



Suffering from problematic smartphone use? Why not use grayscale setting as an intervention! – An experimental study[☆]

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ABSTRACT

Increasingly, problematic smartphone use behavior (PSU) and excessive consumption are reported. In this study, an experiment was developed to investigate the influence of screen coloration using the grayscale setting on smartphone usage time in repeated measurements. We also investigated how individuals perceived suffering correlates with smartphone usage time and PSU, and whether differences exist by smartphone usage type (social, process, habitual). 240 subjects completed a questionnaire about smartphone usage time, PSU, perceived suffering, and smartphone usage types. Afterward, their smartphones were switched to grayscale setting for at least 24h, and thereafter 92 of these participants completed the second questionnaire. Analyses showed that grayscale setting decreases usage time and that there is a positive correlation between PSU, smartphone usage duration, and perceived suffering. The types of use (process and habitual) influence one's perceived suffering. Thus, it shows that individuals are aware of their PSU and suffer from it. Using grayscale setting is effective in reducing smartphone use time.

1. Introduction

One's smartphone has become an essential part of life. It is anchored at every level, serving as inspiration, as a source of information, for entertainment or comparison purposes. The importance of the smartphone is growing as time goes on, with around 98% of German households and 94% of German young people aged 12-19 having smartphones in their possession and 92% of young people use smartphones daily for leisure activities (JIM-Study, 2021). As part of the Mental Smartphone Project, it was shown that the users studied picked up their smartphone every 18min and spend a total of over two and a half hours a day with the device (Montag, 2018).

While on the one hand, the smartphone brings many positive aspects, such as interaction possibilities and everyday life facilitation, it also brings undesirable side effects due to the wide range of possible uses. These include effects on mental and physical health, stress perception, and addiction-like tendencies, as well as neglect of essential tasks to be accomplished, in short procrastination (Beeres et al., 2021; Montag, 2018; Orben & Przybylski, 2019). Due to these aforementioned negative aspects, excessive use is now referred to as PSU (Panova & Carbonell, 2018).

1.1. Uses-and-gratifications approach as a theory on the motives for smartphone use

The uses-and-gratifications approach is a model of media use research and examines or describes the extent to which recipients devote themselves to certain media offerings to derive certain benefits from the respective media. The approach focuses on gratifications (satisfaction of needs) that result from the use of the chosen offers and can thus be added as motivation-theoretical aspects to represent media use and media effects (Krämer et al., 2016). Meanwhile, users are considered active, goal-oriented subjects who have individual needs and expectations for specific media offerings (Katz et al., 1973). The following needs or motives exist for media use: 1. the need for information (orientation, seeking advice, learning), 2. the need for entertainment (escapism, relaxation, sexual stimulation), 3. the need for personal identity (search for models of behavior, reinforcement of personal values), and 4. the need for integration and social interaction (substitute for sociability, role model, conversation) (Mangold et al., 2004).

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1.2. Problematic smartphone use

Billieux (2012) refers to PSU as “an inability to regulate one’s use of the smartphone, which eventually involves negative consequences in daily life” (p. 299). Because the term is an abstract concept, Billieux et al. (2015) developed a model in which PSU was divided into three pathways. Here, they distinguish between excessive, impulsive, and extraverted use. Furthermore, they categorize individual risk factors and the intensity of use and consequently identify three different types of PSU. These include addictive behavior, an antisocial pattern of use, and high-risk use. Furthermore, Kuyulu and Beltekin (2020) explain: “The use of smartphones both gives pleasure to the person as a result of use and saves them from pressure or anxiety. Such reinforcement makes it easy to be addicted to the smartphone” (p. 305). Since some symptoms are consistent with those of addicts, including mood regulation or loss of cognitive functions, some scientific studies also describe the concept of “smartphone addiction” (Mei et al., 2022; Ting & Chen, 2020).

Smartphone addiction and PSU are often used interchangeably (Nahas et al., 2018), but smartphone addiction is not an identified psychological disorder. In this regard, it is important to distinguish that smartphone addiction does not correspond to officially recognized addictions and thus cannot be found in the DSM-5 or ICD-10 classification systems, since the consequences of PSU cannot be compared with the severity and constraints of other addictions (Panova & Carbonell, 2018). Rather, it is a concept that has been overly pathologized in the scientific context (Panova & Carbonell, 2018). Therefore, Long et al. (2016) use the term PSU instead of an addiction term to prevent the phenomenon from being automatically pathologized and to describe excessive smartphone use that leads to functional impairment and negative life outcomes (Holte et al., 2021). This notion is also applied in this paper. Even without formal status as a behavioral addiction, an increasing number of studies show that PSU can have negative effects such as insomnia and neck muscle fatigue (Xie et al., 2018), social isolation (Kato et al., 2020), family problems (Guo et al., 2019; Mangialavori et al., 2021), cyberbullying (Qudah et al., 2019), and neglect of daily tasks (Aljomaa et al., 2016).

While looking at PSU, it is critical to have a more differentiated perspective on the smartphone, as it is not the technological gadget itself that is addictive, it is rather the different types of uses that the smartphone has to offer. Those offers are meant to fulfill desires and, if misused, can turn the smartphone into a platform for multiple addictions (Park et al., 2021). With that in mind, for example, the desire for distraction may be gratified by the different types of use, however, can have negative consequences on one’s emotions, relationships, psychological stability, and completion of daily or long-term tasks (Marino et al., 2018; Pivetta et al., 2019). Beyond that, studies show that permanent digital attention overstrains our cognitive (Korte, 2020), psychological (Horwood & Anglim, 2019), and social capacities (Tugtekin et al., 2020). Because of these issues, an increasing number of mass media are covering the gravity of the problem, and studies on the symptoms of overdependence as well as the development of suitable instruments are continuously expanding to forecast fewer negative outcomes associated with smartphone use (Vahedi & Saiphoo, 2018).

Studies which analyze self-reports of people’s smartphone use and their actual smartphone use show that there are often discrepancies between the own perception of smartphone use and their actual smartphone use. These findings show the issue of self-report measures in studies conducted about problematic smartphone use, since they do not reflect the usage accurately and may reduce the validity of the findings (Parry et al., 2021). This means, that smartphone use needs to be objectively measured. This can be enabled by analyzing screen time and number of screen unlocks (Rozgonjuk et al., 2018).

1.3. Perceived suffering due to own smartphone use

Many people now suffer more from their smartphones than they did a

few years ago. The stress caused by (new technologies) *the smartphone* is reported to be increased (Almeida et al., 2020), and the smartphone is sometimes perceived as a burden rather than an enrichment (Stodt et al., 2018). In this context, many affected individuals are aware of the problematic nature of their behavior and suffer from their behavior. Parallels can be drawn here with other behavioral addictions, such as computer gaming disorder or Internet addiction. Those affected notice the increased screen time and also realize that other tasks can be done less efficiently, or not at all, due to the increased use of the smartphone. In addition, many gradually become aware of how much their usage behavior can negatively impact their environment and relationships (Lindenberg & Holtmann, 2022).

PSU can also have an impact on the individual’s environment and relationships. In the professional environment, one’s reputation suffers if tasks are not completed on time or well enough and strains working relationships with colleagues and superiors. In the private environment, reliability is likewise doubted in case of doubt, and private relationships can also suffer from the changed behaviors (Wang et al., 2022). Often, at a certain level, a clear desire for change arises in those affected. According to Teske et al. (2013), people affected by Internet addiction also explicitly expressed the desire to participate more in social life again. However, the level of suffering must assume a comparatively high value, since, for example, sufferers of computer game addiction trivialize their symptoms over a long period (Lindenberg & Holtmann, 2022). A high level of suffering due to PSU can lead to a restriction on quality of life (Kliesener et al., 2022), similar to suffering that also often accompanies Internet addiction, resulting in more and more people seek therapeutic help (Teske et al., 2013). Therefore, the higher the level of suffering, the more likely it is that one’s assessment of the problem will be objectively accurate, to be able to satisfy the desire to change one’s behavior and improve relationships. Studies also show significant bivariate relationships between health anxiety and PSU (Elhai et al., 2021), showing that those with higher levels of health anxiety report higher problematic internet use, following internet searches for medical information (Fergus & Dolan, 2014).

1.4. Types of use as a factor of PSU

The type of use can be seen as a differentiating factor for PSU (Wickord & Quaiser-Pohl, 2022). The type of use and how it satisfies the user plays an essential role in this context. In an overall sense, a differentiation is made between social, procedural, and habitual use.

Social use consists of engaging with an individual’s own social network through social media and instant messaging, satisfying the desire for social interaction. Process use, in contrast, involves content-related media consumption like reading news websites, streaming videos, or playing in-app games, satisfying the desire to indulge in entertaining activities (Elhai, Hall et al., 2017). Habitual use can be characterized as habitual behavior that is an automatic response to specific stimuli arising from within, e.g., a specific desire or emotion, or arising from outside, e.g., a ringtone or a light-up smartphone screen (Limayem et al., 2003), resulting in the phone being automatically unlocked to check for new notifications (Park et al., 2021). When this behavior results in satisfying results, it is executed with greater frequency, and habitual use expands based on satisfaction (van Deursen et al., 2015). Studies have established a greater association between either habitual and procedural smartphone use (van Deursen et al., 2015) or social use (Panek et al., 2018) and problematic use behaviors.

Elhai et al. (2017) et al. showed in their study that in the relationships of process and social use with PSU, smartphone-related positive anticipation behaviors played a positive role. Results show that process use, as a hedonic type of usage, can have even a stronger effect of compensating negative emotions and then again lead to higher levels of PSU than social use. Also, people perceive that greater process and social use facilitate tasks in everyday life, since smartphone tools seem to make them more productive and save more time.

In their study, Rozgonjuk et al. (2019) discuss that an intolerance of uncertainty especially plays a role in non-social smartphone use. The non-social type of use could be a way for individuals make use of their smartphone to cope with their uncertainty. The reason for this maladaptive behavior might be the association of intolerance of uncertainty and social-related anxiety. Furthermore, the relationship between PSU levels and intolerance of uncertainty, was mediated by non-social smartphone use, showing that anxiety caused by intolerance of uncertainty might lead to avoidant behaviors, in the form of PSU (Rozgonjuk et al., 2019).

1.5. Grayscale setting

The continuous use of the smartphone very quickly becomes a habit through the so-called intermittent reinforcement schedule (Dau et al., 2017). This describes a temporary reward when we activate the smartphone, for example, because of a push notification or a message from a friend. The brain responds to this type of reinforcement, which is why constant use quickly becomes an unhealthy habit and can lead to neglect of essential things (Montag, 2018). Montag et al. (2017) additionally found, using the app "Facebook" as an example, that continuous users have a smaller nucleus accumbens. Similar to addicts, a particularly large amount of dopamine is released when a certain pleasant action is performed. This increases the likelihood that the behavior will be repeated. Visual stimuli, such as the bright colors in apps, additionally draw users' attention to the smartphone (Honey, 2018). Therefore, there is a lot of interest in smartphone color and its impact on usage time as well as problematic smartphone usage.

Olson et al. (2022) discover positive effects of a combination of interventions, resulting in a decrease of PSU, screen time, meanwhile improving sleep quality. The combination consists of small, so called nudges, decreasing or disabling non-essential notifications, reducing accessibility, changing display settings and others. Grayscale settings were part of the successful interventions made by changing the display settings, raising the question of the effectiveness of this intervention alone.

Holte and Ferraro (2020) discovered that individuals who changed their smartphones to grayscale setting for one week decreased the time on their smartphones by 37.9 min per day. They observed that when people's phones were in grayscale setting, they invested less time on social media and web surfing. Those features tend to become less appealing to consumers. The researchers discovered the grayscale smartphone screen display to be "boring" and "annoying," though some saw their departure from color as a "relief". When color is absent from display screens, it seems that it is not as gratifying and pleasurable, despite maintaining the same communication features. The premise of this intervention is that coloration alone is amplifying the usage of the smartphone. The devices are designed to capture and hold the person's attention. It is accomplished through the utilization of appealing luminous saturated colors that stimulate the visual attention system (Holte & Ferraro, 2020). In a replication of this study, Holte et al. (2021) found that with grayscale settings, the daily screentime decreased by 21.76 min. As previously stated, PSU occurs through reinforcement evoked by the habitual use of the device and watching enjoyable content (Park et al., 2021). Vibrant saturated colors, which are physiologically satisfying, add to the reinforcement evoked in the growth of PSU. As a result, by extracting color from smartphones, the usage decreases regarding gratification. Therefore, there is the assumption, that the smartphone use is less pleasurable, what is minimizing the urge to engage with the device. Previous research has demonstrated that shifting one's smartphone screens to grayscale is an effective way to decrease smartphone use (Holte et al., 2021; Holte & Ferraro, 2020).

However, it has not yet been examined how this interacts with individuals' perceived suffering, the various types of smartphone use and what the participants think of the change. Finally, considering the need for replications in psychology (Pashler & Wagenmakers, 2012), attempts

to repeat and broaden study results are critical to determining how and if the grayscale screen display is effective as an intervention for PSU and individuals perceived to be suffering from it.

1.6. Hypotheses

In the following study, the effectiveness of an intervention to reduce PSU as well as increased smartphone use time and its correlates with the different types of smartphone use as well as one's perceived suffering will be investigated. For this purpose, both a cross-sectional and a design with repeated-measurements will be used. For this purpose, both questionnaires and a quasi-experiment will be used.

Many individuals with high scores in PSU gradually become aware of how much their usage behavior can negatively impact their environment and relationships (Horwood & Anglim, 2019; Lindenberg & Holtmann, 2022). This can be compared to the emotions felt during Internet addiction. Teske et al. (2013) described, that people affected by Internet addiction explicitly expressed the desire to participate more in social life again. This can also be assumed for PSU as a similar condition to Internet addiction.

Therefore, it is suspected, that PSU is associated with perceived suffering of smartphone use. (H1).

It is assumed that the more time one spends on the smartphone, the less time can be spent on other activities or the environment and relationships (Lindenberg & Holtmann, 2022). Based on this, it is considered that as smartphone usage time increases, the perceived suffering also increases, as individuals become aware that smartphone usage is harming them and less time can be spent in other important areas of life, which leads to life impairments (Holte et al., 2021).

This leads to the hypothesis, that smartphone usage time is associated with perceived suffering of smartphone usage (H2).

The type of use can be seen as a differentiating factor for PSU (Wickord & Quaiser-Pohl, 2022), because every type of use leads to another gratification, regarding the uses-and-gratification approach (Mangold et al., 2004). In particular, habitual use as an automatic response to certain stimuli that comes from within and results in the phone being automatically unlocked to check for new notifications (van Deursen et al., 2015) clearly shows that smartphone use has addiction-like tendencies, which could lead to perceived suffering. As previous studies have found a larger association between habitual and procedural smartphone use (van Deursen et al., 2015) or social use (Panek et al., 2018) and problematic use behavior, we now aim to exploratively search for correlates with perceived suffering due to own smartphone use.

Therefore, the hypothesis is made, that the types of smartphone use is associated with one's perceived suffering due to own smartphone use (H3).

Because many smartphone applications, like social media, games, and entertainment apps, depending on the usage of color, it would be expected that the lack of color would lead to reduced smartphone satisfaction. It is assumed, that a grayscale setting is less attractive, and therefore the smartphone is less frequently used. This would replicate the results of Holte and Ferraro (2020) and Holte et al. (2021), who discovered that individuals who changed their smartphone to grayscale setting decreased the time on their smartphones.

This leads to the hypothesis that using grayscale setting decreases smartphone usage time (H4).

In addition to the hypotheses, there were also open research questions about the experienced changes through the grayscale setting and future interest in the use of the grayscale setting conducted. In particular, the aim was to explore the perceived strengths and limitations and the participant's attitude toward using the grayscale setting.

2. Materials and method

2.1. Participants and procedure

The data basis, which was used to conduct quantitative and qualitative analyses was a sample consisting of $N = 240$. Participants were recruited via the university network. 30 participants did not fill in the demographic questionnaire. The remaining subjects consisted of 74.8% women, 23.8% men and 1.3% people who describe themselves as diverse ($n = 150$ female, $n = 50$ male, and $n = 3$ diverse). They were between 14 and 66 years old at the time of the interview. The mean age was 24,4 years ($SD_{age} = 8.8$). In terms of educational level, it can be seen that the majority have a high school diploma with 70% ($n = 147$). This is followed by 8,1% who have another school-leaving qualification ($n = 17$) and 13,8% ($n = 29$) who have already graduated from university. 7,2% ($n = 15$) have completed vocational training and 1% ($n = 2$) have no qualifications. The occupational fields of the subjects show that 5.2% ($n = 11$) are still in school. 69% ($n = 145$) are students, 20.5% ($n = 43$) are employees, and 1% ($n = 2$) are employers. Additionally, 1.9% ($n = 4$) are already retired and 2.4% ($n = 5$) indicate "others" for their occupational status.

The requirement to participate in the study was to own a smartphone at the time of the survey. To be able to answer the questions at measurement time point two, the subjects had to have managed to set their smartphone to grayscale setting. Consequently, 92 subjects took part in both measurement point.

The study conducted here is a panel survey since intraindividual developments over time are to be shown. For this purpose, there were online questionnaires at two measurement times and an intervention in between. In the questionnaire of the first measurement point, a socio-demographic questionnaire, self-generated questions on the duration of smartphone use, the Mobile Phone Problem Use Scale-10 (MPPUS-10), the adapted scales used by van Deursen et al. (2015) to determine the type of smartphone use and the perceived suffering were queried.

After all items of the first questionnaire had been answered, the subjects were prompted to create a code that they had to enter again before completing the second questionnaire so that the questionnaire could be assigned to measurement time one. Furthermore, they had to enter their e-mail address to receive the link for the second questionnaire. Due to the separate storage of the email addresses, the processing of the questionnaire was anonymous. The intervention was then introduced and, with the help of a detailed description (see Appendix A), the subjects were asked to set their smartphone screen to grayscale setting, which meant that they could no longer see any colors on their smartphone, as can be seen in Fig. 1.

The aim was to have the subjects leave their smartphone in the grayscale setting for at least 24 h so that any effect of the color setting could be detected. The emails for the second measurement time point were sent manually depending on when the subjects participated in the baseline questionnaire. At the second measurement time point, the self-generated questions on the duration of smartphone use as well as the experiences, through the intervention of the grayscale setting, especially difficulty and attractiveness of use in grayscale setting, were queried. Additionally, the participants were asked to respond to some open questions about their experience with the grayscale setting and their future interest in using it again.

The questionnaire was posted online from 12/27/2021 to 2/10/2022 and 4/11/2022 to 5/10/2022 via the online platform SoSciSurvey. The first questionnaire took about 20 min to complete and the second about 2 min. The survey was conducted in German.

2.2. Material

The materials utilized are standardized questionnaires intended to collect self-assessment data. Initially, sociodemographic data (gender, age, occupation, education, and self-assessment of smartphone use and screen time) were surveyed. The average smartphone usage time was measured and then the questionnaires Mobile Phone Problem Use Scale-



Fig. 1. Color vs. grayscale setting (printing in color is needed for this figure). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

10 (MPPUS-10) and the adapted scales used by [van Deursen et al. \(2015\)](#) to determine the type of smartphone use were used. In addition, self-generated questions asking about the perceived suffering from own smartphone use and questions about the Grayscale setting were filled out.

2.2.1. Mobile Phone Problem Use Scale (MPPUS)

PSU was assessed using a shortened version of the Mobile Phone Problem Use Scale (MPPUS) by [Bianchi and Phillips \(2005\)](#). In the abbreviated version, subjects were allowed to answer ten different items on a 10-point Likert scale ranging from 1 (“strongly disagree”) to 10 (“strongly agree”). The ten items examined each loaded highly on one of five different factors. Three items described “Loss of Control,” three “Withdrawal,” two “Negative Life Consequences,” one “Craving,” and one “Peer Dependence.” An example item to elicit “Loss of Control” would be “I am engaged with the smartphone for longer periods than intended.” All items were summed to a total scale score. The questionnaire has a good reliability with a Cronbach’s alpha of .85 ([Foerster et al., 2015](#)) and 0.82 for this study. No fixed cutoff score is defined above which smartphone use behavior is considered problematic; the scale is viewed as a continuum with greater scores indicating an increased likelihood of problematic use ([Bianchi & Phillips, 2005](#); [Foerster et al., 2015](#)).

2.2.2. Types of use

The type of use was queried using the items from the study by [van Deursen et al. \(2015\)](#). The English survey was translated into German following the back-translation method ([Behr et al., 2016](#)). The translated items can be found in [Appendix B](#). The type of use can be categorized into three types of use: social use, process use, and habitual use. The several types of use are surveyed on independent scales. Habitual smartphone behavior was assessed by the habitual Internet use instrument from [Limayem et al. \(2003\)](#), which has been adjusted to measure habitual smartphone use by [van Deursen et al. \(2015\)](#). For assessing procedural and social smartphone use, [van Deursen et al. \(2015\)](#) adjusted a questionnaire by [Chua et al. \(2012\)](#), that is applied here.

The scales are all scored on a 5-point Likert scale with responses starting from 1 (strongly disagree), to 5 (strongly agree). Social use is scaled with five items forming a sum score spanning from 5 to 25. Internal consistency is found to be acceptable with a Cronbach’s alpha $>.77$ ([Blanz, 2015](#)). Process use is assessed with seven items and a sum score is calculated that reaches from 7 to 35. Internal consistency is rated as questionable with a Cronbach’s alpha $>.62$ ([Blanz, 2015](#)). Habitual use is collected with six items and a sum score is generated, varying from 6 to 30. Cronbach’s alpha $>.85$ can be considered good for internal consistency ([Blanz, 2015](#)). Larger scores on the scales suggest a stronger preference for the particular type of use ([van Deursen et al., 2015](#)).

2.2.3. Screen time measurement

The Screen Time Feature has been used to collect objective smartphone screen time metrics for iPhones and Smartphones with Android Software. The Screen Time Feature records the metric for up to three weeks and is free to the user because it is available on all updated iPhones and phones running Android software. Subjects were able to indicate the applicable number of hours of smartphone use on a 11-point Likert scale, each given at 30-min intervals, ranging from 0 to 0.5h to $>5h$. For the purpose, the subjects were provided with instructions and could search for screen time on their smartphone. On a scale in 30-min intervals from 0 to $<5h$ they could select the applicable number of hours.

2.2.4. Question regarding the perceived suffering due to own smartphone use

A question was developed for self-assessment of the problematic nature, and thus the perceived suffering, of one’s smartphone use behavior: Do you generally suffer from your smartphone usage

behavior?” It is graded on a 5-point Likert scale, with 1 being strongly disagree and 5 being strongly agree.

2.2.5. Open questions

Participants were requested to respond to the following questions in free texts so that the following questions could be used to qualitatively analyze their experiences with using the grayscale setting: (1) “Could you imagine leaving the Grayscale setting like this in the future? Why/why not?”, (2) “Here you have the opportunity to tell us something about your experience with the grayscale setting”. Answering these questions was not mandatory and could be skipped to proceed to the end of the questionnaire [Appendix C](#).

2.3. Statistical analysis

The data analysis consists of descriptive statistics (means and standard deviations) and multivariate statistical analyses, primarily multiple linear regressions, a repeated measurement ANOVA and univariate ANOVA. The analyses used the variables MPPUS-10, types of use, and the self-generated questions about screen time, perceived suffering, and the intervention of grayscale setting. The statistics program IBM SPSS was used to analyze the data.

The preconditions of the tests were checked and, if not described in more detail, fulfilled. For the open-ended questions, similar answers were first clustered. The answers were initially separated into positive and negative aspects. The clusters were then further differentiated by looking at which upper groups of topics could be found, such as the use of social media, Internet shopping, etc. in the upper group of negative aspects or prevented procrastination, greater learning effects, etc. in the upper group of positive aspects. The frequency of mentions per cluster was then examined and individual statements were selected to highlight the aspects mentioned.

3. Results

In [Table 1](#) the mean values and standard deviations of the raw scores for MPPUS, types of use (process use, social use, habitual use), perceived suffering due to own smartphone use, and screen time measurements 1 and 2 can be seen as well as the bivariate correlations between all variables used.

3.1. Hypothesis 1: PSU and perceived suffering of smartphone use

A linear regression was calculated for the hypothesis that PSU is associated with the perceived suffering of smartphone use. This shows that the model has a moderate variance explanation with an R^2 of 0.20 according to [Cohen \(1988\)](#). The predictor PSU statistically significantly predicts perceived suffering, $F(1,179) = 44.49, p < .001$. With $b = 0.45, p < .001$, there is a moderate positive effect.

3.2. Hypothesis 2: smartphone usage time and perceived suffering of smartphone use

To answer the hypothesis that smartphone usage time is associated with the perceived suffering of smartphone usage, a linear regression was calculated. The preconditions for this were tested and because the Shapiro-Wilk test was significant with $p < .004$, a normal distribution can not be assumed and bootstrapping (1000 samples) was used.

The model has a low variance explanation with $R^2 = 0.11$. The predictor smartphone usage duration statistically significantly predicts perceived suffering of smartphone usage, $F(1,190) = 23.63, p < .001$. With $b = 0.33, p < .001$, there is a medium positive effect.

Table 1

Descriptive statistics and Pearson’s bivariate correlations for MPPUS, types of use (process use, social use, habitual use), perceived suffering due to own smartphone use, and screen time measurements 1 and 2.

	Mean	SD	1	2	3	4	5	6
MPPUS	44.76	15.28						
Process Use	25.32	3.73	.492**					
Social Use	20.82	2.95	.165	.250*				
Habitual Use	26.39	3.38	.486**	.457**	.431**			
Perceived suffering	3.41	1.08	.446**	.313**	.094	.331**		
Screen Time Measurement 1	7.52	2.90	.390**	.320**	.105	.307**	.333**	
Screen Time Measurement 2	3.97	2.50	.091	.142	.021	.066	.188	.422**

Note. $N = 183$, ** $p < .01$ /* $p < .05$, Correlations were corrected with Bonferroni correction for multiple testing.

3.3. Hypothesis 3: types of smartphone use and perceived suffering of smartphone use

To answer the hypothesis that the types of smartphone use is associated with one’s perceived suffering due to own smartphone use, a multiple linear regression was calculated. The preconditions for this were tested and because the Shapiro-Wilk test was significant with $p < .01$, a normal distribution can not be assumed and bootstrapping (1000 samples) was used. Since the independence of the residuals and homoscedasticity are not given as preconditions, a univariate analysis of variance and estimation of the robust standard errors, respectively, are performed. The model has a medium variance resolution of $R^2 = 0.15$ (corrected $R^2 = 0.13$). The predictors were able to statistically significant predict perceived suffering of smartphone use, $F(3, 179) = 10.29$, $p < .001$.

Habitual use predicts perceived suffering of smartphone use better than process use, social use however was not able to statistically predict perceived suffering of smartphone use, as can be seen in Table 2.

3.4. Hypothesis 4: grayscale setting and smartphone use time

To answer the hypothesis that using grayscale setting decreases smartphone use time, an ANOVA with repeated measurement was calculated. The preconditions for this were tested and even though the Shapiro-Wilk test was significant with $p < .001$, a normal distribution can be assumed due to the sample size of $N > 30$ ($N = 92$) and the robustness of rmANOVAs (Lange & Mosler, 2017). The smartphone usage duration with colored display setting ($M = 7.61$, $SD = 2.69$) is higher than the smartphone usage duration in grayscale setting ($M = 4.04$, $SD = 2.56$). Smartphone usage time was significantly different, $F(1,91) = 141.39$, $p < .001$, partial $\eta^2 = 0.61$.

3.5. Open questions

Participants’ answers to the question about the reasons for or against using a grayscale setting emphasized the quantitative analyses finding that the smartphone is less interesting in grayscale mode. One participant, for example, noticed: “It was no fun to use the phone, WhatsApp still worked but everything else only works with color. The handling alone, but of course the entertainment factor. I found the setting very unpleasant, but actually, it led to the fact that I was hardly on Tiktok and not at all on YouTube.” Another participant said, “It wasn’t as attractive for me to be distracted by my smartphone, as pictures/videos/games (Insta, etc.) look much more boring.” Or as another participant pointed

Table 2

Predictors of “Perceived suffering due to own smartphone usage behavior” ($N = 183$).

Predictors	β	t	p	R^2
Habitual Use	.266	3.193	.002	.147
Social Use	-.074	-.966	.335	
Process Use	.210	2.706	.007	

out: “I think the screen is a) more pleasing to the eyes, as it doesn’t feel like sensory overload and b) not as appealing, so I spend less pointless time on the phone.”. Many participants describe their smartphone after switching to the grayscale setting as boring, dull, and even sad: “Seems dull and like a filter you want to remove”. In addition, however, some participants noted that the grayscale setting was unfamiliar, tiring, and inconvenient for the eyes.

As a suggestion or solution, some participants state that it would be useful to be able to use the grayscale setting individually for individual applications to specifically reduce their attractiveness: “It would be good if there were a selective setting, e.g. grayscale setting for social media and gaming apps but color setting in the gallery.

4. Discussion

This empirical study aimed to examine how individuals perceived suffering from their smartphone usage has an impact on smartphone usage time and PSU, and whether differences exist by smartphone usage type (social, process, habitual). Additionally, the effectiveness of an intervention to reduce an increased smartphone use time using grayscale setting was investigated.

PSU is a topic that receives a lot of attention in both scientific and social discourse and that, although the first smartphones have only been around since 2007, is already viewed controversially. While the positive aspects of the smartphone, as a mini-computer that is always at hand due to its diverse functions such as the use as a calendar, a camera, an email program, a navigation system, but also as an entertainment and a contact option are beyond question, negative voices are also increasingly being heard, which warn of a loss of boundaries and report the excessive and problematic smartphone consumption. At the same time, the question is how negatively consumers themselves view smartphone use. Since a consciousness of the negative effects of smartphone usage behavior on their own life is growing within individuals (Horwood & Anglim, 2019; Lindenberg & Holtmann, 2022), which can cause a desire to change that behavior, hypothesis one investigated whether PSU is associated with the perceived suffering of smartphone use. The hypothesis was accepted, showing that individuals are aware that their usage behavior includes negative aspects from which they suffer.

To investigate this further, not only the concept of PSU was referred to, but also smartphone usage time was used as a predictor in hypothesis two, since a high screentime can cause a reduction of relationships and free-time activities (Lindenberg & Holtmann, 2022) which then again can lead to higher suffering and life impairments (Holte et al., 2021). Again, this shows that smartphone usage duration has an impact on the perceived suffering due to own smartphone use. This shows that the more time spent on the smartphone, the greater the suffering.

In reference to the uses-and-gratification approach (Mangold et al., 2004), types of smartphone use can have different effects of gratifications (Wickord & Quaiser-Pohl, 2022), or more specifically, there can be differences in the associations of habitual, procedural or social usage types (Panek et al., 2018; van Deursen et al., 2015). Hypothesis three then investigated that there are differences between the types of smartphone use in regard to the perceived suffering, to be able to make

more differentiated statements about which aspects of smartphone use exactly lead to increased suffering. This showed that process use and habitual use predict the perceived suffering due to own smartphone use. Habitual use has a slightly larger effect compared to process use. This could be because habitual use as a habitual behavior that is an automatic response to specific stimuli is not perceived as a conscious decision of the individual and since it is often perceived as a specific desire or emotion to check the smartphone as lying outside of one's conscious sense of control (Cho et al., 2021). Individuals are made aware of their dependence through constant checking and this can therefore lead to greater suffering. Process use, consisting of the consumption of content-related media such as reading news websites, streaming videos, or playing in-app games, satisfying the desire to indulge in entertaining activities (Elhai, Hall et al., 2017; van Deursen et al., 2015), increases the level of suffering. This may be since the feeling of indulging is accompanied by a guilty conscience, since one could simultaneously engage in a more meaningful, productive, or future-oriented activity than, for example, playing an in-app game. In a contrast to this, it could be seen that social use does not influence suffering. Since social use involves engaging with the individual's own social network through social media and instant messaging and thus satisfies the desire for social interaction, it can be perceived as a meaningful activity, which means that there is no need to feel guilty and therefore no increased level of suffering.

Tools and applications used on smartphones contain a variety of colors, so that its lack might lead to a reduction of the satisfaction during their use, decreasing smartphone use (Holte et al., 2021; Holte & Ferraro, 2020). So that in hypothesis four, it was subsequently shown that Using grayscale setting decreases smartphone usage time. Thus, it was shown that this intervention, which is simple and economical to implement, is effective and can therefore compete with other intervention programs, such as mindfulness (Lan et al., 2018) or educational programs (Khoshgofar et al., 2019). Additionally, this allowed us to replicate the findings of Holte et al. (2021) and Holte and Ferraro (2020).

To gain further information about the effectiveness of the intervention and to gather the experiences of the subjects, qualitative questions were asked about what the subjects thought of the Black and White setting. Both positive and negative experiences were reported, and subjects indicated that they had become more aware of their smartphone use as a result of the intervention, which made them more aware of their own problematic and excessive use. This self-awareness on the part of the subjects is a benefit to the study, as well as to future research.

4.1. Strengths and limitations

Our study had several strengths. Involving (1) the design of the study, which enabled us to investigate the decrease in smartphone usage caused by the grayscale setting intervention, (2) the multi-method approach, which integrated quantitative and qualitative analyses, and with this combination providing a better validity and reliability of the findings and avoiding possible limitations and (3) the comparatively large sample size, particularly when compared to previous studies investigating the grayscale setting, ensuring a better representativity of the sample. (4) Following the advice of Elhai et al. (2019), we used a repeated measurement approach to collect objective smartphone metrics over two time points. Using this method, we were able to establish causation with our experimental hypotheses. (5) While many studies seek to discover relationships between PSU and other psychological concepts, our work utilized psychological research to reduce PSU severity practically, as proposed by Mahapatra (2019) and Turel et al. (2008). It is critical to not only acknowledge these constructs but also how they interact with others, but also to generate tangible change that may enhance the lives of smartphone users. Including interventions in the study results in not only supporting theories, but also determining the effects of these interventions and their impact on individuals. Lastly,

(6) due to their own control group in measurement two, participants can be compared to themselves, illustrating the effectiveness of the intervention.

Despite these benefits, our study had some drawbacks that should be discussed. Although we discovered that the grayscale setting was effective in decreasing screen time, we would have liked to check the effect on PSU as well. However, since we asked this construct as a trait, it was not possible to obtain a situational picture of PSU after the intervention. In addition, the intervention was only 24 h long. Future research should employ a longer study period to determine whether these results can be replicated also after a longer exposure period to the grayscale setting and should use a state questionnaire to examine the construct PSU. Since this study found that people reported decreased rates of pleasure and felt less motivated to look at their smartphones when they were in grayscale mode, it should be mentioned that these metrics were retrieved using single-item scales. Given the fact that single-item scale research has evidenced equivalent accurate predictions as multi-item scale research (Drolet & Morrison, 2001; Hyland & Sodergren, 1996; van Doorn et al., 2010), future studies might establish and include multiple item scales for these concepts to determine if these results can be reproduced.

4.2. Conclusions

This study has been successful in demonstrating specifically, that an increased risk of PSU as well as certain types of use, particularly habitual and process use, are being linked to a greater sense of suffering from own smartphone use. Simultaneously, a majority of individuals are conscious of the possible problems related to their smartphone usage behavior but are unwilling to change their behavior. The consequence is, that they are unaware of the dangers and scientifically established outcomes of exaggerated smartphone use on mental health (rise in depression, sleeping disorders, eating disorders, etc.; Yang et al., 2020; Kartal & Ayhan, 2021) and, as demonstrated here, on their own perceived suffering. Additionally, the study was able to show that there is no need to purchase expensive interventions, but an effective way to reduce smartphone usage time is already built in within the setting of one's smartphone.

As a result, it is essential to keep educating individuals about the early symptoms and health consequences of potentially PSU and how to get help or find interventions to reduce the duration of time and problematic use of the smartphone. This furthermore involves disseminating information about interventions to reduce own smartphone use and, as a result, perceived suffering. More interventions are required to assist individuals in dealing with unhealthy smartphone usage. Having this knowledge and the required interventions at hand, the smartphone can be viewed as a pleasant addition and improvement in everyday situations, without bad conscience about expanded durations of use, problematic use, or an increased level of suffering.

Author contributions

Lea-Christin Wickord: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft.

Claudia M. Quaiser-Pohl: Writing - review & editing.

Declarations of interest: none.

Ethics

This is to certify that the guidelines of the Declaration of Helsinki were followed and that no application to the local ethics committee was necessary due to the operationalization. Informed consent was obtained and privacy rights of human subjects were always observed.

Declaration of competing interest

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

Appendix

Appendix A

Instruction Black and White Screen:

As a final step, here is a little experiment.

First, switch your screen to black and white mode. The instructions for doing this can be found further down the page. Try to leave your phone in the black and white setting for as long as possible but at least 24 h. You will fill out a short feedback in 2 days, which we will send to you. Thank you very much for your participation and we hope that you will have an exciting experience with our study. iPhones.

Data availability

The data used to analyze the results reported here are available for public review at <https://osf.io/7v3qj/>.



Fig. 2. Introduction to select grayscale setting on iPhones..

Android.

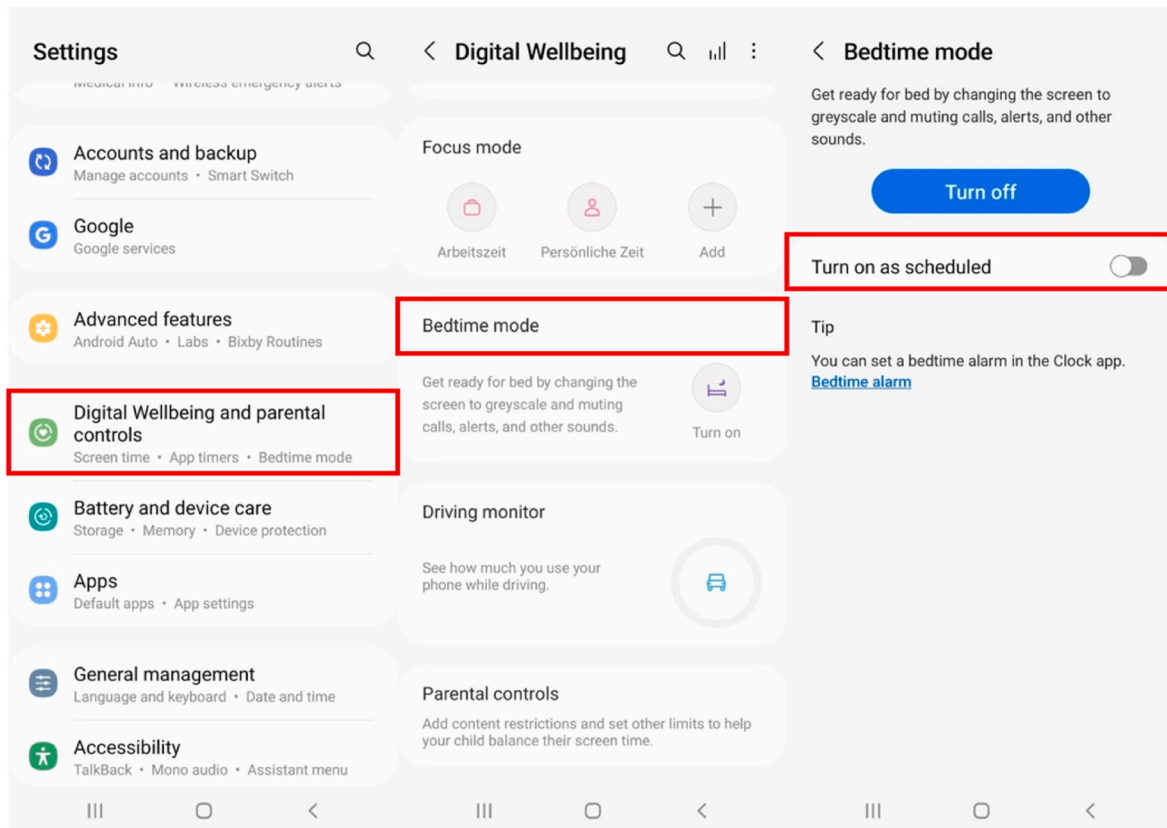


Fig. 3. Introduction to select grayscale setting on smartphones using Android software. .

Appendix B

German translation of the items on types of use adapted by [van Deursen et al. \(2015\)](#).

Process use:

- Ich benutze mein Smartphone, um dem "echten Leben" zu entfliehen.
- Ich benutze mein Smartphone, um mich zu entspannen.
- Ich benutze mein Smartphone, weil es unterhaltsam ist.
- Ich benutze mein Smartphone, weil es mich über tagesaktuelle Ereignisse informiert. Ich benutze mein Smartphone, um über die aktuellsten Nachrichten informiert zu sein. Ich benutze mein Smartphone, weil es mir hilft, Zeit zu vertreiben.
- Ich benutze mein Smartphone, weil es eine angenehme Abwechslung meiner täglichen Routinen bietet.

Social use:

- Ich benutze mein Smartphone, um mit Menschen zu interagieren.
- Ich benutze mein Smartphone, um Beziehungen zu pflegen.
- Ich benutze mein Smartphone, um andere Menschen anzurufen.
- Ich benutze mein Smartphone, um anderen Menschen zu schreiben.
- Ich benutze mein Smartphone, um andere Menschen durch Soziale Medien zu kontaktieren.

Habitual use:

- Die Nutzung meines Smartphones ist Teil meiner täglichen Routine.
- Das Checken meines Smartphones ist zu einer Gewohnheit geworden.
- Ich benutze mein Smartphone automatisch.
- Es ist eine Gewohnheit, mein Smartphone zu benutzen.
- Mein Smartphone ist ein Teil meines Lebens.
- Die Nutzung meines Smartphones zur Erledigung bestimmter Aufgaben ist für mich selbstverständlich.

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