addictive' SNS use to result in similar modifications of explicit and implicit motivation. Our preliminary findings indicated that more problematic SNS users do indeed display modified explicit cue-induced cravings and a dissociation between SNS wanting vs. liking, whereby wanting was more predictive of problematic use (Ihssen & Wadsley, 2021). Thus, one of the rationales for the study presented in chapter three was to expand on these findings and determine whether the effects would replicate in a larger and more diverse sample of young adults. In addition, we also included an experimental task to assess potential modifications of SNS 'wanting' implicitly. Here we opted to use an online version of the approach avoidance reaction-time task (i.e., Visual Approach/Avoidance by the Self Task; Rougier et al., 2018), adapted using SNS app icons and iPhone app icons as control stimuli. The task allows the measurement of automatic approach reactions to addiction-related cues, with faster approach tendencies to these stimuli (vs. controls) being indicative of increased implicit 'wanting'. Versions of this task have been used extensively in addiction research and faster approach reactions to addiction-related cues have been shown to be associated with a range of substance use addictions and problematic behaviours, including

alcohol (Field et al., 2008), tobacco (Wiers et al., 2013), cannabis (Cousijn et al., 2011), heroin (Zhou et al., 2012), binge eating (Paslakis et al., 2017), gambling (Boffo et al., 2018), and pornography use (Sklenarik et al., 2019). There is also some evidence that automatic approach reactions to Facebook-related stimuli are associated with more problematic Facebook use (Juergensen & Leckfor, 2019). Yet, we noted this was the only previous study investigating problematic SNS use to have employed this paradigm, and that research using a conceptually similar task with a larger sample had failed to observe an association between SNS approach tendencies and SNS-related self-control failures (Du et al., 2020). Clearly more research is needed to determine whether problematic SNS use is associated with modifications of implicit approach biases to SNS stimuli, which provided another rationale behind the study presented in chapter three.

The measures assessed in this study were included as part of a larger online survey assessing SNS use motives described in chapter two, and thus employed the same sample of young adults (N = 411; see chapter two). Replicating our previous findings, we found that self-reported SNS 'wanting' explained a greater proportion of the variance in problematic SNS use and checking frequency, above and beyond that explained by SNS 'liking'. However, in contrast to our initial results explicit cue-reactivity to SNS icons was not associated with problematic SNS use, although it was weakly correlated with SNS checking frequency. Furthermore, while the approach avoidance task revealed a large approach bias for SNS stimuli within the sample as a whole, faster approach tendencies to SNS stimuli were not associated with more problematic SNS use. Therefore, our findings suggested a more nuanced effect of motivational responses to SNS stimuli than we had initially predicted, whereby modifications of explicit SNS 'wanting' appears to explain problematic

SNS use to some small extent, while explicit cue reactivity and implicit approach motivation are not reliably associated with more problematic use. Such findings are inconsistent with effects observed in other addictive disorders and problematic behaviours, and thus provide a challenge for the conceptualisation of problematic SNS use as a behavioural addiction.

Do problematic SNS users experience withdrawal-like effects when SNS use is restricted? (Chapter 4)

A withdrawal syndrome is a hallmark feature of drug addiction (Bayard et al., 2004; Hughes & Hatsukami, 1986). When drug use is ceased abruptly, addicted individuals tend to experience a range of negative psychological and physiological consequences. Common psychological effects include increased cravings, anxiety, irritability, restlessness, disorientation, insomnia, and reduced mood. Physiological withdrawal symptoms can include altered autonomic activity (e.g., heart rate, sweating), tremors, muscle aches, vomiting, hallucinations, and in more severe cases seizures. The experience of withdrawal is thought to arise due to a homeostatic stress response to a drug-free state (Koob & Le Moal, 2008b; Koob & Volkow, 2010), and thus the concept of withdrawal is controversial for behavioural addictions (due to the lack of intoxication). However, there is evidence that pathological gamblers experience withdrawal effects when they attempt to stop gambling (Blaszczynski et al., 2008; Lee et al., 2020). While some studies have also identified withdrawal-like effects in SNS users who attempt to abstain or cut down their use, the majority of research reports positive or null effects of "digital detox" interventions on indices of mood and well-being (Radtke et al., 2022). This is problematic for arguments in favour of a 'SNS addiction' being recognised as an addictive disorder. However, we

identified a number of limitations with previous studies, including the reliance on self-report measures, that we sought to address in our research.

Chapter four presents a study in which frequent SNS users attempted to abstain from using their SNS accounts for a week. Emotional and motivational measures were assessed continuously across a period of 15 days using ecological momentary assessments. Additionally, behavioural paradigms were employed to assess potential modifications of implicit SNS motivation. These included the approach avoidance task (described in chapter three), as well as a modified effort expenditure for reward task (Treadway et al., 2009), and assessment of time distortion (Turel, Brevers, et al., 2018). Behavioural measures were implemented in two lab sessions which took place immediately before and at the end of the abstinence intervention. Contrary to our hypotheses, no clear pattern of withdrawal-like effects emerged when participants reduced their SNS use. Instead, our findings indicated a nuanced and potentially offsetting effect on mood, whereby reducing SNS use may simultaneously produce positive and negative consequences to wellbeing. However, such effects appear to be small and were not associated with more problematic SNS use. Furthermore, explicit and implicit motivational measures were unaffected by the intervention which is inconsistent with the experience of a withdrawal syndrome. Despite withdrawal being a core component of traditional addictions, more recently the concept of withdrawal has been argued to be less relevant in diagnosing behavioural addictions such as gaming disorder (Castro-Calvo et al., 2021; Kaptsis et al., 2016). Similarly, our findings suggest that the concept of a SNS-related withdrawal syndrome may not be useful for diagnosing a 'SNS addiction'. This conclusion suggests a crucial distinction between problematic SNS use and substance use disorders and would also have important ramifications for

existing diagnostic tools that include withdrawal criteria. However, we noted that our findings need to be interpreted in context of some important limitations including the small sample size and poor participant compliance rates.

Are there physiological markers of problematic SNS use? (Chapters 5 and 6)

As well as cognitive and behavioural symptoms, addictive disorders are known to involve a number of physiological indicators. These include changes in autonomic activity during exposure to drug cues (Ehrman et al., 1992) or after ceasing drug consumption (i.e., during withdrawal; Hughes et al., 1994), as well as significant neuroadaptations as a result of prolonged exposure to the substance (Koob & Volkow, 2016). Evidence of dramatic changes to brain structure and function has been extensively documented in the substance addiction literature, and similar neural abnormalities have also been reported in pathological gamblers (Balodis et al., 2012; Limbrick-Oldfield et al., 2017). Yet evidence of physiological markers of problematic SNS use is comparatively scarce. Thus, a final objective of this thesis was to establish whether such physiological indicators of addiction are present in problematic SNS users.

First, we sought to determine whether changes in heart rate and skin conductance (i.e., sweating) during brief periods of SNS exposure and cessation could serve as reliable markers of more problematic SNS use. In an experiment presented in chapter five, the physiological responses of 54 Instagram users were recorded across three 15-minute phases, comprising a baseline phase, Instagram exposure phase, and Instagram cessation phase. Our findings revealed distinct physiological changes during SNS exposure and cessation, that were indicative of increased appetitive arousal and attentional immersion during SNS exposure and

increased aversive (i.e., stress-related) arousal during SNS cessation. But importantly these changes in physiology were present in the whole sample and were not associated with symptoms of problematic SNS use. These findings therefore contrast with predictions from theories of addiction (e.g., Wise & Bozarth, 1987) and are also inconsistent with the idea of a physiological withdrawal syndrome in problematic users.

Additionally, we evaluated the existing neuroimaging literature for evidence of altered brain structure and function in more problematic SNS users. In a systematic review presented in chapter six we searched the literature for magnetic resonance imaging (MRI) studies that had investigated the neural correlates of SNS use. Our systematic search returned 28 research articles meeting our inclusion criteria, of which only 13 had investigated compulsive or problematic SNS use. While existing evidence did point to some similarities between problematic SNS use and substance use disorders, our review also highlighted important limitations with current MRI studies including large heterogeneity in the methods employed, thus limiting comparability between studies. Furthermore, the lack of longitudinal research suggesting that SNS use causes neuroadaptations led us to conclude that the classification of problematic SNS use as an addictive disorder would be premature.

Chapter 2

The predictive utility of reward-based motives underlying excessive and problematic social networking site (SNS) use

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Abstract

Compulsive seeking of reward is a hallmark feature of drug addiction, but the role of reward is less well understood in behavioural addictions. The present study investigated the predictive utility of ten reward-based motives, which we identified in the literature, in explaining excessive and problematic use of social networking sites (SNSs). These motives were examined in a cross-sectional survey of 411 young adults, revealing that prolonged use and excessive checking were predicted by distinctly different motives. More frequent checking of SNSs was most closely associated with motives related to obtaining social rewards (impression management/social comparisons/fear of missing out) and the desire to find/consume enjoyable content. In contrast, the amount of time an individual spends on SNSs was predicted by the desire to engage in negative social interactions or to fulfil personal needs (self-expression/documentation of life events). Problematic SNS use was best explained by the motivation to obtain social rewards and to a lesser extent by enjoyment and negative social potency (e.g., trolling) motives. Our results highlight the importance of social reward in explaining excessive and problematic SNS use, suggesting that a focus on reducing the desire to obtain social reward (e.g., through likes, social comparisons, continual connection) may be most beneficial in tackling problematic SNS behaviours.

Introduction

Social networking sites (SNSs) now play a major role in many people's day-to-day lives. Especially amongst the younger generation, the use of SNSs has become so ingrained into the daily routine that it forms an integral part of life. Recent estimates indicate that 49% of the world's population are active social media users, with the average user spending 2 hours 24 minutes on these sites each day (DataReportal, 2020). As technology continues to improve exponentially and the capabilities of SNSs expand it seems only likely that these media will occupy an even more important role in the future. This has led to mounting pressure to understand the consequences that SNS use has on our health and wellbeing, and there is now growing concern regarding its addictive potential (Kuss & Griffiths, 2017). However, in order to better understand compulsive forms of SNS use, we must first understand the individual motivations for SNS use and how they might predict excessive and problematic use.

Within this report we focus specifically on platforms with a primary function of social networking through microblogging or content sharing, in which users can navigate a community-based environment and publicly share personal information whether it be text, image, audio or video, and view content publicly shared by others. Examples of such include Facebook, Instagram, Snapchat, Twitter and YouTube. Although the current literature suffers from a lack of clarity regarding what is and what is not considered a SNS, our focus is consistent with the definition of SNSs as "*virtual communities where users can create individual public profiles, interact with real-life friends, and meet other people based on shared interests*" (Kuss & Griffiths, 2011, p. 3529). While it has been argued by Kuss and Griffiths (2017) that the term SNS is eclectic and encapsulates sites dedicated to gaming (e.g., *World of Warcraft*),

dating (e.g., *Tinder*) and instant messaging (e.g., *WhatsApp*) these types of social media were not the focus of this study because their primary function (i.e., instant messaging/dating/gaming) distinguishes them from the microblogging/content sharing platforms previously outlined. Correspondingly, the reward-based motives explaining the use of these platforms might be qualitatively different (e.g., sexual gratification for the use of dating sites) than the motives examined here.

Much discussion currently surrounds the question of whether SNSs (as defined above) can evoke behavioural addictions. Currently the only behavioural addiction formally recognised as such is gambling disorder and while the DSM-V also acknowledges internet gaming disorder as a condition warranting further research, there is no such recommendation for SNS addiction (American Psychiatric Association [APA], 2013a). Different authors have questioned the need for the formal recognition of excessive behaviours as addictions. Some have argued that pathologizing everyday behaviours could damage the relevance and credibility of the addiction field (Kardefelt-Winther et al., 2017). According to this view, researchers are being increasingly led to divert resources towards the study of excessive behaviours that lack the hallmarks of addiction and fail to substantially deviate from normative functioning. As such the validity of the construct 'behavioural addiction' is weakened (Billieux et al., 2015; Blaszczynski, 2015). Conversely, others have argued that the similarities between substance addictions and excessive behaviours should not be overlooked (Griffiths, 2017) as there is now accumulating evidence to suggest that some compulsive SNS users display symptoms traditionally associated with substance use disorders (Andreassen, 2015; Kuss & Griffiths, 2011).

There is consensus that substance use disorders are characterised by compulsive seeking and consumption of a chemical substance that directly activates

the brain's reward system and thus evokes pleasure and/or a desire to consume the substance again. This focus on the reward system is reflected in the approach the DSM-V has taken to conceptualise substance-related and addictive disorders in its introductory section (APA, 2013b, p. 481). However, unlike drug addictions in which there is clear evidence that repeated exposure to a rewarding chemical substance results in neural and physiological adaptations that produce physical dependence characterised by withdrawal (Koob & Le Moal, 2008b), reward-related factors that contribute to the development and maintenance of behavioural addictions are less well understood. Thus, in the absence of a psychoactive substance producing neurochemical reward, it is important that we understand the motivational and hedonic incentives behind SNS use. Identifying these antecedents of dysfunctional behaviours is also an essential requirement for the development of targeted interventions.

Previous research has adopted the "uses and gratifications" framework when attempting to identify the motives underlying SNS use (Raacke & Bonds-Raacke, 2008; Whiting & Williams, 2013). However, few studies have considered how the various motives identified in this research might elicit reward or explain problematic SNS use. Focusing specifically on Facebook, Nadkarni and Hofmann (2012) proposed that use is primarily motivated by two basic needs: the need to belong and the need for self-presentation. In a later systematic review of the uses and gratifications of Facebook, Ryan et al. (2014) point to relationship maintenance and passing time as the most important motives underlying its use. However, the spectrum of motives identified by different authors is broad and different studies attribute varying importance to each single motive.

Given the significance of reward for the classification of substance use disorders within the DSM-V, in the present article we consider the capacity of different SNS motives to elicit reward when evaluating their potential to generate excessive and problematic use. Based on a targeted literature review, we identify ten reward-based motives that might explain the development and maintenance of excessive or problematic SNS use. Typically, the term 'reward' is used to refer to stimuli or activities that are positive reinforcers based on their incentive properties, that means, their capacity to elicit either pleasure or a motivation (urges or desires) to consume/have the reward (Schultz, 2015). However, given the importance of negative reinforcement for addictive processes (e.g., withdrawal, Koob & Le Moal, 2008a) and the overlap between neural systems underlying positive and negative reinforcement (Schlund et al., 2011), we expand the term 'reward-based motives' to refer to motives for SNS use that can be either positive reinforcers (= producing a pleasurable or desired state) or negative reinforcers (= producing a less aversive or undesired state). While not necessarily an exhaustive list, the ten motives identified provide a useful framework for understanding how problematic SNS use might be initiated or maintained. It is likely that individual SNS users possess multiple motives for their use and although we argue that each of the ten reward-based motives represent distinct domains, certain motives may overlap with each other to some extent.

Impression management

One of the appealing features of conducting social interactions from behind a screen is the control it affords the user in managing how they are perceived. SNSs allow users to easily modify aspects of their identity so that they appear exactly as

they wish to be seen by others. Users are able to publicly post content that portrays them as possessing more socially desirable characteristics (e.g., more attractive/healthier/happier) than they might be able to convey in real life interactions. When such actions are affirmed by their peers (e.g., a 'like' on Facebook), this elicits a boost in self-esteem and thus a reward (Burrow & Rainone, 2017). Not only does this provide confirmation to the user that their peers approve of their post, it also publicly conveys their popularity to other users who view the post. This social approval may serve to reinforce the use of SNSs in order to maintain favourable appearances and improve one's standing in the social hierarchy. From an addiction perspective, the user may then begin to seek these rewards more frequently and monitor their social acceptability to avoid a drop in self-esteem. In turn, this could result in compulsive checking of the user's SNS accounts and a behaviour that has been referred to as 'chasing the like' (i.e., posting content with the aim of obtaining more and more likes, and deleting content that fails to obtain sufficient likes; La Sala et al., 2015). It should also be noted that such social approval might also be achieved without the need to obtain a 'like' for a post. For example, receiving praise through public comments on the post, receiving a friend request or being 'followed' or 'retweeted' on Twitter or even viewed (e.g., Snapchat provides users with a list of friends who have viewed their story) may produce a similar reward.

A number of studies have reported that seeking attention and acknowledgement from others are primary motives for the use of social media (Stefanone et al., 2011; Sung et al., 2016). Research has also shown that receiving affirmation from peers on content posted on SNSs is associated with increases in self-esteem and subjective wellbeing (Burrow & Rainone, 2017; Oh et al., 2014), yet overreliance on validation from others in pursuit of self-esteem can be costly to well-

being in the long-term (Crocker & Park, 2004). In addition, neuroimaging research has shown that viewing photos with many (compared to few) likes resulted in increased activity in brain regions associated with reward processing, social cognition, imitation, and attention (Sherman et al., 2016). For some individuals the reward associated with obtaining a high number of likes may be a significant determinant in their use of SNSs. Research suggests that adolescents and in particular female adolescents may be especially driven to use SNSs because of this motive, as they are more subjected to peer mediation and pressure (Chua & Chang, 2016; Mascheroni et al., 2015).

Self-expression

Another potential rewarding aspect of SNSs is the ease with which users can clearly express their thoughts, opinions, ideas and beliefs. Regardless of how the content they share is evaluated by others, the user may experience gratification from communicating aspects of their identity. This may be especially important for individuals who might otherwise lack the social skills to communicate aspects of their identity or those who require a wider audience than their immediate social groups in real life (Caplan, 2005). As values related to self-expression have risen in recent decades (Inglehart & Oyserman, 2004; Inglehart, 2008), individuals have increasingly relied on the convenience of online platforms to express themselves (Orehek & Human, 2017).

The rewarding nature of self-expression may be the positive self-affirmation that comes from publicly presenting your true self (Toma & Hancock, 2013). Thus, unlike impression management the use of SNSs for self-expression might be driven by the desire to accurately portray one's own identity, rather than the desire to obtain

positive feedback (e.g., through 'chasing likes'). Although it seems likely that these two motives might overlap to some extent (i.e., the user may wish for their traits to be viewed both positively and accurately), it is also possible that they manifest independent of each other. Around 30% of everyday conversational speech is devoted to informing others about our own personal experiences (Dunbar et al., 1997) and a content analysis of twitter posts indicates that 41% of all 'tweets' consist of announcements about one's current activities or experiences (Naaman et al., 2010). It therefore seems likely that the need to express information about the self may represent a strong motivational factor in the desire to use SNSs.

It has previously been demonstrated that disclosing information about oneself is strongly associated with increased neural activity in the mesolimbic dopamine system, the same system that is activated by drug and food rewards (Tamir & Mitchell, 2012). Moreover, Tamir and Mitchell (2012) found that individuals are often willing to forgo money in order to disclose information about the self. It is therefore apparent that self-expressing is an inherently rewarding process. Research has also suggested that self-disclosure on SNSs may increase well-being by increasing perceived social support (Lee et al., 2013).

Social comparison

Festinger (1954) originally proposed social comparison theory to explain how individuals compare their own opinions and abilities to others in order to generate accurate self-evaluations. Since it was initially proposed research has continued to advance the theory and focus on ways that social comparisons can be used for self-enhancement. Humans show an automatic tendency to evaluate themselves relative to their counterparts (Gilbert et al., 1995; Wood, 1996) and are

able to process status cues in others with ease (Zitek & Tiedens, 2012). This serves an obvious evolutionary function. The ability to accurately identify where we stand in a social hierarchy enables us to define social roles and facilitates cooperation (Halevy et al., 2011; Koski et al., 2015). It is well established that social status is strongly associated with self-esteem, wellbeing and health in both humans and animals (Haught et al., 2015; Sapolsky, 2004; Singh-Manoux et al., 2003). The subjective perceptions we form about our own social status will inevitably be influenced by the types of social comparisons we make. It therefore follows that individuals might be motivated to strategically make social comparisons to seek self-enhancement or improve self-esteem.

SNSs offer a unique and unobtrusive means of gathering large amounts of information about the lives of others. Thus, a potential reward-based motive for the use of SNSs might be to make downwards social comparisons with people who are deemed of lower social standing. The concept of downwards social comparisons was first introduced by Wills (1981) who described its basic principle as an attempt to increase one's subjective self-esteem by making comparisons with a less fortunate other. Thus, individuals might use SNSs to seek information that allows them to make downwards social comparisons generating a rewarding boost in self-esteem. By contrast then it would seem that individuals might avoid upwards social comparisons (i.e., comparing oneself to more fortunate others), as these result in more negative self-evaluations and lower self-worth (Tesser et al., 1988). However, studies have since demonstrated that this is not always the case as individuals can use upwards social comparisons to identify similarities between themselves and the superior other or as a way of gaining inspiration on how to improve (Collins, 1996; Guyer & Vaughan-Johnston, 2018). Thus, it might still be potentially rewarding for

individuals to seek upwards social comparisons in an effort to learn how to achieve higher social status. For example, it is possible that individuals might develop compulsive use of SNSs to follow updates from more popular peers or celebrities in order to emulate their behaviours.

In addition, research has shown that using SNSs to make social comparisons is associated with depressive symptoms, and this relationship is particularly strong in females and less popular individuals (Nesi & Prinstein, 2015). For some individuals, making comparisons with others on SNSs may produce a negative cycle of behaviour whereby they attempt to make comparisons for self-enhancement but are unsuccessful in processing the information obtained in a way that enables them to view themselves more positively. A survey of 425 undergraduate students found that those who used social media more frequently were more likely to believe that others were happier and had better lives (Chou & Edge, 2012). Furthermore, Vogel et al. (2014) found that the relationship between chronic SNS use and low self-esteem was mediated by greater exposure to upwards comparisons, and temporary exposure to someone else's social media profile containing more positive information than one's own profile (e.g., a high number of 'likes' and more healthy life-style) resulted in more negative evaluations of the self. Therefore, social comparisons as a motivation for the use of social media might represent a particularly important indicator of problematic SNS use and negative consequences associated with SNS use.

Habitual time passing

One commonly reported use of SNSs is passing time (Barker, 2009; Hollenbaugh & Ferris, 2014; Papacharissi & Mendelson, 2011; Smock et al., 2011; Whiting & Williams, 2013). There are many instances throughout the day when it

becomes desirable to occupy oneself with an activity in order to pass time. When standing in a queue for example, using smartphone applications can help to ease the tedium of waiting. Research has shown that our sense of time is altered by emotions such that it seems to pass faster when in a state of arousal compared to a drag when bored (Droit-Volet & Meck, 2007). Checking the latest updates on social media is an engaging activity that provides a convenient way of alleviating momentary feelings of boredom.

However, SNSs are designed to capture and hold our attention (Alter, 2017). The more engaging a SNS is the more advertisements are able to be sold, thus generating more revenue for the company. One of the ways that SNSs may encourage repeated use is through the algorithms of the newsfeed page that enable 'infinite scrolling' and recommend user specific content. Rather than searching for the content we wish to see; SNS newsfeeds provide a seemingly endless stream of content without a natural stopping point. Such design features have been recognised as encouraging prolonged use, providing a pathway to excessive and problematic SNS use (Montag et al., 2019; Noë et al., 2019) and there have been recent calls for these features to be banned (Hern, 2019). When repeatedly scrolling or refreshing their newsfeeds the user may become lulled into a 'hypnotic' state. Such states have become known as 'ludic loops' in the context of gambling research and describe a potential mechanism as to how slot machines facilitate compulsive use (Schüll, 2012). Much like slot machines, the very design of a SNS newsfeed creates cycles of uncertainty (i.e., there is always the possibility that the next spin on the slot machine will return a win). When checking their newsfeeds, every so often the user may encounter novel or interesting information that produces a reward. Perhaps they might learn that an old school friend has got married or they will see an interesting

news article about a favourite celebrity. However, precisely when the user might encounter an interesting piece of information is often unpredictable, and thus the reward is delivered in what is referred to as random-ratio schedules (Haw, 2008). This uncertainty may reinforce the need to keep checking SNSs as there is the persistent feeling that the next post might be particularly interesting (i.e., highly rewarding). Thus, the user may become locked in a cycle of repeatedly checking SNSs in unconscious anticipation of the next reward, irrespective of whether a reward is actually forthcoming. Once learned, we suggest that the mere process of passing time may become rewarding in and of itself. Consistent with this idea, it has been shown that the anticipation of reward can be a more powerful mediator of addiction than the reward outcome itself, with less predictable outcomes producing greater arousal (Fiorillo et al., 2003; van Holst, Veltman, et al., 2012).

We thus suggest that through these mechanisms, using SNSs as a means to pass time may carry the risk of creating periods of intense, repetitive use behaviour or patterns of 'mindless' checking without a specific purpose. A study by Sagioglou and Greitemeyer (2014) found that the negative relationship between Facebook usage and mood was mediated by how meaningful the user believed their activity had been. Accordingly, the habitual use of social media to pass time may likely result in the user feeling that they have achieved less compared to what they might feel when using SNSs with more goal-orientated motives (e.g., to self-express). As a consequence, this motive may be especially salient in problematic users.

Mood alteration

In contrast to habitual time passing, the motive of mood alteration emphasises deliberate attempts of the SNS user to escape from issues or emotions in

the real (offline) world. Sometimes also referred to as ‘escapism’ (Young et al., 2017), mood alteration may facilitate excessive use through negative rather than positive reinforcement: Individuals learn that by using SNSs they can distract themselves from negative affect, such as depressive moods or anxiety.

A number of studies have investigated the relationship between excessive behaviours and the desire to distract oneself from negative emotions. One study comparing the motives of recreational and competitive (esport) gamers found that escapism was a powerful predictor of problematic use in both groups (Bányai et al., 2019). Others have also found an association between problematic social media use and escapism (Brailovskaia, Schillack, et al., 2020; Gao et al., 2017; Kircaburun & Griffiths, 2019; Masur et al., 2014). Escapism is also listed as one of the DSM-V criteria for gambling disorder (APA, 2013b) and different authors have proposed escapism or mood alteration as a clinical marker for gaming (Lemmens et al., 2009), social media (Van den Eijnden et al., 2016) and work (Andreassen, Griffiths, et al., 2012) addictions. Empirical evidence for the importance of this motive is less clear. For example, Smock et al. (2011) found no association between escapism and Facebook use, while Young et al. (2017) demonstrated that escapism in passive Facebook use (i.e., consuming content) was not associated with Facebook addiction. However, it might be that individuals who use SNSs for mood alteration do so through active use (i.e., communicating with others) and that this is associated with addiction. The contradictory literature on the role of escapism in the use of SNSs casts doubt on the importance of this motive in predicting problematic use and more research is needed to clarify these inconsistencies.

Fear of missing out

Fear of missing out (FoMO) is defined as "*a pervasive apprehension that others might be having rewarding experiences from which one is absent*", which evokes a desire to maintain a constant social connection with others (Przybylski et al., 2013, p. 1841). SNSs provide a method to achieve this with a wide network of friends regardless of where they are in the world. Users are able to observe each other's online activity and keep themselves up to date with the latest events in each other's lives. In turn, individuals who are particularly orientated towards continual connection with what others are doing may develop feelings of exclusion and anxiety during periods when they are not using SNSs, which continue to build until they check their accounts. Thus, individuals with FoMO may be motivated to use SNSs more frequently in order to alleviate this anxiety which is intensified by their non-use. This desire to be kept 'in the loop' may result in compulsive checking behaviours to relieve the anxiety that being 'out of the loop' generates, which may have negative and potentially dangerous consequences. For instance, higher levels of FoMO have been shown to be associated with distracted learning and distracted driving as a result of social media use (Przybylski et al., 2013).

While the contribution of FoMO to problematic SNS use is not yet fully understood, this is a topic that has gained considerable attention and there is now a growing body of literature examining the relationship between FoMO and digital technologies. Across multiple cultures FoMO has been shown to correlate with more intense and problematic social media use in adolescents and young adults (Alt, 2015; Beyens et al., 2016; Blackwell et al., 2017; Moore & Craciun, 2021; Oberst et al., 2017; Sheldon et al., 2021; Vaidya et al., 2016). Furthermore, some individuals report using SNSs to create FoMO in others rather than experiencing it themselves

(Hetz et al., 2015). Therefore, the use of social media by others may serve to exacerbate FoMO in users who are already predisposed to experiencing fear of social disconnection. Although research has primarily focused on the relationship between FoMO and SNSs in adolescents, some studies have shown that while experiences of FoMO decrease with age, 50% of adults (mean age = 30.8) report experiencing FoMO at least once a month (Milyavskaya et al., 2018). In addition, recent research has found no differences in the levels of FoMO between age cohorts in a sample ranging from 14-47 years old, suggesting that the experience of FoMO may exist independent of age (Barry & Wong, 2020). Therefore, even in older populations, the fear of missing out may represent an important motivation in the desire to use SNSs.

Relationship maintenance

The need to belong is one of our most basic human needs. Baumeister and Leary's (1995) influential need to belong theory suggests that humans have an ingrained desire to form lasting relationships, with frequent non-aversive interactions. This fundamental need is assumed to originate from our tribal past, when belonging to groups was essential for survival (DeWall et al., 2011). While group membership can no longer be considered as essential to surviving in modern society, an unmet need to belong can be detrimental to our health and wellbeing. A sense of belonging is associated with increased self-esteem (Cameron & Granger, 2020) and a lack of belonging has been shown to result in greater instances of depression and suicidality (Fisher et al., 2015; Steger & Kashdan, 2009). Furthermore, neuroimaging research has demonstrated that simulated interactions with friends can activate the brain's reward circuitry, particularly the striatum and ventro-medial prefrontal cortex (Güroğlu et al., 2008). It is therefore clear to see why

maintaining stable relationships is such a powerful and pervasive goal. However, the use of SNSs may fuel the desire to form lasting relationships beyond what might be realistically achieved. Because social interactions with a wide network of individuals are possible through the use of social media, our perception of the extent we can form meaningful bonds with those individuals might become exaggerated.

Early investigations of the uses of SNSs found relationship maintenance to be a primary motive (Raacke & Bonds-Raacke, 2008). This is perhaps unsurprising given that a main function of any social media is to facilitate social interaction. However, the extent to which this motive can be attributed to facilitating problematic use is debateable. While a sizeable body of literature has drawn links between excessive SNS use and lower wellbeing, Clark et al. (2018) suggest that when used as a tool to form meaningful connections with others, SNSs can actually improve wellbeing. In their analysis of Facebook communications between 1544 online friendships Sosik and Bazarova (2014) found that frequent and varied Facebook communication predicted the development of stronger relationships while the actual linguistic content of communications did not. Other research has shown that having Facebook friends who are more responsive is more important for satisfying psychological needs than the actual number of Facebook friends one has (Greitemeyer et al., 2014). Thus, individuals may be motivated to engage in excessive and diverse interactions (i.e., likes, comments, tags) to ensure that relationships are strengthened. Through excessive social grooming, users are able to generate a rewarding sense of belonging which may provide another pathway into compulsive use.

Entertainment

Individuals may also be motivated to use SNSs for entertainment, which can be defined as the intentional consumption of enjoyable content. This motive thus contains a clear pleasure-, and hence reward-seeking component, which might be susceptible to the development of compulsive behaviours similar to other pleasure-evoking activities or substances.

Many previous studies have highlighted the importance of entertainment as a motivation for the use of SNSs. In a survey of YouTube users (Khan, 2017) found that an entertainment motive was the strongest predictor of the passive consumption of content (i.e., watching videos). Similarly, studies of Facebook users have found entertainment to be the strongest predictor of the intensity of Facebook use (Alhabash et al., 2014; Dhir & Tsai, 2017). However, others have reported entertainment to be a less important motive than using for psychological benefits (e.g., escapism) or social networking (e.g., relationship maintenance; Balakrishnan & Shamim, 2013). While entertainment might be an important motive for SNSs such as Facebook and YouTube, recent research has found no relationship between this motive and compulsive Instagram use (Ponnusamy et al., 2020). Thus, further research is required to establish the role this motive might play in developing problematic use behaviours.

Archiving

Although SNSs primarily provide a platform to share content amongst friends, they are also commonly utilized as an easy and efficient tool to record our personal life and build personal repositories for meaningful memories (i.e., as a photo album/diary/video diary). Garde-Hansen (2009) describes users' personal

Facebook pages as "*a database of their life, making [it] a collection of collections and collectives*" (p. 141), and Facebook has been recognised as a contemporary way of recording personal identities and histories (Sinn & Syn, 2014). Reflecting on past events through social media may trigger a nostalgic reverie that might reinforce frequent documentation of one's life. Neuroimaging studies have also linked the experience of nostalgia with activity in the brain's reward system (Oba et al., 2016). The experience of nostalgia is thought to play an Important role in psychological resilience and is positively associated with a sense of meaning in life (Routledge et al., 2011).

Few studies investigating the uses of SNSs have considered archiving as a potential motive. However, the desire to document one's life has been found to be a primary motive in some studies, especially in the case of Instagram (Sheldon & Bryant, 2016). In a survey of 212 Korean Instagram users, archiving, along with 'peeking' (i.e., browsing the photos of others), were shown to be the strongest motivations predicting both positive attitudes towards and intention to use Instagram (Lee et al., 2015). The association between Instagram and archiving might be attributed to the fact that Instagram is primarily a site for sharing photos, and self-documentation through images (e.g., selfies) may be a more popular method of archiving than text for example (Sheldon & Bryant, 2016).

However, Sung et al. (2016) has shown that while archiving significantly predicted the intention to post selfies on SNSs, only narcissism – which might be more closely associated with the impression management motive – predicted selfie-posting frequency. This suggests that while archiving may motivate SNS use, it is not necessarily associated with excessive use.

Negative social potency

Rather than experiencing reward through positive relationships with other SNS users, some individuals may experience reward when engaging in negative online interactions. Consistent with this, individuals with psychopathic traits are less inclined to form meaningful long-term relationships and exhibit atypical experiences of social reward (Mokros et al., 2008; White, 2014). For instance, they may experience prosocial behaviour towards others as less rewarding and derive pleasure from the callous treatment of others (Foulkes, McCrory, et al., 2014). Because SNSs offer a platform to engage in widespread social interactions, individuals who experience reward from antisocial behaviours may be motivated to exploit these functionalities. This is most apparent in 'trolling' behaviours, which aim to disrupt or antagonize others online by deliberately posting inflammatory, irrelevant, or offensive content. According to a YouGov survey, as many as 28% of Americans admitted to engaging in troll behaviour by antagonizing a stranger online (Gammon, 2014). As SNSs offer abundant trolling opportunities, it is thus possible that the rewarding nature of these actions may generate compulsive use patterns in some users.

Cheng et al. (2017) argue that under certain circumstances ordinary internet users can become willing to behave like trolls. In their experiment simulating an online discussion, they found that negative mood and seeing troll posts by other users both increased the user's own trolling behaviour. This suggests that negative social potency might be rewarding even for the average SNS user, when they are in a state of low mood or after witnessing others engage in such behaviour. Offending others or causing harm to others enables individuals to make downward social comparisons with the victim, who is perceived to lose social status through the

offense (Wills, 1981). To this extent, the motives of negative social potency and (downward) social comparisons may overlap with each other.

Other research has shown that trolling behaviours are associated with the Dark Tetrad of personality (i.e., narcissism, Machiavellianism, psychopathy, and sadism; Buckels et al., 2014) and in turn, these traits have been associated with more problematic social media use (Kircaburun et al., 2019). However, other research has suggested that reward can be derived from causing social mayhem and that the motivation to do this is a significant predictor of trolling behaviours, above and beyond personality traits (Craker & March, 2016). A recent study assessing the relationship between trait social reward preferences and problematic social media use found that negative social potency was positively correlated with problematic Facebook and Snapchat use (Meshi et al., 2020). Interestingly, of the six social rewards measured, negative social potency was the only reward that produced a significant positive correlation with the problematic use of both platforms. This suggests that the desire to engage in negative online interactions may represent an important indicator of problematic SNS use. However, despite the wide prevalence of trolling, there is currently a lack of research investigating a potential link between negative social potency and compulsive SNS use.

Present study

The present study sought to investigate the predictive utility of the ten reward-based motives identified in our literature review in explaining excessive and problematic SNS use. Using an online survey, we presented 20 items (two items per motive) to assess the presence of these motives in young adults and their relationship with excessive and problematic SNS use. We predicted that the presence of self-

reported reward-based motives (across different types) would be positively associated with frequency of checking SNSs and problematic usage. All items were pre-tested with a sample of 30 participants (28 females, 2 males; mean age: 19.63 years [SD = 2.08]) and pilot data showed adequate associations between motive measures and self-reported SNS usage variables (frequency of checking), with impression management and entertainment potentially showing stronger effects than the other motives. Methods and hypotheses for this study were preregistered on the Open Science Framework website (https://osf.io/jqm57).

Method

Participants

An international sample of 411 participants completed the survey (190 male, 214 female, 7 other). The most common nationalities were British (21.4%), Polish (15.3%), Portuguese (11.7%), Italian (5.4%) and Mexican (3.6%). The majority of participants were recruited through external recruitment platforms, such as Polific.com and SurveySwap.io (69.4%), with the rest of the sample being recruited through internal channels or other means (30.6%). Participants received small monetary incentives or course credits for their participation or took part without reimbursement. Participants were aged between 18-30 (M = 22.9, SD = 3.55) and had normal or corrected-to-normal vision. The majority of participants were students (61.6%) and most had completed an undergraduate degree or higher (60%). Data collection took place between April – July 2020. The study was approved by the Ethics Sub-Committee in the Department of Psychology at Durham University and all participants provided fully informed consent.

Procedure

The survey was set up with PsyToolkit (Stoet, 2010, 2017) and all participants were required to access the survey on a device with a real keyboard and using a browser other than Safari (because of incompatibility with the experiments coded on PsyToolkit). The SNS use behaviour and motive scales were embedded in a larger online study that also included experimental measures not relevant to the current research question, such as reaction-times to SNS logos. The average time taken to complete the entire study was 20.09 minutes. The data which support this publication are available on https://doi.org/10.17605/osf.io/dkr9q.

Materials

Usage intensity

The intensity of SNS use was measured as (a) self-reported daily time spent using SNSs (hours), and (b) the frequency of checking using a 7-point scale (less than daily, daily, every 3-5h, 2h, 1h, 30mins, 15mins). Both usage intensity questions were asked twice, giving separate estimates for usage before and after the COVID-19 virus outbreak. As in this study we were more interested in typical usage behaviour, only the estimates relating to usage frequency before COVID-19 were used.

Social Media Disorder Scale

The Social Media Disorder Scale (SMDS; Van den Eijnden et al., 2016) was used as a measure of problematic SNS use. The scale consists of 9 items based on the DSM-V criteria for Internet Gaming Disorder (Preoccupation, Tolerance, Withdrawal, Persistence, Displacement, Problem, Deception, Escape, Conflict) and

uses a dichotomous yes-no scale. Wording of one item (item 9 assessing conflict with parents and siblings in adolescents) was adjusted to make it more appropriate to the age of participants in our sample. Problematic SNS use was measured as the sum of affirmative responses across all items. Scores were not calculated for participants with missing responses on the scale.

Reward-based motives

Twenty items were used to assess the ten reward-based motives outlined in the introduction (two items per motive). Each item consisted of a statement (e.g., "I use social media to compare myself to others") and a 5-item Likert-scale (1 = disagree, 2 = slightly disagree, 3 = neither agree nor disagree, 4 = slightly agree, 5 = agree). Two blocks of 10 items were created with one item for each motive in each block. Block order was randomised across participants. Item order within each block was randomised but constant across participants (see Table 1). The two items per motive were averaged producing ten motive scores that could range from 1-5. Participants were asked to indicate their agreement with each item with regard to their behaviour before the outbreak of COVID-19.

Table 1. Items assessing reward-based motives as presented to participants.

Measure	Item
Block 1	
Social comparison	I use social media to compare myself to others.
Archiving	I use social media to document my life.
Impression management	I frequently check social media to see how many likes/retweets my posts have received.
Habitual time passing	I repetitively scroll through social media to pass time.
FoMO	When I don't use social media I experience 'fear of missing out'.
Relationship maintenance	I use social media to maintain my relationships.
Entertainment	I use social media as a source to find entertaining content (e.g., videos/memes).
Negative social potency	I use social media to 'troll' others.
Self-expression	I use social media to provide my update/share my opinion.
Mood alteration	I use social media to take my mind off things or calm myself down.
Block 2	
Relationship maintenance	I regularly interact with people on social media to ensure we remain friends.
Impression management	If something I post doesn't get many likes/retweets I will delete it.
Self-expression	I use social media to express my actual self (who I really am).
Negative social potency	I regularly provoke arguments on social media.
Habitual time passing	I often get stuck in a loop of mindlessly checking social media with no real purpose.
Entertainment	I use social media because I can easily search for content that I enjoy.
Archiving	I frequently post content so that I'm able to look back through my life.
Social comparison	I evaluate myself based on other people's social media profiles.
Mood alteration	If I experience negative emotions I will distract myself through social media.
FoMO	I get anxious if I don't check what my friends are doing on social media.

Results

Descriptive statistics

The most frequently used SNS in our sample was YouTube (86.4%), followed by Facebook (84.2%), Instagram (83.5%) Twitter (50.1%) and Snapchat (37.5%). Other SNSs used by participants included Reddit (13.1%), TikTok (7.3%) and Tumblr (3.2%). Two participants (0.5%) reported that they did not use a SNS of any kind.

Participants reported spending an average of 3.33 hours (SD = 2.56) on SNSs each day. The median frequency of checking social media was 5 (i.e., once every hour), and the mean SMDS score was 2.01 (SD = 1.64). Thirteen participants with missing data on one or more items in the SMDS were not included in the calculation of the mean SMDS score.

Mean scores for the ten reward-based motives are displayed in Figure 1. The most strongly agreed with motive for using SNSs was entertainment, followed by time passing, relationship maintenance and mood alteration. The motive with the lowest level of agreement was negative social potency. Spearman-Brown coefficients indicated acceptable reliability for measures of social comparison (r_s = .754), archiving (r_s = .801), relationship maintenance (r_s = .750), negative social potency (r_s = .675), self-expression (r_s = .617), mood alteration (r_s = .670) and FoMO (r_s = .603). However, Spearman-Brown values indicated unacceptable reliability for measures of impression management (r_s = .461), time passing (r_s = .586) and entertainment (r_s = .527). Because of a lack of internal consistency in some of our motive measures we conducted an exploratory factor analysis before entering motives into a regression model.

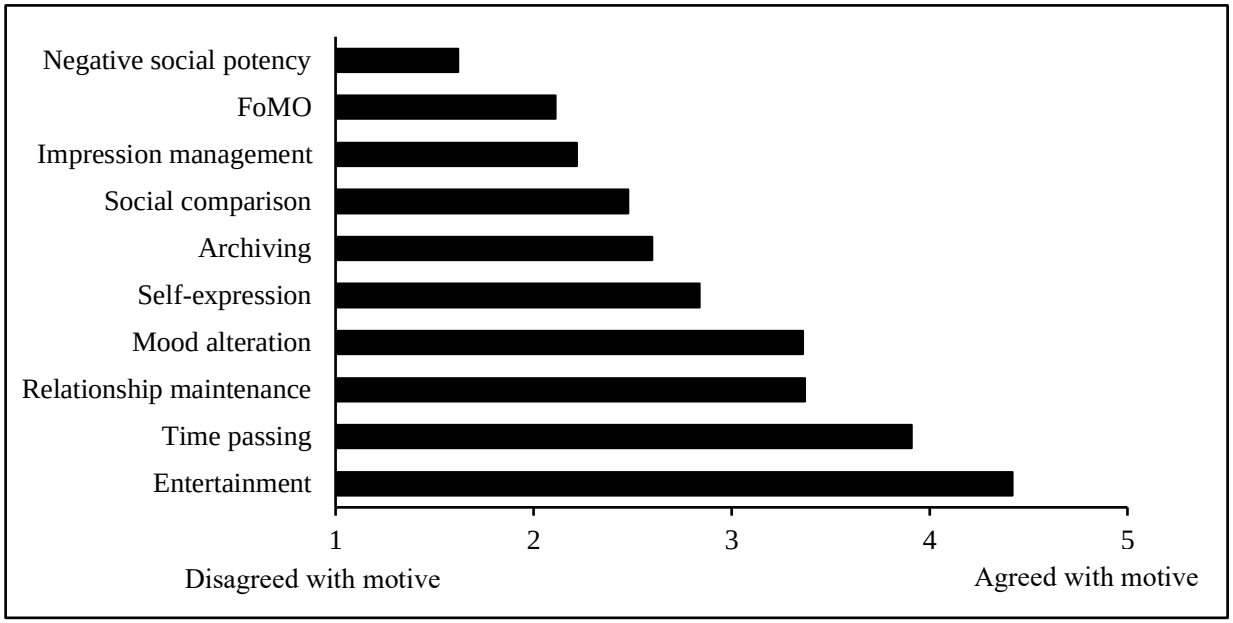

Figure 1. Agreement with ten reward-based motives in the current sample (mean Likert-scale scores). N = 411 for all motives apart from entertainment (N = 410) where an average score could not be calculated for one participant due to missing data.

Dimension reduction

An exploratory factor analysis using the principal component method with varimax rotation was conducted on the 20 motive items. One item measuring habitual time passing ("I often get stuck in a loop of mindlessly checking social media with no real purpose") was removed because of comparable factor loadings with factor 1 (.482) and factor 3 (.432). The factor analysis was performed again, and the results of the analysis are displayed in Table 2. Five factors with eigenvalues greater than 1 were extracted and they collectively accounted for 58.48% of the variance of the original item variables. Cronbach's α values for each factor ranged from 0.66 to 0.78 indicating acceptable reliability. Factor 1 contained 6 items consisting of both measures/items of social comparison, FoMO and impression management. These items are related to rewards obtained by (actively or passively)

interacting with others, either by comparing oneself to another, obtaining 'likes' from another or by staying connected with what others are doing. Therefore, we named this factor 'social reward'. 'Social reward' was associated with the highest eigenvalue among all 5 factors. Factor 2 contained 4 items consisting of both measures of archiving and self-expression. These items are related to personal motivations for SNS use where the reward is obtained by fulfilling one's own goals (i.e., expressing personal views and looking back on past events). Therefore, we named this factor 'personal utility'. Factor 3 contained 5 items consisting of both measures of entertainment and mood alteration and one measure of time passing. These items all relate to the use of SNSs for enjoyment purposes (associated with accessing specific SNS content), either to escape negative emotions, pass time or for entertainment. We therefore named this factor 'enjoyment reward'. Factors 4 and 5 contained only two items each, consisting of both items related to a single motive (negative social potency or relationship maintenance). As such, factor 4 was named negative social potency and factor 5 was named relationship maintenance.

Table 2. Factor analysis using varimax rotation of the reward-based motives to use SNS.

Factors	Loadings
Factor 1: Social reward (α = .76, M = 2.27, SD = 0.88)	
Social comparison (B1)	.794
Social comparison (B2)	.794
FoMO (B1)	.578
FoMO (B2)	.567
Impression management (B1)	.545
Impression management (B2)	.516

Variance (eigenvalue)	15.31 (2.91)
Factor 2: Personal utility (α = .78, M = 2.72, SD = 1.14)	
Archiving (B2)	.790
Archiving (B1)	.788
Self-expression (B2)	.699
Self-expression (B1)	.668
Variance (eigenvalue)	13.66 (2.60)
Factor 3: Enjoyment reward (α = .66, M = 3.94, SD = 0.72)	
Entertainment (B1)	.694
Mood alteration (B1)	.654
Time passing (B1)	.640
Entertainment (B2)	.611
Mood alteration (B2)	.589
Variance (eigenvalue)	11.50 (2.19)
Factor 4: Negative social potency (r_s = .68, M = 1.63, SD = 0.98)	
Negative social potency (B2)	.829
Negative social potency (B1)	.807
Variance (eigenvalue)	9.50 (1.81)
Factor 5: Relationship maintenance (r_s = .75, M = 3.37, SD = 1.27)	
Relationship maintenance (B1)	.875
Relationship maintenance (B2)	.822
Variance (eigenvalue)	8.50 (1.62)

Note. B1 refers to the item in block 1 whereas B2 refers to the item in block 2.

Regression analysis

Because the exploratory factor analysis reduced our 10 proposed motives to 5 factors with acceptable internal consistency, we ran our pre-registered stepwise regression analyses for each dependent measure (time spent using SNSs, frequency of checking SNSs, and SMDS score) using the 5 variables generated from the factor analysis. Results are shown in Table 3. Before running our regression analyses potential gender differences in our dependent measures were explored using independent *t*-tests. Males (M = 3.46, SD = 2.79) and females (M = 3.25, SD = 2.37) did not significantly differ in their self-reported time spent using social media [$t(402) = 0.82$, $p = .414$]. Nor did males (M = 4.41, SD = 1.48) and females (M = 4.52, SD = 1.51) differ in their self-reported frequency of checking [$t(402) = -0.79$, $p = .429$]. However, females (M = 2.28, SD = 1.71) did score significantly higher than males (M = 1.73, SD = 1.52) on the SMDS, indicating more problematic use [$t(389) = -3.32$, $p = .001$]. Because of this significant gender difference, the gender variable was dummy coded and included in our regression model to predict SMDS score. Assumption checks revealed no evidence of outliers, multicollinearity or heteroscedasticity.

The model for daily time spent using SNSs was significant [$F(2, 408) = 14.75$, $p < .001$] with an $R^2 = .067$. The only two significant predictors were negative social potency and personal utility, which both predicted greater SNS use. The stepwise regression of SNS checking frequency revealed two different significant predictors: social reward and enjoyment reward, $F(2, 408) = 23.20$, $p < .001$, $R^2 = .102$, with social reward showing a substantially higher regression coefficient (see Table 3). Finally, the 5 factors and dummy coded gender variables (male, female and other) were entered into a stepwise regression analysis to predict problematic use

(SMDS scores). The four significant predictors included in the model were social reward, enjoyment reward, negative social potency and female, $F(4, 392) = 42.84$, $p < .001$, $R^2 = .304$, with social reward showing the highest beta.

Table 3. Results of the stepwise regression analyses using factors generated from the factor analysis to predict daily time spent using SNSs, frequency of checking SNSs and SMDS score.

Variables	*B*	*SE B*	*β*	*p*
Time spent using				
Negative social potency	0.451	0.127	.173	< .001
Personal utility	0.367	0.110	.163	.001
Frequency of checking				
Social reward	0.427	0.083	.251	< .001
Enjoyment reward	0.297	0.101	.143	.004
Problematic use (SMDS score)[a]				
Social reward	0.653	0.085	.353	< .001
Enjoyment reward	0.422	0.103	.182	< .001
Negative social potency	0.364	0.078	.217	<.001
Female	0.403	0.154	.123	.009

[a] Thirteen participants were excluded from the analysis because of missing data on one or more items in the SMDS.

Together, our results suggest that gender and reward-based motives might better explain problematic social media use (accounting for 30.4% of the variance) than excessive use (accounting for 6.7% of the variance in time spent using and 10.2% of the variance in frequency of checking). Moreover, both the frequency of checking and problematic use appear to be most strongly determined by social

reward, and to a lesser extent by the desire to find enjoyable content (enjoyment reward). Notably, our results also indicate an important role of antisocial motives (negative social potency) in predicting problematic use behaviour and prolonged time spent on SNSs.

Discussion

The present study sought to investigate the predictive utility of ten reward-based motives in explaining excessive and problematic SNS use. Consistent with previous research, descriptive statistics showed that on average entertainment, time passing, and relationship maintenance were most salient when participants self-rated the presence of different motives (Ryan et al., 2014). Interestingly however, when predicting actual use behaviour (quantity and problematicity), other types of motives also played a role.

Based on an analysis of internal consistency of our 10 original motive measures, we conducted a factor analysis that reduced our ten motives to five factors, each with acceptable reliability. The reduction from 10 to 5 constructs confirmed our initial suspicion (see introduction) that some concepts identified in our literature review overlapped with each other to some extent. The 5 extracted factors were labelled ‘social reward’ (consisting of social comparison, FoMO and impression management motives), ‘personal utility’ (archiving and self-expression motives), ‘enjoyment reward’ (entertainment, mood alteration and time passing motives), ‘negative social potency’ and ‘relationship maintenance’.

Using the predictor variables generated from the factor analysis, we then ran our preregistered stepwise regression analyses. These analyses revealed that daily

time spent using SNSs and frequency of checking were associated with distinctly different motives. More prolonged SNS use was associated with the factor 'personal utility' (for self-expression/archiving) and the motivation for engaging in negative social interactions (e.g., trolling). Conversely, more frequent checking was associated with the factor 'social reward' (e.g., gaining social approval/making comparisons with others/maintaining continual social connection) and the desire to find and consume enjoyable content ('enjoyment reward'). These differences in the motives that predict frequent checking versus prolonged use suggest a behavioural dissociation between manifestations of excessive SNS use that might warrant further investigation. If excessive SNS use is to be considered a marker of behavioural addiction, then the distinction between excessive time spent using and excessive checking may be an important aspect of determining what constitutes problematic use. As our findings indicate that the motives predicting checking frequency more closely resemble the motives that predict problematic use, it might be the case that compulsive checking represents a more important indicator of addiction than the actual duration an individual user spends on SNSs.

Consistent with this idea, our results show that the motivation to obtain social rewards has not only an important relationship with checking frequency but also in explaining problematic SNS use (SMDS score). Indeed, the factor 'social reward' (consisting of the average score of the items measuring impression management, social comparison and FoMO) was the strongest predictor of both measures, underscoring the significance of social reward processes for SNS behaviours more generally. Our finding adds to the growing recognition of social reward as being a fundamental driver of human behaviour, similar to non-social rewards (Bhanji & Delgado, 2014). The important influence of approval, acceptance and other social

rewards on behaviour is also demonstrated by neuroimaging work, showing that being liked and accepted by others activates similar brain regions as those that are activated by powerful non-social rewards, such as money or food (Davey et al., 2010; Fareri & Delgado, 2014). Our finding is also consistent with previous research suggesting that addictive SNS use reflects a need to feed the ego and inhibit negative self-evaluations (Andreassen et al., 2017). Thus, the boost in self-esteem associated with gaining social approval (Burrow & Rainone, 2017), the temptation to engage in social comparisons (Chua & Chang, 2016) and the desire to maintain continual connection with what others are doing (Przybylski et al., 2013) may all play an important role in facilitating compulsive SNS use. In turn, in 'healthy' SNS users the presence of desires to excessively engage in these behaviours might represent useful indicators of risk factors for developing problematic use. Interventions that aim to reduce the motivation to gain approval and make comparisons on SNSs, might therefore be most beneficial in reducing problematic use behaviours. For example, Instagram has recently trialled removing the ability to view the 'like' count on other people's posts in some countries (BBC News, 2019). Although this trial has only been conducted on one social media platform and is restricted to a few countries, recent research has suggested that the decision has been well-received by Instagram users with the majority reporting that removing the ability to view likes on social media would improve mental health (e.g., by reducing validation anxiety; Prichard et al., 2021).

The regression analyses also showed that, to a lesser extent, checking frequency and SMDS score were predicted by the factor 'enjoyment reward'. Therefore, individuals who excessively use SNSs as a means to find and consume pleasure-inducing content - either to escape, pass time or for entertainment - may

also be at risk of developing problematic use behaviours. Compulsive use of SNSs for enjoyment purposes may be facilitated by the inherent properties of SNSs – offering uncertain reward and creating a more or less permanent state of reward anticipation, similar to slot machines (Schüll, 2012) – ultimately leading to excessive checking behaviours. These unpredictable patterns of reward delivery (i.e., random-ratio schedules) have long been understood to be highly engaging compared to more predictable schedules of reward (Ferster & Skinner, 1957). Furthermore, random-ratio schedules have been shown to maximize the release of dopamine in the midbrain and parts of the basal ganglia known to be involved in reinforcing reward seeking behaviour (Fiorillo et al., 2003; Zald et al., 2004). As outlined in the introduction, there are specific SNS features that promote unpredictable reward experiences, such as newsfeeds that enable infinite scrolling. Many SNS newsfeeds are constantly updated with new content and offer no natural stopping point, making continual scrolling or persistent checking in anticipation of the next reward a highly engaging activity. Thus, interventions that place caps on the amount of content that can be viewed through a user's newsfeed over a specified period of time may have certain utility in the same way that setting voluntary bet limits can help intense online gamblers control their betting behaviour (Auer & Griffiths, 2013). Taken together, our results support the findings of recent research which found that time passing, socializing, presenting a more popular self and entertainment motives all predict more problematic social media use (Kircaburun et al., 2020).

An unexpected finding of our study was that negative social potency significantly predicted SNS use duration and SMDS score. Few studies have investigated negative social potency as a motivation for using social media, and fewer still have investigated its association with excessive or problematic use.

Nonetheless, a recent study corroborates our finding, showing that a motive to cause social mayhem online predicts problematic SNS use (Meshi et al., 2020). In their study the authors correlated scores on the Social Reward Questionnaire (SRQ; Foulkes, Viding, et al., 2014) with scores on measures of facebook and snapchat addiction. Interestingly, of the six social rewards measured only negative social potency was correlated with more problematic use across both platforms. The researchers suggest that individuals with a motivation to be cruel and callous to others might be more likely to repeatedly engage in negative online behaviours, such as trolling and cyberbullying. The abundant opportunities that SNSs offer to engage in these behaviours might reinforce problematic use and provide a pathway to addiction. We suggest that future research should explore the potential relationship between negative social potency and problematic social media use further as there is currently a lack of research explaining how this motive might facilitate SNS addiction.

Interestingly, despite predicting prolonged use, the factor ‘personal utility’ did not predict problematic SNS behaviours. ‘Personal utility’ was constructed by combining the motive measures of self-expression and archiving. The reward underlying this motive can be described as a positive self-affirmation derived from expressing one’s true self and/or documenting one’s life. Possessing motives for self-expressions and archiving seems to encourage extended periods of use. However, research on the importance of this motive remains scarce and it seems that an archiving/self-documentation motive may be more important for certain platforms, such as Instagram (Sheldon & Bryant, 2016). While some studies have shown that self-expression and self-documentation motives predicted more intense Facebook use (Alhabash et al., 2014), others have found that a motive to use SNSs as a task

management tool (e.g., to store and organise photos) did not predict social media use (Kircaburun et al., 2020). However, our data suggest that while a personal utility motive may promote prolonged SNS use, individuals with this motive are less likely to report using SNSs problematically.

While on average ‘relationship maintenance' was the third most popular motive for SNS use in our sample, it did neither explain excessive nor problematic use. As outlined above, this motive can be considered as a manifestation of the need to belong (Baumeister & Leary, 1995), whereby users seek frequent, diverse and reciprocal interactions with friends online. The lack of association between the relationship maintenance motive and problematic SNS use is in line with research showing that the use of SNSs may have positive effects on wellbeing when they are used to make meaningful connections (Clark et al., 2018). This suggests that using SNSs for relationship maintenance motives may represent a ‘healthier’ use behaviour than using SNSs for other, more self-related purposes, such as gaining approval or social comparisons.

Finally, while males and females did not significantly differ from each other in regard to their self-reported usage intensity, we did observe that females scored significantly higher than males on the SMDS indicating more problematic use. We therefore controlled for this gender difference in our regression model predicting SMDS score. Our results are consistent with findings showing that females are more likely to display higher levels of SNS addiction whereas males are more prone to developing an internet gaming disorder (Su et al., 2020).

Limitations

Similar to other survey-based research, the above findings are limited by biases inherent in self-report measures, such as socially desirable responding and self-consistency (Podsakoff et al., 2003). Further, despite a comprehensive review of the existing literature the list of motives investigated in our study is non-exhaustive and it is possible that other motives may also play a role in explaining SNS behaviours. Identifying new motives underlying SNS use in future studies is especially important insofar as social media technologies will continue to evolve and diversify over time, limiting the temporal validity of our findings. The cross-sectional design also limits the ability to make causal inferences and consequently the direction of the reported effects cannot be determined (i.e., certain motives may be the consequence of more problematic use). Thus, more longitudinal research is needed to ascertain the directionality of the relationship between reward-based motives and excessive/problematic SNS use. Finally, while our study used a multinational sample, the age range was restricted to young adults, with a majority of participants being university educated students. Previous studies have shown a moderating role of age and other sociodemographic variables on SNS use behaviours (Andreassen et al., 2017; Rumpf et al., 2014; Su et al., 2020). It thus seems important to examine differences in reward-based motives contingent on such variables in future research.

Conclusion

Taken together, our findings provide evidence for the importance of reward-based motives in determining the intensity of SNS use but also in explaining compulsive or problematic use behaviours. In general, reward-based motives appear

to predict problematic use (SMDS score) more accurately (with regard to explained variance) than use intensity (checking frequency and time spent on SNSs). Our data also suggest that distinct motives are associated with the frequency of checking SNSs and the actual use duration. Importantly, a high motivation to obtain 'social rewards' (e.g., through social approval, continual connection and social comparison) is the most important indicator of excessive checking and problematic SNS use. The pivotal role of social rewards for SNS behaviour corroborates the notion that social and non-social reward signals converge on a common brain system that guides human behaviour in a diverse range of contexts (Fareri & Delgado, 2014). Given the importance of social reward for SNS use, our results suggest that interventions that target social reward processes (such as removing the visibility of 'likes') may offer the most promising avenue to reduce compulsive SNS use.

Chapter 3

The roles of implicit approach motivation and explicit reward in excessive and problematic use of social networking sites

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Abstract

Despite growing concerns about the addictive potential of social networking sites (SNSs), little is known about the precise neural, cognitive, and emotional processes underpinning compulsive SNS behaviours, such as excessive checking of SNSs. Recent evidence points to the important role of reward in SNS behaviours and one avenue to examine reward processes related to SNSs is the use of behavioural paradigms that allow for the measurement of implicit motivational responses, such as the approach avoidance task (AAT). The AAT has been successfully utilised to capture changes in unconscious reward processes in substance use disorders and other behavioural addictions, with faster approach reactions to addiction-related stimuli reflecting increased wanting/urges to have/consume the reward. In the present study 411 young adults completed an online Visual Approach/Avoidance by the Self Task (VAAST) with social media and control logos as well as other subjective (explicit) measures of reward experience related to SNSs. Our results showed that across participants SNS logos elicited strong approach reactions (compared to control stimuli) and that stronger SNS approach tendencies predicted more frequent SNS checking. Importantly, increased approach motivation was not associated with more problematic use. However, both checking frequency and problematic use were related to alterations of explicit reward processing, including the subjective experience of SNS urges or wanting. We conclude that changes in automatic approach motivation towards SNS stimuli are common in most SNS users, which suggests that implicit imbuement of social media with reward has become pervasive among young adults. Problematic SNS use however may be more reliably indicated by changes in explicit reward processing, such as subjective wanting.

Introduction

Despite a burgeoning literature purporting to demonstrate the addictive potential of social networking sites (SNSs) and describing behavioural patterns of "problematic" or "compulsive" SNS use, the formal recognition of SNS addiction as a mental disorder remains controversial (Griffiths, 2017; Kardefelt-Winther et al., 2017). Many studies are limited by their atheoretical approach and do not offer an explanation of the conditions under which compulsive SNS use develops or how it is maintained (Billieux et al., 2015). Nevertheless, a growing body of research has begun to employ behavioural experimental paradigms to examine the cognitive and motivational processes (such as inhibitory control and attentional bias) that might contribute to general SNS use behaviours and the development and maintenance of problematic SNS use (e.g., Johannes et al., 2019; Moretta & Buodo, 2021; Nikolaidou et al., 2019). If problematic SNS use is to be considered a candidate behavioural addiction then such studies investigating the cognitive/motivational components of SNS use are important in order to demonstrate that it warrants recognition as an addictive disorder (Wegmann & Brand, 2020).

Recently, we have proposed that adopting a reward and incentive-sensitisation approach to understanding SNS use and its addictive potential may be of substantial use to researchers (Ihssen & Wadsley, 2021). The incentive-sensitisation theory of addiction emphasises a dissociation between drug liking and drug wanting, whereby repeated drug use leads to sensitisation of the brain's *wanting* system, rendering it hyper-reactive to the drug and drug associated stimuli (Robinson & Berridge, 1993). This happens without concurrent change to the brain's *liking* system, explaining how addicts can develop increasingly compulsive urges to take the drug without experiencing increased pleasure from drug consumption. While the

theory was originally proposed to explain substance use disorders, evidence now also exists that these mechanisms may extend to addictive behaviours (Berridge & Robinson, 2016). Thus, dopamine dysregulation resulting from the rewarding aspects of SNS use may produce intense *wanting* without *liking* that gives rise to compulsive urges to use SNSs and potentially addiction (Ihssen & Wadsley, 2021). As such, research that can demonstrate modifications of *wanting* in excessive and problematic SNS users may provide key evidence in support of its addictive potential. In our previous study (Ihssen & Wadsley, 2021) we have presented preliminary data showing that subjectively reported wanting co-varies with the frequency users check their SNSs and with diagnostic markers of problematic SNS use. Importantly, according to the incentive-sensitisation theory and its associated incentive salience model (e.g., Berridge & Robinson, 2003), wanting processes (and its dysregulation in addiction) do not only manifest at a conscious subjective level (i.e., in explicit urges and desires) but also entail "implicit", unconscious changes of motivation. Such an account is also upheld by dual-process models of addiction that view addictive behaviours as being driven by both an "impulsive" system, responsible for the automatic evaluation of stimuli, and a "reflective" system, responsible for more controlled and deliberate processing that enables self-regulation of behaviour (Deutsch & Strack, 2006; Noël et al., 2010; Wiers et al., 2007; Wiers & Stacy, 2006). Thus, addictive behaviour can be understood as the outcome of an imbalance between implicit and explicit cognitions that results in a more reactive impulsive system (e.g., modified RTs to addiction-related cues), and a reflective system that is less able to voluntarily inhibit the behaviour or regulate emotional responses (e.g., self-reports of increased subjective craving). Furthermore, explicit and implicit cognitions have been shown to uniquely predict substance use behaviours,

underscoring the utility of assessing both the conscious and unconscious mechanisms underlying addictive disorders (Reich et al., 2010; Wiers et al., 2002).

The present study set out to identify markers of implicit wanting in excessive and problematic SNS users by employing an approach-avoidance task. A second objective was to extend our previous study by systematically measuring subjective (explicit) reward responses using a large sample of SNS users and a range of established reward paradigms, including visual cue reactivity, reward choice, and self-reports of wanting/liking. Demonstrating a distinct profile of behavioural responses in these tasks in excessive/problematic users would add further weight to the idea of SNS use having an addictive dimension.

Implicit wanting and the approach-avoidance task

One way to demonstrate incentive salience (and incentive-sensitisation) in humans is to employ behavioural tasks that capture changes in attention during exposure to visual stimuli associated with the reward (e.g., pictures of the drug). During the course into addiction, these cues can become associated with the rewarding effects of the drug (or behaviour) and imbued with heightened incentive salience, increasing the likelihood that they will attract attention and create an "attentional bias" (Field & Cox, 2008; Field et al., 2009). Two frequently used measures of attentional bias in the laboratory are the Dot Probe task (MacLeod et al., 1986) and visual search task (Wolfe, 1998). While such paradigms have received substantial interest in drug addiction research (Ehrman et al., 2002; Huang et al., 2020) and are increasingly employed to investigate potential behavioural addictions (Mechelmans et al., 2014; van Holst, Lemmens, et al., 2012), studies examining attentional bias in excessive SNS users have reported conflicting results. Nikolaidou

et al. (2019) used eye-tracking whilst participants completed a Dot Probe task with SNS-related stimuli and matched controls. They found that compared to non-problematic SNS users the gaze of problematic users dwelled significantly longer on SNS-related stimuli compared to non-computer related control stimuli and this effect occurred without problematic users rating the SNS images as more pleasant. However, when employing a visual search task Johannes et al. (2019) found no impairment in performance when SNS logos (either with or without notification signs) were used as distractors compared to non-social iPhone app controls. In line with this study but using a novel and more ecologically valid visual search task, Thomson et al. (2021) found no evidence that an attentional bias to SNS logos is correlated with addiction severity. However, while measures of attentional bias have so far not shown clear evidence of altered attentional processing of SNS cues (in both "regular" and compulsive users), these cues might still elicit stronger motivational responses than control cues and/or differentiate motivational responses of regular users from those of compulsive users.

One task to investigate (implicit) motivational responses directly is the approach-avoidance task (AAT; Rinck & Becker, 2007). The AAT is a behavioural reaction time task that measures automatic approach and avoidance tendencies by presenting pictures which participants are instructed to either approach (move or pull towards) or avoid (move or push away from) using joystick push/pull (arm extension/flexion) movements or variants thereof. As motor approach behaviour towards conditioned reward cues directly reflects the motivation to engage or have the reward (Berridge & Robinson, 2003), the AAT allows to measure wanting implicitly. Researchers have previously employed modified versions of this task to investigate changes in implicit wanting associated with alcohol misuse (Field et al.,

2008; Wiers et al., 2009), problem gambling (Boffo et al., 2018) and food rewards (Brockmeyer et al., 2015; Paslakis et al., 2017). Yet, we are currently aware of only one study that has utilized this paradigm to investigate problematic SNS use. Juergensen and Leckfor (2019) used an AAT with Facebook related icons (e.g., Facebook app icon, like button, friend request icon) and neutral control stimuli (e.g., unfamiliar SNS icons) and found that greater scores on a measure of Facebook addiction were correlated with stronger approach biases for SNS stimuli but not control stimuli. Thus, participants who self-reported more problematic Facebook use were more likely to display faster approach reactions to Facebook-related stimuli.

More recently, a conceptually similar task, the stimulus response compatibility task (SRC task; De Houwer et al., 2001; Mogg et al., 2003) has been employed in a study using Facebook (vs. control) cues to measure implicit approach and avoidance reactions (Du et al., 2020). In this task participants make symbolic approach or avoidance movements to addiction-related or control stimuli by moving a manikin figure towards or away from the image (typically using keyboard responses). In contrast to Juergensen and Leckfor (2019) the results of Du et al. (2020) indicate a general approach bias for Facebook stimuli in the whole sample of Facebook users, however this effect was unrelated to Facebook self-control failures (i.e., using social media when it conflicts with other goals). Critically, so far the studies that measure automatic SNS-related approach and avoidance reactions have employed a modest sample size (cf. Juergensen & Leckfor, 2019) and/or exclusively used Facebook-related cues. Thus, while the measurement of automatic approach and avoidance tendencies appears to be a promising tool to demonstrate implicit approach motivation in substance-related and other behavioural addictions, more

systematic work is needed to ascertain whether these effects reliably translate to the problematic use of SNSs.

In the present study we sought to investigate this issue by measuring implicit approach responses to SNS cues in a well-powered sample of 411 young adults. To facilitate online testing we employed an adapted version of the Visual Approach/Avoidance by the Self Task (VAAST) which has been shown to produce larger compatibility effects than the SRC (Manikin) task (Rougier et al., 2018). Previous AATs have relied on push/pull movements (e.g., using joysticks) to infer automatic approach/avoidance tendencies, however Rougier et al. (2018) have challenged the necessity of these motor processes. Instead, the VAAST simulates the visual information associated with whole body movements by enlarging or reducing the size of an image (depending on button-press responses), giving the perception of an approach or avoidance movement.

Explicit motivational responses to SNS stimuli

Importantly, apart from the AAT, we also included three measures of explicit motivational (reward) responses in our study. First, we included a measure of visual cue reactivity to establish whether social media logos with notification icons induce explicit wanting or craving of SNS use as a function of usage frequency or problematic use. While the cue reactivity paradigm is often used to probe implicit reward processes (e.g., neural or physiological responses), cue exposure can also be used to measure variations in explicit motivation, such as self-reported wanting urges assessed in our study. Our previous preliminary findings suggested a positive association between cue reactivity and usage frequency/problematic use (Ihssen & Wadsley, 2021) but were limited by the lack of control/baseline measures – which

we include in the present study – to account for differences in general trait levels of wanting. Secondly, and similarly to our previous study, we incorporated questionnaire-based measures of SNS liking (pleasure) vs. wanting (motivation). Following the incentive-sensitisation theory (Berridge & Robinson, 2016; Robinson & Berridge, 1993), we aimed to establish a potential dissociation between these measures in predicting excessive and problematic SNS uses.

Finally, we used a reward choice task in which participants were asked to decide between a variable monetary reward and a SNS reward (obtaining likes). Choice tasks are a cornerstone in animal research on reward, offering an objective readout of the motivational value attributed to a stimulus relative to an alternative (e.g., Lenoir et al., 2007). They have also been used in various versions with humans (e.g., choice between different food rewards, Finlayson et al., 2007).

Mirroring findings in substance addiction, we predicted that (1) the difference between the approach RTs to SNS logos and approach RTs to control logos was negatively associated with frequency of checking and problematic usage (i.e., faster SNS approach tendencies predicted more excessive/problematic usage); (2) the difference between visual cue reactivity to SNS versus control logos was larger in individuals with more frequent checking and larger in individuals with more problematic usage; and (3) self-reported wanting but not pleasure/liking of social media use was positively related to frequency of checking and problematic usage. Data from the reward choice task and other secondary measures (see below) were examined in exploratory analyses. All hypotheses and analyses were preregistered on the Open Science Framework website (https://osf.io/jqm57).

Method

Participants

The link to the online study was accessed 466 times. Only responses from individuals who participated in the study to completion were included in the analysis. This resulted in a final sample of 411 participants (190 male, 214 female, 7 other) aged between 18-30 (M = 22.9, SD = 3.55) who completed the study between April - July 2020. An international sample was recruited, the majority of which were students (61.6%) and the most common nationality was British (21.4%). Most of the recruitment (69.4%) took place through Polific.com and SurveySwap.io, with the remaining participants (30.6%) being recruited through internal channels at Durham University or by other means. Participants were either reimbursed with small monetary incentives or course credits for their participation or took part without reimbursement. The study was approved by the Ethics Sub-Committee in the Department of Psychology at Durham University and all participants provided fully informed consent.

Materials

Implicit reward measure (approach/avoidance tendencies)

Participants completed a Visual Approach/Avoidance by the Self Task (VAAST; Rougier et al., 2018) with SNS logos and matched control stimuli. Online versions of the VAAST using PsyToolkit have previously been shown to be a reliable measure of approach/avoidance tendencies and produce effects that are of a similar magnitude to those obtained in lab versions of the task (Aubé et al., 2019). In this task participants were required to move towards or away from SNS or control logos using the computer keyboard. Participants were instructed to approach SNS logos

and avoid control logos in the first block, and vice versa for the second block, while others completed the same blocks in the reversed order (randomised across participants). SNS stimuli consisted of Facebook, Instagram, Twitter, Snapchat and YouTube logos. Control stimuli consisted of 5 iPhone app icons (Maps, Weather, App Store, Books and Photos). A training phase with feedback occurred before the experimental trials in each block. The training phase consisted of 10 trials where every stimulus was presented once in a random order (i.e., 5 social media and 5 control stimuli). During each trial an image of a hand holding a smartphone was displayed on a grey background. Participants pressed the 'H' key to initiate the trial. A fixation cross was shown in the middle of the screen for a random duration between 800-2000ms at intervals of 100ms. This was followed by the stimulus presentation (i.e., SNS or control app icon overlayed on the smartphone screen) which remained on screen until a response was made. Participants pressed the 'Y' key to approach or the 'N' key to avoid, depending on the condition. As a result of the key press the hand holding a smartphone and app icon either increased (approach) or decreased (avoid) in size, giving the appearance of movement (see Figure 2 for an illustration of the trial sequence). An inter-stimulus-interval of 500ms occurred after each response. Incorrect responses consisted of making approach responses (i.e., pressing the ‘Y’ key) on avoidance trials, making avoidance responses (i.e., pressing the ‘N’ key) on approach trials, or pressing the ‘H’ key on either trial. During the practice trials an error message was displayed after incorrect responses. No feedback was given about the accuracy of responses during the experimental trials. In the experimental phase a total of 40 trials occurred in random order for each block. Participants completed a total of 100 trials (including blocks of 2 × 40 experimental trials and 2 × 10 training trials).

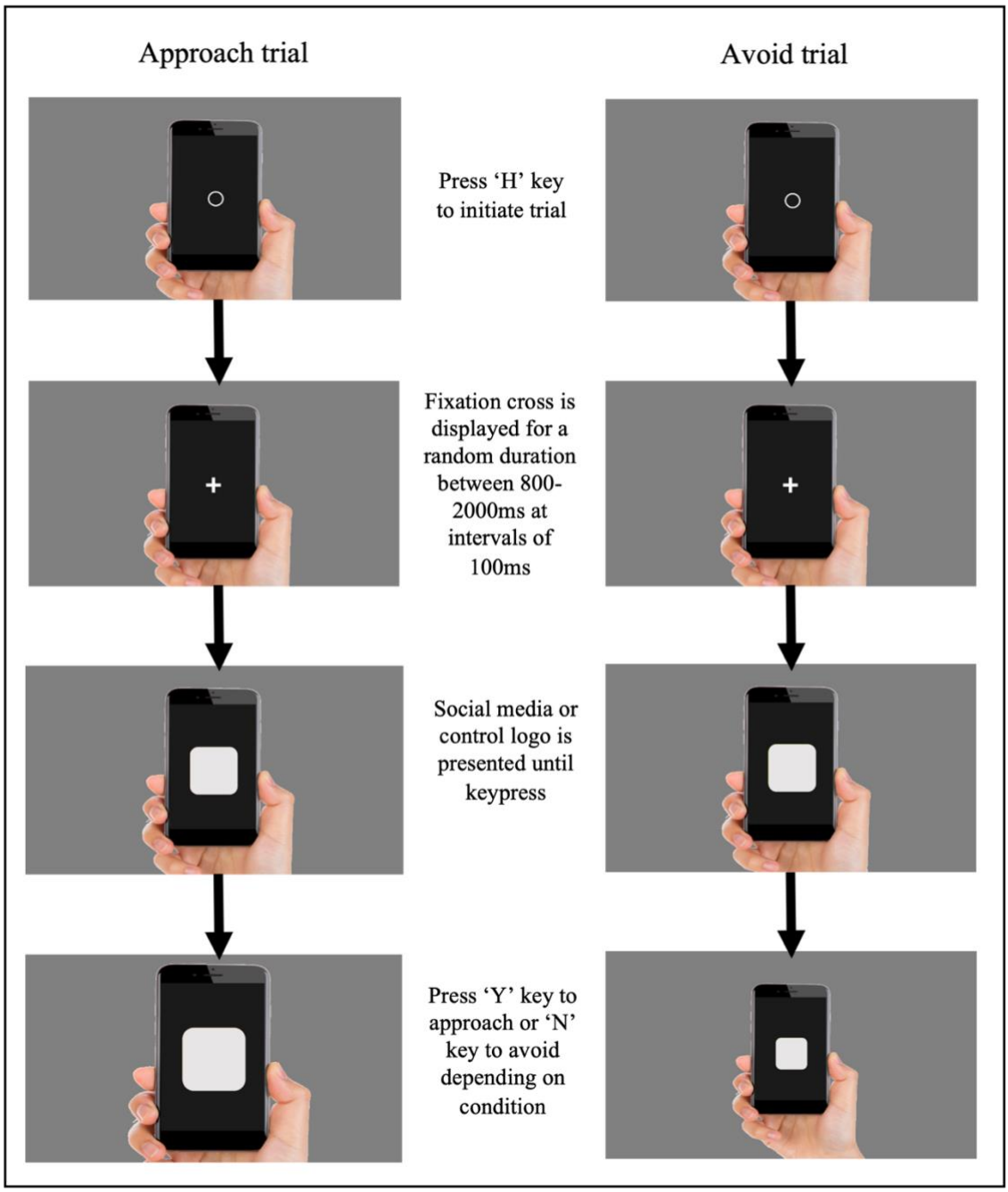

Figure 2. Example of the trial sequence in the social media VAAST with an approach instruction (left) and avoid instruction (right). Social media and control app logos have been removed for copyright reasons.

Explicit reward measures

Cue reactivity

Participants were shown the logos of different social media platforms including Facebook, Instagram, Snapchat, Twitter and YouTube. Participants were only presented with those social media that they reported having used in the previous week. Each logo appeared with a red notification icon in the top right corner of the logo, containing the number one. For each logo shown, participants were asked to report the extent to which the image made them want to check the corresponding social media account. Responses were made using a 5-item Likert-scale (1 = disagree, 2 = slightly disagree, 3 = neither agree nor disagree, 4 = slightly agree, 5 = agree). In addition, participants were presented with two control logos consisting of either the App Store or Play Store logo (depending on whether they reported using an iPhone or Android) and the BBC iPlayer logo. As before, participants rated the extent to which these logos made them want to check the corresponding app using a 5-item Likert-scale. A cue reactivity score was calculated for each participant by subtracting the average response to control logos from the average response to the social media logos.

Wanting vs. liking

Participants were asked to respond to four statements that assessed the extent to which they enjoyed using social media (e.g., “Using social media is an activity that gives me pleasure”), and four statements that assessed the extent to which they experience wanting or urges to use social media (e.g., “When I see my phone, I experience a strong desire to check social media”). Participants indicated their agreement with each statement using a 5-item Likert-scale. Scores across the four

wanting measures and the four liking measures were averaged to produce overall wanting and liking scores for each participant.

Money-or-likes

Participants reported the average number of "likes" or "retweets" they would expect to receive on a typical SNS post. They also completed an experimental reward choice task, in which they first indicated their preference for receiving either £1 or double the likes on their next social media post. When participants chose the social media reward the question was repeated with incremental increases in the value of the money reward, with the increments approximating a doubling of the previous value (i.e., £2, £5, £10, £25, £50, £100). Accordingly, the point at which participants discontinued incrementing the monetary value was interpreted as the subjective reward strength of receiving likes on an SNS post, with higher monetary values representing stronger reward.

Other variables

Excessive and problematic SNS use

Two different measures of excessive SNS use assessed (a) self-reported daily time spent using SNSs (hours), and (b) the frequency of checking using a 7-item scale (less than daily, daily, every 3-5h, 2h, 1h, 30mins, 15mins). Participants were asked to provide separate estimates of their usage intensity before and after the COVID-19 virus outbreak. Participants were also prompted to use the screen time app on their phone (where possible) for questions related to their current usage to enable more accurate estimates. As the present study was more interested in current

usage behaviour, only the estimates relating to participant's more recent usage intensity (post-COVID-19 outbreak) are reported.

Problematic SNS use was assessed using the Social Media Disorder Scale (SMDS; Van den Eijnden et al., 2016). The scale measures nine proposed criteria for SNS addiction (Preoccupation, Tolerance, Withdrawal, Persistence, Displacement, Problem, Deception, Escape, Conflict) using a dichotomous yes-no response scale. The level of problematic use was calculated for each participant by summing affirmative responses across all items (scores could range from 0-9). It is suggested that a score of 5 or more on the SMDS indicates an SNS addiction. Scores were not calculated for participants who had missing data on one or more items in the scale.

General sensitivity to reward

Participants responded to 10 questions taken from the SPSRQ-20 (Aluja & Blanch, 2011), a short form of the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (Torrubia et al., 2001). Only the questions relating to general sensitivity to reward were used (e.g., 'Does the good prospect of obtaining money motivate you strongly to do some things?'). Participants responded to each item using a dichotomous yes-no scale. Scores across the 10 questions were summed to produce an overall sensitivity to reward score for each participant. Scores were not calculated for participants with missing data.

Self-awareness of problematic use

At the end of the study participants were asked to respond to two statements relating to their own perception of their social media use: "I believe I use social

media too much" and "I believe I am addicted to social media". Participants responded to each statement using a dichotomous yes-no scale.

Procedure

Participants who met the eligibility criteria (between the ages of 18-30 years old and with normal or corrected-to-normal vision) were invited to take part in an online study programmed using PsyToolkit (Stoet, 2010, 2017). The experimental and questionnaire measures reported in this article were embedded in a larger online study that also investigated different motives underlying SNS use. These data were not directly relevant to the current research questions and have been reported elsewhere (Wadsley et al., 2022). All participants accessed the study on a device with a real keyboard and using a browser other than Safari (for compatibility with the experiments coded on PsyToolkit). The average time taken to complete the study was 20.09 minutes. The data which support this publication are available on https://doi.org/10.17605/osf.io/dkr9q.

Results

Descriptive statistics

The most frequently used SNS in our sample was YouTube (86.4%), followed by Facebook (84.2%), Instagram (83.5%), Twitter (50.1%) and Snapchat (37.5%). Other types of SNSs that were not explicitly assessed but which participants reported using included Reddit (13.1%), TikTok (7.3%) and Tumblr (3.2%). Only two participants (0.5%) reported that they did not use a SNS of any kind.

When asked to estimate their current social media usage intensity to the nearest hour, participants reported spending an average of 4.57 hours (SD = 2.79) on SNSs each day. The median frequency of checking social media was 6 (i.e., every 30 mins), and the mean SMDS score was 2.01 (SD = 1.64). Thirteen participants were excluded from the calculation of the mean SMDS score and one participant was excluded from the mean time spent using due to missing data.

Responses to the 'self-awareness of problematic use' measures revealed that 60.8% of participants believed that they used social media too much (1.2% did not respond). Furthermore, 29.9% of participants believed that they were addicted to social media (0.7% did not respond). According to Van den Eijnden et al. (2016) (and also in accordance with the cut-off point for internet gaming disorder proposed in the DSM-5) a score of five or more (out of nine) on the SMDS is required to be diagnosed as a disordered social media user. Examination of SMDS scores in our sample revealed that only 6.2% of participants met these criteria, suggesting that participants over-diagnose themselves as addicted.

Preregistered analysis

Approach avoidance tendencies

Only RTs of correct responses were included in the analysis. RTs of correct responses that were below 200ms or above 3000ms were removed as outliers (see https://osf.io/jqm57), resulting in the exclusion of 0.68% of the trials. Participants with an accuracy rate less than 60% on either experimental block were excluded from the analysis. This resulted in the exclusion of 21 participants from the analysis. The overall accuracy rate of participants included in the analysis was 96.55% (SD = 3.78).

First, the main effects of stimulus type (SNS vs. control logo) and movement (approach vs. avoid) as well as their interaction were analysed using a (non-preregistered) 2 × 2 repeated measures ANOVA. This revealed a significant main effect of stimulus type [$F(389) = 184.95$, $p < .001$, $\eta_p^2 = 0.322$], whereby participants responded faster to SNS stimuli (M = 706, SD = 157) compared to control stimuli (M = 754, SD = 162). The main effect of movement was also significant [$F(389) = 7.69$, $p = .006$, $\eta_p^2 = 0.019$], and revealed that participants were faster at making approach responses (M = 725, SD = 165) compared to avoidance responses (M = 735, SD = 155). Finally the interaction effect was also shown to be significant [$F(389) = 99.38$, $p < .001$, $\eta_p^2 = 0.203$], and this effect was further explored using (preregistered) paired t-tests. As shown by paired t-tests, mean approach RTs (ms) to SNS stimuli (M = 666, SD = 142) were significantly faster than approach RTs to control stimuli (M = 784, SD = 187), suggesting that SNS cues elicit speeded approach reactions [$t(389) = -14.74$, $p < .001$, $d = 0.75$]. In contrast, avoidance RTs to SNS stimuli (M = 745, SD = 172) were significantly slower than avoidance RTs to control stimuli (M = 725, SD = 137), indicating that social media cues produce more slowed avoidance reactions [$t(389) = 2.71$, $p = .007$, $d = 0.14$]. The mean RTs for each condition are displayed in Figure 3.

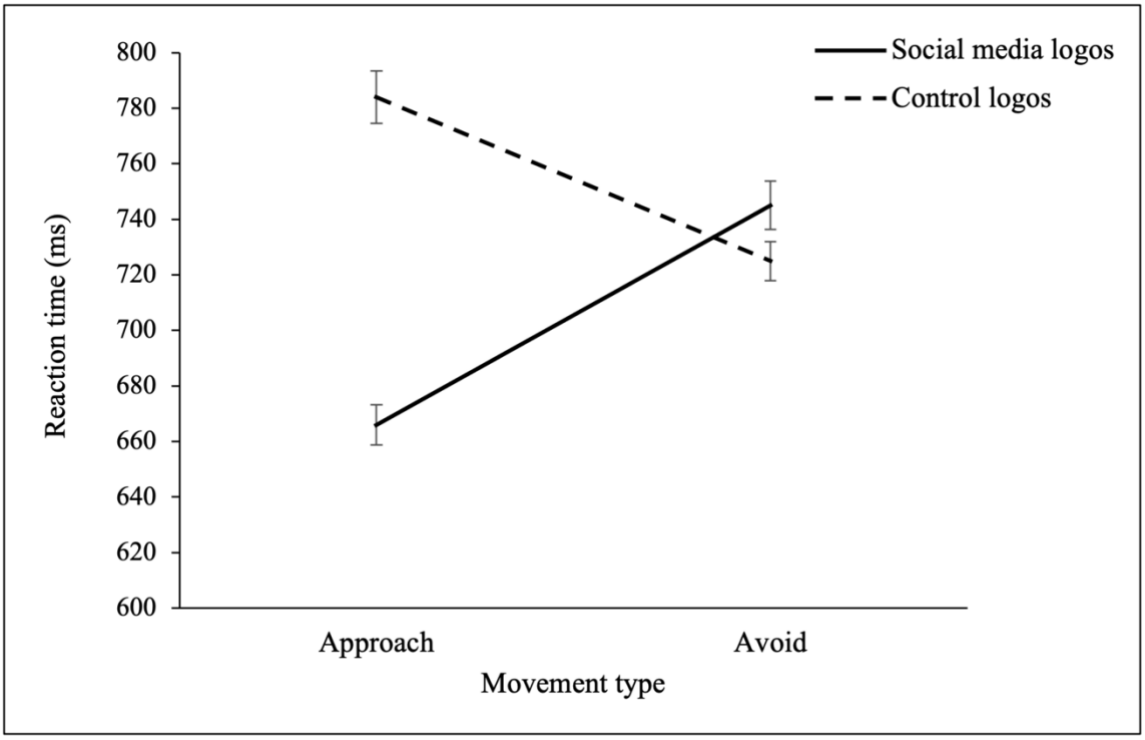

Figure 3. Mean approach and avoidance RTs (ms) to social media and control logos. Error bars represent mean SE.

Accuracy rates were also compared using a (non-preregistered) 2 × 2 repeated measures ANOVA. The main effects of both stimulus type [$F(389) = 36.95$, $p < .001$, $\eta_p^2 = 0.087$] and movement [$F(389) = 52.54$, $p < .001$, $\eta_p^2 = 0.119$] were shown to be significant, revealing that participants were more accurate when responding to control logos and when making approach responses. The interaction effect was also significant [$F(389) = 26.80$, $p < .001$, $\eta_p^2 = 0.064$] and was further explored using paired t-tests. This revealed a significant difference between the accuracy on SNS approach trials (M = 0.96, SD = 0.06) and control approach trials (M = 0.99, SD = 0.03), indicating less accurate approach responses to SNS cues [$t(389) = -9.70$, $p < .001$, $d = 0.49$]. However, the difference in accuracy between SNS avoidance trials (M = 0.96, SD = 0.06) and control avoidance trials (M = 0.96, SD = 0.07) was nonsignificant [$t(389) = -0.32$, $p = .750$, , $d = 0.02$].

Overall SNS approach tendencies were calculated for each participant by subtracting mean RTs on control approach trials from mean RTs on SNS approach trials. Similarly, overall SNS avoidance tendencies were also calculated for each participant by subtracting mean RTs on control avoidance trials from mean RTs on SNS avoidance trials. Approach and avoidance tendencies were negatively correlated with each other (r = -.58, p < .001) indicating that participants who were quicker to approach SNS stimuli were also slower to avoid SNS stimuli, when compared to control stimuli. SNS approach and avoidance tendencies were entered into three separate two stage hierarchical regressions to evaluate their unique contribution to time spent using, frequency of checking and problematic SNS use. For each regression approach tendencies were entered at stage one and avoidance tendencies at stage two. Results of the regression analyses are displayed in Table 4. For the regressions predicting time spent using and problematic use, SNS approach tendencies were not a significant predictor. Additionally, the inclusion of SNS avoidance tendencies did not provide a significant contribution to either model. However, SNS approach tendencies did significantly predict checking frequency (β = -.127, p = .012), whereas the inclusion of SNS avoidance tendencies did not provide a significant contribution to the model. Furthermore, the contribution of SNS approach tendencies remained significant after the inclusion of SNS avoidance tendencies (β = -.132, p = .034). Thus, while we observed a large SNS approach bias and a smaller but significant avoidance bias within the sample as a whole, stronger SNS approach tendencies did not predict prolonged or problematic SNS use. However, our results indicate that stronger SNS approach tendencies predict more frequent SNS checking to some small extent.

Table 4. Summary of regression analyses for the prediction of problematic use, frequency of checking and time spent on SNSs from approach and avoidance tendencies.

Variable	R^2 change	F change	β	p
Time spent using				
Step 1				
Approach	.004	$F(1, 387) = 1.69$	-.066	.195
Step 2				
Avoidance	.000	$F(1, 386) = 0.17$	-.026	.681
Frequency of checking				
Step 1				
Approach	.016	$F(1, 388) = 6.38$	-.127	.012
Step 2				
Avoidance	.000	$F(1, 387) = 0.02$	-.008	.902
Problematic use (SMDS score)				
Step 1				
Approach	.002	$F(1, 376) = 0.65$	-.042	.419
Step 2				
Avoidance	.000	$F(1, 375) = 0.00$	-.002	.979

Cue reactivity

Cue reactivity scores were not significantly correlated with either time spent using SNSs ($r = .03$, $p = .582$) or problematic use ($r = .08$, $p = .096$). However, cue reactivity scores were significantly correlated with frequency of checking ($r_S = .21$, $p < .001$) suggesting that individuals who are more reactive to SNS logos are more likely to check SNSs more frequently.

Furthermore, cue reactivity scores were significantly correlated with wanting scores ($r = .21$, $p < .001$) but not liking scores ($r = .07$, $p = .134$), confirming that cue

reactivity to SNS logos is associated with urges/cravings to use SNS and not the pleasure experienced from using SNSs.

Wanting vs. liking

Wanting and liking scores were significantly correlated with each other (r = .38, $p < .001$). However, to assess the unique contribution of wanting above and beyond liking in predicting each of our SNS use measures we used a two-stage hierarchical regression analysis with liking scores entered at stage one and wanting scores entered at stage two (see Table 5). Liking scores significantly predicted time spent using SNSs, explaining 5.3% of the variance. However, the inclusion of wanting scores made a significant contribution to the model, explaining a further 2.1% of the variance. Nevertheless, liking scores (β = .171, p = .001) still provided the strongest contribution to the model after the inclusion of wanting scores. Liking scores also significantly predicted frequency of checking, explaining 6% of the variance. However, the inclusion of wanting scores explained 12.9% more of the variance and weakened the contribution of liking scores to the model (β = .097, p = .045). Similarly, liking scores predicted SMDS scores, explaining 5.4% of the variance. However, the inclusion of wanting scores explained 12.4% more of the variance and made the contribution of liking scores nonsignificant (β = .088, p = .076).

These results suggest that the experience of urges to use SNSs is a strong predictor of excessive checking and problematic use above and beyond the perceived enjoyment of using SNSs. They also suggest that the actual duration a user spends on SNSs is better predicted by how much they like the SNS rather than by urges or cravings.

Table 5. Summary of regression analyses for the prediction of problematic use, frequency of checking and time spent on SNSs from wanting when controlling for liking.

Variable	R^2 change	F change	β	p
Time spent using				
Step 1				
Liking	.053	$F(1, 408) = 22.96$	.231	< .001
Step 2				
Wanting	.021	$F(1, 407) = 9.21$	.156	.003
Frequency of checking				
Step 1				
Liking	.060	$F(1, 409) = 26.00$	.244	< .001
Step 2				
Wanting	.129	$F(1, 408) = 65.04$	.389	< .001
Problematic use (SMDS score)				
Step 1				
Liking	.054	$F(1, 396) = 22.51$	.232	< .001
Step 2				
Wanting	.124	$F(1, 395) = 59.55$	.380	< .001

Exploratory analysis

Exploratory correlations were conducted between secondary variables (expected likes, money-or-likes and general sensitivity to reward) and each of our three outcome measures (time spent using, frequency of checking and problematic use). Results of these correlations are displayed in Table 6. We found that the number of "likes" an individual expects to receive on a typical post and the extent to which they would prefer to double the "likes" on a future post rather than receive money, were both positively correlated with frequency of checking. General sensitivity to reward was positively correlated with time spent on SNSs and problematic use but

showed the strongest correlation with problematic use. Thus, individuals with increased sensitivity to the experience of reward may be more at risk of using SNSs problematically.

Table 6. Associations between secondary measures and the three usage variables.

	Time spent on SNSs	Frequency of checking	Problematic Use
Expected likes (N = 378)	r = .03, p = .629[a]	**r_s = .18, p < .001***	r = .03, p = .614[b]
Money-or-likes (N = 400)	r_s = .04, p = .383[c]	**r_s = .14, p = .005**	r_s = .03, p = .535[d]
GSR score (N = 370)	**r = .12, p = .020[e]**	r_s = .09, p = .089	**r = .20, p < .001*[f]**

Note. GSR score refers to general sensitivity to reward score. Non-parametric correlation analysis (Spearman's Rho, r_s) was used for *frequency of checking* and *money-or-likes* for which interval scaling could not be assumed.

* Indicates significant correlations that survive Bonferroni corrections for multiple tests.

[a] N = 377
[b] N = 366
[c] N = 399
[d] N = 389
[e] N = 369
[f] N = 365

Discussion

The present study sought to identify implicit and explicit reward responses related to social networking sites (SNSs) in young adults and whether these are associated with use intensity and problematic use (social media addiction). We found that SNS logos elicited strong implicit approach motivation relative to control stimuli. Implicit approach motivation was also positively associated with the frequency of checking SNSs but not with addictive SNS use, which partially supported our first hypothesis.

Similarly, our second hypothesis was also partially supported as SNS cue reactivity scores were correlated with more frequent checking, but not with problematic use. Finally, partial support was found for our third hypothesis as although self-reported liking showed significant positive relationships with measures of excessive and problematic use, self-reported wanting explained a greater proportion of the variance in frequency of checking and problematic use above and beyond liking.

The clear presence of implicit approach tendencies in SNS users regardless of clinically relevant functional impairment (i.e., no association with social media addiction scores) signifies the special motivational status that social media have acquired in young adults' lives. Social media app icons appear to have become potent reinforcers that are imbued with reward to the point of modulating basic processes of approach vs avoidance. The pervasive attractiveness of SNSs and their ability to elicit automatic approach responses is comparable to effects elicited by more basic rewards, such as food or sexual stimuli (Booth et al., 2018; Kahveci et al., 2020). Our previous survey results showed that SNS use is best understood as a behaviour motivated by the prospect of gaining social reward (Wadsley et al., 2022). Specifically, we showed that problematic use and checking frequency were correlated with the motivation to obtain social approval from others, to make social comparisons or to mitigate fears that others have rewarding experiences without one's own presence (Fear of Missing Out; Przybylski et al., 2013). The present results suggest that despite their seemingly more complex nature, these social rewards may be associated with neurocognitive mechanisms, such as automatic approach motivation, that are similar to those underpinning responses to primary rewards, including food and sexual stimuli.

Interestingly, the present data indicate that the control stimuli used in the approach-avoidance task elicited significantly faster avoidance responses compared to approach responses, suggesting a possible "avoidance bias" for these stimuli. We opted to use common non-SNS iPhone app icons as control stimuli since they share similar visual properties to SNS app icons, and we expected them to be relatively neutral with regard to their rewarding/aversive associations. However, if our control stimuli were truly neutral, we would expect no significant difference between approach and avoidance RTs to these images. It is thus possible that in regular SNS users these app icons have become devalued and are perceived as "less interesting" compared to the SNS logos being associated with reward and approach.

To our knowledge only two other studies have investigated automatic approach tendencies to SNS stimuli (Du et al., 2020; Juergensen & Leckfor, 2019). Du et al. (2020) found speeded approach RTs to Facebook stimuli in the whole sample, which were unrelated to social media self-control failures. These results were thus in line with the present findings and our interpretation that – similar to primary rewards – SNSs have high motivational salience in young adults. While Juergensen and Leckfor (2019) did find a relationship between approach responses and Facebook addiction, effect sizes were small and significant correlations were found for only two of the six subscales used to assess addictive behaviours. Taken together, existing research in this area is limited and contains many methodological differences. Thus, it is currently too early to draw firm conclusions about the utility of implicit approach paradigms as markers of problematic SNS use.

Importantly, we found problematic use was predicted by explicit measures of SNS reward. Self-reported urges to use SNSs (= wanting) explained a significant proportion of the variance in both frequency of checking and problematic use.

Pointing to a special role and possible dissociation of motivational (wanting) versus pleasure-related (liking) aspects of SNS use, wanting explained problematic use above and beyond self-reported liking (see also Ihssen & Wadsley, 2021). However, in contrast to our previous study, in the present study liking played a more important role in explaining the actual SNS usage duration. Additionally, the measure of cue reactivity produced a different pattern of results to those in our previous study (Ihssen & Wadsley, 2021). While we replicated the finding that cue reactivity to SNS logos was correlated with more frequent checking, no associations were found with the usage duration and problematic use variables. However, a notable difference in the present study is that non-SNS logos were used as a baseline measure of general cue reactivity. Thus, when accounting for trait levels of reactivity to cues in general, the relationship between SNS cue reactivity and problematic/excessive use appears to be less important. We also found a significant positive correlation between general sensitivity to reward (measured with the SPSRQ) and problematic SNS use. This suggests that, similar to other addictions (Sistad et al., 2019), the experience of greater reward sensitivity may represent a risk factor in the development of problematic SNS use behaviours (Lyvers et al., 2019). Exploratory correlations also revealed that individuals who expect to receive a greater number of "likes" on their SNS posts and those who prefer to receive "likes" over money are more likely to check their accounts more frequently. This illustrates the powerful role that SNS "likes" might play in facilitating compulsive checking (cf. Sherman et al., 2016).

The present study is not without some important limitations. Firstly, the cross-sectional design does not permit us to make causal inferences about the direction of the reported effects, for instance whether frequent SNS checking produces an approach bias to SNS cues or whether pre-existing approach tendencies

increase checking frequency. We also note the need to further control the stimuli used in the social media VAAST. The present study used non-SNS iPhone app icons as control stimuli, however these stimuli might not have been motivationally 'neutral' for all participants. Post-experimental stimulus ratings (e.g., on valence and motivational dimensions) may help to address this issue. Further, it is possible that the SNS logos were more familiar than control logos to participants. Differences in familiarity might partially account for the diverging pattern of RTs in approach vs avoidance trials in the present study, thus it might be useful to add familiarity ratings to future research. It is also notable that participants made significantly more errors on SNS approach trials compared to control approach trials and thus faster SNS approach tendencies could potentially be attributed to less accurate responding on these trials, indicating a speed accuracy trade-off. However, such an account would not explain the significantly slower RTs on SNS avoidance trials compared to controls since accuracy did not differ between these two conditions. Moreover, while speed-accuracy trade-offs can be problematic in RT tasks that use response times as a performance indicator (e.g., as a reflection of stimulus recognisability), here we interpret RT variations as being driven by motivational differences. In fact, increased approach tendencies or biases could be predicted to produce both faster AND less accurate responding, indicating the prioritisation of reward engagement over stimulus processing. Finally, while we did observe a significant relationship between self-reported checking frequency and implicit SNS approach tendencies, the correlation was weak and explained less than 2% of the variance. More research is needed to clarify the strength of this relationship, especially when checking frequency is assessed objectively through device-based tracking apps.

In sum, our results indicate that SNS logos elicited faster approach reactions compared to control app logos. Unlike some previous research (Juergensen & Leckfor, 2019) and contrary to our predictions, the difference between these RTs were not associated with diagnostic criteria of problematic use. However, approach tendencies to SNS stimuli were significantly (albeit weakly) associated with self-reported SNS checking (i.e., participants with faster approach RTs to SNS compared to control stimuli reported more frequent SNS checking). Checking frequency was also positively associated with urges elicited by SNS logos, corroborating the idea that sensitisation to cues associated with SNS reward constitutes an important determinant of use behaviours (Ihssen & Wadsley, 2021). One tentative interpretation of the present pattern of results is that frequent SNS use goes along with dose-dependent changes in basic reward processes, including increases in automatic approach and use desires when confronted with SNS cues. However, for frequent checking to develop into social media addiction (i.e., continued use despite harmful consequences) other processes need to be present. These may include the subjective experience of SNS craving (wanting) regardless of the presence of cues but also the presence of pre-disposing trait variables, such as general reward sensitivity or impulsivity (lack of inhibitory control). Evidence for the role of inhibitory control comes from a study by Wegmann et al. (2020). Using an auditory Go/No-Go task with SNS ringtones (e.g., WhatsApp message tone) and analogous control stimuli (e.g., a bike bell) the authors showed that symptoms of disordered SNS use were highest in individuals who exhibited both weaknesses on measures of general attentional impulsivity and task-related inhibitory control (reacting to SNS ringtones when instructed to withhold responding). In another study, Gao et al. (2019) employed a Go/No-Go task with SNS logos and control stimuli whilst also

recording neural activity using an electroencephalogram (EEG). Although the behavioural data revealed no significant difference between excessive and non-excessive SNS users, EEG recordings revealed event related potentials (ERPs) indicative of inhibitory control difficulties in excessive compared to non-excessive SNS users. In a similar study using Facebook-related and affective images Moretta and Buodo (2021) observed that problematic Facebook users displayed reduced accuracy to Go and No-Go trials regardless of image type and ERPs suggesting less efficient inhibitory control to natural and Facebook-related rewards (as indicated by reduced P3 amplitudes on No-Go trials).

To conclude, our study highlights an association between self-reported excessive checking of SNSs on the one hand and automatic approach tendencies and responses to SNS cues on the other hand. It also suggests altered explicit reward experiences in users displaying addictive use behaviours, including heightened SNS craving and amplified general reward sensitivity. At the same time, our study shows that more research employing experimental paradigms with SNS stimuli, such as the approach-avoidance or Go/No-Go task, is needed before inferences can be made about the similarities in the cognitive/motivational underpinnings of substance use addictions and problematic SNS use. The approach-avoidance task has previously been successfully implemented as a training tool to help reduce the consumption of addictive substances, including alcohol and tobacco (Kakoschke et al., 2017). Therefore, future studies might also assess whether approach bias modification to SNS cues can be used as an effective tool to reduce excessive SNS checking and thus potentially interrupt the pathway into social media addiction.

Chapter 4

Restricting social networking site use for one week produces varied effects on mood but does not increase explicit or implicit desires to use SNSs: Findings from an ecological momentary assessment study

The following chapter is currently under review in *PLOS ONE* and has been submitted as: Wadsley, M., & Ihssen, N. (under review). Restricting social networking site use for one week produces varied effects on mood but does not increase explicit or implicit desires to use SNSs: Findings from an ecological momentary assessment study. *PLOS ONE.*

Abstract

Recent research on the addictive potential of modern technologies such as the internet, smartphones, or social networking sites (SNSs) has suggested that emotional and motivational changes associated with the sudden discontinuation of engagement with the technology mirror the aversive consequences seen when drug use is ceased abruptly. This has been observed even in moderate users and interpreted as a manifestation of withdrawal, an important marker of physical dependence in substance use disorders. On the other hand, a growing literature emphasises the positive effects of "digital detox" on mental health and well-being. Using a battery of affective and motivational measures, both explicit and implicit, the present study tracked the effects of a week of significantly reduced SNS use in moderate to heavy SNS users (N = 51). Our pre-registered analyses showed that the intervention elicited affective changes neither consistent with a general withdrawal syndrome (i.e., increased negative affect and cravings) nor with a general beneficial effect on well-being: While our data indicated some abstinence-related decreases of negative affect and boredom, they also showed a reduction of positive affect. These changes occurred regardless of problematic/addictive use behaviours. Importantly, restricting SNS use for one week had no effect on implicit measures of SNS use motivation (i.e., approach biases, time distortion and effort expenditure for SNS access) nor did it influence explicit cravings and SNS cue-reactivity. Together our findings suggest that restricting SNS use has nuanced and potentially offsetting effects on well-being. These could arise because use reduction may concurrently remove experiences that trigger negative emotions (e.g., upward social comparisons or Fear of Missing Out) but also those that elicit positive emotions (e.g., social approval). The hypothesised lack of a net effect on well-being would be consistent

with our finding that voluntary reduction of SNS use does not mitigate or exacerbate SNS-related urges.

Introduction

Excessive use of social networking sites (SNSs) is widely understood to have harmful consequences to our mental health and wellbeing (Keles et al., 2020; Oberst et al., 2017; but see Orben & Przybylski, 2019), and numerous studies have shown that some SNS users display patterns of behaviour that resemble diagnostic criteria for traditional substance use addictions (Andreassen, 2015; Cheng et al., 2021). Nonetheless, no formal diagnosis for 'SNS addiction' currently exists and many researchers dispute whether certain excessive behaviours should be conceptualised as addictions, fearing that this could lead to an over-pathologization of normal everyday activities (Billieux et al., 2015; Kardefelt-Winther et al., 2017). In support of this view, when similar diagnostic criteria were applied to offline social activities 69% of individuals could be classified as addicted to spending time with their friends (Satchell et al., 2021). While there is rightly no desire for 'friend addiction' to be recognised as a mental health disorder, the findings highlight that those scales claiming to measure a 'SNS addiction' cannot be assumed to capture a clinically relevant pathology. Thus, the existence of 'SNS addiction' should be treated with a degree of scepticism when diagnoses are based solely on criteria adapted from scales used to diagnose traditional substance use addictions without proper validation. More theory-driven, empirical research is needed to better understand whether more excessive/problematic SNS users do indeed display a similar symptomatology to that of individuals affected by traditional substance use disorders.

Substance addictions are diagnosed not only by the symptoms that occur when an individual is using the substance but also by the symptoms that present when they are unable to use the substance or have to curb their consumption levels. Withdrawal symptoms, relapse and rebound effects are all hallmark features of

addiction in substance use disorders. That is, individuals with an addiction experience negative psychological (e.g., increased cravings, reduced mood) and physical (e.g., increased sweating and muscle pains) effects when drug consumption is stopped abruptly (i.e., withdrawal), an inability to maintain drug abstinence (i.e., relapse), and increased drug consumption compared to baseline after a temporary period of full or partial abstinence (i.e., rebound). As such, if problematic SNS use warrants recognition as an addictive disorder then similar experiences can be expected to occur in more excessive/problematic users who undergo a period of SNS abstinence or use reduction.

Indeed, a number of studies have found negative, potentially withdrawal-like, outcomes from SNS abstinence. One key feature of withdrawal is an increase in cravings when the drug/behaviour is unavailable. In line with this, when abstaining from SNSs for one week, Stieger and Lewetz (2018) found that participants experienced increases in cravings, boredom and social pressure to use SNSs, as well as (nonsignificant) reductions in positive and negative affect. In addition to these withdrawal-like effects the researchers also report that around 60% of participants 'relapsed' at least once during the intervention, suggesting that the majority of SNS users experience difficulties controlling their use behaviours. Similarly, Wilcockson et al. (2019) found that when participants were prevented from using their smartphones for 24 hours (including the use of mobile SNS apps), they reported significantly increased cravings. However, inconsistent with the experience of withdrawal, smartphone abstinence had no significant effect on measures of mood or anxiety. Withdrawal effects can also be inferred from assessments of time distortion. Turel and Cavagnaro (2019) showed that when participants completed a task requiring them to reflect on their SNS use, those who had abstained from SNSs for a

week displayed a significantly larger upwards time distortion bias (i.e., believing more time had passed than actually had) compared to those who had not abstained. Furthermore, this effect was more pronounced in individuals with more addiction symptoms. The authors argued that more addicted individuals had experienced more negative emotions (e.g., increased stress and cravings) when deprived from using SNSs, making it seem as though the task had taken longer than it actually did (Turel, Brevers, et al., 2018). Other potential withdrawal effects resulting from a week of SNS abstinence have been shown to include a decline in life satisfaction and increases in negative affect and loneliness (Vally & D'Souza, 2019). During a 48 hour period of Facebook abstinence Sheldon et al. (2011) found that participants reported feeling less connected, and the experience of greater disconnection during abstinence predicted more excessive Facebook use in the future. Additionally, Hanley et al. (2019) showed that the experience of withdrawal effects may depend on how individuals use SNSs. They found that active, but not passive SNS users reported reduced positive affect after abstaining from Facebook and Instagram for one week. According to the authors, active users may be more likely to experience benefits from their SNS use, but reduced positive affect resulting from SNS abstinence could also reflect a withdrawal-like symptom in these users.

Conversely, a period of SNS abstinence can also be predicted to alleviate the harmful psychological effects associated with SNS use, producing positive outcomes. In one of the most comprehensive studies to investigate the effects of SNS abstinence it was found that deactivating Facebook for a period of four weeks increased subjective wellbeing and reduced post-experiment Facebook use (Allcott et al., 2020). Furthermore, another large-scale study showed that after a week of Facebook abstinence participants reported increases in life satisfaction and positive

affect (Tromholt, 2016). Fioravanti et al. (2020) showed that quitting Instagram for a week increased life satisfaction and positive affect, but only for women with a tendency towards making social comparisons. The positive effects associated with a week of SNS abstinence have also been shown to include a reduction in the 'fear of missing out' (FoMO) and increased social connectedness (Brown & Kuss, 2020), as well as a reduction in perceived stress (Turel, Cavagnaro, et al., 2018). One study has even shown that five days of SNS abstinence may have positive physiological effects (Vanman et al., 2018). While Facebook abstinence did not affect perceived stress in this study, participants who abstained did show reduced cortisol levels (the body's primary stress hormone). However, despite this reduction in physiological stress, Facebook abstinence also resulted in lower self-ratings of life satisfaction. Other studies have shown that limiting SNS use, rather than quitting completely, can result in similar beneficial effects. Brailovskaia, Ströse, et al. (2020) found that Facebook users who restricted their use to 20 minutes per day for two weeks reported increased well-being and reduced depressive symptoms. Similarly, SNS users who limited their use to 30 minutes per day over a period of three weeks experienced reduced loneliness and depression (Hunt et al., 2018). Consistent with the positive effects of use reduction, Graham et al. (2021) found that limiting daily SNS use to 10 minutes per app for one week improved wellbeing and sleep quality.

Nonetheless, other research has failed to observe any effects of SNS abstinence or use reduction on mood and wellbeing. In one such study participants were randomly assigned to one of five experimental conditions, consisting of varying abstinence durations (1-4 weeks) and a control group continuing with their regular use (Hall et al., 2021). Surprisingly the researchers found that SNS abstinence, even after four weeks, had no effect on daily measures of subjective wellbeing, loneliness

and quality of day. Collis and Eggers (2022) also report no effects of restricting SNS use. When participants limited their SNS use to 10 minutes per day for a period of nine weeks, no effect on their wellbeing or academic success was observed. Similarly, van Wezel et al. (2021) found no effects on wellbeing or behavioural measures of attention when participants reduced their SNS screentime by 50%. Other research using a shorter abstinence manipulation has shown that preventing SNS use for one day has no effect on well-being, although some individuals showed reduced social relatedness and satisfaction with one's day (Przybylski et al., 2021). Schwarz et al. (2022) also report that while participants who abstained from Instagram for one week showed improvements in general mental state and self-esteem as well as a reduction in depressive symptoms compared to baseline, these improvements did not significantly differ from those observed in a control group who did not restrict their Instagram use.

As outlined above, the available literature appears inconsistent regarding the potential beneficial and detrimental effects of SNS use cessation or reduction. This is corroborated by a recent systematic review of digital detox interventions, showing that previous research has reported both positive and negative effects of abstinence on measures of mood and wellbeing, with other studies finding no effects at all (Radtke et al., 2022). Variability in the reported effects may partly be accounted for by differences between studies in terms of abstinence requirements (complete abstinence vs restricted use) and duration, the focus on different SNS platforms and other factors.

In the present study we tracked self-reported affect and motivation on a day-by-day basis using ecological momentary assessments (EMAs) across a 7-day intervention which asked participants to abstain from SNS use. To allow for the

assessment of potential rebound effects and compensatory behaviours the present study also employed baseline (3-days) and post-intervention (4-days) assessments. A recent systematic review of abstinence effects across different behavioural addictions has indicated that rebound effects and compensatory behaviours have not been adequately assessed in previous research (Fernandez et al., 2020). Such assessments are important as short-term SNS abstinence interventions may not be advisable if individuals substitute their SNS use for equally harmful activities or if the harmful consequences of their SNS use are exacerbated when normal use is resumed. For example Collis and Eggers (2022) found that when students had to limit their SNS use they spent more time using instant messaging apps and did not reduce their overall digital screen time. In fact, the participants in the abstinence condition overcompensated for their lack of SNS use and spent significantly more time using digital devices than those in a control group. There is also some evidence that reducing online activity increases TV watching (Allcott et al., 2020) but may also encourage beneficial behaviours such as increasing exercise and reducing smoking (Brailovskaia, Ströse, et al., 2020).

Most previous research using abstinence/use reduction interventions also suffers from a reliance on self-report assessments of emotional and motivational states. In the present study, we therefore included a number of lab-based experimental measures to gauge the effects of the intervention period on implicit use motivation. In substance addiction, such measures (e.g., unconscious changes in drug wanting) have been shown to be associated with the experience of withdrawal (Cox et al., 2006; Waters & Feyerabend, 2000). Similarly, in behavioural addictions implicit measures of reward processes have been used to demonstrate modifications of attentional bias to gambling cues in abstinent pathological gamblers (Ciccarelli et

al., 2016). Implicit use motivation also appears to characterise SNS use more generally, and we have recently demonstrated the existence of increased implicit approach motivation towards SNS stimuli in a large sample of young adults (Wadsley & Ihssen, 2022). In two lab sessions immediately before and after the abstinence intervention, the present study assessed implicit SNS wanting using an adapted Visual Approach/Avoidance by the Self Task (VAAST; Rougier et al., 2018), an assessment of time distortion, and an adapted Effort Expenditure for Reward Task (EEfRT; Treadway et al., 2009). Furthermore, using a visual cue reactivity task the lab sessions also assessed changes in explicit motivational responses to SNS app icons that might be modified by a period of abstinence.

For the EMA measures we predicted that abstinence would reduce positive affect and increase negative affect from baseline (t1) to the intervention period (t2) and that these effects would be correlated with more problematic SNS use (Hypothesis 1a). We also predicted that abstinence would increase self-reported experiences of boredom, loneliness and cravings to use social media from t1 to t2 and that these effects would be correlated with more problematic SNS use (Hypothesis 1b).

For the experimental measures obtained in the two lab sessions we predicted that visual cue reactivity to social media would be stronger at session 2 (last day of intervention period) compared to session 1 (first day of intervention; Hypothesis 2a). We also hypothesised that larger cue reactivity scores after abstinence would be correlated with more problematic SNS use (Hypothesis 2b). Further, we predicted that the approach bias to SNS stimuli in the social media VAAST would be greater at session 2 compared to session 1 (Hypothesis 3a) and that a stronger approach bias to SNS stimuli after abstinence would be correlated with more problematic use

(Hypothesis 3b). For the time distortion task, we predicted a stronger time distortion effect at session 2 compared to session 1 (Hypothesis 4a) and that this effect would be correlated with more problematic SNS use (Hypothesis 4b). Finally, we predicted that participants would exert more effort in the adapted EEfRT at session 2 compared to session 1 (Hypothesis 5a) and that these effects would also be correlated with more problematic SNS use (Hypothesis 5b). The method and hypotheses for this study were preregistered on the Open Science Framework (https://osf.io/pe7aw).

Method

Participants

Fifty-five young adults between the ages 18-25 were recruited from the student population at Durham University and took part in the study between January-June 2022. Three participants withdrew from the study and data from one participant was excluded from the analysis as they did not meet the inclusion criteria (iPhone user). The final sample of 51 participants (M_{age} = 19.92, SD = 1.16, 16 males, 35 females) all reported using at least one SNS daily, using an iPhone with the Screen Time app enabled, and being willing to abstain from using SNSs for one week. Additionally, 16 participants were excluded from analysis of the mood data due to inadequate survey response rates (see results section, final N = 35 for analysis of mood changes), and three participants were excluded from analysis of the VAAST data due to insufficient response accuracy (< 60 % of trials correct; final N = 48). To ensure the sample included participants with varying levels of problematic use, separate adverts were used to target more problematic users (those who score 4 or more on the Social Media Disorder Scale; SMDS; (Van den Eijnden et al., 2016)) and less problematic users (those who score less than 4 on the SMDS). Participants

received course credits or £30 Amazon vouchers for their participation. The study was approved by the Ethics Sub-Committee in the Department of Psychology at Durham University on 8th March 2021 (PSYCH-2021-01-25T15_08_42-hxck16) and all participants provided written informed consent.

Materials

Ecological momentary assessments

Daily questionnaires comprised five dependent measures (nine items in total), assessing similar affective and motivational variables as comparable abstinence studies (Stieger & Lewetz, 2018): (1) Boredom ("How bored do you feel right now?"), (2) loneliness ("How lonely do you feel right now?") and (3) SNS cravings ("How much do you want to use social media right now?") were assessed using single item measures. Additionally, three questions assessing (4) positive affect and three questions assessing (5) negative affect were taken from the International Positive and Negative Affect Schedule-Short Form (I-PANAS-SF; Thompson, 2007). These questions asked participants to report their current happiness, cheerfulness and liveliness (positive affect) as well as sadness, miserableness and madness (negative affect). Responses to each question were made using a 0-100 sliding scale (0 = not at all, 100 = very bored/lonely/happy etc.) and question order was randomised for each questionnaire.

End-of-day questionnaire

An end-of-day questionnaire was used to obtain daily measures of SNS screen time, total iPhone screen time and reports of any behaviours that participants had used to compensate for the non-use of SNSs. When reporting their screen times,

participants were always instructed to report their usage from the previous day using the Screen Time app on their phone in order to ensure that each measure represented a whole 24-hour period. Thus, for measures of screen time, the baseline phase was 4 days, and the post-intervention phase was 3 days. Participants were first asked to use the Screen Time app to report the number of minutes spent on SNSs during the previous day. When calculating their SNS screen time participants were asked to subtract any time spent using instant messaging apps (e.g., WhatsApp) but to include any time spent on SNSs not listed under the 'social' category in the Screen Time app (e.g., YouTube, categorised as 'entertainment'). They were then asked to estimate any additional time spent using SNSs on other devices during the previous day. These two measures were summed to calculate daily SNS usage. An additional question asked participants to use the Screen Time app to report their total iPhone screen time on the previous day. A final question asked participants to report potential compensatory behaviours by asking "Have you done any of the following activities today more than you would do usually?". Participants responded to six categories of activities and rated the extent of their engagement for activities they reported doing more than usual using a 1-7 sliding scale (1= slightly more than usual, 7 = much more than usual). The assessed compensatory behaviours consisted of 1) Watching TV or video streaming sites (e.g., Netflix); 2) Eating junk food; 3) Playing video games; 4) Drinking alcohol; 5) Gambling; 6) Online shopping. In cases where participants did not complete an end-of-day questionnaire the researcher followed up with them to obtain the screen times for the missed days. However, participants were not asked to provide retrospective estimates of compensatory behaviours.

Visual cue reactivity

Similar to our previous research (Ihssen & Wadsley, 2021; Wadsley & Ihssen, 2022), participants were asked to rate the extent to which images of 6 SNS icons (Facebook, Instagram, Snapchat, Twitter, TikTok and YouTube) and 6 iPhone app control icons (Settings, Maps, App Store, Photos, Weather, Books) made them want to check the corresponding application. Participants were asked to respond to each statement (e.g., "this icon makes me want to check the Facebook app?") using a 7-item Likert scale (strongly disagree – strongly agree). Cue reactivity scores were calculated at pre- and post-intervention by subtracting the average response to control icons from the average response to the SNS icons. During the second session participants were also asked to provide ratings of familiarity ("I am familiar with this icon"), valence ("this icon is visually appealing"), and arousal ("this icon is exciting") for each icon. Participants were instructed to respond to each statement with regard to the image itself rather than how much they liked a specific app.

Approach/Avoidance Task

Participants completed an adapted Visual Approach/Avoidance by the Self Task (VAAST; Rougier et al., 2018) with SNS and control stimuli, previously described in Wadsley and Ihssen (Wadsley & Ihssen, 2022). In this task participants were required to move towards or away from SNS or control icons using the computer keyboard. Approach vs avoidance movements were reflected by increases/decreases in the size of the visual stimuli. Participants were instructed to approach SNS icons and avoid control icons in the first block, and vice versa for the second block, while others complete the same blocks in the reversed order (counterbalanced across participants). The block order for each participant was the

same across the two testing sessions. The SNS stimuli consisted of Facebook, Instagram, Twitter, Snapchat, TikTok and YouTube app icons, whereas the control stimuli consisted of Maps, Weather, App Store, Books, Photos and Settings iPhone app icons. A training phase with feedback occurred before the experimental trials in each block. The training phase consisted of 12 trials where every stimulus was presented once in a random order (i.e., 6 SNS and 6 control stimuli). During each trial an image of a hand holding a smartphone is displayed on a grey background. Participants pressed the 'H' key to initiate the trial. A fixation cross was then shown in the middle of the screen for a random duration between 800-2000ms at intervals of 100ms, followed by the stimulus presentation which remained on screen until a response was made. Participants pressed the 'Y' key to approach or the 'N' key to avoid and were instructed to only use the index finger of their dominant hand when making responses. An inter-stimulus-interval of 500ms occurred after each response. In the experimental phase a total of 60 trials occurred in a random order for each block (participants completed a total of 144 trials, including 2 × 60 experimental trials and 2 × 12 training trials).

Time distortion

Immediately after completing the VAAST participants were asked to estimate to the nearest minute, how long it took to complete the task. The actual time taken to complete the VAAST was automatically recorded to the nearest minute. Time distortion was calculated at pre- and post-intervention by subtracting the actual time from the participant's estimated time taken to complete the task, with 0 representing no bias, positive values representing an overestimation and negative values representing an underestimation.

Effort Expenditure for Reward Task

Participants completed a modified version of the Effort Expenditure for Reward Task (EEfRT; Treadway et al., 2009). Here participants worked to gain brief exposure to their SNS accounts. On each trial participants chose between completing an easy task (repeatedly pressing the spacebar with the index finger of their dominant hand) or hard task (repeatedly pressing the spacebar with the little finger of their non-dominant hand). Participants had the opportunity to practice both the hard and easy task before completing 12 experimental trials. To win the easy task participants were required to press the spacebar more than 35 times in 7 seconds whereas the hard task required more than 70 presses in 15 seconds. However, participants were not told the number of presses required to win each task. A win on the easy task rewarded the participant with 10 seconds on a SNS, whereas a win on the hard task rewarded 30 seconds on a SNS. A fail on either task resulted in 0 seconds to spend on SNSs. Unlike the original EEfRT (Treadway et al., 2009), in this simplified adaptation there was no variation in reward value or probability of winning. In order to make the possibility of gaining access to their SNSs more salient, before beginning the task participants were told to place their phone face down on the desk next to them and they were informed that they would not be allowed to touch their phone again until after the task. After completing the 12 experimental trials there was a 6-minute period during which participants were able to use the time they had accumulated in the task to spend on a SNS of their choice. However, participants were informed at the beginning of the task that they would have to wait in silence for the duration of the 6-minutes that they had not won time to spend on SNSs. For example, a participant who selected and won the easy task on each of the 12 trials would have won 2 minutes to spend on a SNS (12 × 10 secs).

Therefore, they would first have to wait 4 minutes before being allowed to access a SNS on their phone for the remaining 2 minutes. The waiting period served as a 'punishment' for not choosing the hard task or failing to exert sufficient effort and was designed to incentivise those participants with higher SNS cravings to select and exert more effort on the hard task. Thus, task choice and number of spacebar presses provided an implicit measure of SNS 'wanting'.

Lab-based questionnaire measures

We obtained a measure of 'SNS addiction' using the Social Media Disorder Scale (Van den Eijnden et al., 2016), which is a 9-item scale based on the 9 suggested DSM-5 criteria for Internet Gaming Disorder. Participants were also asked to self-report the frequency that they check their SNS accounts (7-item Likert scale, less than daily – every 15 mins). Measures relating to the number of different SNS platforms used, the expected number of 'likes' on typical SNS post, and general sensitivity to reward (assessed using 10 questions taken from the SPSRQ-20; Aluja & Blanch, 2011) were also obtained but were not further analysed.

Procedure

Ecological momentary assessments (EMAs) of mood and urges to use SNSs were collected across a period of 15 days. The experimental design comprised a 3-day baseline phase (normal SNS use), 6-day intervention phase (SNS abstinence) and 4-day post-intervention phase (normal SNS use). EMA data from the start and end dates of the intervention period (i.e., 4th and 11th days) were not included in the pre-registered analysis, since these days consisted of both abstinence and normal use periods. Upon signing up to the study participants were required to download the

SEMA[3] app on their mobile device (https://sema3.com/), which was used to administer the EMAs and delivered notifications 3 times a day (at random times between 10 AM and 9 PM). Participants had 30 mins to complete an assessment after receiving a notification. To avoid the occurrence of successive notifications within a short period, one EMA was delivered during three separate time windows (10:00-13:00, 14:00-17:00, 18:00-21:00). In addition to the EMAs, participants also received a notification at 21:30 each day to complete an end-of-day questionnaire and had a 2-hour period in which to complete it.

On the 4th day of the study participants were invited into the psychology department to complete the first lab experiment. During this session participants completed computer-based experiments including measures of approach-avoidance tendencies in relation to SNS stimuli, time perception and effort expenditure for SNS reward, as well as a SNS cue reactivity task and questionnaire measures. The effort task was programmed using PsychoPy (Peirce et al., 2019) and all other lab measures were programmed using PsyToolkit (Stoet, 2010, 2017). At the end of the session participants were instructed to abstain from using all SNSs (e.g., Instagram, Facebook, Twitter; but not including instant messaging or voice/video calling apps e.g., WhatsApp or Messenger) for the next 7 days. Participants were advised to turn off SNS notifications and to prevent/limit access to SNS apps using the iPhone Screen Time app. However, participants were not instructed to delete these apps to avoid participants using other devices to access their SNSs. By leaving SNSs functional, associated screen time data was not deleted, and we could thus track any "relapse" periods more accurately.

Seven days after the first session (11th day of the study) participants completed the second lab session. Both sessions took place at the same time of day

and in the same environment. The measures in the second session were identical to those in the first session except that the questionnaire measures were not repeated. At the end of the session participants also provided ratings of familiarity, arousal, and valence for the SNS and control stimuli used in the VAAST. After the second session was completed, participants were told that they could resume using social media as normal. The researcher had access to information that could identify individual participants during the data collection period, but all data were made anonymous at the end of the study.

Results

Screen time

We first examined compliance with the abstinence instruction in our sample. All but two participants reported reduced SNS use during the intervention period compared to baseline. The two participants who reported higher SNS use during the intervention were not removed since their performance would still reflect an effect of attempting to abstain from SNSs. As shown in Figure 4, the average daily SNS screen time (mins) during the intervention period (M = 34.50, SD = 52.88) was significantly lower than at baseline (M = 207.94, SD = 115.19) [$t(50) = 10.93$, $p < .001$]. During the post-intervention phase (M = 146.07, SD = 82.06) SNS screen time became significantly higher than during the intervention phase [$t(50) = -9.00$, $p < .001$] but was still significantly lower than during baseline [$t(50) = 3.78$, $p < .001$]. Examination of the total iPhone screen times also revealed a similar pattern with all differences between the three time points being significant ($p < 0.01$).

We also examined the number of participants who ‘relapsed’ during the intervention period. While most participants were able to substantially reduce their

SNS usage during the intervention, only 7 participants (13.7%) managed to successfully abstain for the full week. Nonetheless, despite low compliance with the abstinence instruction, during the intervention phase participants did reduce their SNS use from baseline by an average of 83.4%.

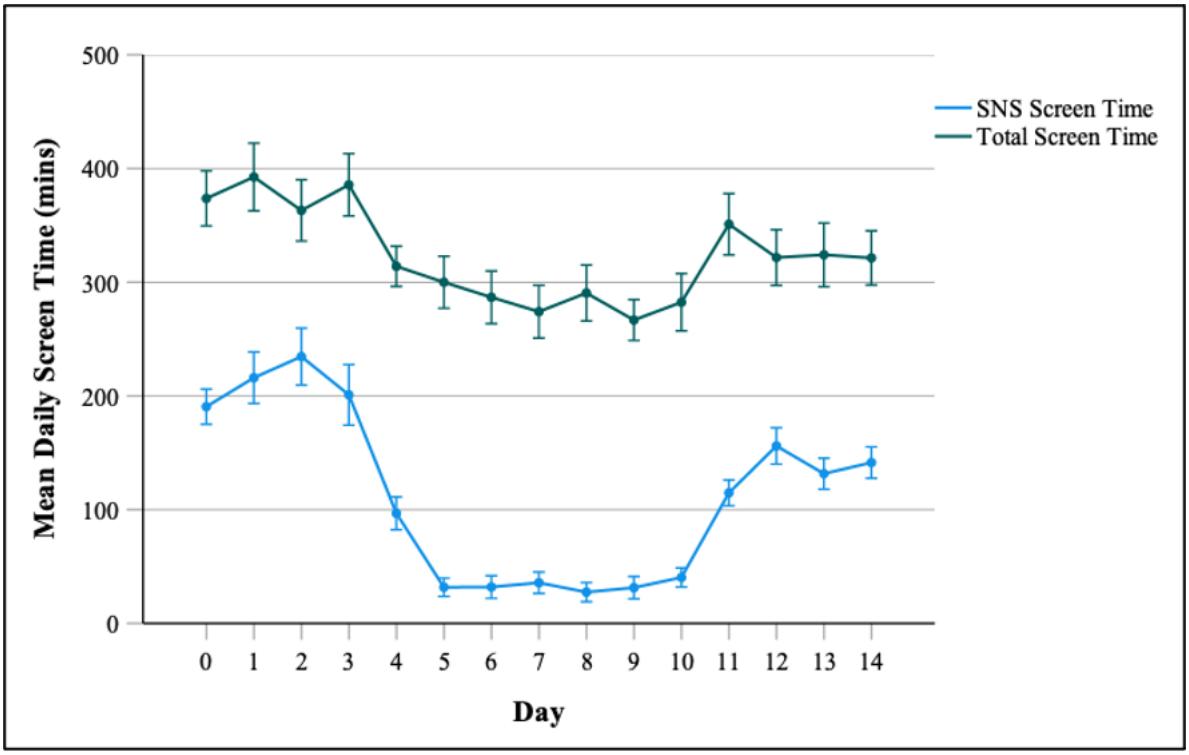

Figure 4. Mean daily screen times (mins) for SNS use and iPhone use. The abstinence intervention began midway through day 4 and ended midway through day 11. Error bars represent +/- 1 SE mean.

Ecological momentary assessments

Only participants who responded to at least 50% of the surveys at each phase of the experiment were included in the analysis, resulting in the exclusion of 16 participants. Of the remaining 35 participants, the mean response rate was 78.1% (SD = 11.71) and response rates did not significantly differ between the three experiment phases [$F(2, 68) = 1.19$, $p = .311$, $\eta_p^2 = 0.034$]. Data from the 4th and 11th

days were discarded owing to the fact that participants began their week of SNS abstinence at different times of the day.

We ran separate repeated measures ANOVAs for each measure of mood, with experiment phase as the within-subjects factor (baseline vs. intervention vs. post-intervention). Where Mauchly's test indicated that the assumption of sphericity had been violated we used the Greenhouse-Geisser corrected degrees of freedom. The ANOVA for positive affect revealed a significant effect of experiment phase [$F(1.61, 54.55) = 8.92$, $p = .001$, $\eta_p^2 = 0.208$]. In contrast, no significant effect of experiment phase was observed for negative affect [$F(1.61, 54.73) = 2.38$, $p = .112$, $\eta_p^2 = 0.065$], boredom [$F(1.55, 52.75) = 3.24$, $p = .059$, $\eta_p^2 = 0.087$], loneliness [$F(2, 68) = 1.37$, $p = .261$, $\eta_p^2 = 0.039$], or cravings [$F(2, 68) = 1.09$, $p = .342$, $\eta_p^2 = 0.031$].

Follow up paired t-tests were conducted to explore the effect of experiment phase on positive affect. This revealed a significant decrease in positive affect from intervention (M = 45.38, SD = 12.31) to post-intervention (M = 41.22, SD =12.63) [$t(34) = 3.42$, $p = .002$, d = 0.58]. Positive affect at baseline (M = 48.32, SD = 11.75) was also significantly higher than at post-intervention [$t(34) = 3.62$, $p = .001$, d = 0.61]. While positive affect was reduced from baseline to intervention, this difference did not reach significance [$t(34) = 1.64$, $p = .111$, d = 0.28]. Exploratory paired t-tests also revealed marginally significant reductions in negative affect [$t(34) = 2.06$, $p = .047$, d = 0.35] and boredom [$t(34) = 2.24$, $p = .032$, d = 0.38] from baseline to intervention. All other comparisons were nonsignificant. Mean scores for each measure of mood are displayed in Figure 5.

For each mood measure 'withdrawal scores' were calculated by subtracting baseline ratings from ratings at the intervention phase. Similarly, 'rebound scores'

were calculated by subtracting baseline ratings from ratings at the post-intervention phase. Withdrawal and rebound effects were correlated with SMDS scores, self-reported checking frequency and baseline SNS screen time. Negative affect rebound effects were weakly correlated with SMDS scores (r = -.34, p = .044), indicating that more problematic users were more likely to experience reduced negative affect when normal SNS use was resumed compared to baseline. However, the correlation did not survive a Bonferroni correction for multiple tests (adjusted α = .017). No other significant correlations were found.

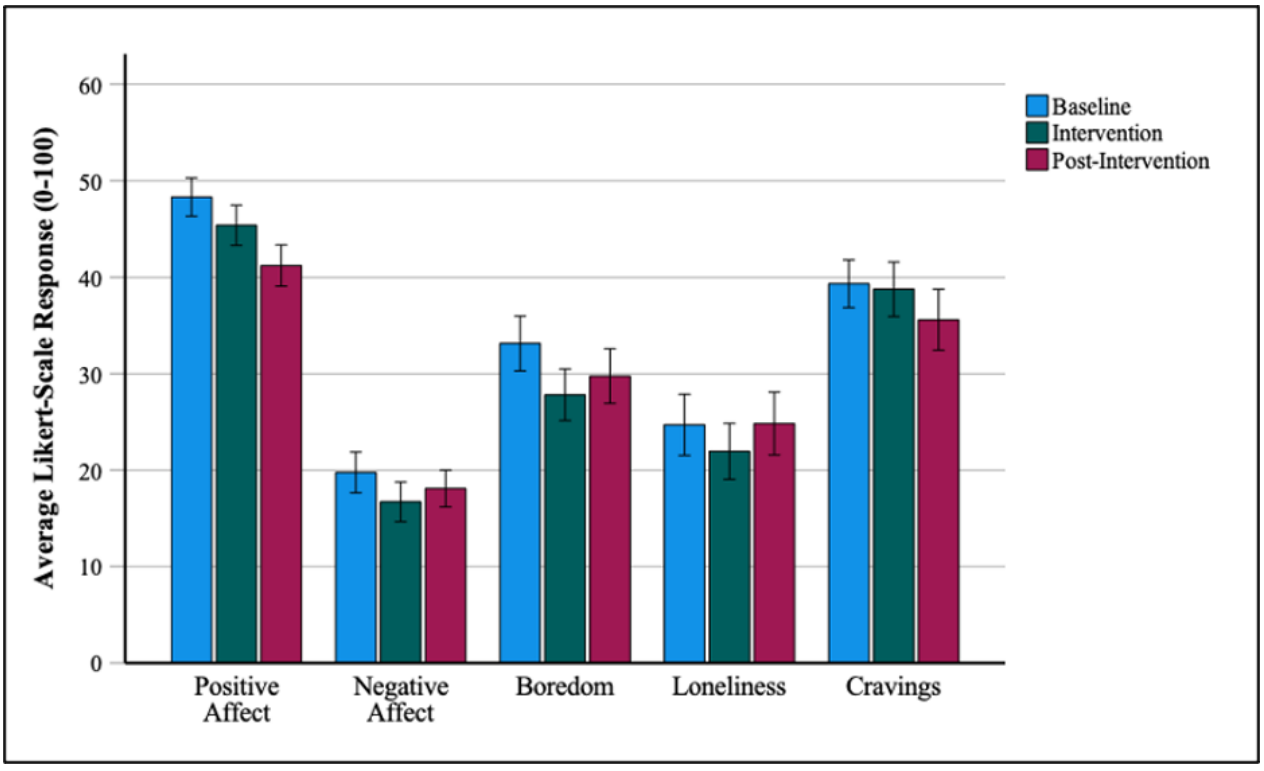

Figure 5. Mean self-report ratings of mood across the three experiment phases. Error bars represent +/- 1 SE mean.

Visual cue reactivity

A paired t-test revealed no significant difference in cue reactivity scores between pre- and post-intervention [$t(50) = -0.24$, $p = .811$, d = 0.03]. The difference between pre- and post-intervention cue reactivity scores were also correlated with SMDS scores, self-reported checking frequency and baseline SNS screen time. However, no significant correlations were found.

Approach/Avoidance Task

Only participants with an accuracy rate of 60% or more on both trial types (approach SNS condition and approach controls condition) were included in the analysis (see preregistration), resulting in the exclusion of three participants. The overall accuracy rate in the VAAST was high (M = 96.89%, SD = 3.13) and accuracy did not significantly differ between the pre- (M = 96.61%, SD = 4.15) and post-intervention sessions (M = 97.17%, SD = 3.14) [$t(47) = -1.00$, $p = .323$, d = 0.14]. Only RTs for correct responses were included in the analysis. Correct responses with RTs less than 200 ms or greater than 3000 ms were also removed as outliers, resulting in the exclusion of a further 0.41% of the trials.

Approach/avoidance bias scores were calculated for each participant at pre- and post-intervention for SNS (RTSNS_Avoid – RTSNS_Approach) and control stimuli (RTControl_Avoid – RTControl_Approach), whereby positive scores indicate an approach bias, and negative scores indicate an avoidance bias. Mean RTs for each condition are displayed in Figure 6. To investigate the effect of abstinence on approach/avoidance biases, bias scores were analysed using a 2 (abstinence: pre vs. post) × 2 (category: SNS vs. control) repeated measures ANOVA. The ANOVA revealed a significant main effect of category, [$F(1, 47) = 50.68$, $p < .001$, $\eta_p^2 =$

0.519], whereby participants displayed an approach bias to SNS stimuli (M = 111.41) and an avoidance bias to control stimuli (M = -73.97). However, the main effect of abstinence was nonsignificant [$F(1, 47) = 2.44$, $p = .125$, $\eta_p^2 = 0.049$], as was the interaction effect [$F(1, 47) = 0.02$, $p = .888$, $\eta_p^2 < 0.001$].

Overall AAT scores were calculated at pre- and post-intervention using the formula [(RTSNS_Avoid – RTSNS_Approach) – (RTControl_Avoid – RTControl_Approach)], with positive scores indicating a stronger approach bias to SNS stimuli relative to control stimuli. The difference in overall AAT scores between the two sessions was also calculated (session 2 – session 1) and these scores were correlated with SMDS scores, self-reported checking frequency and baseline SNS screen time. Self-reported checking frequency (analysed using nonparametric Spearman's Rho) was weakly correlated with overall AAT difference scores ($r_s = .30$, $p = .041$), indicating that individuals who reported checking SNSs more frequently exhibited a stronger approach bias for SNS stimuli relative to controls after a week of attempting SNS abstinence when compared to baseline. However, the correlation did not survive a Bonferroni correction for multiple tests (adjusted $\alpha = .017$). No other significant correlations with overall AAT difference scores were found.

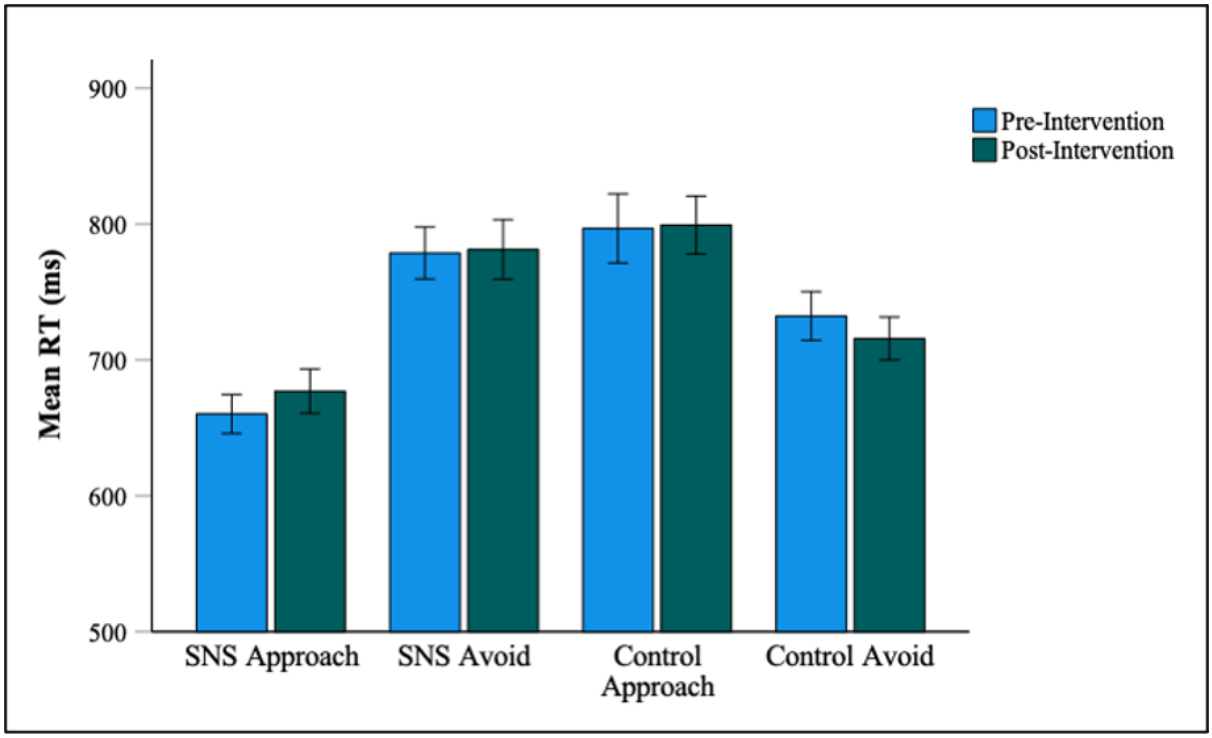

Figure 6. Mean VAAST RTs for each condition at pre- and post-intervention. Error bars represent +/- 1 SE mean.

Time distortion

The time taken to complete the VAAST ranged from 9 – 14 minutes, whereas participants estimated time taken to complete the VAAST ranged from 4 – 22 minutes (see Table 7). Participants became faster at completing the VAAST on their second attempt (post-intervention) [$t(50) = 9.70$, $p < .001$, d = 1.36] and correspondingly there was a marginally nonsignificant reduction in their time estimates [$t(50) = 1.99$, $p = .052$, d = 0.28]. Time distortion was calculated at pre- and post-intervention by subtracting the actual time from the participant's estimated time taken to complete the task. While we did observe a larger upwards time distortion bias at post-intervention, the difference was nonsignificant [$t(50) = 0.70$, $p = .488$, d = 0.10]. The difference between pre- and post-intervention time distortion

were also correlated with SMDS scores, self-reported checking frequency and baseline SNS screen time. However, no significant correlations were found.

Table 7. Descriptive stats for estimated VAAST time, actual VAAST time and time distortion measured in minutes.

Measure	Minimum	Maximum	Mean	SD
Pre-intervention				
Estimated time	4	22	11.43	4.02
Actual time	9	14	11.22	1.25
Time distortion	-8	11	0.22	3.90
Post-intervention				
Estimated time	5	18	10.43	3.42
Actual time	9	12	9.86	0.83
Time distortion	-4	7	0.57	3.30

EEfRT

During the easy task participants pressed the spacebar an average of 41.08 times (SD = 5.47), whereas during the hard task the mean number of spacebar presses was 77.20 (SD = 9.47). The number of times participants chose to complete the hard task served as a measure of willingness to exert effort and the total number of keypresses served as a measure of actual effort expenditure. Contrary to what was predicted, participants selected the hard task on fewer occasions during the second session, although this difference was not significant [$t(50) = 1.10$, $p = .278$, d = 0.15]. Similarly, participants also exerted less effort in the task during the second session, but this difference was also not significant [$t(50) = 1.67$, $p = .102$, d = 0.23]. The difference between pre- and post-intervention (t2 – t1) hard task choices and

total keypresses were also correlated with SMDS scores, self-reported checking frequency and baseline SNS screen time. Self-reported checking frequency (analysed using nonparametric Spearman's Rho) was negatively correlated with the difference in total keypresses (r_s = -.30, p = .031), indicating that individuals who report checking SNSs more frequently exerted less effort on the task after a week of attempting SNS abstinence when compared to baseline. While this effect was opposite to the hypothesised direction, the strength of the correlation was weak and did not survive a Bonferroni correction for multiple tests (adjusted α = .017). No other significant correlations were found. Descriptive statistics for the EEfRT are displayed in Table 8.

Table 8. Descriptive stats for number of hard task choices (willingness to exert effort) and total number of keypresses (actual effort expenditure) in the EEfRT.

Measure	Minimum	Maximum	Mean	SD
Pre-intervention				
Hard task choices	0	12	7.43	3.38
Total keypresses	431	1108	766.76	165.08
Post-intervention				
Hard task choices	0	12	6.88	4.04
Total keypresses	398	1067	731.31	166.72

SNS vs. control stimuli properties

Familiarity, valence and arousal rating for the SNS and control icons used in the VAAST and cue reactivity task were obtained at the end of the second lab session. Paired t-tests revealed that familiarity ratings for SNS and control stimuli

did not significantly differ [$t(50) = -0.40$, $p = .689$, d = 0.06]. However, SNS stimuli were rated significantly higher on both valence [$t(50) = 2.21$, $p = .032$, d = 0.31] and arousal [$t(50) = 7.55$, $p < .001$, d = 1.10] measures. Therefore, while participants recognised the SNS and control app icons to the same extent, they reported liking the SNS icons more than controls as well as finding them more exciting.

Compensatory behaviours

Compensatory behaviours were assessed in exploratory analyses by comparing self-reported engagement with other potentially problematic behaviours during the intervention phase versus periods of normal SNS use (i.e., baseline phase + post-intervention phase). Only responses from participants who responded to at least 50% of the end-of-day surveys during both the intervention phase and normal use phase were analysed. Consequently, the responses of 38 participants were included in the analyses. Paired t-tests revealed that participants reported spending significantly more time than usual playing video games during the intervention phase compared to periods of normal SNS use [$t(37) = -2.08$, $p = .045$, d = 0.34]. Participants also reported spending more time engaged with online shopping during the intervention phase, although this difference did not reach significance [$t(37) = -1.72$, $p = .094$, d = 0.28]. No significant difference in watching TV/video streaming sites [$t(37) = 0.41$, $p = .682$, d = 0.07], eating junk food [$t(37) = 1.48$, $p = .147$, d = 0.24], drinking alcohol [$t(37) = -0.64$, $p = .529$, d = 0.10], or gambling behaviours [$t(37) = -1.00$, $p = .324$, d = 0.16], were identified between periods of normal SNS use and SNS abstinence. Mean behaviour engagement responses are displayed in Figure 7.

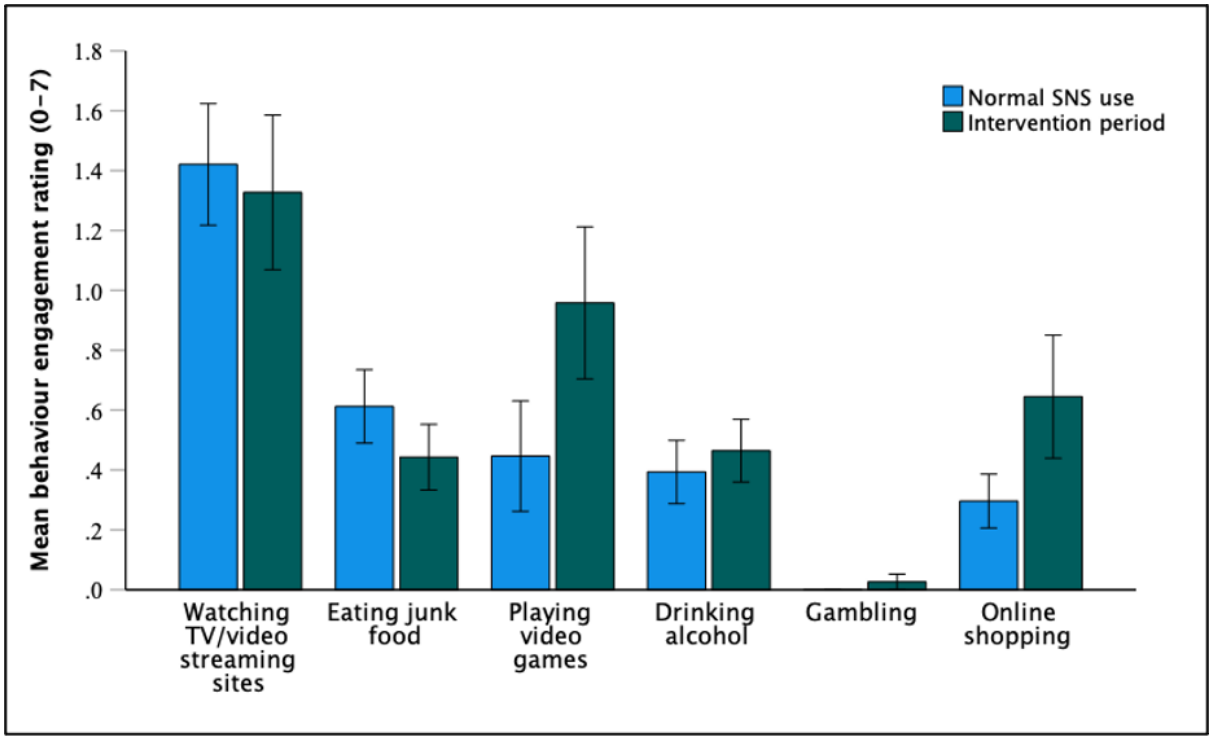

Figure 7. Mean Likert-scale responses to items assessing abnormal engagement with compensatory behaviours during normal SNS use vs. SNS abstinence. Error bars represent +/- 1 SE mean.

Discussion

The present study sought to assess potential changes in affect and motivation (both explicit and implicit) when restricting or abstaining from SNS use for one week. Ecological momentary assessments of mood were administered across a 15-day period, including baseline and post-intervention assessments which also allowed for the assessment of compensatory behaviours and rebound effects. Contrary to our pre-registered hypotheses but consistent with a growing body of recent research, we found no evidence that restricting SNS use produces withdrawal-like effects in SNS users or that such effects would be more pronounced in more problematic users. There was also no evidence to suggest that limiting SNS use is associated with clear positive effects on well-being. Instead of a generally negative or positive impact on

mood, we observed partially opposing effects, with a reduction of positive affect from the baseline to the post-intervention period and a concurrent reduction of negative affect and boredom during the intervention. Importantly, reduced SNS use did not increase or decrease implicit motivation for SNSs (as indexed by approach biases, time distortion, and effort expenditure measured in two lab sessions pre- and post-intervention).

Analyses of screen time data showed that despite being willing to abstain from SNSs for one week, the vast majority of participants struggled to maintain abstinence, with 86.5% 'relapsing' at least once. High 'relapse' rates have also been observed in similar studies employing a SNS abstinence intervention (e.g., Stieger & Lewetz, 2018). Such difficulties in maintaining abstinence despite initial willingness could be argued to be indicative of the addictive properties of SNSs. Yet on the other hand, almost all participants were able to significantly reduce their SNS use during the intervention period (mean use reduction of more than 80%) suggesting that users maintain some degree of control over their SNS behaviours. Furthermore, this reduction in SNS use had no consistent aversive effects on emotional well-being, which is contrary to expected effects during the experience of withdrawal. Given that SNSs are now so ingrained into normal everyday life and are often used to carry out essential communications it might not be helpful to interpret failures to comply with the abstinence instruction as 'relapses', especially since most participants were able to substantially cut down their SNS use. Additionally, unlike addictive substances, restricting SNS use had no effect on subjective cravings or measures of implicit wanting. Thus, our findings, along with most previous research (e.g., Brailovskaia, Ströse, et al., 2020; Graham et al., 2021; Hall et al., 2021; Hunt et al., 2018; Schwarz

et al., 2022), suggest that even excessive SNS users do not tend to experience psychological withdrawal-like effects when voluntarily limiting their SNS use.

Interestingly, analyses of mood data indicated potentially offsetting effects of use reduction on mood, with concurrent decreases of both positive and negative affect. One potential account of the observed decrease of positive affect is a reduction of opportunities to seek and obtain social rewards on SNSs, including social approval through likes, positive comments, followers etc. We have recently demonstrated the key role of social reward underpinning SNS use behaviours (Wadsley et al., 2022). On the other hand, our data also indicated slight decreases in self-reported negative affect, with a specific dip during the intervention period. We speculate that such changes arise as a result of reduced exposure to subjectively negative experiences on SNSs, including upward social comparisons (Vogel et al., 2014), Fear of Missing Out (Przybylski et al., 2013), or even bullying and harassment (Craig et al., 2020). Future research should determine whether such concurrent and psychologically counter-acting reductions of both positive and negative social experiences are indeed characteristic of SNS abstinence and can potentially explain the lack of consistent effects on well-being in some recent studies (Collis & Eggers, 2022; Hall et al., 2021; van Wezel et al., 2021). Such a nuanced perspective on the emotional effects of limiting SNS use would also be consistent with the Goldilocks hypothesis of digital screen use, which posits that a moderate amount of SNS use may be beneficial to mental well-being (Przybylski & Weinstein, 2017). However, we acknowledge that the analysis of the mood data in the present study was limited by removing participants who did not complete a sufficient number of EMAs and the lack of a control group – both aspects should be addressed in future work.

When examining usage behaviour across the three experiment phases both SNS and total screen time remained lower than baseline levels during the post-intervention phase, suggesting the absence of a rebound effect. It may be that participants developed strategies for limiting their SNS use during the intervention phase and that participants continued to implement some of these strategies when normal use was resumed. Therefore, temporary periods of restricted SNS use might be beneficial in helping to reduce excessive use in the long-term. Consistent with this, one large-scale study found that participants who abstained from Facebook for four weeks were more likely to report using Facebook less or having quit altogether several weeks after the intervention (Allcott et al., 2020). However, there is also evidence that a rebound effect might occur in individuals who are more prone to experiencing greater disconnection during SNS abstinence (Sheldon et al., 2011). Furthermore, our study also provides some evidence that individuals may engage more with other potentially problematic activities to compensate for their lack of SNS use. Participants reported spending significantly more time playing video games as well as a descriptive increase in online shopping during the intervention period compared to periods of normal SNS use. In another study where participants had to limit their SNS use to 10 minutes per day, they were found to spend more time using instant messenger apps and did not reduce their overall digital screen time (Collis & Eggers, 2022). However, while the present study allowed for the assessment of potential compensatory behaviours and rebound effects, these were only measured for the four days following the intervention period. Thus, we are unable to draw conclusion regarding the long-term effects that restricting SNS use may have on affect, motivation and screen time.

Our results using the AAT as a proxy of implicit SNS use motivation replicated those reported in our previous study (Wadsley & Ihssen, 2022), showing a large approach bias for SNS icons, relative to control stimuli. The present study demonstrated that this bias is unaffected by a week of SNS abstinence/use reduction, pointing to the robust nature of learned approach responses towards SNS stimuli. Consistent with our previous findings, we also observed an avoidance bias for control app icons, potentially indicating that these icons are devalued among regular SNS users when confronted with motivationally salient SNS stimuli. In the present experiment we also included post-experiment ratings of familiarity, valence and arousal. SNS and control app icons were rated as equally familiar by participants, ruling out an important confound of the present findings. In contrast to familiarity, SNS stimuli were rated significantly higher on both positive valence and arousal, confirming the high reward value of SNS stimuli and thus their capacity to elicit approach behaviour. Importantly, AAT scores did not differ between the pre- and post-intervention conditions. We acknowledge that the null effects of the intervention on motivation will need to be replicated in the future with a larger sample size. At present, the interpretation of the absence of motivational changes is also hindered by the substantial amount of noncompliance with the abstinence instruction. Nonetheless, as previously noted, the considerable reduction in SNS use exhibited by the majority of participants can still be expected to produce effects on mood and motivation when such behaviour is considered to be compulsive/problematic. However, it may be the case that participants were using SNSs ‘just enough’ to quell the negative consequences of non-use, providing a potential explanation for our null effects.

Interestingly, we did not observe the predicted variation of affective/motivational responses contingent on individual differences, including problematic use behaviours. However, conclusions regarding the lack of correlations between the assessed variables and problematic SNS use across our measures are weakened by the fact that we did not recruit from a 'clinical' population. It is possible that only individuals with extreme scores on assessments of problematic use exhibit withdrawal-like effects during SNS abstinence and thus more research sampling from clinical/treatment-seeking populations is required.

In sum, the present study indicates that abstaining or reducing SNS use is not associated with any substantial effects on affective or motivational responses. Importantly, and contrary to our hypotheses, we found no evidence that restricting SNS use resulted in withdrawal-like effects in more problematic SNS users. Our findings suggest that similar to recent consensus regarding the diagnostic guidelines for gaming disorder which have eschewed withdrawal criteria (Castro-Calvo et al., 2021), the concept of withdrawal may also be unimportant for the diagnosis of problematic SNS use. However, our results also provide evidence that SNS use reduction has subtle and potentially offsetting effects on mood and that urges to use SNSs are a robust element of motivational hierarchies in individuals exposed to modern technologies.

Chapter 5

The Psychophysiology of Instagram – Brief bouts of Instagram use elicit appetitive arousal and attentional immersion followed by aversive arousal when use is stopped

The following chapter is currently under review in *Computers in Human Behavior* and has been submitted as: Wadsley, M., & Ihssen, N. (under review). The Psychophysiology of Instagram – Brief bouts of Instagram use elicit appetitive arousal and attentional immersion followed by aversive arousal when use is stopped. *Computers in Human Behavior.*

Abstract

Checking social networking site (SNS) accounts periodically has become a quintessential daily habit for billions of people. The present study tracked the psychophysiological impact of brief periods of SNS use and subsequent use cessation, designed to mimic natural usage patterns. It specifically aimed to identify markers of problematic/compulsive use during these periods in 54 Instagram users varying in problematic SNS behaviors. Heart rate, galvanic skin response (GSR) and affective/motivational ratings were recorded across three 15-minute phases consisting of a baseline reading task, Instagram exposure and Instagram cessation phase. Participants reported increased stress, anxiety and SNS cravings following Instagram cessation. Instagram exposure resulted in a large decrease in heart rate and increase in GSR compared to baseline, potentially indicating increased appetitive arousal and a state of deep attentional engagement. Instagram cessation resulted in an increase in heart rate and GSR compared to exposure, potentially indicating increased aversive (stress-related) arousal. Importantly, changes in physiology were *not* associated with problematic use symptoms. Our findings indicate that brief engagement with SNSs elicits reward-driven arousal and attentional immersion while ending such states can induce aversive physiological and subjective stress in both problematic and regular SNS users.

Introduction

For many, the use of social networking sites (SNSs) penetrates a significant part of their day-to-day activities, with usage behavior typically characterized by multiple bouts of engagement throughout the day (Cheever et al., 2014). Users report that SNS sessions tend to last for 10-20 minutes, with 56% of individuals checking their accounts more than ten times a day (Panko, 2018). Little is known about the psychological and physiological impact of such usage patterns, for instance, with regard to stress, arousal and affect. Nonetheless, high use intensity is often portrayed as representing a dependency on these technologies that might reflect a behavioral addiction. However, no formal diagnosis of 'SNS addiction' currently exists and consensus on the classification of problematic SNS use is yet to be reached. Some researchers have questioned whether the excessive use of modern technologies are best conceptualized as behavioral addictions (Billieux et al., 2015; Kardefelt-Winther et al., 2017). We have recently advocated the utility of using a social reward perspective for understanding (excessive) SNS use (Ihssen & Wadsley, 2021) and demonstrated that implicit approach biases towards SNS stimuli are present in both problematic and regular users (Wadsley & Ihssen, 2022). Ultimately, whether a 'SNS addiction' is to be recognized as a relevant pathology will depend on the psychological and neurocognitive profile exhibited by users who report harmful consequences from their use. Thus, more theory driven empirical research is required to establish whether certain patterns of SNS use behavior can be understood as representing an addictive disorder.

One avenue to assessing the addictive potential of SNS use is to measure the physiological responses elicited during exposure to and discontinuation from the activity. In substance use addictions, physiological responses (e.g., heart rate and

skin conductance) are affected when drug consumption is ceased abruptly, reflecting a state of withdrawal. However, the nature of these effects vary across substances (Carter & Tiffany, 1999). For instance, the cessation of drugs that can have sedative effects on the central nervous system, such as alcohol and cannabis, has been shown to produce increased physiological responses (e.g., increased blood pressure; Ceccanti et al., 2006; Vandrey et al., 2011). In contrast, ceasing the consumption of stimulants such as MDMA and nicotine can lead to a reduction in physiological measures (e.g., decline in heart rate; Hughes et al., 1994; Kalant, 2001). As reviewed by Carter & Tiffany (1999) in a meta-analysis of research investigating physiological responses to drug cues, individuals with an addiction also tend to display increased heart rate and skin conductance when exposed to drug-related stimuli. For example, when smelling alcoholic beverages problem drinkers exhibit increased heart rate and skin conductance (Kaplan et al., 1985). Similarly, cocaine addicts display increased heart rate when viewing cocaine-specific stimuli compared to neutral stimuli or those depicting other drugs (Ehrman et al., 1992). Furthermore, heart rate reactivity to alcohol consumption has been found to represent a risk factor for alcohol misuse (Ray et al., 2006). While altered physiological responses during exposure to and withdrawal from the drug/activity have been shown to represent useful markers of addiction in substance use disorders and established behavioral addictions (e.g., gambling disorder; Lole et al., 2014), few studies have investigated the physiological changes associated with problematic (and non-problematic) use of modern technologies such as SNSs.

Reed et al. (2017) found that problematic internet users exhibited increased heart rate and systolic blood pressure after ending a 15-minute internet session. Correspondingly, more problematic internet users reported increased anxiety and

negative mood after ceasing internet use, potentially reflecting a withdrawal-like state in these users. Using a similar experimental design the researchers also investigated how galvanic skin response (GSR) is affected by internet use and cessation (Romano et al., 2017). Results revealed that higher, but not lower, problematic internet users showed elevated GSR following the cessation of internet use. Furthermore, increased GSR was correlated with higher levels of self-reported anxiety after internet cessation. In another study skin conductance was measured whilst participants received smartphone notification tones but were prohibited from reading or answering the messages/calls (Hsieh et al., 2020). It was found that GSR increased during exposure to smartphone sounds/vibrations compared to baseline, and this effect was stronger in younger, female and student participants. However, increased GSR during the experimental phase was not associated with problematic smartphone use or self-reported anxiety. Taken together these findings suggest that, akin to substance use addictions, the use of modern technologies can induce physiological symptoms reminiscent of withdrawal in some users. Increased physiological responses after abrupt internet use cessation in more problematic internet users likely reflects the experience of elevated anxiety/cravings in these users since states of aversive arousal are known to be correlated with increased blood pressure, heart rate and skin conductance (Abel & Larkin, 1990; Noteboom et al., 2001).

Present study

SNS use is often characterized by intermittent and brief patterns of use and non-use. To better understand the biopsychological impact of such periodic engagement with SNSs, the present study sought to track physiological changes

during controlled periods of SNS exposure and subsequent enforced cessation. Specifically, we aimed to determine whether physiological reactivity varied as a function of maladaptive use behaviors and compared responses between users scoring high versus low on a problematic SNS use instrument (assessing e.g., loss of control over use behaviors and functional impairment in daily life). Our study also measured changes in psychological states expected to accompany cessation-related changes in physiology (i.e., anxiety, stress, and cravings). We decided to focus specifically on the use of Instagram as this tends to be one of the most popular SNSs in our population of interest (18-30 year olds; DataReportal, 2023).

We expected that more problematic users would show increased physiological reactivity during both exposure and cessation compared to baseline, reflecting appetitive and aversive arousal, respectively. We also predicted that more problematic users would show increased self-rated anxiety/stress/craving following SNS cessation compared to baseline and that these physiological/psychological changes would be positively correlated with problematic use scores. The method and hypotheses for this study were preregistered on the Open Science Framework (https://doi.org/10.17605/OSF.IO/AHXUM).

Method

Participants

Fifty-four participants (44 females and 10 males) aged 18-30 (M = 20.98, SD = 2.59) who reported using Instagram regularly (at least once per day) were recruited from the Durham University student population. Participants received course credits or £15 Amazon vouchers for their participation. A power analysis (calculated with G*Power) indicated that a sample size of 44 would be sufficient to detect medium

effects ($f = 0.25$) with a power of 95% at $p < .05$. The study was approved by the Ethics Sub-Committee in the Department of Psychology at Durham University and all participants provided fully informed consent.

Measures

Physiological measures

A BIOPAC MP 150 modular data acquisition and analysis system connected to a laptop was used to collect the physiological data (BIOPAC Systems, Inc., Goleta, CA). Electrocardiogram (ECG) data were collected using a Dual Wireless Respiration and ECG BioNomadix amplifier module (BN-RSPEC) with electrode leads attached to a transmitter worn around the participants chest. Participants were equipped with a 2-lead ECG setup consisting of Ag/AgCl disposable electrodes with adhesive backing and a small amount of electrode gel. One lead was placed below the right clavicle and the other below the left clavicle. Participants were directed to place the electrodes themselves and the ECG signal was subsequently verified by observing a QRS complex. Skin conductance data was acquired using two reusable skin conductance transducers filled with electrode gel and connected to a BIOPAC GSR-100C amplifier module. Transducers were placed on the distal phalanges of the index and middle finger of the participant's nondominant hand. All physiological data were acquired using AcqKnowledge Data Acquisition and Analysis Software Version 4.2 (BIOPAC Systems, Inc., Goleta, CA).

State-level anxiety, stress and cravings

Single item measures were used to assess state anxiety (“I feel anxious right now”), stress (“I feel stressed right now”) and cravings (“I want to use/check social

media right now"). Participants responded to each statement using a 7-item Likert scale (1 = Strongly disagree, 7 = Strongly agree).

Problematic SNS use

The Assessment Criteria for Specific Internet-Use Disorders (ACSID-11; Müller et al., 2022) was used to measure problematic SNS use. The ACSID-11 is a new instrument for assessing specific internet use disorders (e.g., problematic SNS use, online gaming, online shopping) consistently. The scale comprises 11 items, with the main criteria of impaired control, increased priority given to the online activity, and continuation/escalation of online activity despite negative consequences, assessed by three items each. Two additional items assess functional impairment in daily life and marked distress due to the online activity. A two-part response format is used for each item whereby participants rate how often they have had the experience in the last 12 months (0 = 'never', 1 = 'rarely', 2 = 'sometimes', 3 = 'often'), and if at least "rarely", how intense each experience was in the last 12 months (0 = 'not at all intense', 1 = 'rather not intense', 2 = 'rather intense', 3 = 'intense'). Responses were averaged across items and therefore ACSID scores could range from 0-3. In the present study participants only responded to the items with regard to their SNS use.

Active vs. passive SNS use

Participants responded to seven items assessing the extent to which they engage in active vs. passive SNS use behaviors (Li, 2016). Three items assessing passive SNS use included: "reading discussions", "reading comments/reviews", and "watching videos or viewing pictures". Four items associated with active SNS use

included: “like/react”, “share others' content”, “comment on or respond to someone else's content”, and “post your own content”. Responses were made on a 6-point scale with options consisting of: “never”, “less than once a week”, “once a week”, “2–6 times a week”, “once a day”, and “several times a day”.

Procedure

Eligible participants were invited into the Psychology department at Durham University to complete the testing session (approx. 75-90 mins). All participants were instructed to refrain from using Instagram for at least 4 hours prior to the start of the experiment. During the testing session participants were first asked to follow a specific Instagram account created by the researchers in order to allow the researcher to send Instagram notifications to the participant’s phone (in a later phase of the experiment). The participant was also asked to ensure that their phone was unmuted with notifications enabled for the duration of the experiment. The participant was then instructed to place their phone face down on the desk and not to touch it again until told to do so. The physiological equipment was then connected to the participant. Participants were instructed to rest the connected hand on the desk and to avoid talking or moving this hand during the experiment.

In the first (baseline) task, the participant was asked to read one of two ‘long read’ news articles (random allocation) on a separate smartphone (provided by the researcher) using their dominant hand not connected to the GSR transducers. Neutrally valanced news articles were chosen for the reading tasks to avoid eliciting emotional responses that could affect the physiological measures (i.e., an article about commercial supersonic planes: https://www.wired.co.uk/article/boom-supersonic-planes; an article about introducing wild bison to the UK

https://www.wired.co.uk/article/uk-woodland-rangers-wild-bison). Participants were instructed to spend the next 15 minutes reading the news article on the smartphone without visiting any other websites or phone applications. The baseline task was designed to account for potential physiological responses associated with operating a smartphone whilst not using a SNS. Immediately after completing the baseline reading task participants completed single item assessments of state anxiety, stress and SNS cravings on a computer.

Next participants completed the SNS exposure phase. Participants were told to open the Instagram app on their own phone with their unconnected hand and spend the next 15 minutes using the SNS app as they would do normally. After this, participants completed the cessation phase where they once again spent 15 minutes reading a neutral news article on a separate smartphone. During the cessation phase participants were assigned to read the news article that they did not read during baseline (counterbalanced across participants). To intensify the motivational salience of not using Instagram, the researcher sent Instagram messages to the participant's phone at intervals of 3 mins (i.e., 4 notifications delivered at 3, 6, 9 and 12 mins) during the cessation phase. Participants were reminded that they were not allowed to touch their own phone during this phase. Immediately after the cessation phase second assessments of state anxiety, stress and SNS cravings were obtained. Finally, participants completed assessments of problematic SNS use, passive vs. active SNS use and provided objective measures of SNS screen time use.

Results

ACSID scores in the present sample ranged from 0.18 – 2.18 (M = 1.07, SD = 0.49). Participants were separated into higher vs. lower problematic SNS use

groups using a median split of ACSID scores (Mdn = 1.045)[2]. Due to technical issues obtaining physiological data, two participants from the lower and two participants from the higher problematic use groups (all female) were excluded from analysis of heart rate, while one female participant from the lower problematic use group was excluded from analysis of the GSR data. Participant characteristics are displayed in Table 9.

Table 9. Participant characteristics for lower vs. higher problematic SNS use groups.

	Lower problematic use group (n = 26)	Higher problematic use group (n = 28)	*t*	*p*
Gender (male : female)	4 : 22	6 : 22	0.33[a]	.568
Age	21.19 (2.73)	20.79 (2.48)	0.57	.569
Passive SNS use	4.19 (1.01)	4.79 (0.83)	2.37	.021
Active SNS use	3.34 (0.79)	3.54 (1.08)	0.80	.425
Daily average Instagram use (hours)	0.73 (0.42)	0.83 (0.71)	0.62	.539
ACSID symptom frequency	0.78 (0.29)	1.56 (0.37)	8.45	<.001
ACSID symptom intensity	0.53 (0.21)	1.34 (0.39)	9.56	<.001
Overall ACSID score	0.66 (0.23)	1.45 (0.35)	9.98	<.001

[a] value represents χ^2 statistic

[2] In exploratory analyses participants were separated into higher (n = 11) vs. lower (n = 14) problematic SNS use groups based on cut-off scores of > 1.5 and < 0.75 on the ACSID. However, all results remained unchanged. ACSID scores were also correlated with HR and GSR at each phase of the experiment, however no significant correlations were identified (all *p*'s > .260).

Heart rate

To examine changes in heart rate we ran a 3 × 2 mixed ANOVA with experiment phase as the within-subjects factor (baseline vs. exposure vs. cessation) and group (lower vs. higher problematic SNS use) as the between-subjects factor. Mauchly's test indicated that the assumption of sphericity had been violated χ^2 (2) = 8.68, p = .013, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.86). The results revealed a significant main effect of experiment phase [F(1.71, 82.15) = 21.80, p < .001, η_p^2 = 0.312]. However, the main effect of group [F(1, 48) = 0.14, p = .707, η_p^2 = 0.003] and the phase*group interaction [F(1.71, 82.15) = 0.47, p = .595, η_p^2 = 0.010] were both nonsignificant.

Post-hoc paired t-tests revealed that heart rate significantly differed across all three phases of the experiment. Heart rate was higher at baseline (M = 77.48, SD = 11.64) compared to both exposure (M = 74.11, SD = 10.62) [t(49) = 6.24, p < .001, d = 0.88] and cessation (M = 74.98, SD = 9.92) [t(49) = 4.10, p < .001, d = 0.58]. Heart rate also increased significantly from exposure to cessation [t(49) = 2.07, p = .043, d = 0.29]. Additionally, the difference in heart rate from exposure – baseline (exposure effects) as well as from cessation – baseline (withdrawal effects) was calculated for each participant and correlated with problematic SNS use scores. However, neither heart rate exposure effects (r = -.03, p = .824) or withdrawal effects (r = -.02, p = .890) were significantly correlated with ACSID scores.

Skin conductance

Changes in GSR were also investigated using a 3 × 2 mixed ANOVA with experiment phase as the within-subjects factor and group as the between-subjects factor. Mauchly's test indicated that the assumption of sphericity had been violated

χ^2 (2) = 25.05, p < .001, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = 0.72). The results also revealed a significant main effect of experiment phase [F(1.44, 73.17) = 57.36, p < .001, η_p^2 = 0.529], with no significant main effect of group [F(1, 51) = 0.01, p = .916, η_p^2 < 0.001] or phase*group interaction [F(1.44, 73.17) = 0.11, p = .835, η_p^2 = 0.002].

Post-hoc paired t-tests revealed that GSR differed significantly across all three phases of the experiment. However, the pattern of results was different to that observed for heart rate. Instead, GSR was lower at baseline (M = 10.69, SD = 4.72) compared to exposure (M = 13.71, SD = 4.69) [t(52) = 7.31, p < .001, d = 1.00] and cessation (M = 14.46, SD = 4.63) [t(52) = 8.77, p < .001, d = 1.20]. GSR also increased significantly from exposure to cessation [t(52) = 3.34, p = .002, d = 0.46]. As before, exposure effects and withdrawal effects for GSR were calculated for each participant and correlated with problematic SNS use scores. However, neither GSR exposure effects (r = -.01, p = .957) or withdrawal effects (r = -.05, p = .726) were significantly correlated with ACSID scores.

Affective and motivational responses

Three separate 2 × 2 mixed ANOVAs were used to investigate changes in self-reported anxiety, stress and SNS cravings with exposure (pre vs. post) as the within-subjects factor and group as the between-subjects factor. The ANOVA for anxiety indicated a significant main effect of exposure [F(1, 52) = 17.37, p < .001, η_p^2 = 0.250], whereby anxiety ratings increased from pre to post. However, the main effect of group [F(1, 52) = 1.27, p = .266, η_p^2 = 0.024] and the interaction [F(1, 52) = 1.56, p = .217, η_p^2 = 0.029] were both nonsignificant.

For ratings of stress the main effect of exposure was significant [$F(1, 52) = 15.44$, $p < .001$, $\eta_p^2 = 0.229$], with stress increasing from pre to post. The interaction effect was marginally nonsignificant [$F(1, 52) = 3.89$, $p = .054$, $\eta_p^2 = 0.070$] and reflected increased stress ratings from pre to post in the higher problematic use group compared to the lower group. The main effect of group was also nonsignificant [$F(1, 52) = 0.54$, $p = .468$, $\eta_p^2 = 0.010$].

The ANOVA for cravings also revealed a significant main effect of exposure [$F(1, 52) = 17.31$, $p < .001$, $\eta_p^2 = 0.250$], whereby cravings increased from pre to post. The main effect of group was marginally nonsignificant [$F(1, 52) = 3.80$, $p = .057$, $\eta_p^2 = 0.068$] with the higher problematic use group exhibiting increased SNS cravings. However, the interaction effect was nonsignificant [$F(1, 52) = 1.88$, $p = .177$, $\eta_p^2 = 0.035$].

Additionally, difference scores were calculated for each measure (post – pre) and correlated with ACSID scores. The correlation between craving difference scores and problematic SNS use was nonsignificant ($r = 0.11$, $p = .418$). There was a positive correlation between anxiety difference scores and problematic SNS use that was approaching significance ($r = 0.24$, $p = .077$). There was a significant positive correlation between stress difference score and problematic SNS use ($r = 0.36$, $p = .008$), whereby more problematic users were more likely to report increased stress after ceasing SNS use compared to their stress levels prior to using a SNS.

Exploratory analysis

We also examined minute-by-minute changes in the heart rate and skin conductance data. We added time (1-15 minutes) as a within-subjects factor to our previous ANOVA models to investigate potential three-way time*phase*group

interaction effects. As can be seen from Figure 8, changes in heart rate across time and phase did not substantially vary between the two groups and the three-way interaction was nonsignificant [$F(13.03, 534.25) = 0.91$, $p = .541$, $\eta_p^2 = 0.022$]. Similarly, as can be seen from Figure 9, GSR did not substantially vary across time and phase between the two groups and the three-way interaction was nonsignificant [$F(7.67, 391.09) = 1.25$, $p = .272$, $\eta_p^2 = 0.024$].

Inspection of Figure 9 also revealed that GSR peaked during the first minute of the exposure and cessation phase. We reasoned that this might be due to a carry-over effect from switching between tasks, reflecting the increased movement involved when completing computer questionnaires or switching smartphones. Therefore, we decided to re-run our initial 3 × 2 mixed ANOVA for GSR whilst excluding the first five minutes of each phase from calculations of mean GSR. However, doing so revealed the same pattern of results as our preregistered analysis. There was a significant main effect of experiment phase [$F(1.51, 77.08) = 35.16$, $p < .001$, $\eta_p^2 = 0.408$], with no significant main effect of group [$F(1, 51) = 0.01$, $p = .916$, $\eta_p^2 < 0.001$] or phase*group interaction [$F(1.51, 77.08) = 0.46$, $p = .578$, $\eta_p^2 = 0.009$]. Consistent with our initial analyses GSR was lowest during baseline and highest during cessation, with all three phases significantly different from each other (all p's < .05).

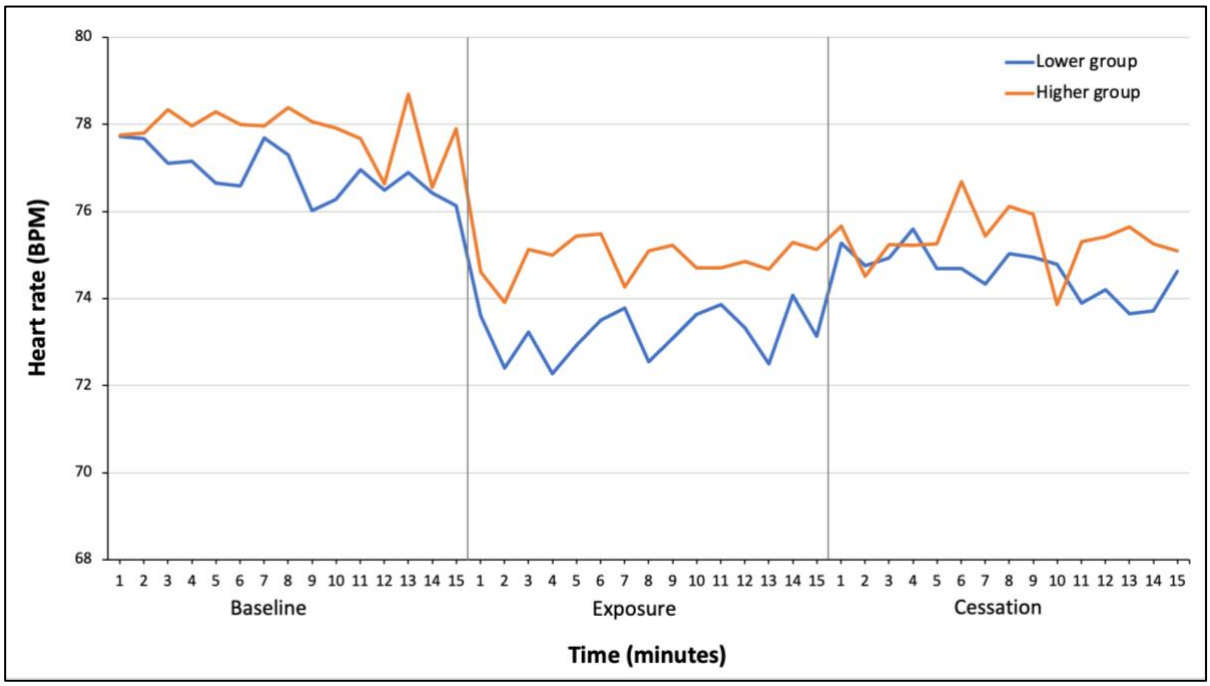

Figure 8. Mean minute-by-minute heart rate changes (beats per minute) across the three experiment phases for lower and higher problematic SNS use groups.

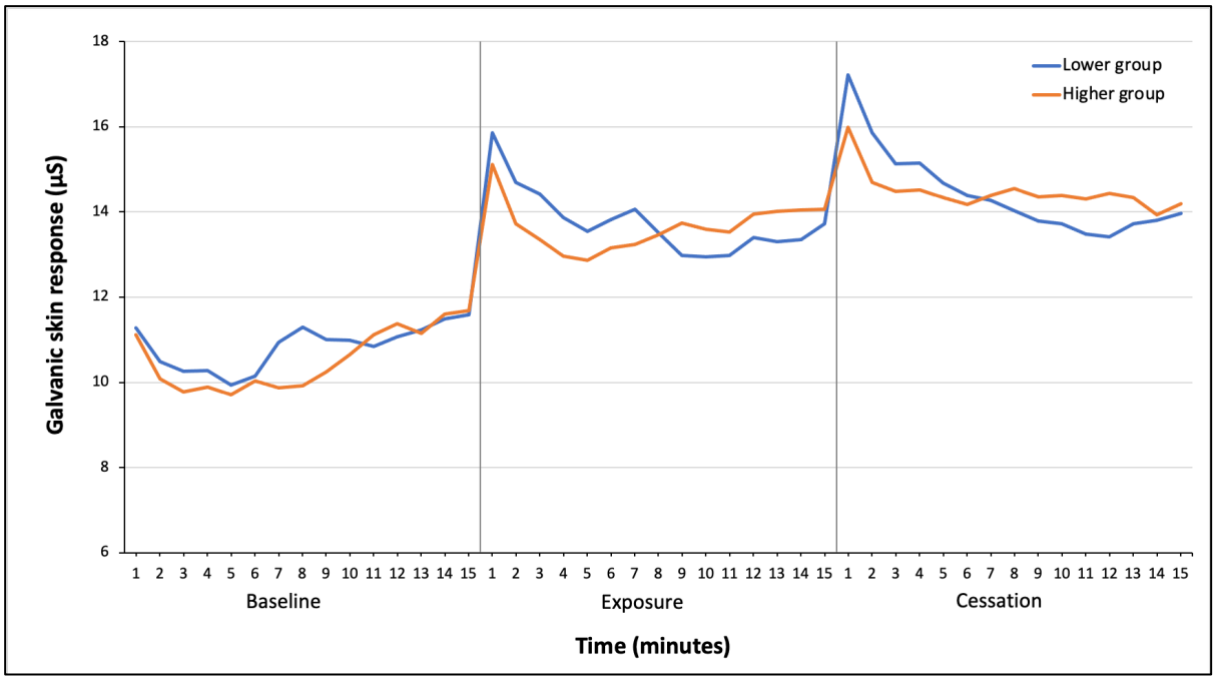

Figure 9. Mean minute-by-minute GSR changes (microsiemens) across the three experiment phases for lower and higher problematic SNS use groups.

Discussion

Smartphones have become a quintessential utensil of modern life and are within immediate reach most of the time – the ubiquity and the ease of access to phones provides users with the attractive opportunity to engage with SNSs periodically throughout the entire day. As we have recently shown, one key motive underlying such behaviors is a desire to seek and obtain social rewards (e.g., likes; Wadsley et al., 2022; see also Sherman et al., 2016). However, there is currently limited knowledge about the short-term consequences of such brief and potentially rewarding use periods on mental and biopsychological processes related to stress, emotion and arousal. The present study tracked physiological and psychological changes across 15-minute periods of use and use cessation in order to identify potential markers of problematic SNS use within those time windows. We found that across users, SNS exposure and subsequent cessation evoked distinct physiological effects, characterized by an increase in GSR and deceleration of heart rate when engaging in SNS use and an increase of both parameters when disengaging. Furthermore, exposure to and subsequent cessation of Instagram resulted in elevated levels of explicit anxiety, stress and SNS cravings within the sample as a whole. Interestingly, we found no support for our pre-registered hypotheses that these physiological and psychological changes were dependent on problematic SNS use. Instead, both the higher and lower problematic use groups displayed similar patterns of physiological responses. Notably, our GSR results are consistent with recent research showing elevated GSR in response to receiving smartphone notifications which was not correlated with problematic smartphone use or anxiety (Hsieh et al., 2020).

Our finding of increased GSR during exposure compared to baseline suggests the presence of increased appetitive arousal, which is prevalent among regular Instagram users. SNSs, particularly Instagram, are often used to view images of friends and to watch short, amusing video clips. In line with this, increased skin conductance has been shown to be associated with viewing positive social stimuli (e.g., watching a comedy film or viewing pictures of people; Britton et al., 2006; Kosonogov et al., 2016). By contrast, elevated GSR during Instagram cessation compared to both baseline and exposure likely reflects an increased aversive arousal state in these participants (Jacobs et al., 1994; Noteboom et al., 2001). Such an account is also supported by the fact that all participants reported significantly higher levels of stress, anxiety and cravings following Instagram cessation compared to baseline. By using a stringent control task (reading a news article on a smartphone), we can rule out that these results are attributable to movement-related or task-unrelated effects on physiology. In exploratory analyses, we also accounted for potential carry-over/task-switching effects by excluding the first five minutes of each phase from the calculation of mean GSR. Doing so revealed the same pattern of results as our pre-registered analysis. In combination with our affective/motivational measures, the present data therefore provide evidence that Instagram use is associated with an increase in GSR that may indicate appetitive arousal whereas cessation is associated with a GSR increase potentially indicative of even stronger aversive arousal in regular SNS users.

In contrast to the GSR results, our electrocardiac recordings indicated a large decrease in heart rate during SNS exposure. This deceleration was not contingent on problematic use scores, which conflicts with the psychomotor stimulant theory of addiction suggesting that individuals who experience greater physiological reactivity

when engaging with addictive stimuli are at greater risk of developing an addiction (Wise & Bozarth, 1987). For example, alcohol-induced heart rate reactivity is associated with increased alcohol consumption and genetic predisposition to alcoholism (Conrod et al., 1997; Peterson et al., 1993; Pihl et al., 1994).

One likely account for the substantial heart rate deceleration during Instagram exposure – which we found relative to reading a news article – relates to the presence of a state of deep attentional engagement with SNS content during the use window. Participants were likely to view multiple motivationally salient and self-relevant social images and videos, eliciting 'motivated attention' (Lang et al., 1997) during the exposure period. It is well known that heart rate deceleration can index an orienting reflex (Graham & Clifton, 1966), which occurs in response to novel and emotionally significant environmental stimuli. The OR is typically seen an adaptive mechanism which facilitates sensory intake and the allocation of attentional resources, enabling the rapid evaluation of unpredictable stimuli. In line with the present interpretation, watching highly arousing films has been shown to increase GSR but slow down heart rate (Codispoti et al., 2008). Similarly, heart rate deceleration has been observed when attending to high arousal images and sounds (Brouwer et al., 2013; Ritz et al., 2005).

However, it is also possible that heart rate was not decelerated during Instagram exposure but accelerated during the baseline phase – participants were instructed to read an unfamiliar news article for 15 minutes and were not given any additional instructions beyond this. As such, accelerated heart rate during this initial phase may reflect increased stress compared to the potentially more relaxing task of using Instagram. Nonetheless, such an account is not corroborated by participants' subjective experience of stress since stress ratings were higher after the cessation

phase (vs. baseline) despite heart rate remaining lower during cessation compared to baseline. Additionally this interpretation of our findings does not fit with evidence that heart rate reactivity is more closely related to states of increased appetitive arousal, rather than states of aversive arousal (Fowles, 1983).

Our findings diverge from previous research which has indicated greater increases in resting heart rate and skin conductance in problematic internet users after terminating a short internet session (Reed et al., 2017; Romano et al., 2017). While these findings have been interpreted as evidence of physiological withdrawal effects in problematic internet users, we found no evidence of distinct physiological responses being associated with SNS cessation in more problematic SNS users. However, problematic internet use is a broad construct encompassing compulsive use behaviors in relation to a spectrum of online activities, including gaming, pornography, shopping and also SNSs. It is possible that the reported effects, especially the increases in heart rate, were driven by a sub-set of problematic internet users, for which a clearer and more distinctive clinical phenotype exists – such as internet gaming (Billieux et al., 2021) – than currently available for SNS use.

The present study is not without some important limitations. Firstly, our sample was recruited from a student population and thus the findings might not generalize to other populations. Other studies have found evidence that students display a heightened GSR in response to receiving smartphone notifications (Hsieh et al., 2020), and thus the pattern of results in the present study may also reflect the student sample employed. Furthermore, while the range of problematic SNS use scores was varied and mean scores significantly differed between the two groups, recruitment did not specifically target individuals with a ‘SNS addiction’. Research sampling from clinical/treatment seeking populations is needed to better understand

the physiological responses associated with problematic SNS use. Additionally, the present study did not control for psychiatric conditions that could have affected participant's physiology or emotional responses (e.g., anxiety, depression, comorbid addictions). Our study also focused on assessing the use of one SNS platform and other SNSs may induce different physiological responses depending on their functionalities. Relatedly, we did not assess how each individual was using Instagram or the type of content they were exposed to. Whether participants were searching for specific content or viewing algorithm generated content, and whether they were actively or passively engaging with content may produce different effects on physiology and subsequent withdrawal responses. Finally, while the two groups significantly differed in terms of their problematic SNS use symptoms, they did not differ in their average daily time spent using Instagram. While more excessive SNS use is not necessarily indicative of more problematic use (Andreassen, 2015), it might be that the problematic SNS users in our sample used other SNS platforms more excessively and thus their physiological responses may not have been as sensitive to experiences of Instagram use and cessation.

In sum, the present study showed that Instagram use and cessation were associated with distinct changes in the physiology of regular Instagram users. These changes can be interpreted as reflecting increased appetitive arousal and attentional immersion during Instagram exposure and increased aversive arousal during Instagram cessation. Importantly, these effects occurred in all Instagram users regardless of problematic use symptomatology. Furthermore, while more problematic users reported Instagram cessation as being more stressful, they did not report increased levels of cravings or anxiety relative to less problematic users. Such findings are therefore inconsistent with the idea of a withdrawal syndrome in

problematic SNS users. Instead, they point to a high reward value of SNS use which is experienced ubiquitously and impactfully by all SNS users.

Chapter 6

A Systematic Review of Structural and Functional MRI Studies Investigating Social Networking Site Use

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Abstract

An understanding of the neurocognitive profile underlying the use of social networking sites (SNSs) can help inform decisions about the classification of problematic SNS use as an addictive disorder and elucidate how/when 'SNS addiction' might develop. The present review aimed to synthesize structural and functional MRI research investigating problematic/compulsive forms of SNS use or regular (non-addicted) SNS use behaviours. We conducted a systematic search for re-search articles published in English using the Web of Science, PubMed, and Scopus databases up to October 2022. Studies meeting our inclusion criteria were assessed for quality and a narrative synthesis of the results was conducted. Twenty-eight relevant articles were identified comprising structural MRI (n = 9), resting-state fMRI (n = 6) and task-based fMRI studies (n = 13). Current evidence suggests that problematic SNS use might be characterised by (1) reduced volume of the ventral striatum, amygdala, subgenual anterior cingulate cortex, orbitofrontal cortex and posterior insula; (2) increased ventral striatum and precuneus activity in response to SNS cues; (3) abnormal functional connectivity involving the dorsal attention network; (4) inter-hemispheric communication deficits. Regular SNS use behaviours appear to recruit regions involved in the mentalising network, the self-referential cognition network, the salience network, the reward network and the default mode network. Such findings are at least partially consistent with observations from the substance addiction literature and provide some provisional support for the addictive potential of SNSs. Nonetheless, the present review is limited by the small number of eligible studies and large heterogeneity in the methods employed, and so our conclusions should remain tentative. Moreover, there is a lack of longitudinal evidence suggesting SNSs *cause* neuroadaptations and thus

conclusions that problematic SNS use represents a disease process akin to substance use addictions are premature. More well-powered longitudinal research is needed to establish the neural consequences of excessive and problematic SNS use.

Introduction

The use of social networking sites (SNSs) is a ubiquitously popular activity that has seen a surge over the last decade. In 2012, it was estimated that there were approximately 1.5 billion SNS users (DataReportal, 2012). In 2022, the number of SNS users had reached 4.6 billion, which represents a global penetration rate of 58.4% and an increase of more than 200% over the last 10 years (DataReportal, 2022)[3]. Not only are more people using SNSs, but users are also spending longer on these sites each day. Worldwide, the daily average time spent using SNSs has risen from 90 min in 2012 to 145 min in 2020 (Statista, 2022). Of concern is that SNS use has been linked to reduced well-being and an increase in mental health disorders, particularly in younger populations (Kelly et al., 2018; Twenge, Joiner, et al., 2018; Twenge, Martin, et al., 2018), although such findings are the subject of debate (Orben & Przybylski, 2019; Vuorre et al., 2021). Additionally, a recent meta-analysis suggests that between 5 and 25% of the global population report symptoms resulting from their SNS use that resemble criteria traditionally used to diagnose substance use disorders and other behavioural addictions (Cheng et al., 2021). Yet, other studies employing experimental methods offer a more sceptical view of the addictive potential of modern technologies (Johannes et al., 2019; Thomson et al., 2021; Wadsley & Ihssen, 2022; Wilcockson et al., 2019), and these findings are mirrored by fears that we could be over-pathologizing normal everyday activities (Billieux et al., 2015; Kardefelt-Winther, 2015; Maraz et al., 2015).

Importantly, addictions are known to result in structural and functional adaptations in the brain that render the user more susceptible to the drug (or

[3] It should be noted that SNS users might not represent unique individuals and thus these data may not be a true reflection of the current number of global users.

behaviour) and associated cues (Koob & Le Moal, 1997; Robinson & Berridge, 1993). Neuroimaging studies have been instrumental in improving our understanding of the neural basis of substance use addictions (Fowler et al., 2007) and have also provided key insights into the neural similarities and differences between the use of addictive substances and pathological behaviours (e.g., gambling disorder; Goudriaan et al., 2010). For example, a study by Limbrick-Oldfield et al. (2017) found that regions in the brain's reward circuit (including the bilateral insula and ventral striatum) were activated in problem gamblers in response to cravings elicited by gambling-related images, which is similar to observations in substance use disorders (Engelmann et al., 2012; Tang et al., 2012). Nonetheless, a recent meta-analysis comparing the activation likelihood estimation from fMRI studies of gambling disorder and alcohol use disorder during tasks of executive function revealed that the two conditions were associated with distinct changes in neural activity (Quaglieri et al., 2020). While gambling disorder was associated with activation in regions of the fronto-striatal reward network, alcohol use disorder was associated with both activations and deactivations of different nodes of this network. Additionally, research comparing brain structure between individuals with alcohol use disorder and problem gamblers has shown dissimilar brain morphology (van Holst, de Ruiter, et al., 2012). While alcohol use disorder was associated with reduced volume of brain regions involved in cognitive control and reward processing, no structural abnormalities were identified in problem gamblers. Such differences might reflect that behavioural addictions do not expose the brain to toxic chemical substances that may be responsible for the neuroadaptations associated with addictions to drugs. Neuroimaging techniques have thus provided a vital tool for improving our understanding of the neural correlates of different addictive

disorders, indicating that similar as well as distinct neural abnormalities might underlie behavioural and substance-related addictions.

More recently, studies have begun to probe the neural underpinnings of SNS use behaviours. Based on neuroimaging research into offline social behaviours, the use of SNSs has been proposed to involve three key neural systems (Meshi et al., 2015): the *mentalising network* (i.e., dorsomedial prefrontal cortex, temporoparietal junction, anterior temporal lobe, inferior frontal gyrus, and the posterior cingulate cortex/precuneus) required for interpreting the emotions and mental states of others, the *self-referential cognition network* (i.e., medial prefrontal cortex and posterior cingulate cortex/precuneus) which enables self-reflections and social comparisons, and the *reward network* (i.e., ventromedial prefrontal cortex, ventral striatum, and ventral tegmental area) which is activated in response to social interactions. Given the pervasiveness of SNS use in society and the knowledge that a significant number of individuals report addiction-like symptoms, it seems also increasingly important to understand whether and how problematic SNS use might be reflected by structural and functional alterations in the brain. Recently we have argued for an incentive-sensitisation perspective to assessing the addictive potential of SNSs (Ihssen & Wadsley, 2021). This theory of addiction posits that repeated drug use 'hijacks' the reward systems of the brain by sensitising them to the incentive properties of the drug, resulting in heightened drug 'wanting' without producing an increase in drug 'liking' (Berridge & Robinson, 2016; Robinson & Berridge, 1993). In line with this, recent evidence has indicated that explicit cravings (i.e., 'wanting') are correlated with more problematic SNS use, independent of self-reported SNS liking (Ihssen & Wadsley, 2021; Wadsley & Ihssen, 2022). Crucially, such an account would also predict adaptations of certain neural substrates in addicted SNS users. Thus,

identifying neural similarities and differences between problematic SNS use and established addictive disorders would provide a valuable contribution in helping to determine whether some forms of SNS use might represent a behavioural addiction.

One way of investigating the neural correlates of SNS use is through the use of magnetic resonance imaging (MRI). Early neuroimaging studies have tended to investigate 'internet addiction' more broadly (e.g., Dong et al., 2011; Yuan et al., 2011; Zhou et al., 2011), and while the term 'internet addiction' is still commonly used to describe research investigating a range of problematic online activities, more recently, research has shifted away from this generalised construct to investigating specific online activities (e.g., online gaming, cybersex, social networking, online gambling, online shopping; Lopez-Fernandez, 2015). It therefore seems most appropriate to review the MRI literature for each of these behaviours in isolation when evaluating the addictive potential of a given activity. To that end, the present review will focus on discussing findings from studies that have specifically investigated SNS use behaviours, rather than internet or modern technology (e.g., smartphones) use more generally. Given that neuroimaging of 'SNS addiction' is still an emerging field, our review did not focus selectively on problematic (addictive) behaviours—as is typical in similar neuroscientific reviews of the drug addiction literature—but encompassed research that used MRI methods to study both problematic and nonproblematic ("healthy") SNS use behaviours.

Method

Search Strategy

A literature search was conducted using the databases *Web of Science*, *PubMed*, and *Scopus.* The systematic review was conducted in accordance with the

PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The search was restricted to peer-reviewed research articles published in English between 2010 and 2022. The following search algorithm and terms were used: ("social media" OR "social network*" OR Facebook OR Twitter OR Instagram OR YouTube OR Snapchat OR TikTok) AND (MRI OR fMRI OR "magnetic resonance imaging" OR neuroimaging OR "BOLD signal" OR "BOLD response" OR "gray matter" OR "grey matter" OR "white matter"). The most recent search was conducted on the 25 October 2022 and returned 774 unique results. A systematic review protocol was not registered.

Study Selection

One author, MW, conducted the screening process and uncertainties regarding the inclusion of studies were resolved through consultation with NI. After removing duplicate studies, titles and abstracts were read and screened for relevance. Articles were excluded if they: (1) did not investigate the functional or anatomical brain correlates of SNS use using MRI methods; (2) only assessed online network size as an alternative index for real-life (offline) social networks and therefore did not directly investigate SNS use as a primary topic; (3) investigated social media marketing. Initial screening reduced the results to 39 potentially relevant articles. Upon closer inspection, a further 11 papers were removed after reading the full-length articles. These studies did not meet the above criteria as SNS use was not the primary topic of investigation or online social network size was used as a proxy for offline social networks. One study employing a 'Tweet Task' was considered for inclusion but deemed ineligible as the aim of the study focused on assessing how individuals from historically marginalised groups were affected by viewing

discriminatory content shared by Donald Trump (Tashjian & Galván, 2020). Both authors agreed that since the study did not report whether participants were SNS users themselves, and because neither regular nor problematic SNS use was assessed, the study was not suitable. Additionally, one study investigated virtual social rejection using a paradigm that simulated an online chatroom (Radke et al., 2021), but the authors agreed that this study did not specifically assess SNS use and thus was not included. Two studies (with the same sample) investigating problematic smartphone users (Lee et al., 2021; Lee et al., 2019) were included because participant recruitment focused on individuals who use smartphones for internet communication/social networking, and those who primarily used smartphones for other purposes (e.g., gaming) were excluded. Similarly, one study investigating the neural correlates of 'mobile technology engagement' (Wilmer et al., 2019) was included since the scale employed specifically assesses phone-based social media use and frequency of public status updating. Furthermore, a study investigating 'specific internet addiction' (Dieter et al., 2017) was deemed eligible for inclusion since the sample comprised subgroups of individuals with internet gaming and social network addiction.

The reference lists of included articles and previous systematic reviews of neuroimaging studies investigating internet addiction more broadly (Kuss & Griffiths, 2012; Sepede et al., 2016; Sharifat et al., 2018) were also hand-searched for any further relevant studies. However, no additional articles were deemed eligible for inclusion. Figure 10 illustrates our applied literature search using a PRISMA flow chart.

Data Extraction

Relevant data were extracted from each of the articles and summarised into tables according to the MRI method employed. The variables for which data were extracted included author names, year of publication, study design, number of participants, mean age, gender, type of SNS use, assessment tool for SNS use, MRI methodology and key findings (i.e., implicated brain regions). The data extraction process was conducted independently by MW.

Quality Assessment

Given that no standardised criteria exist for assessing the quality of neuroimaging studies, previous systematic reviews of MRI research have modified criteria from existing tools (Yin et al., 2019). We opted to use a modified version of the Effective Public Health Practice Project (EPHPP) tool for quality assessment/risk of bias (Thomas et al., 2004), similar to other systematic reviews of neuroimaging studies (Hengstschläger et al., 2022; McLachlan et al., 2020). Our modified EPHPP comprised 10 quality criteria which assessed studies for selection bias, study design, neuroimaging methodology, and statistical analysis. Meeting a criterion was scored as 1 = 'Yes' or 0 = 'No' or 'Unclear', and ratings were summed to produce an overall quality score (range 0–10). A low (score = 0–4), moderate (score = 5–7) or high (score = 8–10) quality rating was then assigned to each study. The quality assessment was conducted independently by MW who consulted with NI to resolve any uncertainty.

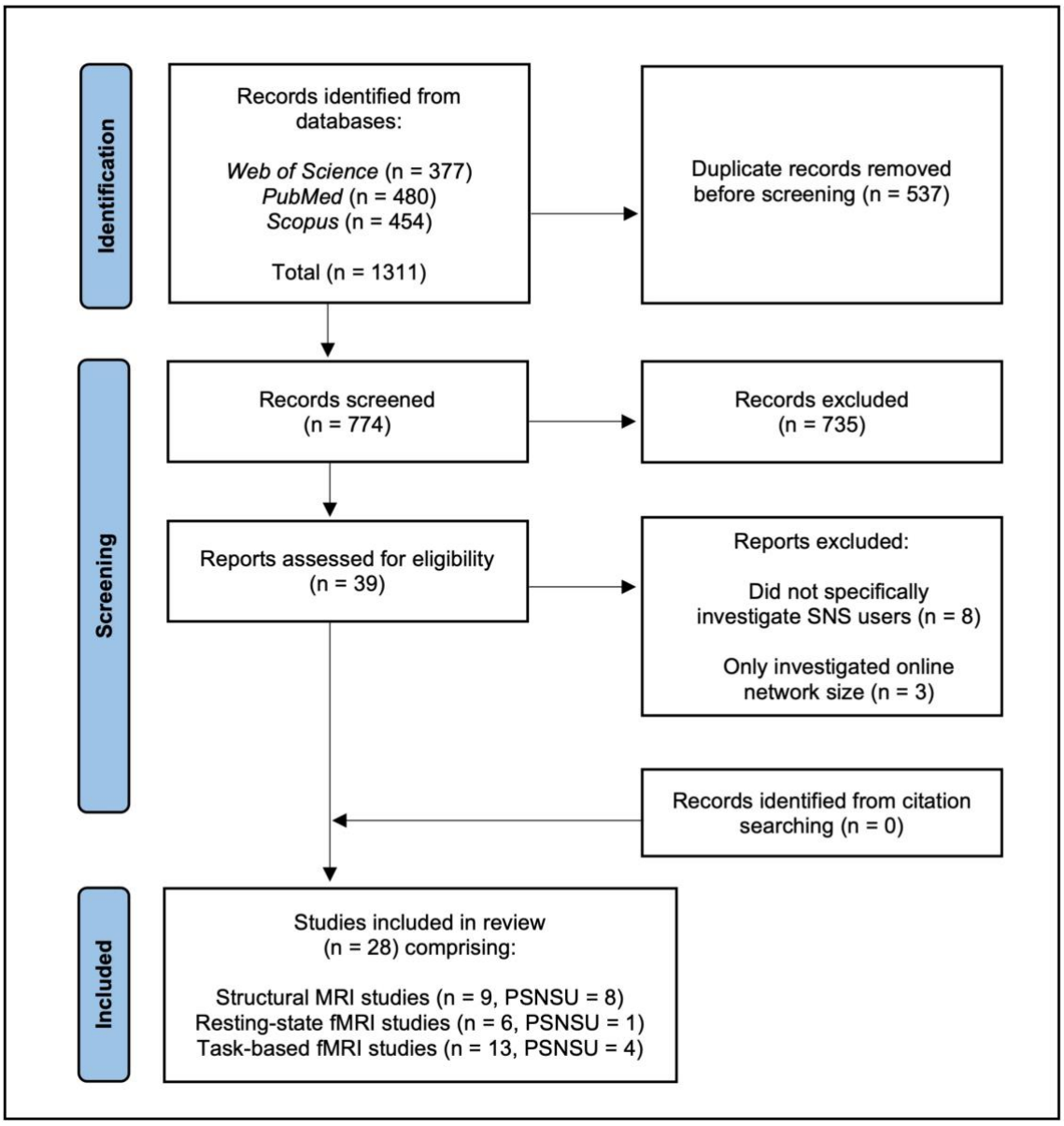

Figure 10. PRISMA flow diagram showing the process of the systematic literature search; PSNSU (problematic social networking site use) refers to the number of studies that investigated the neural correlates of problematic/compulsive SNS use.

Results

A total of 28 papers that met the eligibility criteria were identified and included in this review. The included studies were all published between 2013 and 2022 and comprised structural MRI studies (n = 9), resting-state fMRI studies (n = 6) and task-based fMRI studies (n = 13). Of the 28 studies only 13 investigated the

neural correlates of compulsive or problematic SNS use (the majority of these being structural MRI studies, *n* = 8). All of the included studies were rated as moderate or high quality. Because of the heterogeneity of MRI methods, a meta-analysis was not conducted.

Structural MRI Studies

Of the nine structural MRI studies identified in the literature search, most employed a sample of Facebook users. The mean age of participants in the included studies ranged from 16 to 31.2. All but two studies used voxel-based morphometry (VBM) to assess grey matter volume (GMV), with one assessing changes in the surface area and cortical thickness of regions of interest (ROIs) using a longitudinal design and another study using diffusion tensor imaging (DTI) to assess the connectivity of white matter microstructure. Two studies were rated as moderate quality and seven studies as high quality. A summary of the included structural MRI studies is provided in Table 10.

Of the studies investigating GMV, the majority observed a negative correlation between excessive/problematic SNS use and GMV in regions that make up the brain's reward systems. However, the implicated brain regions varied across studies and results are largely inconsistent. Three studies reported structural alterations of the nucleus accumbens (NAc; a component of the ventral striatum), which plays a key role in motivating reward-related behaviour. Montag et al. (2017) found a negative correlation between bilateral NAc GMV and Facebook use intensity and reduced GMV in the right NAc was also associated with higher Facebook addiction scores. Correspondingly, He, Turel, Brevers, et al. (2017) reported a negative correlation between GMV of the right ventral striatum and

compulsive Facebook use. The only other study to report significant structural alterations of the NAc found that reduced GMV in this region was associated with higher use of the WeChat paying function (Montag et al., 2018). However, in this instance, the specific association of smaller NAc GMV with the paying function and not with other functions (e.g., messaging and voice calling) or WeChat addiction scores could be argued to be more indicative of compulsive buying/shopping-related problems rather than as representing an SNS addiction. It has also been argued that the failure to observe reduced NAc structure for more problematic SNS users in other studies might indicate an important difference between SNS and substance use addictions (He, Turel, & Bechara, 2017). Nonetheless, it is important to consider that the study by Montag et al. (2017) employed a larger sample size (n = 62) and used the most objective index of Facebook use when compared to most other studies that have failed to observe this effect. In the study, participants installed a mobile app that tracked their use of Facebook across a 5-week period, whereas in all other structural MRI assays self-reports of usage/addiction severity were acquired. Thus, other studies may have been too underpowered to observe an effect or their reliance on self-report measures may have influenced the results.

Two studies found correlations between problematic SNS use and GMV of the anterior cingulate cortex (ACC) but in different directions. In their study of WeChat users, Montag et al. (2018) found that reduced GMV of the subgenual ACC was associated with higher addiction scores and this relationship remained stable after controlling for age, gender, anxiety and depression. This finding seems to square with the important role of the ACC in the cognitive control network (MacDonald et al., 2000) and thus reduced ACC volume would likely result in the inhibitory control deficits exhibited by individuals with addictive disorders (Jentsch

& Pennington, 2014). However, no other structural MRI study investigating SNS use has corroborated this finding and notably one study reports the opposite association. He, Turel and Bechara (2017) found that increased GMV in the ACC and midcingulate cortex (MCC) was associated with more addictive Facebook use. The authors postulated that the finding could be the result of an adaptation and compensation process in which the ACC/MCC increases in volume to improve the efficiency of the inhibitory system in response to reduced GMV in other regions implicated in more problematic SNS use (e.g., amygdala). However, there are also important differences between these two conflicting studies that could potentially account for their results. Compared to Montag et al. (2018), the study by He, Turel and Bechara (2017) employed a substantially smaller sample size (61 vs. 20) and both assessed different SNS platforms, using different scales to assess addiction severity. Since Montag et al. (2018) was the only study to investigate WeChat users, the findings could potentially highlight a difference between SNSs that are primarily used as a communication tool (i.e., for instant messaging) and other content sharing/microblogging based platforms. Additionally, Montag et al. (2018) used a more specific ROI analysis to investigate subregional differences in ACC GMV. Findings were specific to the subgenual ACC and no correlations with other subregions of the ACC were found, whereas the positive correlation reported by He, Turel and Bechara (2017) related to more dorsal ACC. Thus, the results might indicate important subregional specificity within the ACC, in which reduced subgenual ACC volume is related to more addictive SNS use.

Two studies by the same group reported reduced amygdala GMV in more excessive/problematic users (He, Turel, & Bechara, 2017; He, Turel, Brevers, et al., 2017). The finding is therefore consistent with substance use addictions, in which

addicts present reduced GMV of the amygdala (e.g., Makris et al., 2004). However, unlike results typically observed in established addictions only one study observed reduced GMV in the prefrontal region, namely in the right orbitofrontal cortex (OFC) in problematic SNS users vs. healthy controls, matched for age, sex and IQ (Lee et al., 2019). Furthermore, reduced GMV of the right OFC was the only significant difference between the two groups and results remained significant when controlling for potential comorbid conditions (i.e., depression, anxiety and alcohol addiction). While being the only structural MRI study to implicate this region in problematic SNS users the study did employ a comparatively large sample size (n = 88) and the results fit with findings from other addictive disorders that suggest an important role for the OFC in reward and decision-making processes.

In one of the few studies to find *positive* correlations between GMV and SNS use, Turel et al. (2018a) reported larger bilateral posterior superior temporal gyrus/middle temporal gyrus, and left posterior fusiform gyrus in more frequent Facebook users. It is suggested that increased GMV of these regions is associated with an improved ability to deal with social-semantic demands involved in Facebook use (e.g., recognising faces and interpreting the mental states of others). While no negative associations between GMV and SNS behaviours were observed, the study did not correlate GMV with a measure of SNS addiction, unlike most other structural MRI studies. Contrastingly, in another study by the same group but employing a measure of Facebook addiction, only negative correlations were observed (Turel et al., 2018b). In this study, participants completed a delay-discounting task before undergoing structural MRI. The results revealed a negative correlation between GMV in bilateral posterior insula (PI) and addiction scores, and this relationship was mediated by delay discounting, showing a stronger relationship in those participants

with a preference for immediate rewards. It is suggested that the PI plays an important role in interoceptive awareness and thus promotes subjective feelings of urges and cravings in addiction (Naqvi & Bechara, 2010). Consequently, abnormal morphology of this region may result in deficits in decision making and inhibition, which is also corroborated by the negative correlation between PI GMV and delay discounting (Turel et al., 2018b). However, no other negative associations, such as those reported in other structural MRI studies and described above, were identified.

While the above studies are useful in demonstrating associations between SNS behaviours and brain morphology, they all share an important limitation in that they are unable to establish whether such structural abnormalities are directly caused by more frequent/addictive SNS use. Nonetheless, in the most recent structural MRI study to investigate SNS use, a longitudinal design was employed in which 189 adolescents were followed across three annual assessments (Achterberg et al., 2022). The researchers used latent class growth curve analysis to assess how the development of cortical thickness and surface area of ROIs differed between high vs. low social media users. The results showed that the high social media use group had higher baseline cortical thickness in the lateral and medial prefrontal cortex (L/MPFC). Over three years, the high social media use group also showed a stronger reduction in the cortical thickness of the lateral prefrontal cortex and reduced surface area of the temporal parietal junction (TPJ). While such findings are consistent with the researchers' hypothesis that more excessive SNS use should result in accelerated thinning of regions involved in processing social information (e.g., TPJ) and cognitive control (e.g., LPFC), these associations did not remain significant after correcting for false discovery rate (FDR). Thus, the findings only provide limited

evidence that more excessive SNS use might be directly responsible for developmental changes in brain structure.

In the only study using DTI to assess white matter connectivity, He et al. (2018) found increased mean diffusivity (MD) in the body and splenium of the corpus callosum in more excessive social media users. While this finding is consistent with those reported in other addictive disorders, the authors note that the results did not reach significance when a more conservative whole-brain voxel-wise analysis (using Tract Based Spatial Statistics; TBSS) was applied. However, the whole-brain analysis did reveal that more excessive SNS use was associated with increased MD in the forceps minor and ventral semantic path. The forceps minor is a white matter bundle that connects the two frontal lobes and thus increased MD in this region is indicative of inter-hemispheric communication deficits between the frontal lobes. Given the important role the frontal lobes play in cognitive control and reward processing, it seems plausible that more problematic SNS users might exhibit less efficient connectivity in these regions. However, since the study by He et al. (2018) is so far the only study investigating white matter microstructure in SNS users, and also given the relatively small sample size employed (n = 20), more research is required to validate these findings. Furthermore, TBSS is not without limitations as there is potential for bias in anatomical specificity and accuracy during the skeleton projection step. Future studies should consider using more reliable methods to achieve a more comprehensive understanding of potential alterations in white matter connectivity underlying problematic SNS use.

Table 10. Summary of structural MRI studies.

Authors (Year)	Sample	Mean Age	PSNSU	SNS Assessment Tool	Design	Main Results	Quality Assessment
Achterberg et al. (2022)	• 189 individuals categorised into high (*n* = 52, females = 68%) vs. low (*n* = 137, females = 45%) SNS use groups.	• 10–25	• Yes	• Modified Compulsive Internet Use Scale (Meerkerk et al., 2009).	• Longitudinal design (3 annual scans). • Assessed cortical thickness and surface area of ROIs.	• The high (vs. low) group had thicker lateral and medial PFC at baseline. • The high group showed a faster reduction in LPFC and TPJ over 3 years (non-FDR corrected).	• High
He, Turel and Bechara (2017) [a]	• 20 Facebook users (females = 10).	• 20.3	• Yes	• Modified Compulsive Internet Use Scale (Meerkerk et al., 2009).	• GMV was used to predict the severity of SNS addiction.	• SNS addiction was associated with reduced GMV in the amygdala but increased GMV in the ACC/MCC.	• Moderate
He, Turel, Brevers, et al. (2017)	• 50 Facebook users categorised into excessive (*n* = 25) vs. non-excessive (*n* = 25) use groups, with 8 females in each group.	• 27	• Yes	• Modified Compulsive Internet Use Scale (Meerkerk et al., 2009).	• GMV was correlated with excessive SNS use scores and differences between groups were compared.	• Excessive use group had reduced GMV in the bilateral amygdala and right ventral striatum. • GMV of these regions were negatively correlated with excessive use scores.	• High
He et al. (2018) [a]	• Sample same as He, Turel and Bechara (2017).	• 20.3	• Yes	• Modified Compulsive Internet Use Scale (Meerkerk et al., 2009).	• DTI was used and ROI analysis was performed using subregions of the corpus callosum. • Supplementary whole-brain voxel-wise analysis (using Tract Based Spatial Statistics; TBSS) also performed.	• Excessive SNS use associated with reduced white matter connectivity in the body and splenium of the corpus callosum (non-FDR corrected). • TBSS analysis revealed reduced connectivity in the forceps minor and ventral semantic pathway.	• Moderate

Lee et al. (2019) [b]	• 88 smartphone users categorised as healthy controls (*n* = 49, females = 17) vs. problematic users (*n* = 39, females = 10).	• 22.6	• Yes	• Korean Smartphone Addiction Proneness Scale (Kim et al., 2014).	• ROI analysis performed on fronto-cingulate region. • Differences in GMV and correlations with addiction severity analysed. • Subsequent whole-brain analysis performed.	• ROI analysis revealed smaller right OFC GMV in problematic users. • Reduced GMV in the OFC correlated with higher addiction scores.	• High
Montag et al. (2017)	• 62 Facebook users (females = 25).	• 23.2	• Yes	• Online Social Network Addiction Scale (Montag et al., 2015).	• Mobile app tracked participants Facebook usage across 5-weeks. • Facebook use and SNS addiction were correlated with GMV in the NAc.	• Left and right NAc GMV was negatively correlated with Facebook use. • Reduced GMV in the right NAc was associated with more addicted Facebook use.	• High
Montag et al. (2018)	• 61 WeChat users (females = 21).	• 22.3	• Yes	• Modified short Young's Internet Addiction Test (Pawlikowski et al., 2013).	• WeChat use intensity and addiction severity were correlated with GMV.	• WeChat addiction was negatively correlated with subgenual ACC GMV. • Reduced GMV in the NAc was associated with higher usage of WeChat's paying function (but not WeChat addiction).	• High
Turel et al. (2018a)	• 33 Facebook users (females = 21).	• 23.1	• No	• N/A	• Using a whole-brain analysis, correlations between GMV and Facebook use were assessed whilst controlling for age and sex.	• Three clusters of GMV: bilateral posterior superior temporal gyrus/middle temporal gyrus (pSTG/MTG), and left posterior fusiform gyrus, were positively correlated with Facebook use.	• High
Turel et al. (2018b)	• 32 Facebook users (females = 6).	• 31.2	• Yes	• Modified Online Video Game Addiction Scale	• Computer-based delay discounting task completed before MRI.	• ROI analysis revealed negative correlations between GMV in left and right posterior insula	• High

	(Van Rooij et al., 2011).	• Using a whole-brain and ROI analysis, GMV was correlated with SNS addiction and delayed discounting whilst controlling for age and sex.	(PI) and delayed discounting as well as addiction. • Delayed discounting mediated the relationship between SNS addiction and reduced GMV in left/right PI.

Note. PSNSU refers to studies that investigated the neural correlates of problematic/compulsive SNS use. [a] He, Turel and Bechara (2017) and He et al. (2018) used the same sample of Facebook users (n = 20) as a task-based fMRI study by Turel et al. (2014). [b] Lee et al. (2019) used the same sample of smartphone users (n = 88) as a resting-state fMRI study by Lee et al. (2021). Although SNS use was not assessed directly, participants who used smartphones primarily for other purposes (e.g., gaming) were excluded.

Resting-State fMRI Studies

Six studies were identified that used resting-state fMRI data to investigate the neural correlates of SNS use. Two studies (with the same sample) recruited high vs. low SNS users based on time spent using three popular Chinese SNSs (Weibo, TikTok and Kwai), one study employed a sample with problematic SNS users, one study employed a sample of Facebook users, another study employed a sample of participants with varying levels of mobile technology engagement and a final study employed a sample of Weibo users. The mean age of participants ranged from 20.9 to 25.7. Three studies were rated as moderate quality and three as high quality. A summary of the included resting-state fMRI studies is provided in Table 11.

In the only study to measure resting-state fMRI data in a sample of problematic SNS users, Lee et al. (2021) employed functional connectivity analysis at seeds in the dorsal attention network (DAN) and the ventral attention network (VAN). No significant differences between problematic SNS users and healthy controls emerged when using functional connectivity analysis with VAN seeds. However, when using seeds in the DAN, problematic SNS users were shown to have stronger functional connectivity between the right intraparietal sulcus and the right middle occipital gyrus. Because the middle occipital gyrus plays an important role in sensory processing the authors suggested that abnormal connectivity between this region and the DAN may interfere with attentional control processes in problematic SNS users. In addition, when compared to controls functional connectivity between

the right frontal eye field and the right dorsolateral prefrontal cortex (DLPFC) was weaker in problematic SNS users. Given the critical role of the DLPFC in exerting executive control, a less efficient control network may consequently result in the inability to manage the amount of time spent on SNSs resulting in more problematic use.

In a study employing a sample of Facebook users, Meshi et al. (2016) investigated whether resting-state fMRI data correlated with the frequency users shared personal information on Facebook. Participants completed a self-related sharing assessment (Carpenter, 2012) and scores were correlated with functional connectivity using seeds at the medial prefrontal cortex (MPFC), central precuneus (CP), caudal anterior cingulate cortex (cACC), and the ventral striatum. No significant correlations were observed when using seeds at the cACC and ventral striatum. However, intrinsic functional connectivity between the MPFC and the right DLPFC, as well as between the CP and right DLPFC, were both positively correlated with self-related sharing. Additionally, connectivity between the CP and the left lateral OFC was positively correlated with self-related sharing, although connectivity between the CP and the left anterior temporal pole (ATP) was negatively correlated with self-related sharing. Increased functional connectivity of both the MPFC and CP to other brain regions is in line with the suggested view that these regions play a role in self-referential processing (Northoff et al., 2006). In particular, since the DLPFC is critical for executive functioning and working memory, stronger

functional connectivity to this region might indicate a greater ability to hold self-related information in working memory, in turn facilitating self-related sharing.

A study by Wilmer et al. (2019) investigated functional connectivity in two dissociable pathways stemming from the ventral striatum. While higher connectivity between the ventral striatum and the ventromedial prefrontal cortex (VMPFC) was associated with higher mobile technology engagement (including increased social media use and more frequent status updates), connectivity between the ventral striatum and DLPFC was associated with reduced mobile technology engagement. The researchers suggest that these findings corroborate the notion of the ventral striatum-VMPFC pathway being involved in reward processing, thus resulting in greater sensitivity to rewards obtain through mobile technologies. Similarly, the association between increased functional connectivity in the ventral striatum-DLPFC pathway and reduced mobile media engagement is consistent with this networks role in exerting executive control over behaviour, resulting in more controlled use of mobile technologies.

Using seeds at the medial prefrontal cortex (MPFC), dorsomedial prefrontal cortex (DMPFC) and temporoparietal junction (TPJ), Zhang and Mo (2016) correlated functional connectivity with participant's reposting rate in an experimental paradigm that simulated Weibo use. During the task, completed after the scanning session, participants were shown a series of 90 Weibo messages of either positive, negative or neutral valence. After reading each Weibo message participants had to

decide whether to ‘repost’ or ‘not repost’ the message. It was shown that overall participants preferred to repost negative, compared to positive or neutral messages. The repost rate of negative messages was positively correlated with functional connectivity between left TPJ and left middle frontal lobe, as well as between the left TPJ and right insula. Additionally, functional connectivity between left DMPFC and medial OFC was also shown to be positively correlated with the repost rate of negative messages. Conversely, the repost rate of positive messages was positively correlated with functional connectivity between the right TPJ and right superior temporal lobe. Finally, the repost rate of neutral messages showed a positive correlation with the functional connectivity between left TPJ and left ventrolateral OFC, in addition to the functional connectivity between bilateral DMPFC. The finding of increased functional connectivity between the TPJ and other regions being associated with an increased repost rate across all message types was argued to corroborate the important role that the TPJ plays in social communication.

A recent study by Hu, Cui, et al. (2022) used dynamic functional network connectivity analysis to investigate the brain dynamics of reading SNS posts on a smartphone. Resting-state fMRI was first recorded at baseline before participants were assigned to either a social media or science fiction reading task, which took place outside of the scanner. Immediately after the reading task participants underwent a second fMRI session. Reading social media posts was shown to decrease functional connectivity between the default mode network (DMN) and

frontoparietal network (FPN), but increased connectivity between the DMN and visual network. It is suggested that since a main function of the DMN is mind wandering (Brewer et al., 2011), SNSs might stimulate the visual network to induce mind wandering, resulting in increased inattention after SNS use. In another study by the same group and recruiting from the same pool of participants, Hu, Yu, et al. (2022) used a longitudinal design to investigate changes in functional connectivity after a month of excessive SNS use. The results showed that the functional connectivity of light SNS users was more similar to that of heavy users after they completed the four-week period of increased SNS use. Using inter-subject correlation analysis, increased SNS use was shown to have a widespread impact on almost all brain networks and functional connectivity between regions that were most affected were associated with selective attention. The study is the first to indicate that more excessive SNS use can result in alterations of cerebral functional connectivity when assessed longitudinally, and results therefore warn of potential neurobiological consequences attributable to just four weeks of excessive SNS use.

Table 11. Summary of resting-state fMRI studies.

Authors (Year)	Sample	Mean Age	PSNSU	SNS Assessment Tool	Design	Main Results	Quality Assessment
Hu, Cui, et al. (2022)	• 70 males categorised as heavy (*n* = 30) vs. light (N = 40) SNS users based on time spent on Weibo, TikTok, and Kwai.	• 20.9	• No	• N/A	• Participants surfed Weibo or read a science fiction novel on their phone after baseline recording and before a second fMRI recording.	• Reading SNS posts reduced functional connectivity between the default mode network (DMN) and frontoparietal network (FPN), but increased connectivity between the DMN and visual network.	• Moderate
Hu, Yu, et al. (2022)	• 49 males recruited from the same pool as Hu, Cui, et al. (2022), categorised as heavy (N = 30) vs. light (N = 19) SNS users.	• 21	• No	• N/A	• Longitudinal design. • Light SNS users were instructed to increase their use to 2 h per day for 4 weeks before undergoing a second fMRI session.	• Difference in functional connectivity between two groups was attenuated after light users increased their SNS use. • Increased SNS use had widespread impact on almost all brain networks.	• High
Lee et al. (2021) [a]	• 88 smartphone users categorised as healthy controls (*n* = 49, females = 17) vs. problematic users (*n* = 39, females = 10).	• 22.6	• Yes	• Korean Smartphone Addiction Proneness Scale (Kim et al., 2014).	• Analysed ROIs in the dorsal and ventral attention network.	• Problematic users had increased functional connectivity between the right middle occipital gyrus and the right intraparietal sulcus but reduced functional connectivity between the right frontal eye field and right dorsolateral prefrontal cortex.	• High

Meshi et al. (2016)	• 35 Facebook users (females = 21).	• 25.7	• No	• Self-Related Sharing Assessment (Carpenter, 2012).	• fMRI data was correlated with the degree to which participants share self-related information on Facebook.	• Functional connectivity between the MPFC and right DLPFC, CP and right DLPFC as well as between the CP and left OFC was associated with sharing personal information on Facebook. • Whereas connectivity between the CP and left ATP was negatively associated with self-related sharing score.	• High
Wilmer et al. (2019)	• 26 healthy SNS users (females = 15).	• 21.4	• No	• Mobile Technology Engagement Scale (Wilmer & Chein, 2016).	• Functional connectivity was assessed at ventral striatum, ventral medial PFC and DLPFC.	• Higher connectivity between the ventral striatum and the ventral medial PFC was associated with greater mobile technology engagement. However, higher connectivity between the ventral striatum and DLPFC was associated with lower engagement.	• Moderate
Zhang and Mo (2016) [b]	• 28 Weibo users (females = 14).	• 21.2	• No	• N/A	• Functional connectivity was assessed at MPFC, DMPFC and TPJ. • After fMRI participants completed an experimental task in which they read valenced Weibo messages and decided whether to 'repost' or 'not repost' each message.	• Reposting positive messages was associated with increased connectivity between right TPJ and right superior temporal lobe. • Greater connectivity between left TPJ, left middle frontal lobe and right insula, and between left DMPFC and medial OFC were positively	• Moderate

		correlated with reposting negative messages. • Connectivity between left TPJ and left ventrolateral OFC, and between bilateral DMPFC was positively correlated with reposting neutral messages.

Note. PSNSU refers to studies that investigated the neural correlates of problematic/compulsive SNS use. [a] Lee et al. (2021) used the same sample of smartphone users (n = 88) as a structural MRI study by Lee et al. (2019). Although SNS use was not assessed directly, participants who used smartphones primarily for other purposes (e.g., gaming) were excluded. [b] Zhang and Mo (2016) used the same sample of Weibo users (n = 28) as a task-based fMRI study by Zhang and Qu (2020).

Task-Based fMRI Studies

The 13 task-based fMRI studies identified in the literature search used a range of different experimental tasks, thus making it difficult to directly compare neural activity between studies. Two studies used cognitive control tasks (Emotional Stroop and Go/No-Go), two studies used a self-retrieval/self-concept paradigm, another used a description task, and the remaining eight studies all used variations of a cue reactivity task or a paradigm that simulated SNS use. The specific SNS platform under investigation also varied between studies. Four studies employed a sample with problematic SNS users, with the remaining studies investigating either Facebook, Instagram, TikTok, Weibo or general SNS users. The mean age of participants ranged from 16.8 to 26.1. Four studies were rated as moderate quality and nine as high quality. A summary of the included task-based fMRI studies is provided in Table 12.

Dieter et al. (2017) investigated neural differences in emotional inhibitory control processing between individuals with a gaming addiction (n = 13) or social network addiction (n = 12) and healthy controls (n = 23). During fMRI the participants completed an Emotional Stroop Task with four categories of positive, negative, neutral and socially anxious words. Behavioural results revealed no significant difference in the reaction times to emotional words between healthy controls and internet addicts (gaming and social network addicts). Similarly, and in contrast to what was hypothesised, the fMRI data revealed no significant difference in dorsal ACC activation between controls and specific internet addicts during socially anxious word blocks. Nonetheless, it was shown that compared to individuals with a social network addiction, participants with an internet gaming addiction exhibited reduced activation in left middle and superior temporal gyrus

during socially anxious words. However, all other between group comparisons of the subgroups revealed no significant differences in activation. The findings were interpreted as social anxiety-related alterations in response inhibition playing a larger role in internet gaming addiction rather than SNS addiction, whereby gaming might represent a coping strategy to avoid face to face interactions. The only other study to employ an established reaction time task investigated inhibitory control using a Facebook-specific Go/No-Go paradigm. In this study, Turel et al. (2014) observed that bilateral ventral striatum activity during Facebook-Go trials was positively correlated with addiction scores. However, contrary to the hypothesis, activity in regions that make up the brain's inhibitory system (prefrontal cortex) during Facebook-No-Go trials were not negatively correlated with addiction severity. This pattern of results suggests that on the one hand, similar to other addictive disorders, Facebook users with more addiction-like symptoms exhibit a hyperactive amygdala-striatal (impulsive) brain system, whereas on the other hand they do not have a hypoactive prefrontal inhibitory system, which is dissimilar to other addictions.

Alterations of ventral striatal activity have also been reported in other fMRI studies investigating SNS use. One study employing a sample of Facebook users recorded neural activity whilst participants completed a 'description task' (Meshi et al., 2013). Here, participants received a description (e.g., intelligent) that appeared with a picture of themselves or another person, with the descriptions ostensibly provided by another participant. The findings revealed that when receiving gains in reputation (vs. observing the gains in reputation of another) activity in the left NAc (a component of the ventral striatum) predicted more intense Facebook use. Furthermore, Meshi et al. (2013) found that left NAc activity in response to monetary rewards did not predict more intense Facebook use, indicating that individual sensitivity

of the NAc in processing social information relevant to the self (rather than its sensitivity to reward more generally) influences the use of Facebook.

Sherman and colleagues also observed alterations in NAc activity in their studies which analysed data from the same sample of teenaged Instagram users. In their experiment, participants completed a paradigm that simulated Instagram use, in which they viewed a series of photos (including some of their own photos) with varying numbers of 'likes'. Each image was ostensibly rated by other participants and appeared with either a high or low like count. After viewing each image participants had to decide themselves whether to like the picture or not. In their first paper which analysed data from 32 teenagers (mean age = 16.8), Sherman et al. (2016) reported increased bilateral NAc activation when participants viewed their own photos that had received many (compared to few) likes. Additionally, when participants viewed 'risky' photos (e.g., images depicting cannabis use) they exhibited hypoactivity in regions implicated in cognitive control (e.g., dorsal ACC, bilateral PFC, and lateral parietal cortex). In their later paper, the authors included data from an additional 26 university students (mean age = 19.9) who underwent the same procedure (Sherman, Greenfield, et al., 2018). The findings revealed that university students displayed a similar pattern of results, showing increased activity in bilateral NAc when viewing their own photos with many (vs. few) likes. While this effect replicated the previous study using an older sample, unlike the teenaged Instagram users, the university students did not display reduced activity in regions involved in cognitive control whilst viewing risky images. In the last paper published by this group, Sherman, Hernandez, et al. (2018) analysed neural activity (in the same sample of Instagram users) when participants decided to like another's photo. Consistent with their hypothesis liking an image was associated with increased

activity in the ventral striatum and VMPFC, as well as a range of other structures involved in reward, salience processing and executive function. The NAc/ventral striatum therefore appears to be a key region involved in facilitating SNS use by becoming hyperactive when receiving peer feedback (e.g., obtaining likes), providing peer evaluation (e.g., distributing likes) and responding to SNS cues (e.g., during SNS-Go trials in the Go/No-Go task).

In a similar experiment to that of Sherman and colleagues, Nasser et al. (2020) employed a sample of problematic (n = 15) and non-problematic (n = 15) Instagram users who completed a paradigm that mimicked Instagram use whilst undergoing fMRI. During the task participants viewed a series of Instagram photos that were categorised as either risky (e.g., a selfie whilst driving), neutral (e.g., greyscale image of an inanimate object), or positive (i.e., photos from the participants own Instagram account), and each appeared with either a high or low number of 'likes'. After viewing each image participants also had to decide whether to 'like' or 'pass' the photo. Behaviourally it was found that problematic Instagram users liked significantly more risky pictures than the control group. Analysis of the fMRI data also revealed that compared to non-problematic Instagram users, problematic users exhibited increased bilateral precuneus activation when viewing risky images. Increased precuneus activity in more problematic users is assumed to reflect the role this region plays in assigning salience and responding to habit-forming stimuli (DeWitt et al., 2015), which is corroborated by the behavioural results (as problematic users were more responsive to risky images). Additionally, activity in the right MPFC when viewing risky photos was negatively correlated with Instagram addiction scores, suggesting that more problematic users might experience decision making/cognitive control deficits when viewing addiction-related cues.

As well as investigating peer feedback in the form of SNS ‘likes’, other studies have investigated neural reactivity to receiving comments on SNS posts. In a task simulating the use of Facebook, adolescent SNS users had to post controversial statements (e.g., “abortions should be illegal”) to a Facebook group and received either positive or negative comments on their post from peers (Wikman et al., 2022). When compared to a control condition (i.e., posting neutral statements and receiving neutral feedback) trials containing emotionally valenced statements elicited activation in the MPFC, precuneus and PCC. Additionally, receiving negative (vs. positive) peer feedback was associated with increased activity in the ventrolateral PFC, MPFC, and anterior insula, whereas viewing positive comments was associated with greater activity in regions including the posterior insula, TPJ, precuneus and PCC. However, the amount participants used SNSs in the real world did not interact with these effects.

Similarly, fMRI cue-reactivity paradigms have also been utilised to investigate the neural regions involved in decisions to repost content on microblogging platforms (e.g., Weibo), where short passages of text are typically shared by users. Analysing data from the same sample as a previous resting-state fMRI study (Zhang & Mo, 2016), Zhang and Qu (2020) investigated task-based neural activity whilst participants completed a paradigm simulating Weibo use. When reposting emotionally valenced (vs. neutral) messages participants showed increased activity in regions implicated in the emotion and cognitive control systems (e.g., DLPFC, insula, precuneus and TPJ), suggesting that these messages recruit more cognitive and emotional resources. Behaviourally participants were more likely to repost negatively valenced messages, which was also reflected by an increase in TPJ activation. Since the TPJ is known to play a key role in social communication

and mentalising, these findings also imply that this region is involved in decisions to promulgate negative information online.

In another fMRI study using an SNS exposure paradigm, 30 TikTok users were shown six personalised recommended TikTok videos (based on user-specific preferences) that were extracted from their own account as well as six generalised recommended videos for new users (Su, Zhou, Gong, et al., 2021). Watching personalised compared to generalised recommended TikTok videos resulted in increased activation in regions of the default mode network (DMN; including the bilateral superior and middle temporal gyri, temporal pole, ventral PCC, MPFC, and angular gyrus) as well as in the left dorsal lateral and inferior frontal regions, anterior thalamus and cerebellum. In addition, voxel-wise psychophysiological interaction analysis was used to assess task-related connectivity changes between seeds in the DMN and other regions. The analysis revealed increased connectivity between the DMN seeds and regions including the visual network, primary auditory cortex, and middle frontal gyrus, but reduced connectivity with the cingulate cortex, cuneus and inferior parietal lobe when watching personalised (vs. generalised) videos. Finally, activation in regions implicated in addiction and reward learning (ventral tegmental area, substantia nigra and NAc) were also explored using ROI analyses. While the substantia nigra was activated by both personalised and generalised videos, increased ventral tegmental activation was specific to watching personalised videos. Interestingly, however, and contrasting with an important role for the NAc in other SNS use behaviours, the NAc was deactivated (although not significantly) when viewing both video types. In an extension of this work, the same group published further analyses of the same dataset using graph theory to investigate the functional connectivity between seven networks (Su, Zhou, Wang, et al., 2021). Results

revealed that viewing personalised videos increased connectivity in the DAN-VAN-DMN pathway, whereas both video types resulted in reduced coupling between the salience network (i.e., anterior insula and dorsal ACC) and VAN as well as between two subsystems in the DMN. Taken together, these findings support a role of the DMN in self-relevant information processing, whereby regions in the DMN are activated by user-specific content and may also facilitate prolonged SNS use through increased coupling of the DMN to visual and auditory pathways, but reduced coupling to regions in the control network. The authors suggest that the results are also consistent with roles for the substantia nigra in saliency-coding and ventral tegmental area in reward-value coding.

In a study by Leménager et al. (2016), participants completed a self-retrieval paradigm in which they rated the extent to which various self-concept-related characteristics described their self, ideal self, and gaming avatar (created by them), whilst undergoing fMRI. The sample consisted of pathological internet gamers (n = 19), pathological SNS users (n = 19) and healthy controls (n = 19). It was found that individuals with a gaming addiction exhibited increased left angular gyrus activation when reflecting on the characteristics of their avatar, whereas individuals with an SNS addiction exhibited striatal hypoactivations whilst making self (vs. ideal)-reflections. The authors suggest that the finding of reduced activity in the dorsal striatum in participants with an SNS addiction compared to healthy controls might indicate that self (vs. ideal)-reflections are less rewarding for SNS addicts. This in turn might suggest that these individuals experience deficits in emotion regulation that could be the result of (or the perception of) social feedback received online. A more recent study used a similar self-concept paradigm in which participants had to make self-judgements on academic, physical and prosocial traits from their own

perspective and from the perspective of others (Peters et al., 2021). It was shown that individuals who reported less SNS use made more positive ratings from self-judgements vs. reflected-peer-judgements and more excessive SNS use was linked to increased MPFC activity during self-judgements and particularly during physical (vs. academic and prosocial) self-judgements. Nonetheless, longitudinal assessments of clinical symptoms, prosocial behaviour and self-concept clarity (at 1-and 2-year follow up) indicated no long-term effects of SNS use or altered MPFC activity. Thus, while the findings are consistent with the MPFC's core role in the self-referential cognition network and suggest that excessive SNS use might modulate activity in this region during self-judgements resulting in more intensified self-refection processes, there is no evidence that this leads to negative long-term consequences.

Table 12. Summary of task-based fMRI studies.

Authors (Year)	Sample	Mean Age	PSNSU	SNS Assessment Tool	Design	Main Results	Quality Assessment
Dieter et al. (2017)	• 48 participants comprising healthy controls (*n* = 23, females =13), internet gaming addicts (*n* = 13, females = 2) and SNS addicts (*n* = 12, females = 6).	• 25.9	• Yes	• Assessment of Internet and Computer game Addiction checklist (Wölfling et al., 2012).	• Participants completed an Emotional Stroop Task (EST) with socially anxious, positive, negative and neutral words whilst undergoing fMRI.	• No group differences in ACC activity were found. • When viewing socially anxious words internet gaming addicts had reduced activity in the left middle and superior temporal gyrus compared to social network addicts.	• High
Leménager et al. (2016)	• 57 participants comprising healthy controls (*n* = 19, females = 12), pathological internet gamers (*n* = 19, females = 5) and pathological SNS users (*n* = 19, females = 10).	• 26.1	• Yes	• Assessment of Internet and Computer game Addiction checklist (Wölfling et al., 2012).	• While undergoing fMRI participants completed a self-retrieval paradigm, in which they rated the extent to which self-concept-related characteristics described their self, ideal, and gaming avatar.	• When making self-reflections (vs. ideal-reflections) pathological SNS users had reduced activation in the dorsal striatum, thalamus and the inferior/middle frontal gyrus (vs. controls). • Reduced activity in these regions was correlated with symptom severity.	• Moderate
Meshi et al. (2013)	• 31 Facebook users (females = 17).	• 23.1	• No	• Facebook Intensity Scale (Ellison et al., 2007).	• While undergoing fMRI participants completed a task in which they received gains in reputation and observed the gains in reputation of another person, and a separate card task where they played for a monetary reward.	• Activity in the left NAc in response to gains in self reputation (vs. observing reputation gains of others) predicted Facebook use. • Whereas activation of the NAc in response to monetary gains did not predict Facebook use.	• High

Nasser et al. (2020)	• 30 Instagram users categorised as problematic users (*n* = 15, females = 5) vs. healthy controls (*n* = 15, females = 8).	• 21.9	• Yes	• Modified short Young's Internet Addiction Test (Pawlikowski et al., 2013).	• Participants completed a fMRI-based cue reactivity task with negative or positive valenced Instagram selfie images and neutral landscape image cues.	• Negatively valenced cues produced increased activation of the precuneus in problematic users. • Activation in the right MPFC in response to addiction-related cues was negatively correlated with Instagram addiction score.	• Moderate
Peters et al. (2021)	• 150 healthy adolescents and young adults (11–21 years old, females = 80).	• 15.7	• No	• N/A	• During fMRI, participants rated themselves on 60 traits related to academic, physical and prosocial characteristics, and also indicated how their peers would judge them on the same traits. • Longitudinal questionnaires assessing positive and negative outcomes were collected at 1- and 2-year follow-up.	• Increased SNS use was associated with medial PFC activity during self-judgements (vs. reflected-peer-judgements), and increased activity when making judgements about physical traits. • SNS use or medial PFC activity had no long-term effect on clinical symptoms, prosocial behaviour or self-concept clarity.	• High
Sherman et al. (2016) [a]	• 32 Instagram users (females = 18).	• 16.8	• No	• N/A	• Participants completed a paradigm that simulated Instagram use whilst undergoing fMRI. • 'Instagram photos' were displayed (including some of the participants own photos), and each appeared with a high or low number of likes. • Participants decided whether to like each photo or move on.	• Viewing photos with a high number of likes was associated with increased activity in the precuneus, MPFC, left temporal pole, lateral occipital cortex, hippocampus, NAc, caudate, putamen and thalamus. • Participants had greater activity in bilateral NAc when viewing own photos with many likes. • Decreased activity in regions implicated in cognitive control was found when participants viewed risky photos.	• High

Sherman, Greenfield, et al. (2018) [a]	• 58 Instagram users, comprising 32 high school (females = 18) and 26 university students (females = 17).	• 16.8 vs. 19.9	• No	• N/A	• The fMRI task was the same as Sherman et al. (2016).	• Replicating Sherman et al. (2016), university students showed greater bilateral NAc activity when viewing their own photos that had received many likes. • Bilateral NAc activity increased linearly with age in the high school sample, but not in the university sample. • Viewing risky images was not associated with decreased activity in regions responsible for cognitive control in the university sample.	• High
Sherman, Hernandez, et al. (2018) [a]	• Same sample as Sherman, Greenfield et al. (2018).	• 16.8 vs. 19.9	• No	• N/A	• The fMRI task was the same as Sherman et al. (2016); however, in this study, the researchers examined neural responses when participants provided 'likes' to others, rather than when they viewed the images.	• When participants 'liked' a photo they showed activation in the ventral striatum, vmPFC, dorsal striatum, thalamus, bilateral insula/OFC, hippocampus, amygdala, ACC, inferior frontal gyrus and the bilateral intraparietal sulcus.	• High
Su, Zhou, Gong, et al. (2021) [b]	• 30 TikTok users (females = 14).	• 23.7	• No	• Modified Young's Internet Addiction Test (Young, 1998).	• Whilst undergoing fMRI participants were shown TikTok videos including generalised recommended videos for new users and personalised recommended videos for experienced users (taken from their personal TikTok account).	• When viewing personalised videos participants showed increased activity in parts of the DMN. • Parts of the DMN also showed enhanced coupling with primary visual and auditory areas, and decreased coupling with precuneus and cingulate cortex when viewing personalised videos.	• High

					• Participants had not seen any of the videos before entering the scanner.		
Su, Zhou, Wang, et al. (2021) [b]	• Same sample as Su, Zhou, Gong, et al. (2021).	• 23.7	• No	• Modified Young's Internet Addiction Test (Young, 1998).	• The fMRI task was the same as Su, Zhou, Gong, et al. (2021). However, in this study, the researchers used graph theory analysis to investigate functional connectivity between ROIs within the DMN, dorsal and ventral attentional networks (DAN/VAN), the frontal-parietal network (FPN) and the salience network (SN).	• Both personalised and generalised videos enhanced connectivity in the DAN-FPN-DMN pathway. • Whereas personalised videos also increased connectivity in the DAN-VAN-DMN pathway. • Additionally, both video types resulted in reduced coupling between the SN and VAN as well as between two subsystems in the DMN.	• High
Turel et al. (2014) [c]	• 20 Facebook users (females = 10).	• 20.3	• Yes	• Modified Online Video Game Addiction Scale (Van Rooij et al., 2011).	• Participants completed a Facebook-specific Go/No-Go task whilst undergoing fMRI.	• Bilateral ventral striatum activity on Facebook-go trials was positively correlated with addiction scores. • However, activity in the inhibitory control system (i.e., ACC and PFC) on Facebook-No-Go trials was not correlated with addiction score.	• Moderate
Wikman et al. (2022)	• 92 healthy adolescents and young adults (17–20 years old, females = 52).	• 18.7	• No	• N/A	• Participants completed a task simulating Facebook use whilst undergoing fMRI. • Participants had to agree or disagree with either neutral or controversial statements and then received positive or negative peer feedback on their opinions in the form of Facebook comments.	• Negative feedback was associated with increased VLPFC, MPFC, and anterior insula activity. • Positive feedback was associated with greater activity in regions including the posterior insula, TPJ, precuneus and PCC. • No association with real-world SNS use.	• High

Zhang and Qu (2020) [d]	• 28 Weibo users (females = 14).	• 21.2	• No	• N/A	• Participants viewed positive, negative, and neutral microblog messages mimicking those on Weibo whilst undergoing fMRI. • Participants decided whether to repost or not repost each microblog.	• Reposting negative microblogs increased activity in postcentral gyrus, superior frontal gyrus and TPJ. • Reposting emotionally valenced (vs. neutral) microblogs resulted in increased activity in DLPFC, insula, precuneus and TPJ.	• Moderate

Note. PSNSU refers to studies that investigated the neural correlates of problematic/compulsive SNS use. [a] Sherman et al. (2016), Sherman, Greenfield, et al. (2018) and Sherman, Hernandez, et al. (2018) all used the same sample of high school students (n = 32). Sherman, Greenfield, et al. (2018) and Sherman, Hernandez, et al. (2018) used the same sample of university students (n = 26). [b] Su, Zhou, Gong, et al. (2021) and Su, Zhou, Wang, et al. (2021) used the same sample of TikTok users (n = 30). While this study administered an assessment of 'TikTok addiction', scores were not correlated with brain activity. [c] Turel et al. (2014) used the same sample of Facebook users (n = 20) as two structural MRI studies by He, Turel and Bechara (2017) and He et al. (2018). [d] Zhang and Qu (2020) used the same sample of Weibo users (n = 28) as a resting-state fMRI study by Zhang and Mo (2016).

Discussion

The present article sought to systematically review existing research employing MRI methods to investigate the neural underpinnings of SNS use. In general, MRI studies investigating 'SNS addiction' are relatively scarce and a larger number of MRI studies have investigated either internet gaming or non-specific internet use addiction (e.g., 44 MRI studies investigating internet gaming disorder were identified in a recent systematic review, Gao et al., 2021). Below, we evaluate the main findings in relation to the key brain regions implicated in SNS use/addiction.

Ventral Striatum/Nucleus Accumbens

The ventral striatum, and in particular the NAc within the ventral striatum, appears to be a key region involved in the use of SNSs. The NAc is known to play a central role in the brain's 'reward circuit' and is responsible for regulating motivation for drug-seeking behaviour in addiction (Salgado & Kaplitt, 2015). Neuroimaging studies of substance use addictions have consistently shown greater ventral striatum/NAc activity in addicts presented with addiction-related cues (David et al., 2005; Kühn & Gallinat, 2011) and there is also evidence that NAc activity is correlated with increased cravings in problem gamblers (Limbrick-Oldfield et al., 2017). Therefore, MRI studies investigating SNS use might reasonably expect neuroadaptations of the ventral striatum/NAc to be associated with excessive/problematic SNS use or responses to SNS cues. Indeed, there is evidence that problematic SNS users show heightened activity in the ventral striatum when responding to SNS cues (Turel et al., 2014) and even regular users show greater activity in this region when performing tasks that simulate SNS use (especially when

the task involves cues related to social reward e.g., 'likes'; Meshi et al., 2013; Sherman, Greenfield, et al., 2018; Sherman et al., 2016). Furthermore, higher SNS engagement may also be characterised by reduced functional connectivity between the ventral striatum and DLPFC (reflecting reduced control) but increased connectivity in the ventral striatum-ventral medial PFC 'reward pathway' (Wilmer et al., 2019). Multiple structural MRI studies have also found associations between more excessive/problematic SNS use and reduced ventral striatum volume. Montag et al. (2017) provides the most compelling evidence for reduced NAc GMV in more excessive SNS users, since the study used a comparatively large sample size and employed an objective measure of SNS usage. Such a finding is also consistent with the substance addiction literature where reduced volume of structures within the brain's reward system are typically observed in addicted individuals (Makris et al., 2008; Seifert et al., 2015). More excessive/problematic SNS use therefore seems to be characterised by reduced ventral striatum volume but heightened activity in this region in response to SNS cues or social rewards related to SNS use.

Prefrontal Cortex

The prefrontal cortex can be subdivided into three broad structures that comprise the lateral, medial and orbitofrontal regions. The lateral prefrontal regions are thought to be responsible for implementing cognitive control and executive functions such as working memory, selective attention and planning, while the medial prefrontal regions play a role in motivation, decision making and self-referential processing (Siddiqui et al., 2008). Due to its many connections with the limbic system the orbitofrontal cortex plays a vital role in emotional behaviour and reward processes and is responsible for forming reward expectations as well as

representing reward value and subjective pleasantness (Kringelbach, 2005). The functions of the PFC are thus clearly relevant to the development of addiction and various structural and functional abnormalities of prefrontal regions have been documented in the substance use addiction literature (Goldstein & Volkow, 2011). Such abnormalities are thought to be responsible for the impaired inhibitory control and increased cravings/impulsivity experienced during addiction. Multiple studies identified in the present review have also implicated prefrontal regions in the use and problematic use of SNSs.

Nonetheless, evidence of structural PFC abnormalities being associated with SNS use is scarce. It is well established that drugs of abuse are associated with grey matter atrophy in the PFC (Crunelle et al., 2014; Liu et al., 1998; Pfefferbaum et al., 1998) and there is also evidence that behavioural addictions such as gambling disorder are related to reduced cortical thickness in frontal regions (Grant et al., 2015). Yet, only one study has reported such a relationship (reduced GMV of the right orbitofrontal cortex) in problematic SNS users (Lee et al., 2019). However, this study did employ a large sample size when compared to the other structural MRI studies identified in this review. Notably, one study found that adolescents with more excessive SNS use showed higher cortical thickness in the lateral and medial PFC (Achterberg et al., 2022). This finding is not entirely inconsistent with other addictive disorders since increased GMV in the right prefrontal cortex has also been observed in problem gamblers and is suggested to be a neuroadaptation in response to the increased cognitive demands required to control gambling impulses (Koehler et al., 2015). However, in their longitudinal study, Achterberg et al. (2022) also reported accelerated cortical thinning in the lateral PFC in excessive SNS users, although this finding did not survive FDR correction. Thus, to date there is only

weak evidence to suggest that SNS use is associated with structural changes in the PFC.

A larger number of studies have reported functional alterations of the PFC at rest and during task performance. The OFC has been implicated in only a few functional MRI studies, none of which correlated activity with excessive or problematic SNS use. Instead, increased functional connectivity between the OFC and central precuneus appears to be associated with sharing personal information online (Meshi et al., 2016), while stronger connections to the dorsomedial PFC and temporal parietal junction facilitates SNS reposting (Zhang & Mo, 2016). Sherman, Hernandez, et al. (2018) also reported increased OFC activity when participants 'liked' another's Instagram post. Thus, while abnormal OFC activity/connectivity has not been associated with more problematic SNS use, this region does seem to play an important role in active SNS engagement (e.g., posting, sharing and 'liking' SNS content).

The lateral prefrontal cortex (particularly the dorsolateral prefrontal cortex; DLPFC) has also been shown to be involved in SNS use behaviours. It is likely that the DLPFC is recruited to manage the cognitive and emotional demands of sharing personal and emotionally valenced content online (Meshi et al., 2016; Zhang & Qu, 2020). Given the key role the DLPFC plays in implementing cognitive control (MacDonald et al., 2000), it is also unsurprising that more efficient connectivity with the ventral striatum is associated with lower SNS engagement (improved control; Wilmer et al., 2019) while reduced connectivity with the dorsal attention network is associated with more problematic use (reduced control; Lee et al., 2021). Limited inhibitory control abilities in more problematic SNS users may also be reflected by reduced white matter integrity in the forceps minor (a white matter bundle

connecting the lateral and medial surfaces of the frontal lobes; He et al., 2018). However, contrary to what might be expected, fMRI studies employing tasks of executive function have reported no abnormalities in PFC activation for problematic SNS users (Dieter et al., 2017; Turel et al., 2014).

Finally, the medial PFC has been implicated in a range of fMRI studies. Increased functional connectivity between the medial PFC and ventral striatum in more excessive SNS users (Wilmer et al., 2019) and increased medial PFC activity in response to viewing SNS photos with many 'likes' (Sherman, Greenfield, et al., 2018; Sherman et al., 2016) could potentially reflect an increased motivation to pursue SNS rewards. However, more problematic SNS users have been found to show reduced medial PFC activity when viewing cues depicting risky behaviours which might indicate impaired decision making abilities (Nasser et al., 2020). Other studies have also supported a key role for the medial PFC in the self-referential cognition network. Reduced medial PFC activity when making self-reflections might indicate deficits in self-referential cognition as a result of excessive SNS use (Leménager et al., 2016). Although, one study found increased medial PFC activity during self-judgements in more excessive users, which had no relationship with long-term negative outcomes (Peters et al., 2021). Increased medial PFC activity when viewing personalised SNS videos (Su, Zhou, Gong, et al., 2021) or when receiving negative SNS comments (Wikman et al., 2022) may also reflect the processing of content relevant to the self.

Amygdala

The amygdala is another key structure implicated in the development of substance use addictions. The amygdala is engaged in emotional and motivational

processes and forms a crucial component of the brain's arousal/stress systems which are thought to play a key role in facilitating the transition to drug dependence and maintenance (Koob, 2009). Meta-analyses of drug cue-reactivity studies have found cue-induced amygdala activity to be one of the most robust findings in the substance addiction literature (Chase et al., 2011; Kühn & Gallinat, 2011), and rodent models have also shown that activating the amygdala intensifies motivation for drug consumption (Warlow et al., 2017). By contrast, no existing research has found an association between amygdala activity and problematic SNS use (although cue-reactivity studies are limited). Nonetheless, Sherman, Hernandez, et al. (2018) did find increased amygdala activity in regular SNS users when 'liking' another's post, which is consistent with the amygdala's role in motivation and reward expectancy ('liking' another's post may in turn increase the likelihood of an individual reciprocating 'likes' on a future post, intensifying reward expectancy). Structurally, two studies reported an association between reduced amygdala volume and more excessive/problematic SNS use (He, Turel, & Bechara, 2017; He, Turel, Brevers, et al., 2017). This finding is in keeping with observations in substance use disorders (Gilman et al., 2014; Makris et al., 2004; Padula et al., 2015; Wrase et al., 2008), where reduced amygdala volume is suggested to be responsible for increased susceptibility to emotion dysregulation, resulting in a reduced ability to manage cravings. Thus, in SNS use, the amygdala appears to play a role in decisions to distribute positive feedback to others, while reduced amygdala size may be predictive of more intense or harmful SNS use.

Cingulate Cortex

The cingulate cortex, principally the ACC (a central node of the cognitive control network; MacDonald et al., 2000) but also the posterior cingulate cortex (PCC), has been widely implicated in substance use addictions (Kühn & Gallinat, 2011; Zakiniaeiz et al., 2017; Zhao et al., 2021). Structural MRI studies have also identified reduced ACC volume in both substance use (Fritz et al., 2014; Yang et al., 2016) and behavioural addictions (e.g., internet gaming disorder; Wang et al., 2015) reflecting diminished cognitive control abilities. In the present review, two studies were identified which found significant correlations between ACC volume and problematic SNS use. Montag et al. (2018) found reduced subgenual ACC volume in more addicted SNS users, whereas He, Turel and Bechara (2017) found an association between increased dorsal ACC volume and higher addiction severity. While this might indicate specific functions for ACC subregions in addiction, the finding of increased dorsal ACC volume in more problematic SNS users is still not consistent with the wider addiction literature. Indeed, neural deficits in the dorsal ACC have been proposed to constitute a hallmark neurocognitive deficit underlying addictive disorders (Luijten et al., 2014) and stimulating the rostrodorsal ACC can help suppress alcohol cravings in individuals with alcohol use disorder (Leong et al., 2020). In line with this, Sherman et al. (2016) found that teenaged Instagram users showed deactivations of regions in the cognitive control network (including the dorsal ACC), when viewing Instagram posts depicting risky (vs. neutral) behaviours ostensibly posted by peers, which suggests disinhibited cognitive control in response to highly salient SNS cues. Although this effect appears to be age-specific (Sherman, Greenfield, et al., 2018), potentially reflecting an immature capacity for cognitive control during adolescence. The finding of increased ACC activity when ‘liking’ a

peers Instagram post (Sherman, Hernandez, et al., 2018) also dovetails with evidence of an integral role for the ACC in linking motivational outcomes to behaviour (Rolls, 2019). Nonetheless, in contrast to what was hypothesised, neither of the two fMRI studies employing cognitive control tasks observed alterations of ACC activity in problematic SNS users (Dieter et al., 2017; Turel et al., 2014), which is therefore inconsistent with similar studies investigating substance use (Ames et al., 2014) and other behavioural addictions (van Holst, van Holstein, et al., 2012).

The PCC constitutes a central structure of the default mode network (DMN), a neural network that is maximally activated at rest (Raichle, 2015; Raichle et al., 2001). The DMN has been found to show increased activation and altered functional connectivity with various other regions (including regions in the dorsal and ventral attention networks) when viewing personalised TikTok videos and after reading SNS microblogs (Hu, Cui, et al., 2022; Su, Zhou, Gong, et al., 2021; Su, Zhou, Wang, et al., 2021). Such findings imply that passively consuming SNS content (particularly personalised content) may activate a neural state similar to that when mind wandering, which may facilitate prolonged use through modulating attention and inducing absent-minded scrolling/browsing of SNS feeds. Modifications of DMN functional connectivity have also been observed in substance use addictions which are proposed to facilitate cravings and relapse (Zhang & Volkow, 2019). The DMN is thought to be predominantly engaged during phases of withdrawal and preoccupation in addiction and is thus active at the expense of the cognitive control network, limiting its capacity to manage cravings and prevent relapse.

Precuneus

The precuneus, a region which neighbours the PCC, is another core hub of the DMN and is therefore also implicated in studies demonstrating alterations of DMN activity and functional connectivity when viewing SNS content (Hu, Cui, et al., 2022; Su, Zhou, Gong, et al., 2021; Su, Zhou, Wang, et al., 2021). The precuneus is also thought to play an important role in a range of complex tasks including visuo-spatial imagery, memory retrieval and self-referential cognition (Cavanna & Trimble, 2006). As previously discussed, enhanced coupling between the precuneus and prefrontal regions appears to be associated with increased sharing of personal information on SNSs, whereas increased connectivity between the precuneus and anterior temporal pole (ATP) is negatively associated with self-related sharing (Meshi et al., 2016). The findings are therefore consistent with a role for the precuneus in self-referential cognition since enhanced connectivity with prefrontal regions is necessary to hold self-related information in working memory. In contrast, the ATP is engaged when thinking about the mental states of others (Schurz et al., 2014), and thus thinking about how others might react to a post may inhibit frequent self-disclosures on SNSs. Other research has shown that the precuneus is also engaged during decisions to repost emotionally valenced messages online (Wikman et al., 2022; Zhang & Qu, 2020) and when viewing posts with many (vs. few) likes (Sherman et al., 2016), suggesting that these SNS behaviours trigger self-relevance processing. As reviewed above, only one study implicated the precuneus in problematic SNS use during exposure to Instagram photos, suggesting a role for this region in cue reactivity and the transmission of visual information to motivational systems (Nasser et al., 2020). Meta-analyses have also found that cue-induced

precuneus activity is associated with substance use (Engelmann et al., 2012; Schacht et al., 2013) and behavioural addictions (Starcke et al., 2018).

Temporal Parietal Junction

One function of the temporal parietal junction (TPJ) is to form a key node of the mentalising network, which enables cognitive empathy and perspective taking, allowing us to interpret the mental states of others (Frith & Frith, 2006). Given that mentalising (or other functions of the TPJ) are not directly implicated in substance use or addictive behaviours, it is unsurprising that TPJ activation is rarely reported in addiction research. One study has linked reduced amygdala-TPJ connectivity to neuroticism, a personality trait which can influence addiction severity (Dean et al., 2020). Nonetheless, the TPJ may be more relevant in the development of behavioural addictions that involve social communication and interpreting another's mental state (e.g., SNS use). Increased grey matter density of the TPJ has been shown to be positively correlated with internet addiction (Liu et al., 2021), yet the only structural MRI study identified in the present review to implicate the TPJ found a stronger decrease in the surface area of this region in more excessive adolescent SNS users over a period of three years (Achterberg et al., 2022). However, such disparities may reflect unique age-related differences between measures of grey matter morphology (Gennatas et al., 2017). Furthermore, while Achterberg et al. (2022) argued that stronger reductions in the surface area of the TPJ in more excessive SNS users was consistent with their hypothesis that SNS use would lead to accelerated maturation of brain regions important for social processing, they also noted that the correlation was weak and did not survive a correction for multiple tests. As reviewed above, the TPJ has also been implicated in regular (non-addicted) SNS reposting behaviours

(Zhang & Mo, 2016; Zhang & Qu, 2020). Thus, when reposting SNS messages (especially emotionally valenced messages) the TPJ may play an important role in enabling an understanding of how such messages will be viewed from another's perspective, while excessive SNS use (at least during adolescence) may accelerate cortical thinning in this region, potentially contributing to a lack of impulse control (Pehlivanova et al., 2018).

Insula

A single structural MRI study has implicated the insula in problematic SNS use (Turel et al., 2018b), indicating that grey matter deficits in this region may result in increased impulsivity and a preference for immediate gains in problematic users. This is consistent with the role of the insula in decision making and delaying gratification. Grey matter deficits of the insula have also been proposed to constitute an important structural marker of drug addictions. For example, in one study, both cocaine and heroin dependent patients were shown to have reduced grey matter in the posterior insula when compared to healthy controls (Gardini & Venneri, 2012). The importance of the insula for addiction processes is further supported by evidence that damage to this region can cause cigarette smokers to spontaneously quit without relapse (Naqvi et al., 2007) and insular reactivity to addiction-related cues can predict relapse (Janes et al., 2017). This is because the insula is thought to be responsible for forming conscious representations of the homeostatic imbalance caused by withdrawal which manifests as urges or cravings for drug consumption (Naqvi & Bechara, 2010). Despite its important role in the maintenance of substance use addictions, research is yet to associate functional alterations of the insula with more problematic SNS use. Nonetheless, as reviewed above, in regular users, insula

activity and its connectivity with the TPJ has been associated with reposting emotionally valenced messages, 'liking' SNS photos and receiving valenced SNS comments (Sherman, Hernandez, et al., 2018; Wikman et al., 2022; Zhang & Mo, 2016; Zhang & Qu, 2020). Such patterns of activity are also consistent with a role for the insula in detecting salient stimuli and modulating emotional responses (Menon & Uddin, 2010).

Other Observations

As well as identifying brain regions associated with SNS use, the present review also highlights methodological issues that future research should address. Firstly, seven different scales were employed across the identified articles to assess problematic/compulsive SNS use. The inclusion of certain diagnostic criteria assessed in some of these scales (e.g., escape/mood management criterion) have also been criticised for lacking clinical validity and pathologising normal use motives (Brand et al., 2020; Kuss et al., 2017). Thus, there is a need to establish consensus regarding the symptomatology of problematic SNS use and for diagnostic criteria to be assessed consistently across studies in order to improve comparability. Furthermore, the majority of studies that assess excessive SNS use have relied on self-reports of use intensity. Recent evidence suggests that individuals are often inaccurate in reporting the duration of their SNS use, displaying a tendency to overestimate their usage intensity (Burnell et al., 2021; Ernala et al., 2020). Future research should aim to utilize objective measures of SNS use to ensure that excessive use behaviours are reliably assessed. Moreover, existing neuroimaging research is limited with large heterogeneity among studies. As such more MRI studies

employing more consistent methods are required to establish firm conclusions about the neural underpinnings of excessive/problematic SNS use.

Additionally, the majority of research to date has focused on investigating the neural correlates of SNS use in adolescents and young adults. While this seems reasonable given that younger populations have increased exposure to SNSs and are thought to be more vulnerable to experiencing negative consequences (Shannon et al., 2022), future research may also wish to assess whether excessive/problematic SNS use in older adults is associated with similar brain changes. Furthermore, many of the studies that implicate regions of the cognitive control network in the use of SNSs have inferred that deficits to these regions may be responsible for the development of more problematic or compulsive SNS use. Yet, neither of the two task-based fMRI studies employing cognitive control tasks have found evidence of dysfunctional activity within the cognitive control network in more problematic users (Dieter et al., 2017; Turel et al., 2014). This lack of evidence is surprising since impaired activity of the cognitive control network during tasks of executive functions has been consistently observed in individuals with substance use disorders and other behavioural addictions (Luijten et al., 2014; Moccia et al., 2017). Thus, more task-based fMRI studies employing behavioural paradigms (e.g., Go/No-Go, Stroop, and Approach/Avoidance) are needed to better understand the cognitive/motivational processes underpinning SNS use and overuse. Moreover, longitudinal research is scarce and existing studies report mixed results. While only subtle differences in brain morphology have been attributed to excessive SNS use (Achterberg et al., 2022), some studies have shown widespread functional connectivity changes as a result of increased SNS use (Hu, Yu, et al., 2022). Yet, other research suggests that abnormal neural activity associated with increased SNS

use has no long-term effects on clinical symptoms (Peters et al., 2021). As such, it cannot yet be concluded that excessive/problematic SNS use is responsible for significant neuroadaptations that represent a disease process, as is observed in substance use disorders. Alternatively pre-existing neural abnormalities may be responsible for facilitating the development of more compulsive or problematic forms of SNS use.

While our review does not directly inform the treatment of problematic SNS use, our findings highlight the important role of (social) reward and its associated brain structures in driving this behaviour. Incorporating elements into intervention packages that focus on controlled and sensible seeking of SNS rewards (e.g., through limiting exposure to SNS notifications or disabling the 'like' function) may thus constitute a viable avenue to tackle problematic SNS use.

Conclusion

In sum, our systematic review of MRI studies investigating SNS use suggests that more excessive/problematic use does share some important neural similarities to substance abuse. In particular, the existing evidence leads us to conclude that problematic use may be characterised by: (1) reduced GMV of the ventral striatum, amygdala, subgenual anterior cingulate cortex, orbitofrontal cortex and posterior insula; (2) increased ventral striatum and precuneus activity in response to SNS cues; (3) abnormal functional connectivity between middle occipital gyrus and DLPFC and the dorsal attention network; (4) impaired white matter integrity in the corpus callosum and forceps minor. In regular users, regions including the temporal parietal junction, ventral striatum, precuneus, insula and frontal lobes have been implicated in active SNS engagement (i.e., sharing/reposting/'liking' SNS content), while

altered functional connectivity of the default mode network is associated with passive consumption of SNS content (particularly personalised recommended videos). Nonetheless, given that these regions are not consistently implicated across studies, and considering the large heterogeneity of current studies (e.g., in the type of SNS under investigation, the scales used to assess SNS use/addiction, and the experimental tasks employed), our conclusions should remain tentative. To date, the majority of research investigating the neural correlates of problematic/compulsive SNS use are structural MRI studies, and thus more fMRI research is required to elucidate the functional alterations that might underpin a 'SNS addiction'. Furthermore, most existing neuroimaging research is limited by small sample sizes, recruiting from student populations, and employing self-reports of usage intensity. More large-scale and longitudinal research employing objective measures of SNS use are essential to establish stronger conclusions regarding the neurobiological effects of SNSs.

Chapter 7

General Discussion

Discussion of key findings

Compared to other potentially problematic behaviours (e.g., gambling), SNS use is a relatively new phenomenon and consequently research investigating problematic SNS use lags significantly behind that of established addictions. A large part of the existing literature has also been criticized for adopting an atheoretical and confirmatory approach, whereby the existence of a 'SNS addiction' is often taken for granted (Billieux et al., 2015; Kardefelt-Winther et al., 2017). Given the controversy surrounding the conceptualisation of a 'SNS addiction' previous research has used the term 'problematic SNS use' to refer to maladaptive use behaviours without assuming the presence of an addiction. Therefore, we also used the term 'problematic SNS use' in this thesis to refer to SNS behaviours that are frequently used as diagnostic markers of 'SNS addiction' in assessment instruments (e.g., use that causes issues at work/school etc.).

The overall objective of this thesis was to better understand excessive and problematic SNS use through a reward and incentive sensitisation perspective. By employing concepts taken from theoretical models of substance use addiction we sought to assess the reward-based mechanisms underlying SNS use in order to evaluate the addictive potential of this behaviour. More specifically, the aims of this thesis were fourfold. We first investigated the reward-related motives that best explained problematic SNS use and whether these motives explained differences in use intensity (chapter 2). Second, we investigated whether problematic SNS use behaviours were associated with alterations of explicit and implicit cognitions (chapter 3). Third, using a SNS abstinence intervention, we investigated whether more problematic SNS users experienced withdrawal-like effects when their SNS use was restricted (chapter 4). Fourth, we investigated potential physiological

markers of problematic SNS use by assessing changes in heart rate and skin conductance in an experimental study (chapter 5) and by conducting a systematic review of the neuroimaging literature (chapter 6). Below the key findings in relation to each research question are discussed.

Can reward-related motives explain problematic SNS use and differences in use intensity?

All addictive substances have the capacity to elicit reward (i.e., produce a drug 'high') through direct activation of the brain's reward system. Established behavioural addictions such as gambling disorder also involve a clear reward component (i.e., monetary reward). However, with SNSs there are a number of potentially rewarding factors that might drive their use. Since SNS use does not involve the ingestion of a substance that directly activates the brain's reward system, in the present project it was important to first understand the hedonic incentives that underlie SNS use, and which might promote excessive and problematic use. While a considerable number of studies have been interested in the reasons why people use SNSs (e.g., Nadkarni & Hofmann, 2012), fewer studies have considered how such motives might elicit reward or whether they predict more problematic SNS use. A better understanding of the motives associated with problematic SNS use behaviours would also aid the development of more targeted prevention and intervention strategies. Regardless of whether problematic SNS use is to be recognised as a behavioural addiction, identifying and reducing the harmful aspects of SNS use is an undoubtably important goal.

In chapter 2 we investigated the utility of reward-related motives in predicting the intensity and problematicity of SNS use in a well-powered and diverse

sample of young adults. We showed that possessing a 'social reward' motive for SNS use was the strongest predictor of more problematic use symptoms. Specifically, 'social reward' comprised motives related to impression management (e.g., seeking social approval by obtaining 'likes'), social comparison, and fear of missing out (e.g., possessing a desire to be continually connected with what others are doing). Social rewards are potent motivators (Jones & Rachlin, 2006; Lehner et al., 2017) and research has shown substantial overlap between the neural substrates activated by social rewards and non-social rewards (e.g., money; Bhanji & Delgado, 2014; Lin et al., 2012). Therefore, similar to the way in which overexposure to the rewarding effects of drugs can lead to alterations in motivational processes and maladaptive drug seeking behaviour, the social rewards provided by SNSs may be powerful enough to incentivise persistent use despite harmful consequences. This interpretation is also in line with neuroimaging research showing that regions in the brain's reward system are activated in response to receiving social approval on SNSs (Sherman et al., 2016), and that the reactivity of the reward system to gains in reputation predicts more problematic SNS use (Meshi et al., 2013).

In addition to 'social reward', we found that possessing an 'enjoyment reward' motive (i.e., using SNSs to find entertaining content, pass time, or distract from negative emotions) or 'negative social potency' motive (i.e., using SNSs to engage in antisocial interactions) also predicted problematic use symptoms, but to a lesser extent. Research investigating the uses of SNSs frequently cite entertainment as a primary motivation (e.g., Alhabash et al., 2014), and some studies have shown that this motive is associated with more problematic use (Kircaburun et al., 2020). Nonetheless, it is clear that many individuals pass time or seek entertainment by engaging in other activities that are not considered compulsive or problematic (e.g.,

reading books, watching TV). Therefore, the specific design features of SNSs may amplify the reward experienced when using SNSs for this purpose. For example, limitless newsfeeds and auto-play videos may facilitate continual scrolling/watching without a natural stopping point (Montag et al., 2019). In addition, the short nature of SNS videos (e.g., average TikTok video length is less than 40 seconds; Statista, 2023) and posts (e.g., twitter has a 280-character limit on posts) is helpful in keeping users engaged as they are constantly being exposed to new content. It may be harder to disengage SNS use when videos/posts are short, as any content that is perceived as uninteresting is quickly replaced by new and potentially more exciting content.

These features alone may be sufficient to encourage excessive or compulsive use, but they are also deployed in combination with SNS algorithms that collect data about the interests of individual users (e.g., the types of videos they have watched or 'liked'), and consequently recommend personalised content. Neuroimaging research has shown that brain regions involved in reward processing are specifically activated by algorithm-recommended (i.e., personalised) TikTok videos, compared to generalised TikTok videos (Su, Zhou, Gong, et al., 2021). By bombarding users with highly salient, novel, and self-relevant content, SNSs seem capable of creating an almost permanent state of reward anticipation, which might therefore facilitate compulsive use (Schüll, 2012). However, while a large body of literature investigates the reasons for SNS use and the personality traits that predict their use, barely any research has investigated how the specific design elements of SNSs might contribute to excessive and problematic SNS use. Montag and Hegelich (2020) have argued that the 'data business model' behind SNSs might be a more important contributor to SNS overuse than personal characteristics (e.g., motives, personality traits), and have thus called for a stronger focus on the design elements of SNSs in future research.

Recently, Sindermann et al. (2022) have shown a strong positive correlation between symptoms of problematic SNS use and design element-driven SNS use. However, more research is needed to better understand the specific features of SNS platforms that might be responsible for adverse effects.

Perhaps most surprising was the finding that a negative social potency motive (i.e., antisocial reward) predicted more problematic use. A sizeable body of literature has investigated bullying and trolling behaviours on SNSs (e.g., Craig et al., 2020), yet rarely has research considered how this behaviour might be involved in the development of addictive/compulsive SNS use. However, similar to our findings, one recent study found that negative social potency was positively correlated with the problematic use of Facebook and Snapchat (Meshi et al., 2020). In their study, Meshi et al. (2020) found that possessing a motivation to be cruel and callous to others was the only factor that predicted the problematic use of both SNS platforms. Thus, negative social potency seems to represent an important driver of more problematic SNS use and a factor which has been largely overlooked in existing research.

Another interesting finding from the study presented in chapter two was the divergence between the motives that best explained SNS checking frequency and use duration. While SNS use duration was best explained by negative social potency and personal utility (i.e., self-expression and archiving motives), SNS checking frequency was predicted by social reward and enjoyment reward motives. These findings may indicate that different use motives are responsible for encouraging different types of excessive SNS use, with the motives underlying excessive checking and problematic use overlapping to a larger degree. Such divergence might be helpful in understanding problematic SNS use as it could suggest that excessive

checking, rather than use duration, represents a more problematic form of SNS overuse. However, these findings should be interpreted with some caution given the potential for self-report biases in estimates of SNS checking frequency and use duration. Although self-reports of SNS use are frequently employed in the existing literature, recent evidence has shown that individuals are often inaccurate at estimating their SNS use (Burnell et al., 2021; Ernala et al., 2020). Thus, research employing objective measures of checking frequency and use duration (e.g., through smartphone screen time recordings) is required in order to validate our findings.

To summarise, reward-based motives do appear to have utility in predicting problematic SNS use symptoms. Specifically, possessing motivations to use SNSs to obtain social rewards, and to a lesser extent enjoyment and antisocial rewards, may indicate that an individual is more at risk of developing problematic SNS use. Furthermore, our findings also revealed that use motives may help distinguish between different types of use intensity (i.e., frequency of checking vs. use duration). These findings suggest that interventions targeting a reduction in the desire for social rewards may provide a viable avenue for preventing or reducing problematic SNS use behaviours.

Is problematic SNS use related to alterations in explicit and implicit cognitions?

An increased motivation to consume/perform the rewarding substance/behaviour is a core aspect of addiction (Kalivas & Volkow, 2005). During the course into addiction certain cues become associated with the rewarding effects of the drug/behaviour and as such these cues become more salient, strengthening their ability to attract attention and trigger cravings/urges (Robinson & Berridge, 1993). Importantly, incentive sensitisation and other theories of addiction predict that

modifications of motivational responses to addiction-related cues occurs at both the conscious (explicit) and unconscious (implicit) level. Research has consistently demonstrated the utility of both explicit and implicit cognitions in explaining substance use disorders (Reich et al., 2010; Rooke et al., 2008). Yet despite this, whether similar motivational changes also characterise more problematic SNS use is currently not well understood.

In chapter three we sought to identify potential alterations of explicit and implicit motivation in more problematic SNS users, employing the same well-powered and diverse sample of young adults as described in chapter two. In an online experiment, participants completed explicit ratings of SNS wanting vs. liking and cue-reactivity to SNS app icons, as well as an adapted approach-avoidance task that assessed motivational responses to SNS cues implicitly. Replicating findings from our previous 'proof-of-concept' study (Ihssen & Wadsley, 2021), we found that increased explicit wanting explained a greater proportion of the variance in problematic SNS use and SNS checking frequency, above and beyond that explained by liking. Nonetheless, in contrast to our earlier results liking explained a greater proportion of the variance in SNS use duration. Our findings suggest that spending long periods of time on SNSs may be more reliably indicated by how much an individual enjoys using the SNS, whereas in line with incentive sensitisation, continued use when it has harmful consequences appears to be better explained by wanting urges to use SNSs. Similar dissociations between the concepts of wanting and liking have also recently been identified in a range of other potentially problematic behaviours (e.g., gambling, overeating, gaming, pornography use; File et al., 2022). Nonetheless, as alluded to in the introduction, such alterations of explicit wanting vs. liking is not necessarily evidence of incentive sensitisation when

assessed cross-sectionally. Future research would need to show that wanting processes become sensitised over time using longitudinal assessments, in order to demonstrate that incentive sensitisation is actually taking place.

Despite replicating our previous findings regarding the presence of modified wanting vs. liking in more problematic SNS users, the explicit cue reactivity data revealed a different pattern of results to our initial findings (Ihssen & Wadsley, 2021). This time self-reported SNS cravings in response to viewing SNS app icons were only weakly correlated with SNS checking frequency. Contrary to our hypothesis, no significant correlations with problematic SNS use or SNS use duration were identified. While this differs substantially from our earlier findings, we did note an important difference between the two studies that might account for the diverging results. This was the inclusion of non-SNS app icons (i.e., BBC iPlayer, and App Store or Play Store icons) as a baseline measure of general cue reactivity. Therefore, in this better controlled study, the findings indicate that the relationship between explicit SNS cue reactivity and problematic/excessive SNS use is less important when accounting for general reactivity to visual cues.

Data from our SNS adapted approach-avoidance task revealed an interesting pattern of results. While we did not observe the expected association between SNS approach tendencies and problematic SNS use, faster approach reactions to SNS icons were weakly correlated with increased SNS checking frequency. Furthermore, we did observe a large significant approach bias to SNS icons in the whole sample, with participants being faster to approach SNS stimuli compared to controls by an average of 118ms. We therefore concluded that the clear presence of implicit approach tendencies irrespective of problematic use symptoms suggests that SNS cues have become imbued with heightened motivational salience, which is

experienced ubiquitously among young adults. Research has shown that stimuli associated with receiving positive social feedback can capture attention in the same way as stimuli associated with extrinsic rewards, such as food and money (Anderson, 2016; Hayward et al., 2018). In chapter two we found that using SNSs to obtain social rewards was the strongest predictor of more problematic use and more excessive checking. Thus, similar to the way in which stimuli associated with social reward can cause an attentional bias, a potential explanation for our findings is that SNS app icons have become associated with the expectation of social reward (e.g., social approval, social comparisons, social connectedness) experienced when using the apps. Our data also indicates that this association between social reward and SNS app icons is strong enough to be able to modulate automatic action tendencies, even in regular (non-problematic) users but especially those who excessively check their SNS accounts.

Nonetheless, the lack of association between SNS approach tendencies and problematic SNS use contrasts with the substance addiction literature where alterations of implicit cognitions (including approach biases) have been consistently identified in addicted or at-risk individuals (Rooke et al., 2008; Stacy & Wiers, 2010). Despite the importance of implicit cognitions for theoretical models of substance use and behavioural addictions (Brand et al., 2016; Noël et al., 2010; Robinson & Berridge, 1993), a recent systematic review has indicated that research assessing the implicit mechanisms underlying problematic SNS use is lacking, with existing studies reporting mixed results (Kessling et al., 2023). For example, studies have reported an increased attentional bias for SNS cues in more problematic SNS users when employing a dot probe task (Nikolaidou et al., 2019; Zhao et al., 2022), but not when using an addiction Stroop task (Zhao et al., 2022), or visual search task

(Thomson et al., 2021). Similarly, the only other study to employ an approach-avoidance task found faster SNS approach tendencies in more problematic SNS users (Juergensen & Leckfor, 2019), whereas in our study employing a larger sample size but using an online task (which differed in the use of keyboard responses rather than joystick push/pull movements) we found no evidence of a SNS approach bias being associated with more problematic use. Evidence of positive implicit attitudes towards SNSs (assessed using an implicit associations test) being associated with problematic use is more consistent, with two studies showing positive (albeit weak) correlations (Brailovskaia & Teichert, 2020; Turel & Serenko, 2020). However, no study has yet investigated semantic memory associations (e.g., as assessed using word association or semantic priming), which are known to be associated with substance use addictions (e.g., Hill & Paynter, 1992; Stacy, 1995). It is clear that more research is needed to better understand the involvement of implicit cognitions in problematic SNS use.

In sum, the findings presented in chapter three suggest that while problematic SNS use is related to alterations of explicit wanting urges, it is not associated with explicit or implicit motivational responses to SNS cues (when assessed via self-reported cue reactivity ratings and automatic approach tendencies). Nonetheless, the fact that we observed a large approach bias for SNS stimuli within the sample as a whole is indicative of the high reward value that SNS cues have acquired, which is comparable to the motivational effects elicited by primary rewards such as food and sexual stimuli (Booth et al., 2018; Kahveci et al., 2020). Yet only recently has research begun to investigate the implicit mechanisms that might underlie problematic SNS use (with the earliest study published in 2019). Thus, more research is required before we can draw stronger conclusions regarding the relevance

of implicit cognitions for the development and maintenance of problematic SNS use (Kessling et al., 2023).

Do problematic SNS users experience withdrawal-like effects when SNS use is restricted?

The experience of withdrawal following the discontinuation of drug use is an essential component of substance use addiction. Withdrawal is thought to be driven by internal cues (i.e., diminishing levels of a drug that was previously overused), with withdrawal symptoms emerging as a result of the body's attempt to maintain homeostasis (Gupta et al., 2022). For this reason the relevance of pharmacological criteria (i.e., tolerance and withdrawal) for diagnosing behavioural addictions is controversial (Castro-Calvo et al., 2021; Starcevic, 2016). Unlike drugs, behavioural addictions do not tend to be able to produce severe physical withdrawal symptoms (Grant et al., 2010), but instead 'withdrawal' often manifests as negative emotional states (e.g., irritability, reduced mood, anxiety). Even so, the majority of studies investigating the effects of SNS abstinence or use reduction have reported null effects on measures of mood and wellbeing, with many also reporting beneficial outcomes (Radtke et al., 2022). In those studies that do report withdrawal-like effects, common symptoms include small increases in negative cognitive/affective states, such as boredom, social pressure and subjective cravings (Stieger & Lewetz, 2018). However, the extent to which these emotional changes truly represent a state of 'withdrawal' rather than a normal reaction to ceasing a pleasurable activity is unclear. Nonetheless, apart from one study (Turel & Cavagnaro, 2019), research is yet to investigate how implicit motivational responses might be affected by reduced SNS use. Furthermore, Fernandez et al. (2020) point out that most existing research

fails to assess the potential counterproductive consequences of abstinence (e.g., rebound effects and compensatory behaviours).

In chapter four we sought to address some of the limitations with existing research investigating SNS abstinence. Using ecological momentary assessments (EMAs), we tracked changes in mood and cravings across two weeks, including at baseline (4-days), during an abstinence intervention (7-days), and during post-intervention (3-days) when normal SNS use was resumed. In two lab sessions (immediately before the start and end of the intervention period) we also assessed changes in implicit motivation for SNSs. Findings from the affective self-report data (EMAs) revealed a pattern of results that was neither consistent with the experience of a withdrawal syndrome, nor with an overall beneficial effect on wellbeing. Instead, we observed small reductions in both negative and positive emotional states. Similar findings have also been reported in other studies (Stieger & Lewetz, 2018), and point towards a potentially offsetting effect of reduced SNS use on wellbeing. According to this view, limiting the use of SNSs may simultaneously alleviate the adverse consequences associated with excessive use, whilst also reducing the rewarding experiences that they provide (e.g., social approval). Our null findings are also in line with accumulating evidence that SNS use is responsible for negligible effects on measures of wellbeing (Hall et al., 2021; Orben, 2020b; Orben & Przybylski, 2019).

Most surprising was the absence of any effect on subjective cravings across the three experimental phases, as an increase in cravings is the most frequently reported abstinence-induced effect in all potential behavioural addictions (Fernandez et al., 2020). Instead, our findings indicated that SNS users in our sample were able to voluntarily reduce their SNS use by an average of 80% without experiencing an

increased desire for more use. Furthermore, changes in cravings were not associated with either excessive or problematic use, which contrasts considerably with substance use disorders. Because even excessive SNS users seem to maintain a large degree of control over their use, prolonged SNS use may be driven more by 'liking' rather than 'wanting' (an interpretation that is also supported by data presented in chapter three). As such, the supposed withdrawal-like effects identified in some other studies could simply reflect a natural response to reducing a pleasurable activity or the result of factors unrelated to SNSs (e.g., compensatory behaviours that are more detrimental to wellbeing). In their systematic review of withdrawal symptoms in internet gaming disorder, Kaptsis et al. (2016) highlight the need for a clearer conceptualisation of gaming-related cravings in order to differentiate them from normal pleasure-seeking experiences. Similarly, within the 'SNS addiction' literature there is a need to systematically assess how SNS cravings manifest in terms of their persistence, intensity, and duration, to better understand whether these feelings are akin to those experienced during drug withdrawal.

In addition to the lack of effect on explicit cravings, our experimental measures also failed to reveal any changes in implicit motivation as a result of reduced SNS use. While results from the approach-avoidance task replicated those reported in chapter three (whereby SNS stimuli elicited a large approach bias irrespective of problematic use), reaction times to SNS stimuli were unaffected by a week of reduced SNS use. We predicted that a period of reduced SNS use would result in increased implicit motivational responses towards SNS cues as some research in the drug addiction literature has found more pronounced behavioural effects (e.g., increased attentional biases) in addicted individuals whilst abstinent (Cox et al., 2006; Waters & Feyerabend, 2000). Such effects have been interpreted as

reflecting the increased incentive salience attributed to drug cues during a state of drug deprivation. However, it could also be predicted that restricting SNS use would lead to reduced implicit wanting (i.e., slower SNS approach tendencies). This is because, individuals would need to effortfully inhibit SNS cravings/urges during abstinence, which might facilitate strategies to intentionally avoid SNS cues. In line with this view Ciccarelli et al. (2016) found that abstinent pathological gamblers displayed an attentional avoidance bias to gambling cues. Nonetheless, our findings did not lend support for either of these hypotheses.

Similarly, results from our measure of time distortion and from our novel effort expenditure for reward task produced null effects. In contrast to our findings, Turel and Cavagnaro (2019) found an increased time distortion bias in more problematic SNS users who had abstained for one week. However, the duration of the task and the task itself was different in their study. While we measured time distortion after completing an approach avoidance task (lasting 9-14 mins), Turel and Cavagnaro (2019) assessed time distortion after an online survey (lasting 18-30 mins) in which participants had to reflect on their SNS use. The authors suggest that when problematic users are forced to think about SNS use but are unable to use SNSs, they experience a deprivation state (i.e., increased cravings/anxiety) which leads to the experience of time slowing down. Therefore, exposure to SNS cues during the approach-avoidance task in our study may not have sufficed in producing a similar deprivation state in more problematic users. Findings from our adapted effort expenditure for reward task also revealed no effect of reduced SNS use or more problematic SNS use. It seems likely that the SNS reward in this task (i.e., working to gain 10 or 30 seconds of SNS use) was not salient enough to incentivise more effort expenditure, and future studies might consider how other SNS-related

rewards could be employed instead (or even hypothetical rewards, e.g., working to gain hypothetical 'likes'). However, since our study was the first to assess the effect of restricting SNS use on both automatic action tendencies and effort expenditure for reward, more studies employing larger sample sizes and different behavioural paradigms are needed to establish the potential impact of reduced SNS use on implicit motivational responses.

In sum, our findings along with the majority of existing research, suggest that abstaining or substantially reducing SNS use does not produce effects consistent with the idea of a withdrawal syndrome. Instead, use reduction is associated with small, counteracting effects on affective responses and has no significant impact on subjective SNS cravings. Our study also provided a novel contribution to the existing literature by providing evidence that implicit motivational responses may remain unaffected by reduced SNS use. Therefore, in concordance with most existing research, our study indicates that the concept of a withdrawal syndrome may not be important for problematic SNS use, which represents an important difference between this behaviour and substance use addictions. Accordingly, existing diagnostic instruments of 'SNS addiction' that include withdrawal criteria (e.g., Andreassen, Torsheim, et al., 2012; Van den Eijnden et al., 2016) may have to be revised.

Are there physiological markers of problematic SNS use?

Certain physiological changes are known to represent important markers of addiction in both substance use disorders and established behavioural addictions. Changes in autonomic activity (e.g., heart rate, sweating, blood pressure) can occur during exposure to the drug/behaviour or addiction-related cues, and can also reflect

a state of withdrawal when use is ceased (Carter & Tiffany, 1999). Additionally, addictions are known to result in dramatic, lasting changes to brain structure and function (Koob & Volkow, 2016). Therefore, if problematic SNS use warrants classification as an addictive disorder, then similar neural/physiological alterations can be expected to characterize more problematic users. To our knowledge, no previous study had specifically investigated how SNS use and cessation might affect heart rate and skin conductance and whether such changes could differentiate problematic SNS users from regular users. Furthermore, while a growing number of studies have investigated the neural correlates of SNS use and problematic use, findings across these studies had not yet been synthesized to enable the evaluation of all available evidence. In chapters five and six we sought to address these two gaps in the existing literature.

In an experimental study presented in chapter five, we tracked changes in the heart rate and skin conductance of SNS users who varied in their levels of problematic use during 15-minute periods of baseline, Instagram exposure and Instagram cessation. Our findings revealed that Instagram use and subsequent cessation were both characterized by distinct physiological responses. Specifically, Instagram use resulted in a large increase in skin conductance and large decrease in heart rate compared to baseline. On the other hand, terminating an Instagram session resulted in a further increase in skin conductance as well as an increase in heart rate compared to Instagram exposure. We reasoned that the observed effects were indicative of an orienting reflex and a state of appetitive arousal during Instagram exposure and reflected an aversive (stress-related) arousal response during Instagram cessation. But importantly, this pattern of physiological responses occurred in the whole sample, irrespective of problematic SNS use symptoms. Our findings diverged

from similar studies that have observed elevated heart rate, skin conductance and systolic blood pressure in more problematic internet users after ending a 15-minute internet session (Reed et al., 2017; Romano et al., 2017). However, it is possible that differences between unspecific internet use and the use of Instagram may be responsible for these inconsistent effects. Since our study was the first to specifically investigate the psychophysiology of a SNS (i.e., Instagram), more research investigating other SNSs is needed to determine if our results generalize to the use of other SNS platforms.

In addition to the lack of effect that problematic SNS use had on physiological responses, we also failed to observe the expected effects on subjective self-report measures of affect/motivation. While explicit ratings of stress, anxiety and cravings increased after Instagram cessation, once again these changes occurred in the whole sample and were not correlated with problematic SNS use nor with changes in physiology. We noted that these findings were similar to result from a recent study in which skin conductance responses to smartphone cues (i.e., ringtone/message sounds) were not correlated with either problematic smartphone use or anxiety (Hsieh et al., 2020). Consistent with a theme emerging from the previous chapters of this thesis, the results presented in chapter five suggest that the physiological effects of SNS use and cessation are experienced ubiquitously by all users regardless of whether their SNS use causes problems. The aversive arousal response during Instagram cessation that was observed in both the physiological and self-report data may simply reflect a natural response to ending a pleasurable/engaging activity rather than a state of ‘SNS withdrawal’ or an indicator of problematic SNS use.

In chapter six we systematically reviewed the structural and functional MRI literature for evidence of physiological markers of problematic SNS use. While we identified 28 research articles meeting our inclusion criteria only 13 of these investigated the neural correlates of problematic SNS use (with the majority of these being structural MRI studies). Therefore, the scarcity of existing research along with the large heterogeneity in the methods employed limited the conclusions we could draw. Nonetheless, we did identify some important similarities between problematic SNS use and substance use disorders from the available evidence. These similarities included reduced volume of regions implicated in reward processing and executive function (i.e., ventral striatum, amygdala, subgenual anterior cingulate cortex, orbitofrontal cortex and posterior insula), as well as increased reactivity of the ventral striatum and precuneus to SNS cues. However, while this indicates some overlap with substance use addictions, findings across studies were largely inconsistent with many studies also failing to implicate the aforementioned regions. The most consistent evidence was provided for reduced amygdala (He, Turel, & Bechara, 2017; He, Turel, Brevers, et al., 2017) and right ventral striatum size (He, Turel, Brevers, et al., 2017; Montag et al., 2017) in more problematic SNS users (for which only two studies each reported reduced grey matter volume of these regions). Some notable differences with substance use disorders included the lack of evidence of grey matter atrophy in prefrontal regions (a consistent finding in substance use disorders; Liu et al., 1998; Pfefferbaum et al., 1998) and lack of executive function deficits in task-based fMRI studies of problematic SNS use (Dieter et al., 2017; Turel et al., 2014). However, the available literature is still very limited (especially fMRI studies of problematic SNS use), and more research is required to confirm our tentative conclusions.

Another important point highlighted in our systematic review was the lack of longitudinal MRI research investigating SNS use. Longitudinal studies are important for assessing the addictive potential of SNSs as they can help to determine causality. While substance use addictions are known to be responsible for substantial changes to neural circuits, it is currently unclear whether the neural abnormalities identified in more problematic SNS users are directly caused by their SNS use. Instead, it could be that pre-existing neural deficits facilitate more excessive or compulsive SNS behaviours. Of the MRI studies reviewed in chapter six, only three employed a longitudinal design. Furthermore, findings from these studies did not provide any conclusive evidence that SNS use is responsible for changes in brain structure (Achterberg et al., 2022), or that the altered neural activity associated with SNS use has long-term effects on clinical symptoms (Peters et al., 2021). However, since our systematic review was conducted another longitudinal fMRI study has been published in which 169 adolescents were assessed across three years (Maza et al., 2023). Results revealed that more frequent SNS checking behaviours were associated with longitudinal increases in the brain's sensitivity to social rewards and punishments (specifically increased amygdala, anterior insula and dorsolateral prefrontal cortex activation during social anticipation). While these findings indicate that certain SNS use behaviours are associated with developmental changes in brain function, it is not clear whether these neural changes also facilitate more problematic SNS use. Thus, more longitudinal research is needed, especially studies investigating brain changes associated with the development of more problematic use symptoms.

In sum, findings from chapters five and six provide limited evidence of physiological markers of problematic SNS use. While SNS use and cessation appears capable of eliciting large changes in heart rate and skin conductance, such changes

were not associated with more problematic SNS use. MRI research has indicated some overlap in the structural and functional brain changes associated with problematic SNS use and substance use addictions, but findings across studies are largely inconsistent and causal inferences are hindered by the lack of longitudinal research. Taken together, the available evidence does not suggest that we can reliably distinguish problematic SNS users from regular users based on physiological markers.

Conceptualising problematic SNS use as a mental disorder

As reviewed in the previous section, the findings of this thesis cast doubt on the conceptualisation of problematic SNS use as a behavioural addiction. One aspect that goes beyond the scope of the present project is whether problematic use actually entails severe functional impairment. With addictions to drugs the harmful consequences are clear and often dramatic, potentially leading to premature death. However, unlike substance use addictions, evidence of physical harms resulting from excessive SNS use is limited. Some research has indicated that excessive smartphone use can lead to neck and hand pain (AlAbdulwahab et al., 2017; İnal et al., 2015), as well as visual impairments (Wang et al., 2020). Excessive SNS use might also indirectly affect physical health when it interferes with sleep and physical activity (Domoff et al., 2019). However, the most abundant evidence of SNS-related harms (although disputed) relates to the potential for use to result in mental health problems and reduced wellbeing (Bányai et al., 2017; Cunningham et al., 2021; Frost & Rickwood, 2017). Yet, some researchers have argued that the predominantly nondirectional associations between negative psychological consequences and SNS use does not support the emergence of a new clinical disorder (Carbonell & Panova,

2017). Other problematic behaviours that are currently not recognised as addictions are arguably associated with clearer evidence of severe functional impairment in comparison to SNS use (e.g., buying/shopping disorder and pornography use disorder; Brand et al., 2022). For example, similar to gambling, a buying/shopping disorder can lead to the accumulation of debt, which can have a severe impact on quality of life and personal relationships (Müller et al., 2019). The psychological harms related to SNS use may be better explained by the specific content individual users are exposed to (e.g., cyberbullying content), rather than SNS use itself. While there is an argument for tighter regulation of content on SNSs (especially content visible to children; Weimann & Masri, 2023), it is currently not clear that general SNS use alone is primarily responsible for poorer wellbeing (Orben, 2020b; Orben & Przybylski, 2019; Vuorre et al., 2021).

SNS use also differs from drug use and most other problematic behaviours in an important way. A primary function of all SNSs is social interaction and therefore SNS use can be thought of as fulfilling a fundamental human need (Baumeister & Leary, 1995), which cannot be said for gambling or shopping for example. In this sense, a 'SNS addiction' may be similar to the concept of 'food addiction', another potential pathology surrounding an adaptive, need-based behaviour (i.e., eating) for which no clear consensus has emerged (Fletcher & Kenny, 2018). Yet, these behaviours are arguably more challenging to conceptualise as addictions as doing so entails the pathologization of a natural, ingrained desire. If excessively engaging in social interactions through SNSs is addictive, then by the same logic individuals who excessively socialise in the offline world could also be considered addicted. Research has already demonstrated that the majority of individuals meet criteria for an 'offline-friend addiction' (Satchell et al., 2021). It seems almost common sense

that individuals who spend large amounts of time with their friends (even when it interferes with other activities/obligations) are not truly addicted. But in the same way, can it really be said that excessively pursuing these activities online (via SNSs) reflects an addiction, or might it just represent a more convenient way to seek the same rewards (i.e., social, enjoyment, antisocial rewards; see chapter two) that we would otherwise pursue offline? It seems that when applied to SNS behaviours the criteria included in most existing diagnostic instruments might not reflect valid indicators of addiction. Thus, caution is warranted when creating new behavioural addictions as we risk pathologizing innocuous activities that would undermine the severity of established mental disorders and the experience of those who suffer from them (Carbonell & Panova, 2017).

A final challenge for the conceptualisation of a 'SNS addiction' relates to the benefits associated with SNS use. Research investigating the use and excessive use of SNSs often negates the positive effects it can have on the lives of users. For example, SNSs can provide an outlet for strengthening friendships (Sosik & Bazarova, 2014), receiving social support (Baker & Yang, 2018), fostering creativity (Vilarinho-Pereira et al., 2021), expressing our identity (Bailey et al., 2020), learning (Evans, 2014), and gaining inspiration (Raggatt et al., 2018). While the harms associated with the excessive consumption of drugs greatly outweigh any perceived benefits (e.g., smoking to look cool; Epstein et al., 2000), it seems the same may not always be true for SNS use. Instead, existing evidence would suggest that it is not SNSs themselves that are harmful, but rather the specific ways in which they are used that might have adverse consequences.

The research presented in this thesis suggests that problematic SNS use does not seem to fit neatly within the diagnostic category of 'addictive disorders'. That is

not to say that we can conclude with any certainty that an addiction classification is unwarranted – further research is definitely needed. But our findings do seem to square with an increasingly clear understanding that SNS use (and digital technology use more broadly) tends to exert only minimal effects (if any at all) on normal functioning (Orben, 2020b; Orben & Przybylski, 2019; Vuorre et al., 2021). The lack of severe functional impairment attributable to SNS use in combination with the indistinct behavioural/physiological profile of problematic users suggests that it may not be appropriate to pathologize this behaviour as a mental health disorder.

Limitations and future directions

There are some important limitations with the research presented in this thesis that are worth reiterating. Firstly, participants predominantly consisted of university educated students. This is also a problem within the 'SNS addiction' literature (Pellegrino et al., 2022) and the field of psychology more generally (Hanel & Vione, 2016). Despite forming the majority of participants used in psychological research, students only make up around 5% of the population (Bolton, 2023). Because university students differ from the general population in a number of important ways (e.g., age, experience, education, socioeconomic status) our findings might not generalise to the wider population. In this thesis we were specifically interested in assessing SNS use behaviours in 18-30 year-olds, but there is a lack of research investigating excessive/problematic SNS use in older adults. While it seems reasonable to assume that younger adults/children are most at risk as they are typically more exposed to SNSs, it is still important to understand whether/how problematic SNS use develops in older adults and potential differences in the mechanisms that explain this.

A related criticism of the current work pertains to the lack of a 'clinical' population in our samples. Across all the studies in this thesis, the range of problematic SNS use scores were diverse enough to conduct correlational analyses with our experimental variables. However, it could be that only individuals with extreme scores on measures of problematic use exhibit a clear behavioural and physiological profile, and that these individuals were not sufficiently represented in our samples. Therefore, research sampling from 'clinical' or treatment seeking populations would be necessary to convincingly demonstrate the presence of (or lack of) dysfunctional affective, motivational, and physiological responses in problematic SNS users.

Furthermore, as highlighted in our systematic review of MRI research (chapter six), comparability across studies is often thwarted by inconsistent assessments of problematic SNS use. Recent reviews have highlighted as many as 37 different instruments assessing problematic SNS use (Varona et al., 2022), with new tools continually being developed. Some of the most popular 'SNS addiction' scales also include criteria that seem to lack diagnostic validity and pathologize normal use motives (e.g., withdrawal, tolerance, escape criteria; Brand et al., 2020; Castro-Calvo et al., 2021; Kuss et al., 2017). Initially in this thesis (chapters 2-4) we opted to use the Social Media Disorder Scale (Van den Eijnden et al., 2016) as our index of problematic SNS use, as this scale was developed based on the proposed DSM-5 criteria for internet gaming disorder. However, recently the 11-item Assessment of Criteria for Specific Internet-use Disorders (ACSID-11; Müller et al., 2022) has been developed based on the more up to date ICD-11 criteria for gaming disorder. The ACSID assesses five criteria groupings (in terms of their frequency and intensity) consisting of: impaired control, increased priority given to the online activity,

continuation/escalation of internet use despite negative consequences, functional impairment in daily life and marked distress due to the online activity. Importantly, the scale can be used to assess the problematic use of all online activities (e.g., online shopping, gaming, gambling, SNS use) which is helpful in improving consistency in the 'internet addiction' field. We therefore opted to use the ACSID in our most recent experimental study (chapter five). More research is required to assess the suitability of the ACSID as a diagnostic tool, and to determine cut-off scores for addiction/problematic use. However, we now believe that this tool provides the most appropriate assessment of problematic online behaviours and includes the most valid diagnostic criteria. The study of problematic SNS use would benefit from the consistent use of this instrument in future research.

The studies presented in this thesis have highlighted a number of areas in which further research is required. A large amount of previous research has focused on the associations between personal characteristics (e.g., motives, personality traits) and problematic SNS use, however the field would benefit from a better understanding of the specific design elements of SNSs that might be responsible for adverse consequences (e.g., infinite scrolling, auto-play videos, like counts; Montag & Hegelich, 2020). While some studies have indicated alterations of attentional bias and implicit associations in more problematic users, there is a clear lack of research assessing the implicit mechanisms that might underlie disordered SNS use. Further clarification of the concept of 'SNS withdrawal' is also needed as this has important ramifications for diagnostic instruments that are frequently used to assess 'SNS addiction'. Qualitative clinical studies are required to develop a clearer understanding of the negative experiences (e.g., cravings) associated with problematic SNS use, and to determine whether these feelings differ from normal

pleasure-seeking urges (Kaptsis et al., 2016). We conducted the first study to specifically assess the psychophysiology of SNS use and therefore research is needed to replicate our findings and assess whether they generalise to the use of other SNS platforms. The lack of consistent neuroimaging evidence for the neural basis of 'SNS addiction' also calls for more research, particularly task-based fMRI studies and longitudinal MRI studies.

While the conceptualisation of 'SNS addiction' remains contentious and requires further investigation, it is clear that a significant number of SNS users perceive their use as causing problems. Regardless of whether an addiction framework is the most appropriate approach to understanding this behaviour, future research is needed to understand how harmful use can best be prevented or reduced. Practical implications for reducing harmful SNS use could involve reducing the 'social reward' aspect of SNS use. This could include hiding the 'likes' count on SNS posts, something that Instagram has recently trialled in some countries. SNS users have previously reported that this change would lead to less social comparisons (Prichard et al., 2021), an element of SNS use that we have shown to be associated with problematic use symptoms (see chapter 2).

Conclusion

To conclude, the work presented in this thesis has not demonstrated clear evidence of a distinct cognitive, behavioural or physiological profile in problematic SNS users, as has been observed in drug and gambling addiction. SNS use does appear to be a highly rewarding and engaging activity, capable of activating the brain's reward centres, altering physiology and imbuing SNS cues with motivational salience (similar to primary rewards such as food and sex). However, the high

reward value that SNSs have acquired seems pervasive among young adults, with no consistent or convincing evidence that motivational dysregulation occurs in more problematic SNS users. The formal recognition of behaviours as new mental disorders requires a solid scientific basis, which does not currently exist for ‘SNS addiction’. The lack of compelling evidence of severe functional impairment attributable to SNS use also weakens the credibility of an addiction diagnosis. Hastily creating new behavioural addictions risks trivialising the field of addiction research and undermines the severity of genuine mental disorders that burden a substantial portion of society. Until more robust evidence is put forward, it is the conclusion of this thesis that the formal recognition of ‘SNS addiction’ as a psychiatric disorder would be premature.

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