# Mobile attachment: Separation from the mobile induces physiological and behavioural stress and attentional bias to separation-related stimuli

**Article** *in* Computers in Human Behavior · February 2017

DOI: 10.1016/j.chb.2017.02.002

**This is the final version of the manuscript sent to journal for publication after acceptance. Note the final printed version might be different from this one due to the editing process.**

**The full citation:**

**Konok, V., Pogány, Á., Miklósi, Á. 2017. Mobile attachment: Separation from the mobile induces physiological and behavioural stress and attentional bias to separation-related stimuli. Computers In Human Behavior, 71: 228-239. doi: 10.1016/j.chb.2017.02.002**

**Mobile attachment: Separation from the mobile induces physiological and behavioural stress and attentional bias to separation-related stimuli**

Veronika Konok[1], Ákos Pogány[2], Ádám Miklósi[1,2]

*1*: MTA-ELTE Comparative Ethology Research Group, Pázmány P. s. 1/c, H-1117 Budapest, Hungary
*2*: Department of Ethology, Eötvös Loránd University, Pázmány P. s. 1/c, H-1117 Budapest, Hungary

Correspondence concerning this article should be addressed to
Veronika Konok
MTA-ELTE Comparative Ethology Research Group, Pázmány P. s. 1/c, H-1117 Budapest, Hungary
Tel: +36-1-381-2179; fax.: +36-1-381-2180.
E-mail address: konokvera@gmail.com

Abstract

Humans have a biological predisposition to form attachment to social partners. This attachment, however, is not restricted to humans: non-human and inanimate targets are often involved. People are increasingly engaged with their mobiles but whether their behaviour toward these devices can be regarded as an attachment behaviour has not yet been experimentally tested.

Here we hypothesized the existence of mobile attachment. We expected people to seek the proximity of the mobile and give stress response upon separation from it, which manifests both at behavioural and physiological level. We also predicted that separation from the mobile should induce specific separation-related emotions, which leads to increased attention to separation-related stimuli. We applied a version of the Strange Situation Test using a mobile phone, with behavioural, physiological, cognitive and self-report measures, and the emotional Stroop test. Additionally, we constructed a questionnaire to self-assess mobile attachment.

Separation from the mobile induced behavioural and physiological stress, proximity seeking behaviour, and an attentional bias to separation-related stimuli for participants with higher mobile attachment. These effects were only observable when no other mobile was present. According to the questionnaire, secure base and safe haven are also relevant aspects of attachment to a mobile.

These results support that humans form attachment toward their mobile which is similar to social attachment. This could emerge by cultural recycling of the attachment system's evolutionary structures.

keywords:
mobile phone, cell phone, human-mobile interaction, attachment, separation, attentional bias

# 1 Introduction

According to Bowlby (1969), humans and many animal species are born with an attachment system that motivates them to maintain proximity to the parent. In contrast to many animal species, this system in humans plays an important role also in adulthood and in different kinds of relationships (Fraley, Brumbaugh, & Marks, 2005; Markiewicz, Lawford, Doyle, & Haggart, 2006). Fraley (Fraley et al, 2005; Fraley & Shaver, 2000) assumed that in these cases, the attachment system has been 'co-opted' by natural selection to serve other survival and/or reproductive functions. Furthermore, people often develop attachment even toward non-human targets, e.g. companion animals (Archer & Ireland, 2011; Zasloff & Kidd, 1994), places (Scannell & Gifford, 2010) or material objects (Cipriani & Kreider, 2009; Myers, 1985). In all forms of attachment, the proximity of the attachment figure provides a sense of security to the individual, a secure base for exploring the environment and a safe haven in stressful situations so that the separation from it results in separation anxiety (Bowlby, 1969; Hazan & Shaver, 1994).

Attachment to material objects has rarely been studied, and such behaviour in adulthood has long been considered pathological (Hooley & Wilson-Murphy, 2012; Winnicott, 1971). However, there is evidence in support that healthy, well-functioning adults also report significant emotional attachment to special objects (Myers, 1985; Wapner, Demick, & Redondo, 1990). The possession of these objects seems to be soothing in times of stress (George, 2013) and contributes to greater psychological health (Wiseman & Watt, 2004).

One of the most prevalent material objects of modern society is the mobile phone. The number of active mobile subscriptions exceeds the total world population (Ericsson, 2014). Young adults in the USA use their mobile for 5.2 hours a day (Salesforce Marketing Cloud, 2014). Researchers assume that excessive mobile usage can become an addiction as it is accompanied by features including withdrawal, tolerance, etc. (Walsh, 2014). However, mobile addiction is not currently an accepted diagnostic category (it has not been included in the DSM-5; American Psychiatric Association, 2013). Additionally, there is neither a standard measure for this type of addiction nor a consensus about terminology (terminology includes "mobile addiction": Davazdahemami, Hammer, & Soror, 2016; "mobile dependence": Toda, Monden, Kubo, & Morimoto, 2006; "problem mobile use": Bianchi & Phillips, 2005).

Besides these concerns, some degree of dependence on the mobile seems to be a general and increasingly prevalent phenomenon. For example, 79% of smartphone owners keep their mobile with them for all but two hours of their hours awake (Levitas, 2013). About two thirds of mobile users report distress on being separated from their mobile ("nomophobia": Bivin, Mathew, Thulasi, & Philip, 2013) and this proportion is even higher in young adults (Sharma, Sharma, Sharma, & Wavare, 2015). Such data suggest that certain dependence on mobiles is not an extremity or a disorder but a normative phenomenon, which may have biological basis and function.

Konok, Gigler, Bereczky and Miklósi (2016) proposed that our relationship with the mobile phone is an object attachment, as it shares the main features of social attachment: proximity seeking, separation anxiety, secure base and safe haven (Bowlby, 1969). Utilising a questionnaire, Konok et al. (2016) showed that young people seek the proximity of their mobile and experience distress upon separation. Clayton, Leshner, and Almond (2015) demonstrated that experimental separation from a mobile resulted in increased anxiety; however, participants could experience anxiety not only because of the mere fact of separation, but because they were prevented to answer their phone that the experimenters rang during separation. Cheever, Rosen, Carrier, and Chavez (2014) also separated participants from their mobile but separation anxiety did not increase compared to the control condition.

Thus, although people report distress upon separation from their mobile (Bivin, Mathew, Thulasi, & Philip, 2013; Konok et al., 2016), we have no experimental data to support this.

Here we test the hypothesis that mobile attachment exists, and address whether the main features of social attachment (secure base and safe haven effect) are relevant to our attitudes and behaviour toward our mobiles. We also test whether the presence of an unfamiliar mobile affects separation anxiety from an individual's own mobile.

## 1.1 Hypotheses

We hypothesized that humans show similar attachment to their mobile phone as towards people. To investigate this hypothesis, we used multiple research approaches: self-report questionnaires and experimental assessments of mobile attachment. For the latter, we applied a modified version of Ainsworth's Strange Situation Test (Ainsworth, Bell, & Stayton, 1971), where we manipulated not only the presence of the participants' own mobile (attachment figure), but also the presence of an unfamiliar mobile (the test is called 'mobile SST' henceforth). Separation anxiety was assessed by self-reports, and cognitive performance, non-verbal behaviour and physiological responses (heart rate and heart rate variability) during behavioural tests. In addition, attentional bias to separation-related words was tested in an emotional Stroop test (Bentall & Kaney, 1989) to investigate whether anxiety is driven by separation.

From our research hypothesis, we predicted the followings for the questionnaire and the mobile SST:

Prediction for the questionnaire:
The main features of human social attachment (proximity seeking, separation anxiety, secure base and safe haven) are relevant to mobile attachment, so that these should emerge as principal components of a mobile attachment questionnaire.

Predictions for the mobile SST:
Participants separated from their mobile should show more anxiety than participants not separated from their mobile. In particular, we expected separated participants to report higher levels of anxiety, and perform worse in the cognitive task because anxiety interferes with attention (Egloff & Hock, 2001; Eysenck, Derakshan, Santos, & Calvo, 2007). Furthermore, we expected separated participants to show more non-verbal stress behaviour (displacement activity) and approach more frequently the place of their separated mobile (proximity seeking behaviour) than those not separated. Regarding the physiological responses, we expected separated participants to have higher and less variable heart rates, with frequency distributions characteristic to physiological stress (i.e. higher power in the lower frequency and lower power in the higher frequency bands, cf. Delaney, 2000).

In addition, we expected separated participants to react slower to separation-related stimuli in the emotional Stroop test than unseparated participants. Emotionally relevant stimuli require more attentional resources (MacLeod, Mathews, & Tata, 1986) and therefore, decrease participant's performance on tasks where the processing of such information is irrelevant for the task. In the Stroop test, specifically, the processing of the words' meaning interferes with the task (i.e. identifying the colour of the word). Thus, participant's performance is weaker for words which are connected to their emotional disturbances or actual emotional state (e.g. Thorpe & Salkovskis, 1997; MacLoad & Rutherford, 1992).

Based on human attachment research (Spangler & Grossmann, 1993; Spangler and Schieche, 1998), we also predicted that the presence of an unfamiliar mobile in separated participants should result in a reduced level of anxiety for all of the above behavioural and physiological responses (i.e. we expected intermediate responses between full separation and no separation).

## 2 Method

### 2.1 Participants

To determine sample size, we performed power calculations using the effect size obtained in a comparable recent study on the effects of mobile phone separation (Clayton et al, 2015). We determined that our sample would require 88 individuals (22 per condition); however, we tested additional subjects in order to compensate for potential data loss or exclusion of individuals/subtests. The participants were 93 Hungarian university students (42 men and 51 women, median age: 21 years (range: 18-26 years). This age group was chosen because they are considered to be "cell phone natives" (Forgays, Hyman, & Schreiber, 2014), therefore we expected that mobile attachment will be most pronounced in this age group. Eighty-seven of the 93 participants (94%) had a smartphone, and participants had possessed their actual mobile for 0.5-86 months (median: 15 months). The participants were studying at different universities and came from a variety of fields of interests. We recruited the participants by the means of poster advertisements, flyers, and Facebook posts and they received a small compensation for their participation (soft drink/beer and chocolate).

### 2.2 Materials and procedures

#### 2.2.1 Test room

The experiments took place in the Laboratory of the Department of Ethology, Eötvös Loránd University, Budapest, Hungary. The test room (Fig. 1) was furnished with everyday objects, including a table, a chair, a cupboard and a beanbag chair. On the table, there was a laptop, some newspapers and a plush animal. There was a poster on the wall and there were two toy animals on the cupboard. Test sessions were video-recorded using four digital cameras to cover participants from various angles. Following the behavioural tests, we asked participants to fill out the questionnaires in the adjacent room, using a PC.

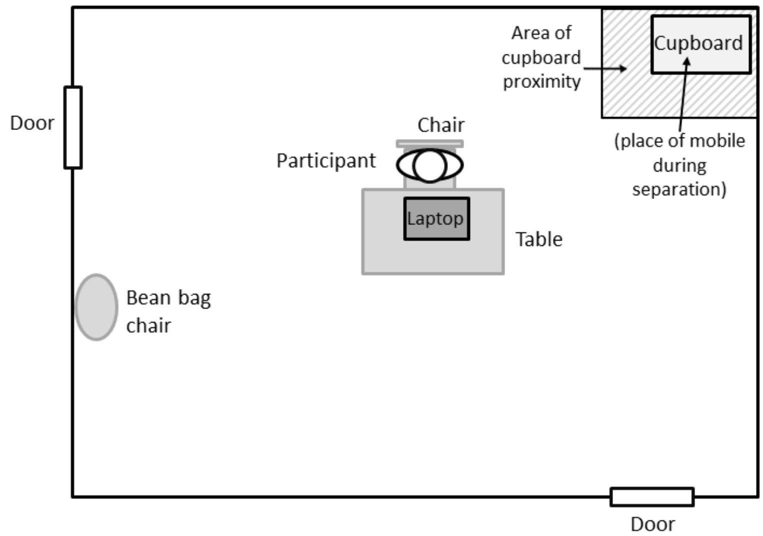



**Figure 1 Layout of the testing room (top view, not drawn to scale)**

#### 2.2.2 Experimental design

For the behavioural tests (Mobile SST), we used a between-subject factorial design with two treatments (own mobile and unfamiliar mobile) each with two levels (present or absent; Table 1). Participants were assigned randomly to the experimental conditions (groups).

#### 2.2.3 Experimental procedure

Participants sat on a chair in the test room in front of the computer. They remained sitting there during the whole test, except for the waiting period (see below). A general description about the study's aim and procedure was given verbally by the experimenter and also on a written information sheet. Both were purposely misleading: participants were told that the experiment's aim was to test a new wireless heart rate monitor, and to observe how heart rate changes with various cognitive tasks. Misleading the participants was necessary to obtain realistic results and participants were informed in advance of the possibility that they may be misled in the informed consent.

Participants were equipped with a heart rate monitor chest strap (see later), which they wore until the end of the experiment. Participants were then asked to do the first set of calculations (consisting of three calculations, see later) on a paper, within one minute. Before the first set of calculations, the participants were informed that they were allowed to use the calculator of their mobile. No further encouragement was needed, and all participants made use of the calculator function of their mobile.

After completing the first set of calculations (or after one minute, whichever was reached first), the following information was provided to them: "That was the warm-up, and now the real test will begin, where we will also measure your performance. In order for the test to be standardised, that is, assuring it is the same for everybody, you will not be allowed to use your phone, but you will get another phone/calculator [depending on the experimental group, see Table 1], that everybody will use for the task." Then the experimenter either asked for the participants' mobile and put it in the cupboard (Group 1 and Group 2), or left it with the participants on the table (Group 3 and Group 4). In the latter two groups, if the participants had put the mobile in his/her pocket or bag after the calculations, then the mobile was left there. Next, the experimenter provided a calculator (Group 1 and 3), or an unfamiliar mobile (Group 2 and 4) for the participants from the cupboard. Participants had one minute to complete the second set of calculations (again consisting of three calculations) with the new instrument (calculator or unfamiliar mobile). Until the end of the behavioural test participants were left with or without their own mobile and with the new device (calculator/unfamiliar mobile; depending on the group).

| | **Without unfamiliar mobile** | **With unfamiliar mobile** |
|---|---|---|
| **Without own mobile** | Group 1<br>N = 23; 13 men, 10 women;<br>age median[min-max]:<br>22[18-25];<br>calculator | Group 2<br>N = 24; 9 men, 15 women;<br>age median[min-max]:<br>20 [18-25];<br>unfamiliar mobile |
| **With own mobile** | Group 3<br>N = 23; 12 men, 11 women;<br>age median[min-max]:<br>21[19-25];<br>calculator | Group 4<br>N = 23; 8 men, 15 women;<br>age median[min-max]:<br>21 [19-26];<br>unfamiliar mobile |

**Table 1 2x2 factorial design of the Mobile SST. Number, age and gender distribution of participants are provided. For each experimental group the device listed in the table was used for the second set of calculations.**

After completing the second set of calculations, the participants were told to wait alone for a couple of minutes while their baseline heart rate was recorded. During this waiting period, they were allowed to do anything in the room until a sound signalled that they should start filling in the tests using the computer. A computer program (developed by Richárd Magócsi) presented the tasks and recorded the answers and the heart rate data (see later). Subsequent tasks started automatically as soon as the previous task had been finished. For each task instructions were provided on the screen, so that no verbal instructions were given. The tasks included the state anxiety measure of the short Spielberger State-Trait Anxiety Inventory, a word search puzzle, and the emotional Stroop test (see below).

The behavioural test ended after the participants had finished the three tasks on the laptop. The experimenter went back to the participant, removed the heart rate monitor and asked a few questions to check whether the participant had any idea about the real aim of the study (see Appendix A). Then the experimenter escorted the participants to another room, where they were asked to fill out the Mobile Attachment Questionnaire (see below) online, using another computer.

#### 2.2.4 Experimental tools and tasks applied during the behavioural test (Mobile SST)

**Calculations** (see Appendix B): the calculation tasks included basic calculations (adding, subtracting, multiplying, and dividing), however, the calculations were difficult to perform without a calculator because they involved multiple operations with 2- or 3-digit numbers. Calculation tasks were used as a deceit i.e. to give a believable reason for taking away the mobile from the participants; performance on these tasks was not analysed. There were two sets of calculations (A and B) used in a random order.

**Short form of the Spielberger State-Trait Anxiety Inventory** (STAI; see Appendix C; Spielberger, Gorsuch & Lushene, 1970; Hungarian adaptation: Sipos & Sipos, 1978; short form: Marteau & Bekker, 1992): we used the state anxiety measure with a continuous rating scale during the experiment.

**Word search puzzle** (based on the method of Clayton et al., 2015): we generated eight word search puzzles using an online generator at http://puzzlemaker.discoveryeducation.com. Each word search puzzle consisted of 15 columns and 15 rows containing 13 words. In both the pre-tests and the real tests, participants had 2 minutes to find as many words (listed next to the tables) as they could. The words in each puzzle belonged to different topics. The eight puzzles were tested for equal difficulty with a sample of university students and workers that differed from the test population ($N = 64$, 8/puzzle). From the eight puzzles available, we selected three with similar difficulties (where the mean number of words found during the tests were not significantly different; Kruskal-Wallis test; $\chi^2\,[2; N = 24] = 0.23$; $p = 0.89$). These three puzzles contained words on plants, animals and countries.

**Emotional Stroop test** (e.g. Bentall & Kaney, 1989): During this task, different words were presented one-by-one on the computer screen. The colours of the words were randomly chosen from the following four colours: red, blue, green and yellow. Participants were instructed to indicate the colour of the word – as fast as possible – by pressing a key on the keyboard marked with a sticker with the respective colour (the four keys that had to be used were the same, but we changed the colour they represented between the tests randomly). Reaction time and the colour identification success for each word were measured using a function of the computer program that presented the tasks to the participants. The task consisted of four blocks, each of them including 10 words, so in total, 40 test words were shown to the participants. The order of the words within a block and the order of the four blocks were randomized. Before the test, participants practiced with 20 neutral words. So in total, 60 words were shown to each participant, but only the data of the 40 test words were analysed.

The four blocks differed regarding the topic and valence of the words, in order to assess whether attentional bias occurs specifically to separation-related stimuli, or to any other type of negatively valenced stimuli. Thus, one block contained negative, separation-related words (e.g. loneliness, divorce); one block contained general negative words (e.g. lie, hell); another block contained physical threat words (e.g. faint, infection) and one block contained neutral words (e.g. scanner, quotation). The neutral and the general negative words were selected from a 480-word pool used by Simor, Pajkossy, Horváth, & Bódizs (2012). Separation-related and physical threat words were collected from the literature (e.g. Asmundson, Sandler, Wilson, & Walker, 1992; Lundh & Czyzykow-Czarnocka, 2001). The collected words (N = 115; 20 separation-related, 22 physical threat, 25 general negative, and 48 neutral words) were rated for valence by laypersons not involved in the tests (N = 154, each was randomly assigned approximately 45 words from the 115 to rate; resulting in approximately 50 ratings per word). In addition, psychologists (N = 57) rated the words for their relevance for separation and physical threat (each was randomly assigned approximately 50 words from the 115 to rate, resulting in approximately 30 ratings per word).

The final words of the four blocks were selected to be matched with respect to word length category (three levels based on number of syllables) and word frequency, and the three negative blocks with respect to valence. Word frequency was determined by means of an application (http://szotar.mokk.bme.hu/szoszablya), which provides the frequency of Hungarian words based on a database built from texts on the internet. Forty test words and 20 practice words were selected based on the ratings of word frequency and word length (see Appendix D for the English translation of the words). The four blocks did not differ in word frequency (Kruskal-Wallis test; $\chi^2$ [3; $N$ = 40] = 0.28; p = 0.96) or word length (Chi-square test of independence; $\chi^2$ [6; $N$ = 40] = 5.35; p = 0.50), and the three negative blocks did not differ from each other in valence (Kruskal-Wallis test; $\chi^2$ [2; $N$ = 30] = 0.19; p = 0.91), but all of them differed from the neutral block (Mann-Whitney tests; all $p < 0.001$). Separation-related words differed from all the other blocks with regards to their relevance to separation (Mann-Whitney tests; all $p < 0.001$), and physical threat words differed from all other blocks with regards to their relevance to physical threat (Mann-Whitney tests; all $p < 0.001$).

**Heart rate measurement**

We used a Garmin ANT+ Heart Rate Monitor (Part No.: 010-10997-00) with an ANT+ USB stick (Part No.: 010-01058-00) to measure heart rate (both devices produced by Garmin International, Inc., Olathe, USA). The Heart Rate Monitor senses the R waves of the QRS complex of the heart's electrical activity, and sends the signals in terms of R-R intervals to an USB stick connected to the laptop, using ANT short-range wireless technology. R-R interval data were analysed using the Kubios HRV 2.2 software with the built-in option for correcting artefacts (R-R intervals which were at least 0.3 sec smaller/larger than the local mean R-R interval were detected as artefacts). As motion can influence heart rate (Bernardi, Valle, Coco, Calciati, & Sleight, 1996), only the relatively motionless periods when subjects completed the tests (STAI, word search puzzle and Stroop) were analysed. We computed the following time and frequency domain parameters to measure sympathetic/parasympathetic activity: (1) mean heart rate (bpm), (2) heart rate variability (SDNN), (3) relative power of the very low frequency ("VLF": 0-0.04 Hz), (4) low frequency ("LF": 0.04-0.15 Hz), (5) high frequency ("HF": 0.15-0.4 Hz) bands and (6) LF/HF ratio.

**Behaviour coding**

Participants' behaviour during the waiting period (3.5 minutes) was coded by the first author using Solomon Coder beta 15.11.19 (developed by András Péter, 2015). Displacement activities (self-contact; see Troisi, 2002), proximity seeking and maintaining behaviours toward the mobile and exploration was coded as defined in Table 2. To assess interrater reliability, a second coder coded eight test videos (two from each experimental group). Interrater reliability was very good for all variables (Cohen's κ was between .75 and 1).

Following behavioural coding, the proportion of the waiting period spent on the given behaviour was analysed.

| Category | Behavioural element | Definition |
|---|---|---|
| Contact | Own mobile contact | Contact with own mobile using hands |
| | Unfamiliar mobile contact | Contact with unfamiliar mobile using hands |
| | Cupboard contact | Contact with the cupboard using hands |
| Looking/exploring | Own mobile look | Looking at own mobile |
| | Cupboard look | Looking at the cupboard |
| | Explore | Looking at anything in the room (e.g. poster) except for the mobiles, the calculator, the newspapers and the cupboard |
| | Newspaper | Reading the newspapers |
| Proximity | Cupboard proximity | Within 60 cm of the cupboard (tiles on floor used as markers)[a] |
| | Own mobile proximity | Within 100 cm of the mobile (except for when the mobile was in the pocket or bag of the participant, which were excluded)[b] |
| Stress behaviour (displacement activity) | Self-contact | Any dynamic contact with own body (e.g. scratching, arranging hair, etc.); static body postures (e.g. arms rest in the lap of the subject) were not coded |

**Table 2 Definitions of behaviours coded during the waiting period. [a]60 cm was used as proximity threshold to separate walking next to the table from approaching the cupboard. [b]100 cm was used as proximity threshold to include situations when the participants sat on the chair and their mobiles were at one side of the table.**

### 2.2.5 Mobile Attachment Questionnaire (MAQ)

We constructed this questionnaire (see Appendix E) for self-assessing mobile attachment. Items were selected so that they described the main aspects of social attachment: proximity seeking, separation anxiety, secure base and safe haven (Ainsworth et al., 1971; Bowlby, 1969) with regards to the mobile, and we also included items regarding the participant's need for continuous contact with others through the mobile (based on a previous questionnaire: Konok et al., 2016). The questionnaire contained 48 items (see Appendix E for the items and the original scales they belonged to before the item-selection and principal component analysis). Participants had to rate each statement on a 5-grade scale based on how characteristic they were to them (from not characteristic at all to very characteristic).

### 2.2.6 Statistical analysis

Assumptions of statistical tests were considered prior to the analyses. Statistical analyses were carried out using SPSS (version 22.0.0). If the analysis and data required, the appropriate transformations were applied to normalise distribution.

**MAQ:** Answers from the questionnaire were processed using an item-selection procedure based on Rattray and Jones (2007). Selection resulted in keeping 46% of items (22 of 48 items were selected; for more details of item-selection, see Appendix F). Principal component analyses were conducted with Varimax rotation on the remaining items. Items that had a 0.4 or greater loading on a single component were retained (Tabachnick & Fidell, 2001).

Component scores and total score (mean of all items) were used for further analyses, and participants who did not have a smartphone were excluded (N = 6).

**Mobile SST:** The random assignment of subjects to the experimental groups was examined using One-way ANOVA, Kruskal-Wallis and Chi-square tests: we investigated whether the four groups differed in age, gender and MAQ total score.

Own mobile look, Own mobile contact and Own mobile proximity were highly correlated (Spearman's r = 0.90; 0.56; 0.56; all $p < 0.001$), so we retained only Own mobile contact for later analyses. Cupboard proximity, cupboard look and cupboard contact were also highly correlated (Spearman's r = 0.60; 0.70 and 0.81, $p < 0.001$, respectively) so we retained only Cupboard proximity. Distributions of all the behavioural responses were zero-inflated (at least 30% of the participants had zero values) and some of them included an excess of maximum values (100%) as well. The variables were therefore transformed into categorical variables with two or three values [0 and 1, or 0, 1 and 2 depending on whether non-zero values could be allocated to one or two (low and high) distinguished groups]. The transformed variables are presented in Appendix G.

For further analysis of the group differences in behavioural, cognitive (word search puzzle), self-report (STAI) and heart rate variables, we merged two groups based on the results of a post hoc analysis. This analysis showed that when their own mobile was present, the behaviour of the participants with or without the unfamiliar mobile were not different, but they behaved differently compared to the participants in the two other groups (results of this post hoc analysis are presented in Appendix H). Therefore, these two groups (Group 3 - with own mobile and without unfamiliar mobile; Group 4 - with own mobile and with unfamiliar mobile) were merged in this analysis of group differences (for the new groupings, see Table 4).

| "No Mobile" Group | "Unfamiliar Mobile" Group | "Own Mobile" Group |
|---|---|---|
| Neither the subjects own, nor the unfamiliar mobile are present<br><br>(previously: Group 1)<br>N= 21;<br>11 men, 10 women;<br>age median [min-max] = 22 [18-25] | Only the unfamiliar mobile was present<br><br>(previously: Group 2)<br>N = 24;<br>9 men, 15 women;<br>age median [min-max] = 20 [18-25] | Own mobile was present (unfamiliar mobile was present/ absent)<br><br>(previously: Group 3+4)<br>N = 42;<br>19 men, 23 women;<br>age median [min-max] = 21 [19-26] |

**Table 4 Revised grouping based on post hoc analysis. For each group the sample size is given.**

Differences in behavioural responses, test scores (STAI and word search puzzle) and heart rate measures among these new groups were analysed using One-way ANOVA, Kruskal-Wallis and Chi-squared tests.

In the Stroop test colour identification was almost perfect for each subject, so we did not analyse the data for colour matching. In the analysis of reaction time, outliers (defined as above mean + 2 SD, i.e. >1112 ms) were excluded (116 of 3116 data points, or 3.7%). Reaction times (response variable) to the 40 test words were analysed in Generalized Linear Mixed Models (GLMM) to investigate the effects of experimental group (fixed factor based on the revised grouping, Table 4), theme of the Stroop words (fixed factor), MAQ total score (covariate), as well as their two- and three-way interactions. The model also included participant ID as a random term.

**Correspondence of the MAQ and mobile SST**

We investigated whether and to what degree the results from the questionnaire (MAQ) and the mobile SST were consistent in two separate analyses, based on mobile presence. First, in separated participants (i.e. Group 1 and 2), we used Pearson and Spearman correlations and independent samples t-tests to investigate whether the attachment levels from the questionnaire (MAQ) are associated with anxiety-related variables (behavioural variables, heart rate variables, STAI score and word-search performance) from the mobile SST. We included only separated participants in this analysis because we expected association only when the mobile was absent.

Second, in unseparated participants (Group 3 and 4), we could investigate whether the attachment levels from the questionnaire (MAQ) are associated with physical contact with the mobile. Using an independent samples t-test, we compared MAQ total scores of participants contacting and not contacting their mobile.

For each statistical test, we provide effect size (e.g. $\Phi$ for chi-square, $\eta^2$ for Kruskal-Wallis and r for Mann-Whitney tests).

### 2.2.7 Ethic statement

The study was approved by the United Ethical Review Committee for Research in Psychology (EPKEB) (reference number of the approval: 57/2015).

## 3 Results

### 3.1 Mobile Attachment Questionnaire

Our prediction that principal components of the MAQ would reflect the main aspects of social attachment (proximity-seeking, separation anxiety, secure base and safe haven) was partly supported. The principal component analysis resulted in four components according to both the eigenvalues (higher than 1) and the scree plot. Items 14, 2, 30, 34, 10, 43 and 16 were removed iteratively (in the listed order) because of cross-loadings (loadings of 0.4 on more than one factor). The final version of the questionnaire contained 15 items (see Appendix E for the original, raw version and the final 15 items with their loadings on the respective principal components).

The four components (Table 5) were interpreted as *Separation insecurity* (decreased sense of security when separated from the mobile), *Separation anxiety* (increased tension or anxiety upon separation from the mobile), *Safe haven* (turning to the mobile in tense situations to decrease anxiety) and *Secure base* (being more confident/at ease in the presence of the mobile). The four components together explained 70.8% of the total variance. The internal consistency of the final version of the questionnaire was excellent (Cronbach’s alpha = 0.91). The Cronbach’s alphas for the sub-scales were 0.91 *(Separation insecurity)*; 0.76 *(Separation anxiety)*; 0.83 *(Secure base)* and 0.74 *(Safe haven)*. However, instead of sub-scale scores we used the component scores and the total score (mean of all items) in the analysis.

| | **Components** | | | |
|---|---|---|---|---|
| | ***Separation insecurity* (46%)** | ***Separation anxiety* (10%)** | ***Safe haven* (8%)** | ***Secure base* (7%)** |
| If my phone runs out of battery, I do not feel safe. | **.84** | .32 | .19 | .15 |

| | | | | |
|---|---|---|---|---|
| If I do not have my phone on me, I do not feel safe. | **.82** | .24 | .31 | .15 |
| If I leave my phone at home, I do not feel safe. | **.81** | .40 | .24 | .08 |
| If I lost my phone, I would not feel really safe for long. | **.69** | .35 | .05 | .16 |
| If I am stressed I take out my phone to calm down. | **.64** | .04 | .35 | .35 |
| If I left my phone at home, I would be willing to go home for it even from a distance (more than 5 minutes away from home). | .14 | **.74** | .27 | .11 |
| I am nervous/ tense when I leave my phone at home. | .39 | **.70** | .08 | .08 |
| It does not bother me when I leave my phone at home/ it runs out of battery. *(reverse scored)* | .27 | **.65** | -.01 | .22 |
| I am nervous/ tense when my phone runs out of battery. | .20 | **.63** | .26 | .15 |
| If I feel uneasy/tense in company, I take out my phone. | .11 | .12 | **.79** | .20 |
| In a tense situation I take out my phone. | .34 | .10 | **.79** | .19 |
| If I am nervous, dealing with my phone does not calm me down. *(reverse scored)* | .21 | .29 | **.68** | .11 |
| If my phone is in my hand, I feel more confident. | .29 | .18 | .18 | **.80** |
| I am not more confident/ easy-going if I have my phone with me. *(reverse scored)* | -.05 | .28 | .13 | **.79** |
| If my phone is in my hand, I can behave more easily/ unreserved. | .36 | .03 | .25 | **.78** |

**Table 5 Item loadings on the principal components of the Mobile Attachment Questionnaire (MAQ) and the percentage of variance explained by the components**

### 3.2 Mobile SST

The four groups did not differ in terms of age ($p = 0.19$), gender ($p > 0.25$) or MAQ total score ($p > 0.25$).

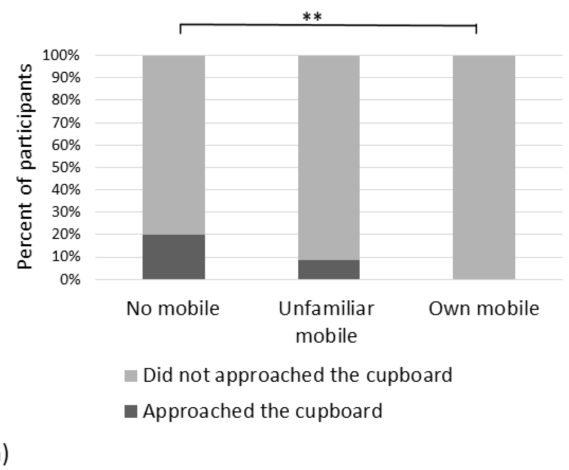
The answers to the post-experiment questions showed that none of the participants had figured out what the experiment's real aim was. Although three participants responded that the experiment was somehow related to the use of mobile phones, they were also far from revealing our research questions ( for instance, one of them replied that we wanted to measure whether the calculation task was more difficult to do using an unfamiliar than their own mobile).

#### 3.2.1 Differences between experimental groups in behaviour, cognitive performance, self-reported anxiety and heart rate parameters

We expected from separated participants to report more anxiety and show poorer cognitive performance, but we found no difference compared to unseparated participants. The three experimental groups did not differ in their STAI state anxiety score and in the number of words found in the word search task.

Separated participants, however, approached the cupboard and showed stress-behaviour (displacement activity) more often than unseparated participants. The three groups differed in the proportion of participants who approached the cupboard (Chi-square test; $\chi^2$ [2, $N$ = 85] = 8.39, p = 0.015; Φ = 0.31) and in the proportion who showed displacement activity ($\chi^2$ [2, $N$ = 85] = 8.6; p = 0.014; Φ = 0.32; Fig. 2). Post hoc Chi-square tests showed that in the „No Mobile" Group more people approached the cupboard than in the „Own Mobile" Group ($\chi^2$ [1, $N$ = 62] = 8.98, p = 0.003; Φ = 0.38). Additionally, more participants showed displacement activity in the „No Mobile" Group than in the „Own Mobile" Group ($\chi^2$ [1, $N$ = 62] = 4.1; p = 0.04; Φ = 0.26), and in the „Unfamiliar Mobile" Group ($\chi^2$ [1, $N$ = 43] = 8.5; p = 0.004; Φ = 0.45). Participants' behaviour in "Own Mobile" and "Unfamiliar Mobile" conditions did not differ significantly.

We found no group differences in exploration and reading the newspapers (p = 0.17 and 0.24, respectively).



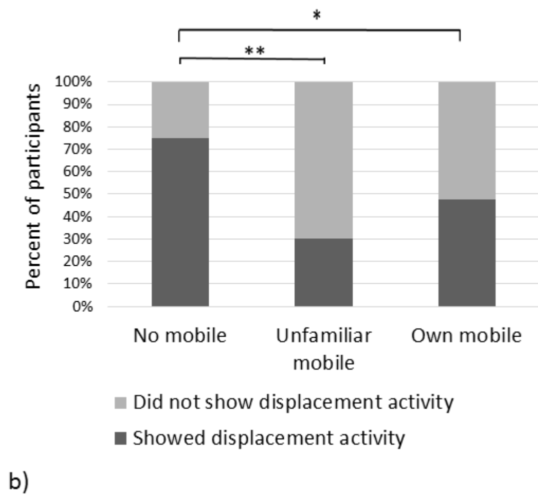




**Figure 2 Percentage of participants (a) that approached the cupboard and (b) showed displacement activity (self-contact) in the three experimental groups. One asterisk indicates significant difference at p < 0.05, whereas two at p < 0.01 level.**

We found partial support for our prediction that separated participants would have a higher and less variable heart rate, with higher power in the lower frequency and lower power in the high frequency bands. The three groups did not differ in mean heart rate and heart rate variability (SDNN), relative power of LF and VLF bands and LF/HF ratio (all p > 0.18). However, experimental groups were different in the relative power of the HF bands (Kruskal-Wallis test: $\chi^2$ [2, $N$ = 83] = 6.58; p = 0.037) and the relative power of VLF band also showed a non-significant difference (One-way ANOVA; F [2, 80] = 2.69; p = 0.074; Fig. 3). Post hoc Mann-Whitney and t-tests showed that in the "No Mobile" Group the relative power of the HF band was lower than in the "Own Mobile" Group (U = 240.50; p = 0.012; r = 0.39), and in the "Unfamiliar Mobile" Group (U = 149.00; p = 0.048; r = 0.35). Additionally, the relative power of the VLF band was higher in the "No Mobile" Group than in the "Own Mobile" Group (t[58] = 2.07; p = 0.048; d = 0.55). Heart rate indices in the "Own Mobile" and "Unfamiliar Mobile" conditions did not differ significantly.

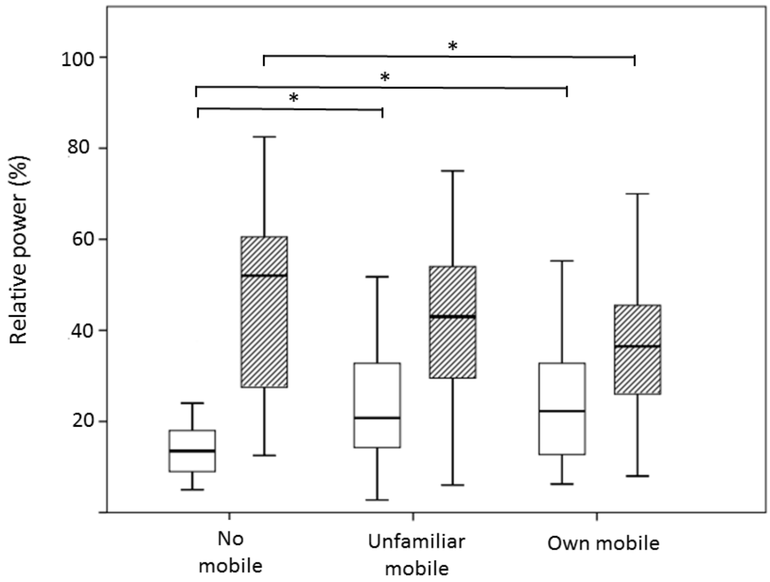



**Figure 3 The relative power of the high frequency (HF; white boxes) and very low frequency (VLF; striped boxes) bands in heart rate variability in the three experimental groups. Asterisks indicate significant differences at $p < 0.05$ level.**

### 3.2.2 Emotional Stroop Test

We expected separated participants to show an increased attentional bias to separation-related stimuli and higher interference with performance on the Stroop test. For participants who had a higher self-reported mobile attachment (MAQ), we found support for this prediction. The GLMM showed that there was a significant three-way interaction between experimental group, MAQ total score and theme of the words on reaction time ($F[6; 2858] = 2.23$; $p = 0.037$).

To reveal the causes of this three-way interaction, we analysed the two-way interactions of experimental group and MAQ separately for each theme. We found that neither MAQ, nor experimental group, nor their interaction had an effect on reaction time in case of neutral (GLMM; all $p > 0.25$), general negative (all $p > 0.08$) and physical threat words (all $p > 0.15$).

However, in case of separation-related words, the interaction of MAQ and experimental group had a significant effect on reaction time (GLMM; $F[2, 721] = 3.34$, $p = 0.036$; Fig. 4, Table 6).

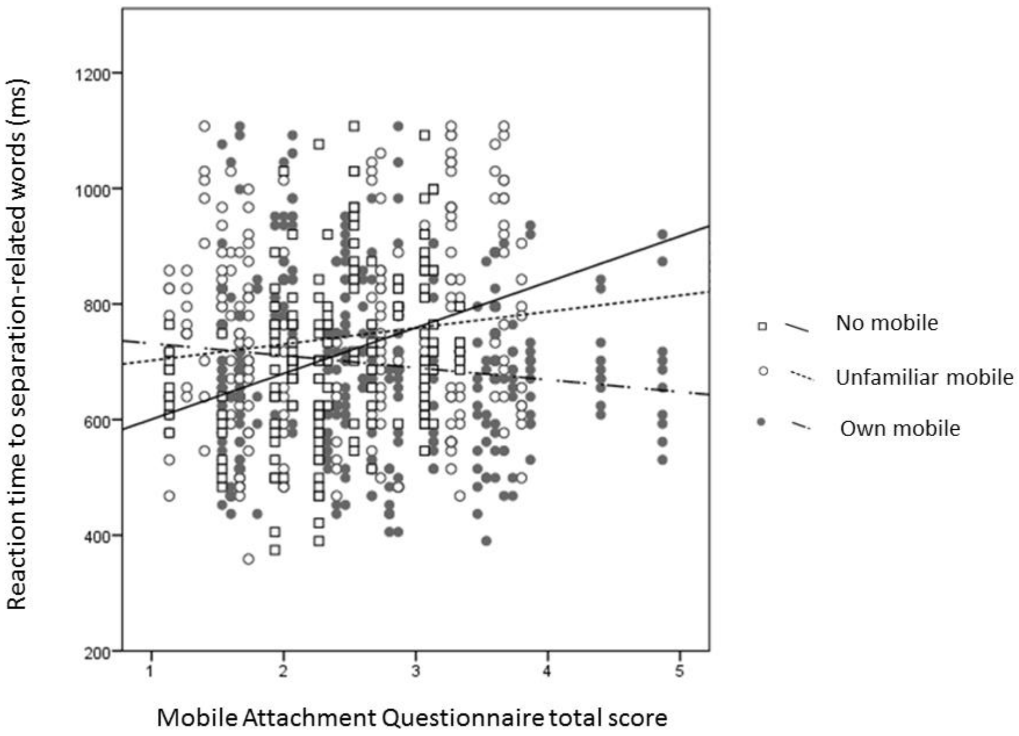



**Figure 4 Relationship between self-reported mobile attachment (MAQ) total score and reaction times to the separation-related words in the Stroop test, separately in the three experimental groups. The relationship between the two variables was significant only in the case of the "No Mobile" Group (GLMM).**

| Parameter | Parameter estimate ± SE | 95% CI | t | p |
|---|---|---|---|---|
| MAQ score * EG [Own Mobile → Unfamiliar Mobile] | 45.08 ± 28.54 | [-10.95; 101.12] | 1.58 | 0.12 |
| MAQ score * EG [Own Mobile → No Mobile] | 100.83 ± 41.94 | [18.49; 183.18] | 2.40 | 0.02 |

**Table 6 Results of the generalized linear mixed model (GLMM) with *reaction time in the Stroop test* as dependent variable, experimental group (EG) as fixed factor and Mobile Attachment Questionnaire (MAQ) total score as covariate. Only the statistics for the interaction of experimental group and MAQ score are presented (changes between levels of the given variable are indicated in squared brackets).**

When analysing the MAQ total score's effect on reaction times to separation-related words separately in the three groups, we found that in the "No Mobile" Group participants with higher MAQ had higher reaction times ($F[1,176] = 3.90$; $p = 0.05$; parameter estimate ± SE = 76.82 ± 38.91; 95% CI = [0.03; 153.61]), while in the "Unfamiliar Mobile" and "Own Mobile" groups MAQ had no significant effect on reaction time ($p > 0.25$ and $p = 0.19$, respectively). Therefore, as we predicted, the increased attentional bias to separation-related words for highly attached participants was only observable in the case of full separation from any mobile phone, but not when an unfamiliar mobile was present.

### 3.3 Correspondence of the questionnaire and the mobile SST

Our prediction that the MAQ would show significant associations with variables in the behaviour test was only partly supported. In those groups where the participant's own mobile was absent, only higher state anxiety (STAI) was associated with higher mobile attachment (MAQ) score ($r_s$ [44] = 0.40, $p < 0.01$; 95% CI = [0.12, 0.64]). Heart rate parameters, displacement activity (self-contact) and proximity to the cupboard showed no association with MAQ (all $p > 0.25$). In those groups where the participant's own mobile was present, those that contacted and those that did not contact their own mobile did not differ significantly in their MAQ score ($t[40] = 1.33$, $p = 0.19$; $d = 0.41$).

## 4 Discussion

### 4.1 Mobile SST

The results of the Mobile SST support that humans form attachment toward their mobile: they seek the proximity of the mobile and show stress response upon separation. First, separation from the mobile in the Mobile SST induced self-contact behaviour (also called as displacement activity; Sevenster, 1961) which was previously reported to correlate with stress/anxiety in humans (Triosi, 2000).

Separated individuals also had different heart rate responses compared to unseparated participants. Different frequency distributions were observed in their heart rate variability: lower power of the HF band and higher power of the VLF band. These parameters reflect higher sympathetic activity and therefore, stress (e.g. Delaney & Brodie, 2000).

Furthermore, separated participants tried to repair proximity to their mobile. They approached the cupboard where their mobile was placed more frequently than unseparated participants. Importantly, separated participants did not explore the room or read the newspapers longer than unseparated participants, suggesting that approaching the cupboard was not due to a general tendency to occupy themselves in the absence of their mobile. Although there are some self-reported data that people try to keep their mobile nearby as much as possible (e.g. Levitas, 2013), our study is the first that revealed proximity-seeking on the behavioural level.

Additionally, we found in case of separation-related words of the Stroop test, that separation influenced reaction time, in interaction with self-reported mobile attachment (MAQ). This is in contrast with neutral, general negative and physical threat words, where separation did not affect reaction time. Therefore, our finding suggests that separation from the mobile induced separation-specific emotions (e.g. loneliness, abandonment) which decreased performance for similar words. Furthermore, previous studies have found that trait differences such as trait anxiety mediate the effect of short-term states (e.g. a stressful situation) on attentional bias and the consequent task-interference in the Stroop test (MacLoad & Rutherford, 1992). Similarly, in our test, separation from the mobile (short-term state) and self-reported mobile attachment (trait difference) together increased attentional bias to separation-related stimuli.

In contrast to Clayton et al.'s (2015) findings, cognitive performance on the word search puzzle was not affected by separation from the mobile. However, in that study the experimenters rang the participants' mobile during separation which might have decreased performance. In our experiment, the increase in anxiety level might have been too mild to affect cognitive performance (note that only stress above a certain level decreases performance; Yerkes and Dodson, 1908; Martens & Landers, 1970).

In contrast to physiological and non-verbal stress responses, self-reported state anxiety (STAI) levels were not affected by separation from the mobile. However, behavioural and physiological parameters often diverge from self-reports (e.g. Borkenau & Liebler, 1993), and could give more reliable information about affective states (Stone and Nielson, 2001; Troisi, 2002).

Interestingly, the effects of separation from the mobile were apparent only when no other mobile was present. The presence of an unfamiliar mobile decreased the effects of separation from their own mobile, similarly to the calming effect of a stranger on children who are separated from the caregiver (Spangler & Grossmann, 1993; Spangler and Schieche, 1998). Naturally, adults have a higher tolerance of separation from attachment figures and a higher acceptance of other social partners. Therefore, although they may be distressed upon separation from their mobile, an unfamiliar mobile has the potential to comfort them.

### 4.2 Mobile Attachment Questionnaire

In addition to proximity-seeking and separation anxiety, other features of social attachment, like secure base and safe haven effects (Bowlby, 1969; Hazan & Shaver, 1994) are also relevant aspects of mobile attachment because these emerged as principal components of the MAQ. In line with our study, previous research also suggested that people may feel more confident in social situations if their mobile is close to them (Stald, 2008), and they may use the mobile as a stress-relieving object (Jung, 2014).

The MAQ proved to be a valid assessment tool of mobile attachment. Although non-verbal behaviour and heart rate responses in the Mobile SST did not show the expected associations with MAQ, self-reported state-anxiety and reaction time to separation-related words in the Stroop test was associated with MAQ score in separated participants.

### 4.3 Conclusion

In summary, our study is the first that gives experimental support for the hypothesis that people are attached to their mobile and it can be understand in Bowlby’s (1969) evolutionary framework. Humans are prone to develop attachment toward their partners, friends (Fraley et al., 2005; Markiewicz et al., 2006) and also members of other species (Archer & Ireland, 2011; Zasloff & Kidd, 1994), suggesting that the ability to form attachments toward group mates has played a significant role in the evolution of our social behaviours. As in our previous work (Konok et al., 2016), we assume that the capacity to form an attachment to the mobile phone may be the consequence of cultural co-option of the neuronal circuits of the attachment system (‘neural recycling hypothesis’, Dehaene & Cohen, 2007; see also Parkinson & Wheatley, 2015). This may explain why our attitude and behaviour toward the mobile may share many of the constraints and features that are characteristic to interpersonal attachment (e.g. proximity-seeking, separation stress, secure base and safe haven).

We do not think, however, that attachment to the mobile would be the same in every aspect as attachment to animate agents, especially humans. Objects (e.g. mobiles) have no agency, and the “responsiveness” they offer is decoupled from the care and compassion people seek from a human partner (Keefer, Landau, Rothschild, & Sullivan, 2012). However, unlike other (social) targets, their presence is much more reliable and controllable so that they may be attractive for many people. This is in accordance with Winnicott's (1971) theory of transitional objects, which states that children can cope with the temporary absence of their caregivers with the reliable presence of a valued object (e.g. blanket).

Despite the differences, we suggest that the interpretation of human-mobile interaction using ethological concepts (cf. Korondi et al., 2015 in case of human-robot interaction), such as attachment, may be more fruitful in driving future research than trying to explain it as a manifestation of extreme behaviour (e.g. addiction). We are in the middle of a nascent digital culture, with children being born into the world of smart devices. There is a need for further research to investigate how these devices change our socioemotional life and cognitions, in order to overcome potential problems or challenges they might cause. The first step in this direction is to clarify how our attitude and behaviour toward the mobile phone shares features of interpersonal relationships.

Acknowledgments
We thank Katalin Tóthné Maros, Richárd Magócsi, Danielle Riffer-Reinert and Lisa Wallis for their help, and we are grateful to all participants. The study was supported by the Hungarian Academy of Sciences (F01/031), and the Hungarian Scientific Research Fund (OTKA K100695).

**Appendix A**
Post-experiment questions:

What do you think the real aim of the test was?
Was there anything strange, unusual or suspicious during the test?
Was there any difficulty or problem with the programs?

**Appendix B**
Calculation tasks

**'A' set of calculations:**
20*(134/13)=
38+110+(45*12)=
(550-342)*16=

**'B' set of calculations:**
662/44-(240/33)=
45*99*0.4=
(78+417+98)/17=

**Appendix C**
**Short STAI**
A number of statements which people have used to describe themselves are given below. Read each statement and mark on the scale the value which indicates the best how you feel right now, that is, at this very moment.
There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

How are you feeling right now?

| | | |
|---|---|---|
| I feel calm. | Not true at all | Completely true |
| | I------------------------------------------I | |
| I am tense. | Not true at all | Completely true |

I------------------------------------------I

| | | |
|---|---|---|
| I feel upset. | Not true at all<br>I------------------------------------------I | Completely true |
| I am relaxed. | Not true at all<br>I------------------------------------------I | Completely true |
| I feel content. | Not true at all<br>I------------------------------------------I | Completely true |
| I am worried. | Not true at all<br>I------------------------------------------I | Completely true |

**Appendix D**

**English translation of the word-stimuli of the emotional Stoop test:**

**Practice words:**
advertisement
assumption
modification
discrepancy
exception
circumstance
paperboard
cylinder
screen
demand
elbow
lawnmower
triangle
selection
plate
heritage
proportion
lamp
benefit
essence

1

**Sample of test words (40 words were presented in blocks of four, with order of blocks and within-block order of words randomized):**

| | |
|---|---|
| **Neutral words:** | **Separation-related negative words:** |
| scanner | mourning |
| quotation | loss |
| wardrobe | loneliness |
| summarize | solitariness |
| trapezoid | abandon |
| Luxembourg | break up |
| surplus | separation |
| chronology | farewell |
| advantage | divorce |
| luxury | neglect |
| | |
| **General negative words:** | **Physical threat-related negative words:** |
| cockroach | breathless |
| lie | infection |
| hell | injury |
| traitor | harm |
| hatred | ulcer |
| viciousness | sickness |
| slave | faint |
| silliness | dizziness |
| failure | pain |
| embarrassed | wound |

**Appendix E**

**Mobile Attachment Questionnaire**

The table shows the items of the raw version of the Mobile Attachment Questionnaire with abbreviations of the original "scales" they belonged to (according to our expectations). Reversed items are indicated with a minus sign next to the abbreviation. Items which were retained after item-selection are in bold. The principal components on which the final items are loaded on are presented in the third column.

SH= Safe haven
SB= Secure base
PS= Proximity seeking
SA= Separation Anxiety
NC= Need for contact
SI= Separation Insecurity

| Item number | Item | Components the items are loaded on in the final questionnaire |
|---|---|---|
| 1 | **In a tense situation, I take out my phone. SH** | SH |
| 2 | If I have my phone on me, I can behave more easily/unreserved. SB | |
| 3 | I do not go to anywhere without my phone. PS | |
| 4 | **I am nervous/tense when I leave my phone at home. SS** | SA |
| 5 | I like to be constantly available for other people. NC | |
| 6 | If I am nervous for some reason, I take out my phone. SH | |
| 7 | **If my phone is in my hand, I can behave more easily/unreserved. SB** | SB |
| 8 | I regularly check my phone even if it does not ring/does not sign a message. PS | |
| 9 | **I am nervous/tense when my phone runs out of battery. SS** | SA |
| 10 | I'm nervous if I cannot be reached on the phone. NC | |
| 11 | **If I am stressed I take out my phone to calm down. SH** | SI |
| 12 | **If my phone is in my hand, I feel more confident. SB** | SB |
| 13 | My phone is within my reach at night, even if I did not set any alarm. PS | |
| 14 | I am nervous/tense, if I do not have my phone on me. SS | |
| 15 | I'm nervous if I cannot get through somebody. NC | |
| 16 | Dealing with my phone calms me down. SH | |
| 17 | If I do not have my phone on me, I am more inhibited/shy with strangers. SB | |
| 18 | **If I left my phone at home, I would be willing to go home for it even from a distance (more than 5 minutes away from home). PS** | SA |
| 19 | **If I do not have my phone on me, I do not feel safe. SS** | SI |

| | | |
|---|---|---|
| 20 | Sometimes I turn off/mute my phone so that people cannot disturb me. NC- | |
| 21 | I do not care whether my phone is with me or not. PS- | |
| 22 | If my phone is not in my hand, I am more inhibited/shy with strangers. SB | |
| 23 | If I left my phone at home, I would be willing to go home for it if I were close by (a couple of minutes away from home). PS | |
| 24 | **If my phone runs out of battery, I do not feel safe. SS** | SI |
| 25 | It's annoying for me to be constantly available for others. NC- | |
| 26 | **If I feel uneasy/tense in a company, I take out my phone. SH** | SH |
| 27 | If I have my phone with me, I can focus on/pay attention to/be absorbed in things better. SB | |
| 28 | When I sit down somewhere (e.g. in a cafe, a lecture, to a dining table, etc.), I put my phone at a visible place, within my reach. PS | |
| 29 | **If I leave my phone at home, I do not feel safe. SS** | SI |
| 30 | I am nervous when I miss something for some reason (e.g. I have not got my phone on me, or it has run out of battery) or I do not get to know if something happened to my acquaintances. NC | |
| 31 | If I get into an uneasy/embarrassing situation, I start to twiddle with my phone. SH | |
| 32 | If I have my phone on me, I am friskier/more curious. SB | |
| 33 | At home I take my phone with me even into the bathroom. PS | |
| 34 | I cannot bear for long without my phone. SS | |
| 35 | If a close friend/family member doesn’t pick up the phone, I start to worry/have a bad feeling. NC | |
| 36 | **If I am nervous, dealing with my phone does not calm me down. SH-** | SH |
| 37 | When I am talking with a friend, I often check my phone. SB | |
| 38 | I always try to keep my phone on me. PS | |
| 39 | I would be sad for long, if I lost my phone. SS | |
| 40 | When I am talking with strangers, I often check my phone. SB | |
| 41 | I like my phone to be in my field of vision when I am working/studying. PS | |
| 42 | **If I lost my phone, I would not feel really safe for long. SS** | SI |
| 43 | If I am in an unfamiliar/new situation, I often take out my phone. SB | |
| 44 | I always carry my phone charger with me. PS | |
| 45 | **It does not bother me when I leave my phone at home/it runs out of battery. SS-** | SA |
| 46 | **I am not more confident/easygoing if I have my phone with me. SB-** | SB |
| 47 | If my phone runs out of battery, I charge it immediately. PS | |
| 48 | I like to constantly hold my phone in my hand. PS | |

**Appendix F**
**Details of the item selection procedure on MAQ**

Items 17, 22, 27, 32, 33, 37, 44, 47 were removed because of low variance in the responses (more than 50% of the responses fell into any of the extremes). Item 20 and 25 were removed because of the corrected item-total correlations were less than 0.3. Inter-item correlations were also checked and resulted in further exclusions of items. Two items (items 1 and 6) had a correlation coefficient greater than 0.8, so the one with the lower item-total correlation (item 6) was removed. Items 3, 5, 8, 13, 15, 21, 23, 28, 31, 35, 38, 39, 40, 41, 48 were removed because they had inter-item correlation coefficients lower than 0.2.

**Appendix G**
**Transformed behavioural responses and the analyses in which they were used**
MAQ = Mobile Attachment Questionnaire

| **Behavioural response** | **Values of the transformed categorical variable** | **Analysis in which the variable was used** |
|---|---|---|
| Own mobile contact | zero, non-zero | MAQ validation (in Group 3 and 4) |
| Cupboard proximity | zero, non-zero | effect of experimental groups (all groups) and MAQ validation (in Group 1 and 2) |
| Explore | zero, non-zero | effect of experimental groups (all groups) |
| Newspaper | low (below median [45%]) and high (above median [45%]) | effect of experimental groups (all groups) |

**Appendix H**
**Post-hoc analysis of the Mobile SST**

The four groups differed in the proportion of participants showing stress behaviour (Chi-square test; $\chi^2$ [3, $N$ = 85] = 9.44; p = 0.024; Φ = 0.33) and in the proportion of those who stayed in the proximity of the cupboard ($\chi^2$ [3, $N$ = 85] = 8.39; p = 0.039; Φ = 0.31).

Post hoc Chi-square tests revealed that more participants showed stress behaviour in Group 1 (when no mobile was present) than in Group 2 (when only the unfamiliar mobile was present; $\chi^2$ [1, $N$ = 43] = 8.50; p = 0.004; Φ = 0.44) and in Group 3 (when only the own mobile was present; $\chi^2$ [1, $N$ = 42] = 4.97; p = 0.026; Φ = 0.34). There was no significant difference between Group 3 and 4 (when both mobiles were present); Group 2 and 4, Group 1 and 4, and Group 2 and 3 (all p > 0.1).

More people approached the cupboard in Group 1 (when no mobile was present) than in Group 4 (when both mobiles were present, $\chi^2$ [1, $N$ = 40] = 4.4; p = 0.035; Φ = 0.33) and in Group 3 (when only the own mobile was present, $\chi^2$ [1, $N$ = 42] = 4.86; p = 0.027; Φ = 0.34). There was no significant difference between Group 1 and 2, Group 2 and 3, Group 2 and 4 (all p > 0.15), and Group 3 and 4 (no statistical test was done because none of the participants approached the cupboard in neither group).

There were no group differences in case of exploration and reading the newspapers (p > 0.15).

**References**:


Ainsworth, M., Bell, S., & Stayton, D. (1971). Individual differences in strange-situation behaviour of one-year-olds. In H. R. Schaffer (Ed.), *The origins of human social relations*. New York: Academic Press.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders*. Washington, DC. Retrieved from http://amberton.mylifeblue.com/media/Syllabi/Winter 2015/Graduate/CSL6820_01.pdf

Archer, J., & Ireland, J. L. (2011). The Development and Factor Structure of a Questionnaire Measure of the Strength of Attachment to Pet Dogs. *Anthrozoos: A Multidisciplinary Journal of The Interactions of People & Animals*, *24*(3), 249–261.

Asmundson, G. J. G., Sandler, L. S., Wilson, K. G., & Walker, J. R. (1992). Selective attention toward physical threat in patients with panic disorder. *Journal of Anxiety Disorders*, *6*(4), 295–303. http://doi.org/10.1016/0887-6185(92)90001-N

Bentall, R. P., & Kaney, S. (1989). Content specific information processing and persecutory delusions: an investigation using the emotional Stroop test. *The British Journal of Medical Psychology*, *62 ( Pt 4)*, 355–364. http://doi.org/10.1111/j.2044-8341.1989.tb02845.x

Bernardi, L., Valle, F., Coco, M., Calciati, A., & Sleight, P. (1996). Physical activity influences heart rate variability and very-low-frequency components in Holter electrocardiograms. *Cardiovascular Research*, *32*(2), 234–237. http://doi.org/10.1016/0008-6363(96)00081-8

Bianchi, A., & Phillips, J. G. (2005). Psychological Predictors of Problem Mobile Phone Use, 39–51.

Bivin, J. B., Mathew, P., Thulasi, P. C., & Philip, J. (2013). Nomophobia-do we really need to worry about? *Reviews of Progress*, *1*. Retrieved from http://www.indianjournals.com/ijor.aspx?target=ijor:jnt&volume=5&issue=3&article=003

Borkenau, P., & Liebler, A. (1993). Convergence of stranger ratings of personality and intelligence with self-ratings, partner ratings, and measured intelligence. *Journal of Personality and Social Psychology*, *65*(3), 546–553. http://doi.org/10.1037/0022-3514.65.3.546

Bowlby, J. (1969). *Attachment and loss: Vol. 1. Attachment*. New York: Basic Books.

Cheever, N. A., Rosen, L. D., Carrier, L. M., & Chavez, A. (2014). Out of sight is not out of mind: The impact of restricting wireless mobile device use on anxiety levels among low, moderate and high users. *Computers in Human Behavior*, *37*, 290–297. http://doi.org/10.1016/j.chb.2014.05.002

Cipriani, J., & Kreider, M. (2009). Understanding object attachment and meaning for nursing home residents: an exploratory study, including implications for occupational therapy. *Physical & Occupational Therapy in Geriatrics*. Retrieved from http://informahealthcare.com/doi/abs/10.3109/02703180903183164

Clayton, R. B., Leshner, G., & Almond, A. (2015). The Extended iSelf: The Impact of iPhone Separation on Cognition, Emotion, and Physiology. *Journal of Computer-Mediated Communication*, *20*(2), 119–135. http://doi.org/10.1111/jcc4.12109

Davazdahemami, B., Hammer, B., & Soror, A. (2016). Addiction to Mobile Phone or Addiction through Mobile Phone? In *2016 49th Hawaii International Conference on System Sciences (HICSS)* (pp. 1467–1476). IEEE. http://doi.org/10.1109/HICSS.2016.186

Dehaene, S., & Cohen, L. (2007). Cultural recycling of cortical maps. *Neuron*, *56*(2), 384–98. http://doi.org/10.1016/j.neuron.2007.10.004

Delaney, J. P. A., & Brodie, D. A. (2000). Effects of short-term psychological stress on the time and frequency domains of heart-rate variability. *Perceptual and Motor Skills*, *91*(6), 515. http://doi.org/10.2466/PMS.91.6.515-524

Egloff, B., & Hock, M. (2001). Interactive effects of state anxiety and trait anxiety on emotional Stroop interference. *Personality and Individual Differences, 31*, 875–882.

Ericsson, J. (2014). Ericsson mobility report, (November). Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Ericsson+mobility+report#1

Eysenck, M., Derakshan, N., Santos, R., & Calvo, M. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion*, *7*(2), 336–53. http://doi.org/10.1037/1528-3542.7.2.336

Forgays, D. K., Hyman, I., & Schreiber, J. (2014). Texting everywhere for everything: Gender and age differences in cell phone etiquette and use. *Computers in Human Behavior*, *31*, 314–321. http://doi.org/10.1016/j.chb.2013.10.053

Fraley, R., Brumbaugh, C. C., & Marks, M. J. (2005). The evolution and function of adult attachment: a comparative and phylogenetic analysis. *Journal of Personality and Social Psychology*, *89*(5), 731–46. http://doi.org/10.1037/0022-3514.89.5.751

Fraley, R. C., & Shaver, P. R. (2000). Adult romantic attachment: Theoretical developments, emerging controversies, and unanswered questions. *Review of general psychology*, *4*(2), 132.

George, J. S. (2013). The things they carry: a study of transitional object use among US military personnel during and after deployment. Retrieved from https://dspace.smith.edu/handle/11020/24248

Hazan, C., & Shaver, P. (1994). Deeper into attachment theory. *Psychological Inquiry*. Retrieved from http://www.tandfonline.com/doi/pdf/10.1207/s15327965pli0501_15

Hooley, J., & Wilson-Murphy, M. (2012). Adult attachment to transitional objects and borderline personality disorder. *Journal of Personality Disorders*. Retrieved from http://guilfordjournals.com/doi/abs/10.1521/pedi.2012.26.2.179

Jung, Y. (2014). What a smartphone is to me: understanding user values in using smartphones. *Information Systems Journal*, 24(4), 299-321.

Keefer, L., Landau, M., Rothschild, Z. K., & Sullivan, D. (2012). Attachment to objects as compensation for close others' perceived unreliability. *Journal of Experimental Social Psychology*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0022103112000194

Konok, V., Gigler, D., Bereczky, B. M., & Miklósi, Á. (2016). Humans' attachment to their mobile phones and its relationship with interpersonal attachment style. *Computers in Human Behavior, 61*, 537–547. http://doi.org/10.1016/j.chb.2016.03.062

Korondi, P., Korcsok, B., Kovács, S., & Niitsuma, M. (2015). Etho-robotics: What kind of behaviour can we learn from the animals?. IFAC-PapersOnLine,48(19), 244-255.

Levitas, D. (2013). Always Connected: How Smartphones And Social Keep Us Engaged. *International Data Corporation (IDC)*. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Always+Connected:+How+Smartphones+and+Social+Keep+Us+Engaged#0

Lundh, L., & Czyzykow-Czarnocka, S. (2001). Priming of the emotional Stroop effect by a schema questionnaire: An experimental study of test orders. *Cognitive Therapy & Research*, *25*(3), 281–289.

MacLeod, C. M., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*(1), 15–20. http://doi.org/10.1037/0021-843X.95.1.15

MacLeod, C., & Rutherford, E. M. (1992). Anxiety and the selective processing of emotional information: Mediating roles of awareness, trait and state variables, and personal relevance of stimulus. *Behaviour Research and Therapy, 30*(5), 479–491.

Markiewicz, D., Lawford, H., Doyle, A. B., & Haggart, N. (2006). Developmental Differences in Adolescents' and Young Adults' Use of Mothers, Fathers, Best Friends, and Romantic Partners to Fulfill Attachment Needs. *Journal of Youth and Adolescence, 35*(1), 121–134. http://doi.org/10.1007/s10964-005-9014-5

Marteau, T. M., & Bekker, H. (1992). The development of a six-item short-form of the state scale of the Spielberger State-Trait Anxiety Inventory (STAI). *The British Journal of Clinical Psychology / the British Psychological Society, 31 ( Pt 3)*(OCTOBER), 301–306. http://doi.org/10.1111/j.2044-8260.1992.tb00997.x

Martens, R., & Landers, D. M. (1970). Motor performance under stress: A test of the inverted-U hypothesis. *Journal of Personality and Social Psychology, 16*(1), 29–37. http://doi.org/10.1037/h0029787

Myers, E. (1985). Phenomenological analysis of the importance of special possessions: An exploratory study. *Advances in Consumer Research*. Retrieved from http://www.acrwebsite.org/volumes/display.asp?id=6447

Parkinson, C., & Wheatley, T. (2015). The repurposed social brain. Trends in Cognitive Sciences, 19(3), 133–41. http://doi.org/10.1016/j.tics.2015.01.003

Péter, A. (2015). Solomon Coder: a simple solution for behavior coding. - 15.11.19. Available online at http://solomoncoder.com/

Rattray, J., & Jones, M. C. (2007). Essential elements of questionnaire design and development. Journal of Clinical Nursing, 16(2), 234–243. http://doi.org/10.1111/j.1365-2702.2006.01573.x

Salesforce Marketing Cloud. (2014). 2014 mobile behavior report. Retrieved from http://www.exacttarget.com/2014-mobile-behavior-report

Scannell, L., & Gifford, R. (2010). Defining place attachment: A tripartite organizing framework. *Journal of Environmental Psychology*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0272494409000620

Sevenster, P. (1961). A causal analysis of a displacement activity (fanning in Gasterosteus aculeatus L.). *Behaviour. Supplement*, (9), I-170

Sharma, N., Sharma, P., Sharma, N., & Wavare, R. (2015). Rising concern of nomophobia amongst Indian medical students. *International Journal of Research in Medical Sciences*, *3*(3), 705. http://doi.org/10.5455/2320-6012.ijrms20150333

Simor, P., Pajkossy, P., Horváth, K., & Bódizs, R. (2012). Impaired executive functions in subjects with frequent nightmares as reflected by performance in different neuropsychological tasks. *Brain and Cognition*, *78*(3), 274–283. http://doi.org/10.1016/j.bandc.2012.01.006

Sipos, K., & Sipos, M. (1978). The developement and validation of the hungarian form of the STAI. In *Cross-Cultural Anxiety* (pp. 51–61). Washington-London, US-UK: Hemisphere Publishing Corporation.

Spangler, G., & Grossmann, K. E. (1993). Biobehavioral Organization in Securely and Insecurely Attached Infants. *Child Development*, *64*(5), 1439–1450.

Spangler, G., & Schieche, M. (1998). Emotional and adrenocortical responses of infants to the Strange Situation: The differential function of emotional expression. *International Journal of Behavioral Development*, *22*, 681–706. http://doi.org/10.1080/016502598384126

Spielberger, C. D., Gorsuch, R. L. & Lushene, R. E. (1970). Manual for the State-Trait Anxiety Inventory (Self-evaluation questionnaire). Palo Alto, CA : Consulting Psychologists Press.

Stald, G. (2008). Mobile identity: Youth, identity, and mobile communication media. Youth, identity, and digital media, 143.

Stone, L. A., & Nielson, K. A. (2001). Intact physiological response to arousal with impaired emotional recognition in alexithymia. *Psychotherapy and Psychosomatics*, *70*(2), 92–102. http://doi.org/10.1159/000056232

Tabachnick, B., & Fidell, L. (2001). Using multivariate statistics. Retrieved from https://www.ulb.tu-darmstadt.de/tocs/135813948.pdf

Thorpe, S. J., & Salkovskis, P. M. (1997). Information processing in spider phobics: The Stroop colour naming task may indicate strategic but not automatic attentional bias. *Behaviour Research and Therapy*, *35*(2), 131–144. http://doi.org/10.1016/S0005-7967(96)00093-9

Toda, M., Monden, K., Kubo, K., & Morimoto, K. (2006). Mobile phone dependence and health-related lifestyle of university students. *Social Behavior and Personality: An International Journal*, *34*(10), 1277–1284. Retrieved from http://www.ingentaconnect.com/content/sbp/sbp/2006/00000034/00000010/art00008

Troisi, A. (2002). Displacement activities as a behavioral measure of stress in nonhuman primates and human subjects. *Stress*, *5*(1), 47–54. http://doi.org/10.1080/10253890290012378

Walsh, E. (2014). A study of object use: adults, special objects, and contemporary American culture. Retrieved from https://dspace.smith.edu/handle/11020/24509

Wapner, S., Demick, J., & Redondo, J. (1990). Cherished possessions and adaptation of older people to nursing homes. *The International Journal of Aging and Human Development*. Retrieved from http://psycnet.apa.org/psycinfo/1991-13627-001

Winnicott, D. (1971). *Playing and reality*. Retrieved from http://books.google.com/books?hl=en&lr=&id=JHMdZC08HhcC&oi=fnd&pg=PR9&dq=Playing+and+reality&ots=y0GKdT9WEb&sig=xxUfi3mPYszZFKEqHNN6_oDX80w

Wiseman, R., & Watt, C. (2004). Measuring superstitious belief: Why lucky charms matter. *Personality and Individual Differences*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0191886904000418

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*(5), 459–482. http://doi.org/10.1037/h0073415

Zasloff, R. L., & Kidd, A. H. (1994). Attachment To Feline Companions. Psychological Reports, 74(3), 747–752. http://doi.org/10.2466/pr0.1994.74.3.747