Original Article

Exploring Problematic Mobile Phone Attachment and Associations to Anxiety and Inhibitory Control After a Short-Term Smartphone Separation

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Abstract

This study investigates problematic smartphone attachment under conditions of short-term smartphone separation. Two experimental studies with randomized group allocation were designed to investigate effects of smartphone separation on anxiety and inhibitory control. Problematic smartphone use pathways were explored using a self-report measure. In the first experiment (N= 85) smartphone addicted participants showed an increase in state anxiety after 20 min of separation from their smartphones compared to a control group of non-addicted participants. There was no evidence for impaired inhibitory control based on a period of smartphone separation. In the second experiment the methodology was slightly varied, and the participants (N= 95) were provided with a task during a smartphone separation of 15 min. This led to a reduction of state anxiety for problematic attached participants but did not result in a change for unproblematic attached participants. Problematic attached participants showed a larger disturbance in inhibitory control undergoing a separation period than unproblematic attached participants. Moreover, the results provide supplementary evidence for the existence of specific problematic smartphone attachment pathways and further variables.

Keywords: anxiety, inhibitory control, problematic mobile phone use, smartphone addiction, smartphone separation.

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Introduction

The digital companionship between smartphone and user which is formed after some time of usage might lead to an attachment with the chance of becoming problematic. The research on smartphone separation comes with variance regarding used methodologies and the definition of how a separation period is conducted and what the consequences are (Cheever et al., 2014; Clayton et al., 2015; Hartanto & Yang, 2016). Commonly used terminologies like *Fear of Missing Out* (Przybylski et al., 2013), *No-Mobile-Phone-Phobia* (King et al., 2013) or *Low Battery Anxiety*, as described in a press release from LG Electronics (2016), suggest that the link between smartphone separation and an anxiety inducing momentum is well on its way to be established. For instance, Przybylski, Murayama, DeHaan and Gladwell (2013) describe *Fear of Missing Out* (FoMO) as a constant worry to miss out on an enriching experience that friends, and acquaintances are having. In a study by Elhai, Levine, Dvorak and Hall (2016), a positive association between an excessive smartphone use and FoMO was found. In a further study Cheever et al. (2014) implemented in their experimental design a 75 min smartphone separation period and were able to observe a linear increase in their participants' state anxiety. However, this occurred only for participants with moderate and high mobile phone usage times.

Due to smartphone-separation induced anxiety, Hartanto and Yang (2016) found an impaired executive function. A conflicting result when compared to Ward et al. (2017) who were able to show that not the smartphone separation induces anxiety but instead the mere presence of the mobile device leads to deficits in executive functions.

In line with recent findings, it seems feasible that not only the time of deprivation or the frequency of smartphone usage matters but also the distinct type of attachment being formed to the smartphone. The attachment theory (Bowlby, 1969) was originally conceived as the bond between caregiver and caretaker. However, attachment research has shown that also inanimate objects which prove to be reliable and have the propensity of constant availability such as smartphones, can form these bonds (Bretherton, 1992; Keefer et al., 2012). Konok, Gigler, Bereczky and Miklósi (2016) observed that people having an anxious-preoccupied attachment are especially prone to becoming problematic smartphone users due to using their phone to satisfy an irrational need for contact.

Lacking a universally accepted concept of addictive behavior towards their mobile phones, Billieux Billieux, Maurage, Lopez-

Fernandez, Kuss and Griffiths (2015) introduced the model of *Problematic Mobile Phone Use* (PMPU) to unify existing evidence and introduce a coherent framework for further research. Based on attachment theoretical considerations it is proposed that the three pathways (PMPU-pathways) Excessive-Reassurance, Impulsive-Antisocial, and Extraversion offer a classification to describe the relationship between owner and smartphone in a cohesive way. It is assumed that the PMPU-pathways overlap with respect to the associated concepts. In their model Billieux et al. describe the Excessive-Reassurance pathway by a dependent form of smartphone use that presents itself with worry about the maintenance of personal bonds, elevated anxiety and depression scores, increased neuroticism and lower feelings of self-worth. The Extraversion pathway in the PMPU model characterizes people who use their smartphone to form new bonds, regulate cravings for appreciation and for sensation seeking purposes. The Impulsive-Antisocial pathway is described as the dominant pathway for people that have low self-control and high impulsivity and use their smartphone whilst driving, on inappropriate occasions, for cyberbullying, or to exchange sexual content (Billieux et al., 2008; Billieux et al., 2010; Dir et al., 2013; Kokkinos et al., 2014).

All proposed pathways are described by the predominant way people are using their smartphone to regulate deprived needs and emotional states (Billieux et al., 2015). Consequently, for problematic smartphone users, this might lead to a period of increased deprivation for previously fulfilled needs which accompanies a separation from their mobile device. This need-deprivation period might then in turn lead to a state of augmented anxiety.

For this study, a short period of smartphone separation was selected to investigate possible changes in state anxiety after separation, as measured in the *State-Trait Anxiety Inventory* (Spielberger et al., 1970), for a sample of German adults. In both experimental designs the main interest was in possible group differences regarding state anxiety: people reporting an addictive attachment towards their mobile phone and non-addicted people following a short separation period. Furthermore, the quality of problematic attachment between smartphone and user during separation time was investigated by using the PMPU-pathways as orientation.

In the first experimental setting (Experiment A) it is assumed that a smartphone separation period of 20 min leads to a higher state anxiety among participants compared to a control condition. Furthermore,

it is hypothesized that a smartphone separation leads to disrupted executive functions as measured via the use of a task focusing on inhibitory control. A similar methodology as in Hartanto and Yang (2016) is applied. More specifically it is assumed that state anxiety increases under separation conditions in addicted participants, yet not in non-addicted participants as measured by the *Smartphone Addiction Scale – Short Version* (SAS-SV) (Kwon et al., 2013). Lastly, the association between degrees of PMPU and state anxiety following a separation period are explored, while controlling for trait anxiety.

In the second experiment (Experiment B) a similar experimental setting is applied mainly to increase a salience of smartphone separation while exploring the interaction between PMPU-pathways and state anxiety, focusing on the edge between problematic and unproblematic smartphone attached participants. More specifically, it is hypothesized that a separation period (15 min) during which participants are presented with a task leads to a decrease in state anxiety for people classified as problematic attached, as measured by the *Smartphone Overuse Questionnaire* (Lee et al., 2017), but not for unproblematic attached participants. Accordingly, possible differences between problematic and unproblematic attached participants undergoing a separation-period regarding inhibitory control performance, as measured via the Stroop task (Stroop, 1935), are scrutinized. The PMPU-pathways are further explored with correlations between a developed measured for the PMPU-pathways, indications of smartphone overuse, FoMO and attachment style.

The research questions, as operationalized in the above hypotheses, are scrutinized within the framework of two separate experimental designs. First, the method of Experiment A and Experiment B are described, followed by the corresponding results of these experiments, before being discussed and summarized.

Experiments

Method Experiment A

Participants

Participants were recruited at the Heinrich-Heine Universit*ät* in Düsseldorf in Germany via flyers and (online) advertisements. Inclusion criteria were smartphone ownership, age between 18 and 35 years and no colorblindness. Our sample (*N*=85, *mean age*= 23.38; *SD*= 3.58 years) consisted of 55 female and 30 male participants. The daily smartphone use in hours was as follows: 1-2 (27.1%), 3-4 (35.3%), 5-6 (18.8%), 7-8 (7.1%) and 11.7% were indicated as

outliers with either a shorter or a longer duration than the majority. Using the suggested cut-off score for the SAS-SV, 20% of participants in our study were categorized as being addicted to their smartphone.

Analyses of differences in demographics for experimental (smartphone separation) and control (surrender identification) condition revealed no statistical differences in age, sex or education. The *Smartphone Bonding Questionnaire* (see Materials and Instruments) revealed that out of the analyzed sample, 43% assigned themselves to the Excessive-Reassurance pathway and 42% to the Impulsive-Antisocial pathway and no participant chose the item that was assigned to the Extraversion pathway. The participation of the predominant student participants was remunerated via course credit or financial compensation. Informed written consent was obtained from all participants. The study was approved by a local Ethics Committee.

Measures and Instruments

Fear of Missing Out scale (FoMOs). The FoMOs was developed by Przybylski et al. (2013) and was translated into German for this study. The self-report measure examines the wish to be in touch with people in the digital world following the concern of missing out on activities or experiences. Its scoring ranges from 1 to 5, with higher numbers reflecting a higher manifestation of the construct (α= .93 in the original version). The internal consistency for the translated version was α= .71.

Sociodemographic Questionnaire. A sociodemographic questionnaire contained questions about age, gender, marital status, educational attainment, daily smartphone usage, regularity of digital media use and drug use.

State-Trait-Anxiety Inventory (STAI). The German version of the STAI (Laux, 1981) was implemented, developed by Spielberger et al. (1970). State (STAI-S; α=.90) and trait (STAI-T α= .90) anxiety were assessed. Overall scoring ranges from 20-80, higher scores indicating higher trait (retest-reliability of r= .68 to .96) or state anxiety (retest-reliability of r= .03 to .76).

Smartphone Addiction Scale - Short Version (SAS-SV). The SAS-SV (Kwon et al., 2013) measures smartphone addiction (α= .91). The short form of this 10-item-questionnaire was published in English and translated into German for this study. Item scoring ranges from 1 to 6 with an overall scale range from 10 to 60. In accordance with the authors, gender-specific cut-off values to classify someone as smartphone addicted are 33 for males and 31 for females.

Smartphone Bonding Questionnaire (SBQ). Three brief forced-choice items which were created for the purpose of this study for participants to indicate their smartphone attachment style according to the proposed pathways Impulsive-Antisocial, Excessive-Reassurance, and Extraverted by Billieux et al. (2015).

Stroop-task. A Stroop task (Stroop, 1935) task was implemented to examine inhibitory control. In the computer version, the Stroop task runs via the program Presentation over a single phase in its colored word paradigm (red, green, yellow and blue), presenting word/color incongruent or congruent trials (Font: Helvetica, size 16) on a 22-inch monitor, with participants being seated approximately 50 centimeters away from the screen. Participants were instructed to name the color into a microphone. A fixation-cross appeared for 500 milliseconds (ms) in the center of the screen, followed by 5000 ms (answer window) of stimulus presentation on a white background which was subsequently followed by an intertrial interval of 500 ms in form of a blank screen. The task consisted of 16 practice trials and 36 congruent and 36 incongruent trials and reaction times and errors were measured.

Procedure

First, participants were asked to fill in the first set of questionnaires online. This set contained information on the purpose of the experiment, an informed consent, sociodemographic questions and the STAI-T. In the laboratory the participants were randomly assigned to either the experimental (smartphone-separation) condition or the control condition and seated in the first of two rooms. Participants in the experimental condition were asked to surrender their smartphone under a pretense. The smartphone was locked up under the eyes of the participant in a drawer. Participants in the control condition were asked to hand out their identification (ID; or student card, if the identification was missing). After 20 min of waiting, the STAI-S was administered. Afterwards, participants were asked to move into the second room to complete the computerized tasks. The Stroop task and the last set of questionnaires (SBQ, SAS-SV) followed. Lastly, participants received their belongings back and were thanked for their participation, debriefed, and received financial compensation or course credit.

Design and Data Analysis

This study followed an experimental design with randomized group allocation. Independent variables are the short-term separation from

an object (smartphone or ID) and addicted or non-addicted towards their smartphone (based on the SAS-SV). The dependent variables were state-anxiety and inhibitory-control as being operationalized by the Stroop task. Outliers in reaction times and errors departing 2.5 *SD* below or above individual response means were removed.

The data was analyzed using SPSS Statistics 25 (IBM) with α level set to .05 and reported *p* values corresponding to one- or two-sided hypotheses. A priory power analyses (following obtained effect sizes in prior literature) for an assumed medium effect-size with power being set at .80 revealed a sample size of N= 85 as adequate (Faul et al., 2009). At first, state anxiety differences between separation condition and control condition after separation and for addicted or non-addicted smartphone users were investigated, using analyses of variance (ANOVA) while controlling for trait anxiety. Non-parametric analyses were implemented for follow-up due to deviations in normality caused by small sample sizes and are noted as such. To test for differences in inhibitory control, a 2x2 RM-ANOVA for the reaction times and errors in the Stroop task with between-subjects' factors (experimental, control) and within-subjects' factors (congruent, incongruent) was used. Pearson-correlations were computed for further exploratory analyses.

Method Experiment B

Participants

The mostly student sample consisted of 95 participants (age: *M*= 21.97, *SD*= 2.43 years), 74 females and 21 males that were recruited online and via flyers at the Heinrich-Heine-Universität Düsseldorf. Inclusion criteria were as follows: age between 18-27, smartphone possession and German mother tongue. Furthermore, participants were required to reach a cut-off score in the *Smartphone Overuse Screening Questionnaire* (Lee et al., 2017) of greater than 42. Exclusion criteria were as follows: suffering from a diagnosed mental illness, illegal substance use, colorblindness and previous participation in Experiment A. The daily smartphone use in hours of the sample was as follows: 1-2 (7.4%), 3-4 (53.7%), 5-6 (23.2%), > 6 (15.8%). The remuneration of the participants could be financial or course credits. Informed written consent was obtained from all participants. The study was approved by a local Ethics Committee.

Measures and Instruments

Following instruments and tasks were included but are already described under Measures and Instruments in Experiment A: *Fear*

of Missing Out Scale (Przybylski et al., 2013), *State-Trait-Anxiety Inventory* (Spielberger et al., 1970), *Stroop task* (Stroop, 1935), *Sociodemographic Questionnaire*.

Experiences in Close Relationships. The original version of the questionnaire *Experiences in Close Relationships* (ECR) from Brennan, Clark and Shaver (1998), *Bochumer Bindungsfragebogen* (BoBi) by Neumann, Rohmann and Bierhoff (2007) in German, measures attachment styles in relationships via two scales *Anxiety* and *Avoidance*. The underlying model for child attachment styles is based on Ainsworth, Blehar, Waters and Wall (1978) which according to Hazan and Shaver (1987) can be adopted to adult attachment styles. Overall scoring of the BoBi ranges from 1 to 7, for *Anxiety* (preoccupied attachment; α= .88) and for *Avoidance* (fearful and dismissing attachment style; α= .85) with higher scores indicating a higher manifestation of the construct.

Smartphone-Attachment-Type Scale (SAT-S). The SAT-S (see Appendix) was developed for this study to assess the problematic smartphone-attachment style based on the PMPU-classification (Billieux et al., 2015) in a differentiated manner. It contains 15 statements of which five items correspond to every pathway-type as measured on a 5-item Likert scale (1= I do not agree at all to 5= I agree completely). Excessive-Reassurance (maintenance of important relationships, reassurance about other's well-being, intense concern and sense of abandonment over delayed response from others and extreme need for self-supportive feedback; α= .69), Impulsive-Antisocial (handling of boredom, longer use of the smartphone as anticipated, use of a smartphone in forbidden places, instant sharing of positive-negative experiences with others and irrational response to messages without taking the consequences into account; α= .39) and Extraversion (facilitation of communication with significant others, establishment of new relationships, risky use of smartphones, sending of sexual content and occupation with gambling and action games; α= .45). In case the participants' score was the same in two categories of the SAT-S, a forced-choice item was consulted to select the primary pathway-type: "I mainly use my smartphone to maintain the relationship with the significant others in my life" (Excessive-Reassurance) or "When I get bored, or I don't have to do something, I preferably occupy myself with my smartphone" (Impulsive-Antisocial) and "I mainly use my smartphone to communicate with my significant others and to build new relationships" (Extraversion).

Smartphone Overuse Screening Questionnaire (SOS-Q). The SOS-Q (Lee et al., 2017) differentiates between non-problematic and

problematic smartphone users. The questionnaire was translated into German for the purpose of this study. It contains 28 items in six main categories: Preoccupation, Loss of control, Craving, Insight, Overuse and Neglect of other areas. Answer possibilities range on a 4-item Likert scale. For the investigation a cut-off score of >49 was applied to classify people as problematic attached towards their smartphone. In its translated version The SOS-Q showed in the present study an internal consistency of α= .87.

Procedure

First, eligible participants were provided online with information about the experiment and an informed consent. After creating their unique identification code further questionnaires were administered, containing sociodemographic characteristics and the SAT-S and SOS-Q. Within a week all participants meeting inclusion criteria received a second link forwarding to another set of questionnaires (STAI-T, BoBi). After this, participants were randomly assigned to the control or treatment group and categorized into one of the smartphone attachment pathways.

Afterwards, participants had contact with the researcher in the laboratory. Participants were asked to fill out the STAI-S (pre) and to surrender their smartphones in a large container. Then, they were led into the recording room which was freed from distracting stimuli. Within the waiting period of 15 min, participants received a neutral short story (Hawking & Kober, 1997) as used in Göritz (2007) for distraction purposes and acoustic cues were presented two times (a vibrating smartphone for 5 to 10 sec which was set up in a small bowl above the box containing the participants' smartphone).

Next, participants were asked to fill in the STAI-S (post) before they were seated in front of the computer on which the FoMOs and the forced choice item of the SAT-S had to be answered digitally and the Stroop task was given. Lastly, participants received their belongings back, were debriefed, remunerated and thanked for their participation.

Design and Data Analysis

This study follows a quasi-experimental design with a separation period of 15 min from their smartphones during which the participants were provided with a distraction. Independent variables were problematic or unproblematic smartphone use and smartphone attachment type. Dependent variables were post-separation state anxiety and inhibitory control. Similar statistical analyses as in Experiment A were

applied. Concerning to the primary hypothesis whether a smartphone separation of 15 min leads to a change in reported state anxiety for participants classifying as problematic attached or unproblematic attached when presented with a task, ANOVAs were carried out with the above-mentioned independent variables as between-factors. To test for a resulting difference in inhibitory control, a 2x2 RM-ANOVA for the reaction times in the Stroop task with between-subjects' factors (problematic, unproblematic) and within-subjects' factors (congruent, incongruent) was carried out. The PMPU-pathways were further explored by computing Pearsons-correlations on the participants' smartphone use, FoMOs and the BoBi subscales.

Results

Results Experiment A

Statistics and Data Analysis

There were no differences between conditions, on degree of smartphone addiction (SAS-SV), FoMO (FoMOs) or trait anxiety (STAI-T) due to group allocation. Further descriptive data are depicted in Table 1.

Table 1. Independent samples t-tests on certain variables between experimental and control condition with standard deviations in parentheses

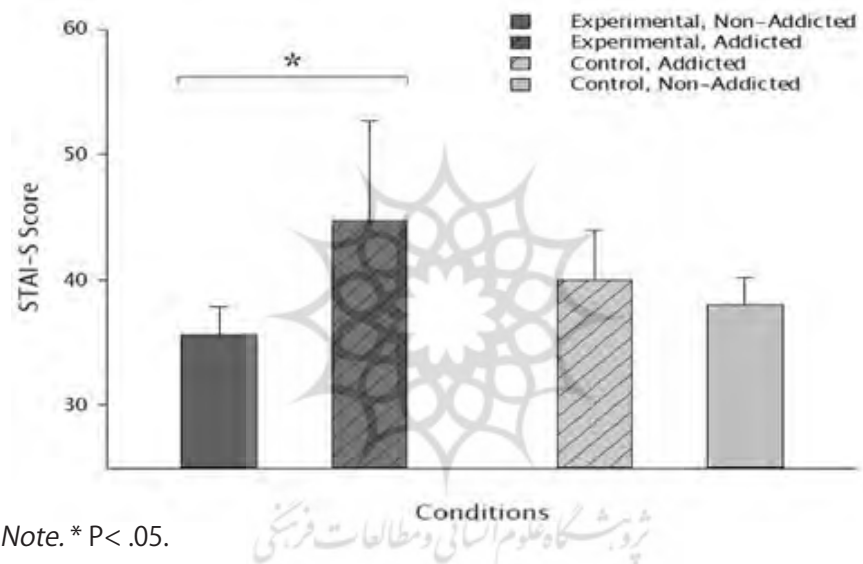
Total (*n*= 85)	Control Condition (*n*= 41)	Experimental Condition (*n*= 44)	*t* (df = 83)	*p*	*d*
SAS-SV	24.95 (8.90)	25.64 (9.25)	0.35	.729	0.08
FoMOs	2.69 (0.59)	2.53 (0.58)	-1.31	.195	0.28
STAI-T	45.27 (10.35)	43.27 (10.23)	-0.89	.374	0.19

Note. SAS-SV= Smartphone Addiction Scale - Short Version (Kwon et al., 2013); FoMOs= Fear of Missing Out Scale (Przybylski et al., 2013); STAI-T = State Trait Anxiety Inventory (Laux, 1981).

There was no overall difference between experimental (*M*= 37.68, *SD*= 8.53) and control condition (*M*= 38.41, *SD*= 5.83) regarding reported state anxiety, while controlling for trait anxiety as a covariate after separation, $F(1,80)= 1.488$, $P= .226$, $\eta p^2= 0.2$. Moreover, there was a statistically significant effect between addicted (*n*=17; *M*= 42.76, *SD*= 9.39) and non-addicted (*n*= 68; *M*= 36.85, *SD*= 6.27) participants on state anxiety, $F(1,80)= 8.433$, $P= .005$, $\eta p^2= 0.1$. Furthermore, a statistically significant interaction

effect between conditions and smartphone addiction was present, $F(1,80)= 4.26$, $P= .042$, $\eta p^2= 0.1$.

Following up by comparing addicted and non-addicted smartphone users in the control condition, state anxiety after separation of addicted participants ($n= 9$) was higher ($M= 40.00$, $SD= 1.71$) than for the non-addicted participants ($n= 32$; $M= 37.97$, $SD= 1.06$) but did not differ statistically significant ($U= 179.5$, $P= .27$). In the experimental condition, the higher state anxiety scores for the addicted participants ($n= 8$; $M= 45.88$, $SD= 4.34$), than for the non-addicted participants ($n= 36$; $M= 35.86$, $SD= 1.06$), reached statistical significance, $U= 216$, $p= .028$ (Figure 1).



Note. * P< .05.

Figure 1. Ninety-five percent confidence intervals around mean state anxiety for non-addicted and addicted participants in the experimental and control condition after separation

As expected, a statistically significant main effect for the Stroop condition on reaction times was revealed $F(1,83)= 229.43$, $P<.001$, $\eta p^2= .73$. There was no significant difference between groups, $F(1,83)= 0.40$, $P= .530$, $\eta p^2= .01$ and no statistically significant interaction effect, $F(1,83)= 3.86$, $P= .053$, $\eta p^2= .04$. Additionally, a statistically significant main effect for the Stroop condition on errors could be shown, $F(1,83)= 5.87$, $P= .018$, $\eta p^2= .07$. There was no difference between groups, $F(1,83)= 1.17$, $P= .285$, $\eta p^2= .01$ and no statistically significant interaction effect, $F(1,83)= .048$, $P= .827$, $\eta p^2= .00$ (see also Table 2).

Table 2. Mean reaction times and errors and Stroop effect with standard deviations in parentheses depending on the condition

	Reaction Times		Errors	
	Control condition	Experimental condition	Control condition	Experimental condition
Congruent condition	654.80 (102.47)	652.80 (113.04)	0.46 (0.98)	0.91 (1.93)
Incongruent condition	773.10 (134.48)	743.93 (120.82)	0.93 (1.40)	1.30 (2.79)
Stroop effect	118.30 (63.43)	91.13 (63.95)	0.46 (1.21)	0.39 (1.92)

Note. Reaction times are in milliseconds.

Furthermore, the Pearson-correlation between smartphone addiction as measured by the SAS-SV and state anxiety while controlling for trait anxiety showed a statistically significant positive correlation of medium effect size for the separation condition, with $r(41) = .47$, $P = .002$, but no statistically significance for the control group, $r(38) = .25$, $P = .13$.

Results Experiment B

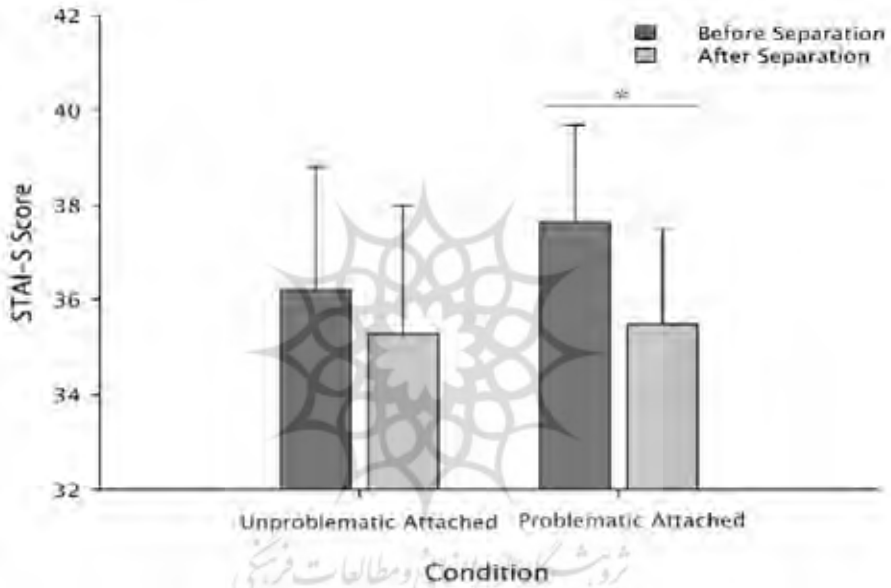
There was as statistically significant difference in smartphone use in hours between problematic and unproblematic smartphone users (Table 3). In addition, the Excessive-Reassurance- and Impulsive-PMPU pathway scores on the SAT-S were statistically significantly higher for problematic smartphone users than for unproblematic smartphone users.

Table 3. Independent samples t-tests with means and standard deviations in parentheses for comparisons on smartphone use in hours and attachment between problematic and unproblematic smartphone attachment

(*N*= 95)	Problematic Smartphone Use (*n*= 63)	Unproblematic Smartphone Use (*n*= 32)	*t* (df= 93)	*P*	*d*
Smartphone Use (hours)	4.68* (1.55)	4.00* (1.48)	-2.06	.043	-0.45
SAT-S					
Excessive	17.27* (3.28)	15.78* (3.05)	-2.14	.035	-0.47
Extraversion	13.11 (3.11)	11.88 (2.39)	-1.93	.052	-0.43
Impulsive	19.30* (2.41)	17.88* (2.03)	-2.87	.005	-0.62

Note. SAT-S = Smartphone Attachment Type Scale, answers range from 5-25 with higher scores indicating a higher extent of the underlying construct.
* P< .05.

A one-way ANOVA revealed statistically significant differences for conditions on pre- and post-anxiety, $F(1,93)= 4.677$, $P= .033$, $\eta p^2= .05$. More specifically, for participants reporting a problematic attachment to their smartphone the level of anxiety was statistically significant higher before the separation period ($M= 37.65$, $SD= 8.0$) than after ($M= 35.48$, $SD= 8.03$), ($t(62)= 2.43$, $P= .018$, $d= .271$), this was not the case for unproblematic attached participants with $M= 36.22$, $SD= 7.23$ before and $M= 35.28$, $SD= 7.49$ after ($t(26)= 0.484$, $P= .632$, $d= .08$). See Figure 2 for bar plots with 95% Confidence Intervals.



Note. * P < .05.

Figure 2. Ninety-five percent confidence intervals around mean state anxiety for unproblematic and problematic smartphone attached participants before and after separation while receiving a distracting task

Furthermore, a statistically significant effect for the Stroop condition on reaction times was shown $F(1,93)= 67.43$, $P< .001$, $\eta p^2= .42$. There was no difference between groups, $F(1,93)= 0.09$, $P= .764$, $\eta p^2= .01$ and a statistically significant interaction effect was present between groups and condition, $F(1,93)= 8.63$, $P= .004$, $\eta p^2= .085$ (Table 4). The Stroop effect on reaction times for both conditions revealed statistically significant higher interference for problematic attached participants than for unproblematic attached participants.

Table 4. Mean reaction times and stroop effect for problematic and non-problematic smartphone users with standard deviations in parentheses

N = 95	Unproblematic smartphone use (*n* = 32)	Problematic smartphone use (*n* = 63)
Congruent condition	816.24 (189.68)	771.88 (163.97)
Incongruent condition	876.60 (187.28)	899.47 (186.91)
Stroop effect	60.36 (82.46)	127.59 (115.25)

Note. Reaction times are in milliseconds.

Further exploratory analyses were conducted to investigate the properties of the SATS-S and variables relating to individual PMPU-pathways. Based on the SAT-S, 74 participants were assigned to the PMPU-pathways of Antisocial-Impulsive (*M*= 18.82, *SD*= 2.37), 20 to Excessive-Reassurance (*M*= 16.77, *SD*= 3.26), and one as Extraversion (*M*= 12.69). The participant belonging to the Extraversion pathway was excluded from further analyses. Participants in the Impulsive-Antisocial pathway showed no statistically significant associations between their SOS-Q score and the subscales in the BoBi (anxiety: $r(74)= .072$, $P= .539$; avoidance: $r(74)= -.034$, $P= .773$); yet a statistically significant positive relationship of medium size between the SOS-Q score and FoMO, $r(74)= .377$, $P= .001$. Participants belonging to the Excessive-Reassurance pathway showed a strong positive correlation between the SOS-Q score and the anxiety subscale in the BoBi ($r(20)= .566$, $P= .009$). The avoidance subscale in the BoBi ($r(20)= -.299$, $P= .200$) and the FoMo scale ($r(20)= .158$, $P= .505$) shared no statistically significant relationship with the SOS-Q score in the Excessive-Reassurance pathway.

Discussion

Experiment A

The primary goal in Experiment A was to investigate the general relationship between smartphone addiction, a short-time smartphone separation, anxiety and inhibitory control in a German, mostly student, sample. The first hypothesis

that addicted participants show statistically significant higher levels of anxiety after smartphone separation for a period 20 min than non-addicted participants was confirmed. This was not the case for addicted participants surrendering their ID or student card. The second hypothesis of possible effects on inhibitory control after smartphone separation could not be confirmed. Even though participants who surrendered their smartphone instead of their ID showed a smaller interference in their inhibitory control, this effect failed to reach statistical significance. Additionally, a positive relationship between increasing (problematic) smartphone attachment or addiction and state anxiety while controlling for participants trait anxiety could be found. This association was only present under the smartphone separation condition.

The gathered results are consistent with Cheever et al. (2014) for an increased anxiety following a separation period among people with an addictive relationship towards their smartphones. Since this was not the case for addicted participants who surrendered valuable personal belonging as a control, it is reasonable to conclude that the increased anxiety was due to the smartphone-separation.

While Hartanto and Yang (2016) presented strong evidence for the association between elicited anxiety due to smartphone separation and problems in executive functioning, Experiment A was unable to replicate these results in a sample with German adults using similar methodology. However, the sample in Experiment A indicated fewer hours of smartphone usage per day and scored on average lower regarding their smartphone addiction than in the described sample by Hartanto and Yang. It might be the case that the extent of smartphone addiction was too low to provide meaningful interference on computer tasks measuring inhibitory control under conditions of smartphone separation. Moreover, the observed trend was a reduction in interference, thus, participants' performances indicated a better inhibitory control during smartphone separation which is congruent with Ward et al. (2017).

Limitations to the interpretability of the results are uncontrolled personal variables such as intelligence or motivational factors, external motivations (most participants belonged to a convenience sample) or possible external confounds during the period the data was gathered.

Experiment B

In Experiment B, participants classified as being problematically attached reported lower anxiety after separation than before; the anxiety level for unproblematic attached participants did not change note worthily after 15 min of separation. Problematic attached participants showed a statistically significant larger disturbance in inhibitory control than non-problematic attached participants. Scrutinizing the PMPU-pathways further, a self-report measure revealed that 78% of the participants categorized themselves as Antisocial-Impulsive, 21% as Excessive-Reassurance and only one participant chose the Extraversion pathway. The overall scores on the SAT-S were statistically significantly higher for participants classified as problematic attached than for unproblematic attached participants. Moreover, associations between the proposed PMPU-pathways, as indicated by the SAT-S, and established instruments measuring constructs which are assumed to belong to the proposed classification were explored. For participants categorizing as Impulsive-Antisocial there was evidence supporting that the extent of problematic smartphone use correlates positively with FoMO. The strength of this relationship was of medium-sized. Lastly, the relationship between the degree of problematic smartphone attachment and relationship anxiety for participants classified as belonging to the Excessive-Reassurance pathway was of large size.

In Experiment B participants had to focus on reading a neutral short story while they were separated from their mobile device. This distraction could explain the decrease in anxiety for problematic smartphone attached participants after a separation period. Cheever et al. (2014) stated that working on a task during the smartphone separation might buffer against the anxiety evoking effects. Since there was no change in anxiety for unproblematic attached participants, this line of reasoning seems plausible.

The experimental setup included a design in which the smartphone was not visible and not accessible for the participants and additionally provided two cues to increase the salience of the inaccessibility. In previous research it was shown that spatial distance and location plays a significant role in how the separation period is perceived if there is a strong reliance on the mobile device (Johannes et al., 2019). In accordance to Ward et al. (2017), cognitive capacity was increased the more distant the

smartphone was from its owner. Hence, given the larger state anxiety of problematic attached participants before separation and the reduction of state anxiety after the separation period, the cues could have acted as a reassuring reminder for participants that their smartphone is out of sight but only temporarily inaccessible.

To allow a classification of the problematic smartphone attached population, a self-report measure was developed to capture the most dominant PMPU-pathway as proposed by Billieux et al. (2015). Except for the subscale Excessive-Reassurance for which adequate internal consistency was found, the internal consistencies for the Extraversion and Impulsive-Antisocial subscales were insufficient. However, the scores belonging to the Excessive-Reassurance and Impulsive pathway types in the developed questionnaire were substantially higher for problematic attached participants than for unproblematic attached ones. Thus, the SAT-S shows promise, though it needs further substantial rework to allow valid classification of the dominant pathway type.

Billieux et al. (2015) mention, that a clear assignment to one of the pathways is not always possible due to an overlap in the associated constructs. Since there was no evidence for participants belonging to the Extraversion pathway, this could mean that the SAT-S was unable to capture the true nature of the pathway and not necessarily implies that this pathway does not exist. The positive association between FoMO and Impulsive-Antisocial pathway and the strongly positive association between Excessive-Reassurance pathway and attachment anxiety is providing supplementary evidence for the existence of the two proposed pathways and benefits future model reworks.

General Discussion

In summary, there was evidence that addicted smartphone users already suffer from an increase of anxiety after a smartphone separation period of 20 min, when there is no distraction during the waiting period. The data showed a reduction in anxiety when problematic attached participants were separated from their smartphone and provided with a task while waiting. There was no evidence that a mere smartphone separation without some prior form of attachment leads to an increase in anxiety or a disturbing effect on inhibitory control. Yet, problematic attached smartphone

users showed a larger cognitive interference in Experiment B. Although not reaching statistical significance it is noteworthy that the response times of problematic attached participants in the Stroop task was better in the congruent condition than for unproblematic attached participants.

In both experiments, the developed self-report measures revealed that (except for one person in Experiment B) participants did not classify themselves as belonging to the Extraversion pathway (Billieux et al., 2015). Besides the already discussed internal consistency issue of the developed measure, behaviors belonging to the Extraversion pathway, such as actively seeking recognition and appreciation could, due to its arguably less societal approved form of behaving in the digital world, represent a social desirability issue that people either do not want to admit or are incapable to reflect on. The importance to consider the specific type of attachment between smartphone and owner should be considered when it comes to the development of viable treatment options for people suffering from problematic smartphone behavior implications.

One of the limitations of this study was the unavailability of a physiological measure for anxiety. The STAI is a self-report measure and although autonomic arousal might not match individuals feeling states, further research can benefit from an experimental setup with physiologic measurements such as skin conductance or heart rate. This goes hand in hand with an overall reliance on self-report measures since participants might have under- or overestimated their smartphone usage or smartphone behavior. Although this study was conducted with adults and not with adolescents, as it is the case for most research focusing on this topic, the study sample was still very young, so generalizations to an older population are not recommended.

Conclusions

This study aimed at understanding the specific nature and implications of smartphone separation by distinguishing between dysfunctional forms of attachment. The first experiment provided further evidence that for addicted users a short-term smartphone separation of 20 min can already lead to increased state anxiety. However, detrimental effects on inhibitory control following smartphone separation were inconclusive. The second experiment revealed that a task provided within a separation period of 15 min might have a buffering effect against an increase in anxiety for

problematic attached smartphone users. Additionally, classifying problematically attached smartphone users based on the PMPU-pathways (Billieux et al., 2015) by a self-developed questionnaire showed that 78% of the participants categorized themselves as Antisocial-Impulsive, 21% as Excessive-Reassurance and only 1% indicated to belong to the Extraversion pathway. Overall, this study provides additional data to design further studies to clarify parts of the heterogeneous landscape of problematic mobile phone attachment research and to develop tailored interventions for people suffering from it.

Ethical considerations

The authors have completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

Conflicts of interests

The authors declare that there is no conflict of interests.

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

Appendix

Smartphone Attachment Type Scale

I) Structured Questionnaire

Answer format 5-Likert Scale

1. I do not agree at all
2. I do not agree
3. neither nor
4) I agree
5) I totally agree

Instruction for the subject:

Below you will find statements that describe a daily use of the smartphone. Please indicate for each statement to what extent it applies to you. For this purpose, a scale from 1 (I do not agree at all) to 5 (I totally agree) is available with corresponding anchors. Please indicate the number that reflects the degree of your consent. The term *important reference persons* refer to friends, family members and partners.

1. I send text messages/messages to important reference persons more often during the day to assure that they are doing well.
2. I mainly use my smartphone to maintain relationships with important people in my life.
3. If I had a particularly positive/enjoyable experience, I would like to report it immediately to important reference persons.
4. Sometimes I use my smartphone in inappropriate situations (e.g. during a divine service, in the cinema/theater/opera, in a lecture, during a date).
5. I respond automatically to SMS/messages/posts on social networks and reply without further consideration.
6. Positive comments among my posts on social networks help me to feel better.
7. Sometimes I use my smartphone while driving (e.g. reading/writing SMS/messages).
8. I often use my smartphone longer than I intended.
9. I use my smartphone most often to communicate with important reference persons.
10. If I have nothing to do or when I am bored, I like to play with my smartphone.
11. If I play something on my smartphone or gamble, I can continue for hours.
12. If an important reference person does not contact me or is not responding to my messages for a longer time, I feel neglected by them.
13. I am very interested in building new relationships/contacts with other people through social networks and instant messengers.
14. Sometimes I send erotic pictures of me or send messages with sexual allusions to my partner or potential sexual partner.
15. I get restless when I cannot reach important people immediately via their mobile phone.

II) Forced Choice Questions

Answer format: Forced Choice

Next to each of the three statements is a box. Only one of the boxes can be ticked and one answer must be indicated.

Instruction for subjects:

Please read the following short descriptions and check the ones that most closely apply to you:

1. I mainly use my smartphone to maintain relationships with important people in my life.
2. If I have nothing to do or when I am bored, I like to work with my smartphone.
3. I use my smartphone mostly to communicate with important reference persons and build new relationships

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