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**Problematic internet users' skin conductance and anxiety increase after
exposure to the internet**

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Abstract

Introduction: To examine the impact of cessation of an internet session on skin conductance responses and anxiety of higher and lower problem internet users, in order to explore possible physiological withdrawal effects.

Method: Participants were measured in terms of their skin conductance before (15min), during (15min), and after (15min) an internet session, and completed self-report measures of state anxiety and problematic internet use.

Results: Higher, but not lower, problem users showed increased skin conductance after internet use was stopped, relative to before their internet session. Higher problem users' GSR scores increased, as the time from internet cessation became longer. Higher problem users also showed increased levels of anxiety, following their internet session, which correlated with their skin conductance scores.

Conclusions: These results suggest that, following termination of an internet session, withdrawal-like effects are seen, both psychologically and physiologically.

Keywords: skin conductance; anxiety; withdrawal; physiological and psychological; problematic internet use.

Problematic internet use (PIU) affects between 2 and 20% of the population¹⁻³, and is typically assessed through the use of self-report questionnaires^{4,5}. Such prevalence figures have led to requests for further study into the nature of any potential internet-related disorder⁶. Those who report PIU also tend to report very high levels of internet usage^{7,8}, poor social relationships^{9,10}, disrupted sleep patterns^{11,12}, poor motivation to work and study¹³, and poor immune function¹⁴. In addition, problematic internet use has been found to be co-morbid with a range of psychiatric problems¹⁵, such as depression^{16,17}, anxiety¹⁸, autism spectrum disorders¹⁹, and even psychosis^{20,21} and impulse control^{22,23}. The phenomenon has been subject to a number of reviews, which have highlighted the different terms used to describe these effects (e.g., internet addiction, pathological internet use, problematic internet use), and provided overviews of the suggested nature of the putative problem^{24,25}.

In addition to the clear links between PIU and a range of psychological and physical problems, there is some evidence relating to whether those reporting PIU display signs of addiction^{21,26,27}. It has been established that when an individual with PIU stops using the internet, they report negative psychological consequences, such as increased negative mood^{21,27} and anxiety^{21,26}, and they may also report decreased positive mood²¹. Furthermore, exposure to the internet in internet-deprived high PIU scorers leads to an ‘internet-conditioning’ effect; aspects of the websites visited during the first internet session following deprivation gain positive hedonic status²⁷, putatively due to the alleviation of withdrawal effects positively conditioning those stimuli – an effect often seen for drugs of abuse^{28,29}. However, although there is growing evidence for psychological withdrawal effects in high problem users, little is known about any physiological effects during any such ‘withdrawal period’.

A recent study has shown that when individuals who score highly on a measure of PIU stop using the internet, they display an increase in heart rate and systolic blood

pressure³⁰. Similar findings also have been noted across a range of drugs, such as alcohol³¹ and cannabis³². However, few, if any, other physiological measures have been studied in the context of internet cessation for individuals with higher and lower PIU scores. The main aim of the current study was to document changes in the galvanic skin responses (GSR) of participants who did, and did not, report PIU across three phases: prior to internet exposure, during internet exposure, and, critically, after internet exposure. GSR has been extensively used as a measure of arousal, and, although it can indicate a wide range of aroused/emotional states across different individuals, it has been shown to increase after exposure to drug-related cues for those addicted to alcohol and opiates³³, and to correlate with cravings for opiate-withdrawn individuals^{34,35}. Given this, GSR was considered to be a suitable and readily-taken measure by which to assess physiological changes after internet cessation. If GSR increases on separation from the internet in those with PIU, then this would present a similar pattern of physiological activity to that noted for individuals undergoing withdrawal from several substances³⁴⁻³⁶, and this would be evidence suggestive of a physiological effect that may be akin to withdrawal.

Such an increase in GSR has been noted to be related to anxiety in a variety of situations^{37,38}. Self-rated anxiety has been noted to increase during an internet-separation period in those with PIU^{18,21,26}. Given this, the relationship between self-reported anxiety and GSR was also assessed to determine whether there was convergence between the physiological and psychological aspects of a putative internet withdrawal effect.

Method

Participants

Sixty participants (46 female and 14 male) were recruited in a Psychology Department of a University in the UK. Younger participants were thought appropriate to

target as they are most commonly affected by PIU^{4,13}. All participants were students, and were volunteers – none received any form of compensation for their participation. The participants had a mean age of 20.73 (\pm 3.28, range 18 – 34) years old, and none reported any history of psychiatric problems or addictions during a post-study debriefing. G-Power calculation revealed that for a medium effect size ($f = .25$), to detect a significant effect at $p < .05$, with a power of .90, a sample size of 46 would be required.

Materials

Internet Addiction Test (IAT)⁵ is a 20-item scale covering the degree to which use of internet disrupts everyday life (e.g., work, sleep, relationships, etc.). Each item is scored on a 1-4 scale, and the overall score ranges from 20 to 100. The factor structure of the IAT is currently debated^{39,40}, but a cut-off score of 40 or more for the total IAT score has been taken as indicating the presence of a degree of PIU^{5,7,21}. The internal reliability of the scale has been found to be between .90⁷ and .93⁵.

Spielberger Trait-State Anxiety Inventory (STAI-T/S)⁴¹ rates the affective, cognitive, and physiological manifestations of anxiety in terms of long-standing patterns (trait anxiety) and current anxiety (state). The total score for each scale ranges from 20 to 80. For the current purposes, the state scale was employed to measure short-term impacts of the manipulation. The internal reliability of the scale is 0.93.

Skin Conductance. Measurement of skin conductance was carried out by an ADInstruments PowerLab 2/25 data acquisition system (model ML825) and the accompanying skin conductance amplifier (ML116). Finger electrodes (MLT116F) were attached to the palmar surface of the intermediate phalanges of the first and third fingers of the non-dominant hand.

Procedure

The participants were tested individually in an experimental cubicle containing a desk, chair, and computer. During a brief introduction to the experiment, participants were told that this was an assessment of personality and physiological reactions, during which they would be asked to complete some forms, relax for 15min, surf the internet for 15min, and then relax for a further 15min, before completing some further questionnaires.

The participants were first asked to complete the STAI questionnaire, and were then attached to the GSR monitor by attaching finger electrodes. Participants were instructed to rest the connected hand on the table, and to refrain from talking and moving their hand during the session in order to avoid interfering with the measurement. The participants were given a period of 3min to adjust to the electrodes, before measurement started. At this point, they were told to relax for 15min, which constituted the baseline measurement period.

After this 15min baseline period, participants were allowed to surf the internet for 15min. A short internet period was used in this study in line with previous investigations of GSR⁴⁰, and as this has been found previously to be long enough to produce psychological changes in high problem users^{21,23}. Moreover, shorter periods of internet use are more reflective of current methods of interacting with the internet since the advent of mobile devices^{23,26}.

After a 15min period of internet exposure, the participants were asked to switch off the internet, and were told to relax for 15min, which constituted the 'withdrawal' period. Following this they were asked to complete the STAI and then the IAT questionnaire.

Results

The mean problematic internet use (IAT) score for the sample was 33.73 (\pm 12.50; range = 13 – 74); 16 (26.7%) participants scored above the cut-off point of 40 for mild or

worse problems. The mean score for males was $34.79 (\pm 12.78; \text{range} = 13 - 64; 28.57\%$ above cut off), and the mean IAT score for females was $33.41 (\pm 12.51; \text{range} = 16 - 74; 26.09\%$ above cut off), $t < 1$. The mean anxiety (STAI) score for the sample at baseline was $43.22 (\pm 5.45; \text{range} = 24 - 53; \text{males} = 44.43 \pm 3.78, \text{and females} = 42.85 \pm 5.85, t < 1)$. The mean anxiety (STAI) score for the sample post-internet was $42.58 (\pm 6.97; \text{range} = 21 - 56; \text{males} = 43.57 \pm 5.47, \text{and females} = 42.28 \pm 7.40, t < 1)$. There were significant correlations between the PIU score and anxiety (STAI) scores at baseline, $r = .309, p < .05$, and post-internet, $r = .417, p < .001$.

 Figure 1 about here

The sample was split at the IAT cut-off point (40) for mild or worse internet problems, to create two groups: a lower-PIU group ($N = 44, \text{IAT} = 27.82 \pm 6.94; \text{range} = 13 - 39$), and a higher-PIU group ($N = 16, \text{IAT} = 50 \pm 9.46; \text{range} = 40 - 74$). Figure 1 shows the group-mean anxiety (STAI) scores before and after the internet session. Inspection of these data reveals that anxiety levels decreased in the lower-PIU group, but increased in the higher-PIU group, after exposure to the internet. A two-factor mixed-model analysis of variance (ANOVA) with group (lower versus higher PIU) as a between-subject factor, and time (before versus after) as a within-subject factor, was conducted on these data. This analysis revealed a significant main effect of group, $F(1,58) = 15.55, p < .001; \eta^2_p = .211$ [$95\%CI = .054:376$]; *Bayes Factor* = .001; $p(H_1/D) = .993, p(H_0/D) = .006$; no significant main effect of time, $F < 1; \eta^2_p = .008$ [.000:100]; *Bayes Factor* = 6.056; $p(H_1/D) = .142, p(H_0/D) = .858$; but there was a significant interaction between the factors, $F(1,58) = 28.16, p < .01; \eta^2_p = .327$ [.138:482]; *Bayes Factor* = .001; $p(H_1/D) = .999, p(H_0/D) = .001$. Simple effect analysis revealed that there was a significant decrease in anxiety for the lower-PIU

group, $F(1,58) = 19.97, p < .001; \eta_p^2 = .419$ [.083:419]; *Bayes Factor* = .001; $p(H_1/D) = .994, p(H_0/D) = .001$, and a significant increase in anxiety for the higher-PIU group, $F(1,58) = 12.24, p < .001, \eta_p^2 = .339$ [.033:339]; *Bayes Factor* = .002; $p(H_1/D) = .987, p(H_0/D) = .012$.

 Figure 2 about here

The mean baseline GSR scores for the two groups were calculated, and were: $10.85 (\pm 5.70; \text{range} = .49 - 22.40)$ for the lower-PIU group; and $7.52 (\pm 6.61; \text{range} = 1.07 - 28.31)$ for the higher-PIU group, $t(58) = 1.92, p > .070, d = .45$. The left panel of Figure 2 shows the minute-by-minute percentage change in GSR during internet exposure relative to the mean GSR score for baseline (calculated by dividing each participant's mean GSR score for each minute during internet exposure by their mean baseline GSR). These data reveal little difference in alteration of GSR from baseline between the groups during internet exposure. A mixed-model ANOVA (group x time) conducted on these data revealed no statistically significant main effects of group, $F(1,58) = 3.89, p > .06; \eta_p^2 = .063$ [.000:207]; *Bayes Factor* = 1.105; $p(H_1/D) = .475, p(H_0/D) = .525$, or time, $F < 1; \eta_p^2 = .013$ [.000:019]; *Bayes Factor* = 5.176; $p(H_1/D) = .162, p(H_0/D) = .838$, and no significant interaction, $F(14,812) = 1.25, p > .20; \eta_p^2 = .021$ [.000:137]; *Bayes Factor* = 4.087; $p(H_1/D) = .197, p(H_0/D) = .803$.

The right panel of Figure 2 shows the minute-by-minute group-mean percentage change in GSR after internet exposure relative to the mean GSR during baseline (calculated by dividing each participant's mean GSR score for each minute post-internet exposure by their mean baseline GSR). There was little change in GSR for the lower-PIU group during the post-internet period, but GSR for the higher-PIU group increased over the period when internet access was stopped.

A mixed-model ANOVA (group x time) conducted on these data revealed no statistically significant main effect of group, $F < 1$; $\eta^2_p = .030$ [.000:124]; *Bayes Factor* = 5.219; $p(H_1/D) = .160$, $p(H_0/D) = .839$, but there was a significant main effect of time, $F(14,812) = 4.32$, $p < .001$; $\eta^2_p = .069$ [.026:089]; *Bayes Factor* = .896; $p(H_1/D) = .527$, $p(H_0/D) = .472$, and a significant interaction between the factors, $F(14,812) = 2.01$, $p < .01$; $\eta^2_p = .036$ [.001:041]; *Bayes Factor* = .348; $p(H_1/D) = .282$, $p(H_0/D) = .718$. The interaction reflected little change in GSR in the lower problem user group, $F(14,602) = 1.43$, $p > .10$; $\eta^2_p = .030$ [.000:040]; *Bayes Factor* = 4.054; $p(H_1/D) = .005$, $p(H_0/D) = .956$, but a significant large-sized linear trend in the higher problem use group, $F(1,15) = 17.93$, $p < .001$; $\eta^2_p = .545$ [.148:723]; *Bayes Factor* = .001; $p(H_1/D) = .999$, $p(H_0/D) = .001$.

There were significant positive correlations between the GSR percentage change from baseline during the last minute of the withdrawal period and the post-internet anxiety (STAI) score, $r = .386$, $p < .01$, and also between this GSR score and the change in anxiety, $r = .274$, $p < .05$.

Discussion

The results demonstrated that GSR increased over time after cessation of the internet session for higher, but not lower, PIU groups. These data extend findings showing that those with higher PIU scores display increased physiological measures of arousal (i.e. heart rate and blood pressure) after internet-session cessation³⁰. That internet cessation produces increased GSR for those with higher PIU scores is similar to effects seen for those experiencing withdrawal from³³, and cravings for^{34,35}, addictive substances. The current data also replicate several previous demonstrations of the negative psychological impact of cessation of internet usage on a higher-PIU group; there being an increase in anxiety for the high PIU group after the internet session relative to before^{21,26}. The increase in self-reported

anxiety seen on cessation of an internet session^{21,26} was correlated with an increase in GSR – an effect previously noted for increases in anxiety in other situations^{37,38}. These findings further strengthen the suggestion of a withdrawal effect on cessation of an internet session, which impacts both psychological²¹ and physiological responses³⁰ (although further research will be needed to validate this interpretation).

The finding that GSR increased following cessation of an internet session for those with self-reported PIU mirrors findings that have previously been noted for self-rated anxiety²⁶. That both GSR and self-rated anxiety get larger as time from cessation increases, suggests that this reflects a withdrawal effect²¹. Although caution is certainly needed in making the assumption that these effects reflect ‘withdrawal’, there are a number of pieces of evidence that would support such a hypothesis. It is known that anxiety will increase on cessation of several substances³⁶, and it may be that cessation of internet use for those with PIU reflects a similar ‘withdrawal’ effect. In addition, it is known that GSR will increase during periods of craving for a range of addictive substances^{31,34,35}.

As with any study, it is important to note a number of cautions, caveats, and limitations that could prompt further explorations of this area. For example, it is unclear how long these ‘internet withdrawal’ effects will last. Studies using self-report have noted an increase in self-reported anxiety in those with higher PIU over the course of hours²⁶, while the current report only studied GSR for 15min after cessation. However, if alleviation of withdrawal by re-exposure to the internet is implicated as a maintaining factor in internet use for those with PIU²⁷, then, given the ease of connecting to the internet through mobile devices²³, this withdrawal effect may not need to last long to trigger an internet response.

Further work will be necessary to explore the precise nature of these putative internet withdrawal effects. For example, although the current GSR changes following cessation of internet use are similar to those noted for self-reported anxiety, they also may be related to

other number of psychological factors. For example, it is known that positive and negative mood also changes after cessation of the internet^{21,26}, and these relationships will need to be investigated when examining this phenomena further. It may also be that the function that the internet use is serving for the individual, and this may vary across problem users, could impact the physiological responses. For example, if the internet is being used to generate excitement⁴², the effects of withdrawal may be different to when it is being used to escape an aversive situation, such as loneliness⁹. The current study employed a straightforward GSR measure of arousal to assess physiological changes for those with higher and lower PIU scores after internet cessation. Use of such a measure makes difficult a completely unambiguous interpretation of the reasons for the increased arousal. It may be that employing a greater range of physiological markers⁴³ would help to separate out the positive and negative psycho-physiological processes.

In summary, the current results have demonstrated a physiological impact of cessation of internet use for higher, but not lower, problem users. This further supports the notion that internet use could be regarded as a form of behavioral addiction, which can have a range of impacts on the individual's physiology and health.

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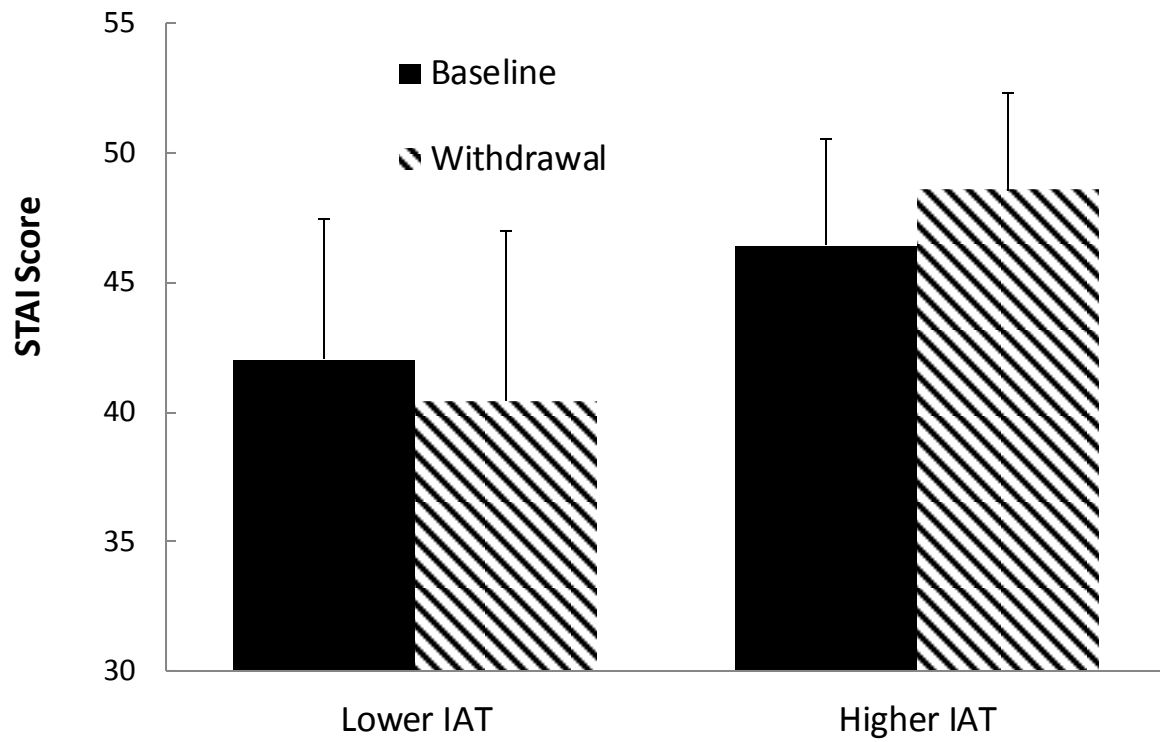
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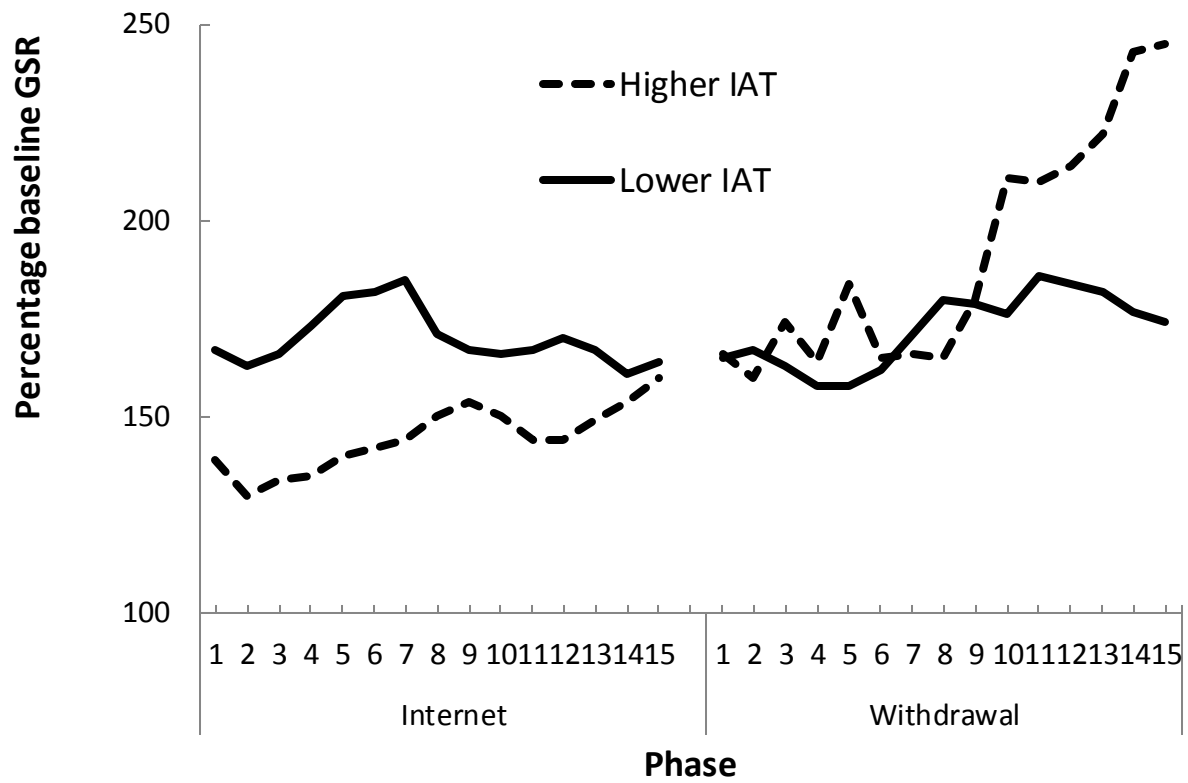
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Figure 1: Mean (standard deviation) anxiety scores (STAI) for the lower and higher problematic internet groups before and after internet exposure.



ACCEPTED

Figure 2: Mean GSR for each minute in the internet-exposure and withdrawal phases as a percentage of the GSR in the baseline phase for both groups.



ACCEPTED

Author Disclosure Statement

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Conflict of Interest – none of the authors have any conflicts of interest.

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Highlights

- The impact of internet-cessation on skin conductance and anxiety was studied.
- Participants' skin conductance was measured before, during, and after an internet session.
- Problem users showed increased skin conductance after internet cessation.
- Problem users had increased anxiety after internet cessation correlated with GSR.
- These results suggest termination of an internet session produces withdrawal-like effects.