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

Michael Wadsley, Niklas Ihssen *

Department of Psychology, Durham University, Durham DH1 3LE, UK

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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-min 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, 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, 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.

1. 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). Given the controversy regarding the creation of new behavioral addictions, previous research has used the term ‘problematic SNS use’ to describe compulsive/addiction-like SNS use behaviors without assuming the presence of an addiction. In the same vein we use the term ‘problematic SNS use’ herein to refer to SNS behaviors 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). We have recently advocated the utility of using a social reward perspective for understanding problematic 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,

* Corresponding author. Department of Psychology, Durham University, Durham DH1 3LE, UK.
E-mail address: niklas.ihssen@durham.ac.uk (N. Ihssen).

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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 and 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-min 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). However, 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). Direct inferences from the reviewed studies on any physiological changes during exposure to/cessation from SNSs are thus difficult to draw.

There exist only a few studies that examined physiological reactivity during or after SNS use directly. Most of these studies focused on the role of stress, showing that SNS can mitigate physiological responses to a preceding or subsequent stressful event (Johnshoy et al., 2020; Rus & Tiemensma, 2018) but is itself not associated with increased physiological stress (Oppenheimer et al., 2024). Beyond the important role of stress in physiological responses there is a clear need for research that addresses the impact of SNS use on physiological changes per se, and related to this, on the physiological effects of use cessation, and how they might differ in individuals with more problematic SNS use behaviors.

1.1. The 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, relative to a baseline period. 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). We tracked physiological responses by two parameters, GSR and heart rate. The inter-relationship between those variables (e.g., concurrent increase of GSR and heart rate vs increase in GSR alone) allows researchers to detect changes in motivational and emotional states (Fowles, 1980). To validate the relationship between the physiological variables and subjective experience, our study also measured changes in psychological states and we expected that exposure- and cessation-related changes in physiology (e.g., increase of heart rate and GSR) would be accompanied by changes of subjective ratings of 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). Finding a distinct psychophysiological profile in more problematic SNS users would add further weight to the concept of an 'SNS addiction'.

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).

2. Method

2.1. 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 $p < .05$ using a 3 (experiment phase) × 2 (group) mixed ANOVA. The study was approved by the Ethics Sub-Committee in the Department of Psychology at Durham University and all participants provided fully informed consent.

2.2. Measures

2.2.1. 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).

2.2.2. 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).

2.2.3. 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 to 3. In the present study participants only responded to the items with regard to their SNS use. Scale analysis suggested high internal consistency for both the frequency questions (11 items, $\alpha = .82$, 95% CI [0.73, 0.88]) and the intensity questions (11 items, $\alpha = .83$, 95% CI [0.75, 0.89]).

2.2.4. 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". Analysis of internal consistency showed acceptable results for active use (4 items, $\alpha = .68$, 95% CI [0.52, 0.80]) and passive use (3 items, $\alpha = .58$, 95% CI [0.44, 0.69]), respectively.

2.3. Procedure

Eligible participants were invited into the Psychology department at Durham University to complete the testing session (approx. 75–90 min). All participants were instructed to refrain from using Instagram for at least 4 h 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 valenced 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 min 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 min using the SNS app as they would do normally. After this, participants completed the cessation phase where they once again spent 15 min 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 min (i.e., 4 notifications delivered at 3, 6, 9 and 12 min) 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 (see Fig. 1).

3. Results

ACSID scores in the present sample ranged from 0.18 to 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). A median split was used since no cut-off score for problematic SNS use currently exists for the ACSID-11. 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 1.

3.1. Heart rate

To examine changes in mean 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 $\chi^2(2) = 8.68$, $p = .013$, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.86$). The results revealed a significant main effect of experiment phase [$F(1.71, 82.15) = 21.80$, $p < .001$, $\eta_p^2 = 0.312$]. However, the main effect of group [$F(1, 48) = 0.14$, $p = .707$, $\eta_p^2 = 0.003$] and the phase*group interaction [$F(1.71, 82.15) = 0.47$, $p = .595$, $\eta_p^2 = 0.010$] 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

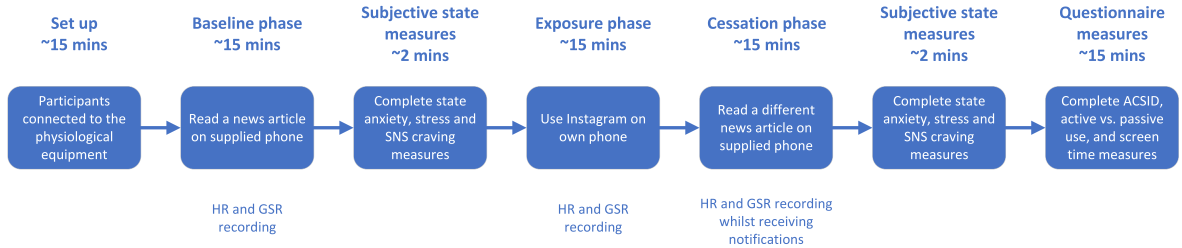

Fig. 1. Diagram of experiment procedure.

Table 1
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]	0.568
Age	21.19 (2.73)	20.79 (2.48)	0.57	0.569
Passive SNS use	4.19 (1.01)	4.79 (0.83)	2.37	0.021
Active SNS use	3.34 (0.79)	3.54 (1.08)	0.80	0.425
Daily average Instagram use (hours)	0.73 (0.42)	0.83 (0.71)	0.62	0.539
ACSID symptom frequency	0.78 (0.29)	1.56 (0.37)	8.45	<0.001
ACSID symptom intensity	0.53 (0.21)	1.34 (0.39)	9.56	<0.001
Overall ACSID score	0.66 (0.23)	1.45 (0.35)	9.98	<0.001

[a] Value represents χ^2 statistic.

= 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 ($r = -0.03$, $p = .824$) or withdrawal effects ($r = -0.02$, $p = .890$) were significantly correlated with ACSID scores.

3.2. Skin conductance

Changes in mean 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 [$F(1.44, 73.17) = 57.36$, $p < .001$, $\eta_p^2 = 0.529$], with no significant main effect of group [$F(1, 51) = 0.01$, $p = .916$, $\eta_p^2 < 0.001$] or phase*group interaction [$F(1.44, 73.17) = 0.11$, $p = .835$, $\eta_p^2 = 0.002$].

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 ($r = -0.01$, $p = .957$) or withdrawal effects ($r = -0.05$, $p = .726$) were significantly correlated with ACSID scores.

3.3. 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 [$F(1, 52) = 17.37$, $p < .001$, $\eta_p^2 = 0.250$], whereby anxiety ratings increased from pre to post. However, the main effect of group [$F(1, 52) = 1.27$, $p = .266$, $\eta_p^2 = 0.024$] and the interaction [$F(1, 52) = 1.56$, $p = .217$, $\eta_p^2 = 0.029$] 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 reflected increased stress ratings from pre to post in the higher problematic use group compared to the lower group, but was nonsignificant [$F(1, 52) = 3.89$, $p = .054$, $\eta_p^2 = 0.070$]. 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 nonsignificant [$F(1, 52) = 3.80$, $p = .057$, $\eta_p^2 = 0.068$] with the higher problematic use group exhibiting increased SNS cravings. The interaction effect was also 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 nonsignificant positive correlation between anxiety difference scores and problematic SNS use ($r = 0.24$, $p = .077$). 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.

3.4. Exploratory analysis

We also examined minute-by-minute changes in the heart rate and skin conductance data. We added time (1–15 min) 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 Fig. 2, 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 Fig. 3, 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 Fig. 3 also revealed that GSR peaked during the first minute of the exposure and cessation phase. We reasoned that this might be due to a task switching effect. Therefore, we decided to re-run our initial 3 × 2 mixed ANOVA for GSR whilst excluding the first 5 min 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 [$F(1.51, 77.08)$

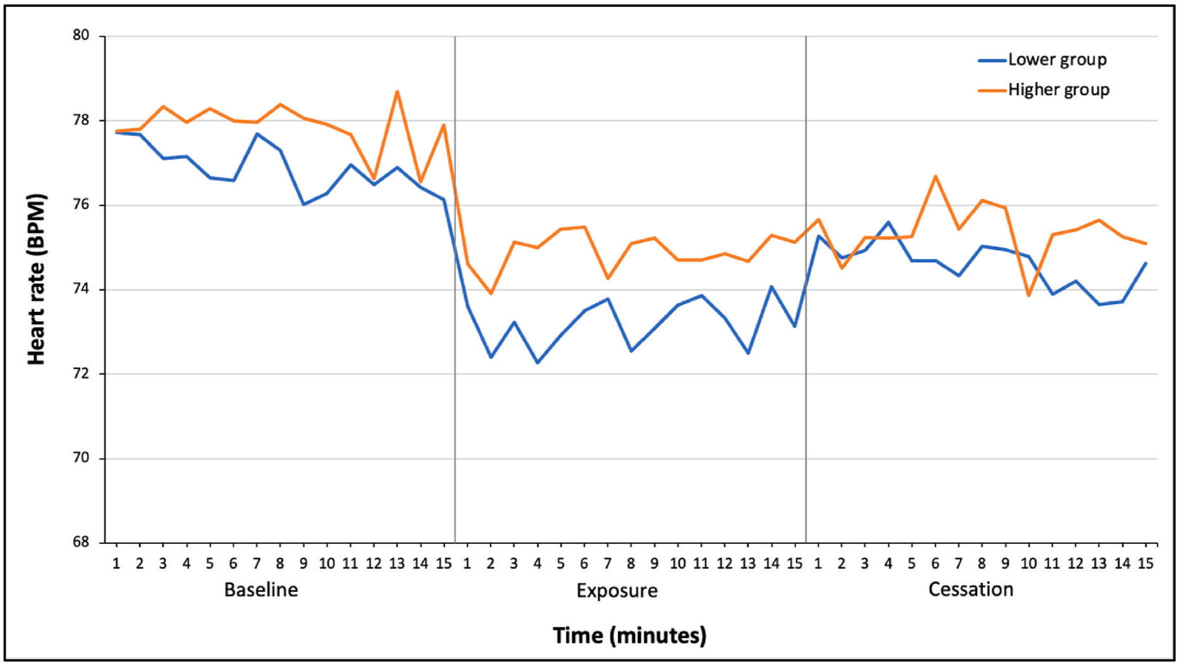

Fig. 2. Mean minute-by-minute heart rate changes (beats per minute) across the three experiment phases for lower and higher problematic SNS use groups.

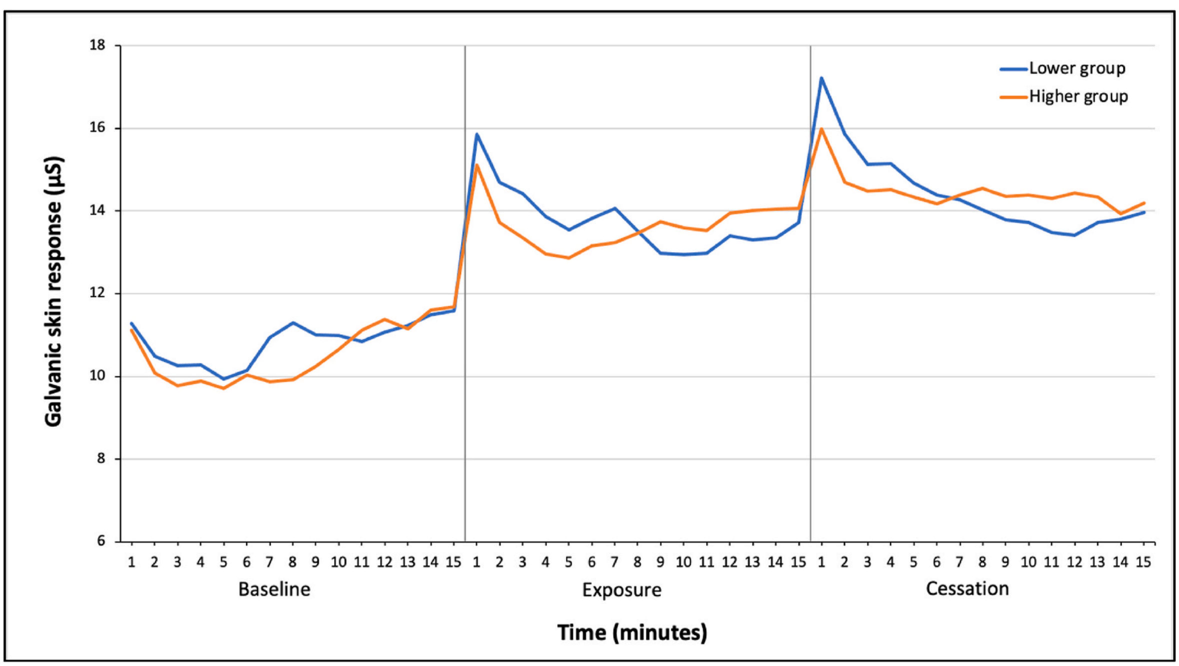

Fig. 3. Mean minute-by-minute GSR changes (microsiemens) across the three experiment phases for lower and higher problematic SNS use groups.

$= 0.46$, $p = .578$, $\eta_p^2 = 0.009$]. 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 < 0.05).

4. 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-min 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 task-switching effects by excluding the first 5 min 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 indicative of appetitive arousal whereas cessation is associated with a GSR increase 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 orienting reflex is typically seen as 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). Interestingly, heart rate deceleration during SNS immersion may also explain the recent finding that recovery from experimentally induced stress-related heart rate increase is facilitated by allowing participants to browse their SNS accounts after the stress induction, relative to a reading activity (Johnshoy et al., 2020). Similarly, the present heart rate slowing corroborates studies showing that using Facebook *before* a stress-inducing event mitigates the ensuing physiological arousal (as reflected in increased heart rate, blood pressure and endocrine responses) and could thus buffer the subjective experience of stress (Rus & Tiemensma, 2018). Considering the joint finding of decreased heart rate *and* increased GSR during SNS exposure in our study, we posit that participants entered a mental state that was characterized by profound immersive engagement and information intake (related to the viewed content) and, at the same time, heightened arousal.

However, one possible weakness of this interpretation is 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 min 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). Notably, our interpretation of increased stress during SNS cessation but reduced heart rate during exposure also echoes a recent study by Oppenheimer et al. (2024) reporting the absence of a physiological stress response – as indexed by increased HR and salivary cortisol – during 20 min periods of Instagram/Facebook use. Closely mapping on the pattern of results in our study, relative to a preceding baseline heart rate decelerated substantially during SNS use but then accelerated after use had ended. Critically, Oppenheimer et al. did not record concurrent GSR. Our study thus extends these findings by demonstrating that the GSR is increased during exposure, which suggests that heart rate deceleration does not just reflect the absence of a stress response, but the presence of an appetitive state characterized by (non-preparatory) arousal or excitement resulting from SNS immersion and information intake.

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 exclusively from a student population and thus the findings might reflect specific use behaviors in this population which may be specifically sensitive towards social information conveyed on SNSs. Other studies have found evidence that students display a heightened GSR in response to receiving smartphone notifications (Hsieh et al., 2020), and future work will need to establish whether such patterns generalize to other populations using SNSs, for instance, older adults. 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. Furthermore, for practical reasons we employed single item measures of state anxiety, stress and cravings. While the convergence of measures across psychological and physiological levels strengthened the validity of our conclusions, it cannot be ruled out that the single item ratings were susceptible to response bias and future work should use more robust affective and motivational instruments. 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.

4.1. Conclusion

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.

CRediT authorship contribution statement

Michael Wadsley: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Niklas Ihssen:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

Deidentified data are available athttps://osf.io/25usm

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