Problematic smartphone use: behavioral, psychopathological, dispositional, and educational correlates

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LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following publications, which will be referred to in the text by their respective Roman numerals:

I **Rozgonjuk, D.**, Levine, J. C., Hall, B. J., & Elhai, J. D. (2018). The association between problematic smartphone use, depression and anxiety symptom severity, and objectively measured smartphone use over one week. *Computers in Human Behavior*, *87*, 10–17. doi:10.1016/j.chb.2018.05.019

II **Rozgonjuk, D.**, Saal, K., & Täht, K. (2018). Problematic Smartphone Use, Deep and Surface Approaches to Learning, and Social Media Use in Lectures. *International Journal of Environmental Research and Public Health*, *15*(1). doi:10.3390/ijerph15010092

III **Rozgonjuk, D.**, Kattago, M., & Täht, K. (2018). Social media use in lectures mediates the relationship between procrastination and problematic smartphone use. *Computers in Human Behavior*, *89*, 191–198. doi:10.1016/j.chb.2018.08.003

IV **Rozgonjuk, D.**, Elhai, J. D., Täht, K., Vassil, K., Levine, J. C., & Asmundson, G. J. G. (2019). Non-social smartphone use mediates the relationship between intolerance of uncertainty and problematic smartphone use: evidence from a repeated-measures study. *Computers in Human Behavior*, *96*, 56–62. doi: 10.1016/j.chb.2019.02.013

The author of the current dissertation contributed to the listed publications as following:

- The lead author for studies I to IV.
- Study conceptualization in studies I to IV.
- Data collection in studies I to III.
- Data analysis in studies I to IV.
- Writing the manuscript in studies I to IV.

LIST OF ABBREVIATIONS

ADHD	Attention deficit hyperactivity disorder
API	Aitken Procrastination Inventory
CBM	Cognitive-behavioral model
CIUT	Compensatory Internet use theory
CMA	Components model of addiction
DSM-V	Diagnostic and Statistical Manual of Mental Disorders, 5th Edition
E-SAPS18	Estonian Smartphone Addiction Proneness Scale
GAD	Generalized anxiety disorder
GIA	Generalized Internet disorder
ICD-11	International Classification of Diseases, 11th Edition
IGD	Internet Gaming Disorder
I-PACE	Interaction of person-affect-cognition-execution
IU	Intolerance of uncertainty
IUS-12	Intolerance of uncertainty Scale Short version
MIA	Model for Internet addiction
MPPUS	Mobile Phone Problem Use Scale
OCD	Obsessive-compulsive disorder
OMSU	Objectively measured smartphone use
PaIU	Pathological Internet use
PDA	Personal digital assistant
PIU	Problematic Internet use
PM	Pathways model
PSU	Problematic smartphone use
PTSD	Post-traumatic stress disorder
R-SPQ-2F	Revised Two Factor Study Processes Qustionnaire
SAS	Smartphone Addiction Scale
SAS-SV	Smartphone Addiction Scale Short Version
SEM	Structural equation model(ing)
SIA	Specific Internet addiction
UGT	Uses and gratifications theory

1. INTRODUCTION

According to a report published by Pew Research Center (2018) encompassing data from 39 countries, approximately three quarters of people surveyed use the Internet. Internet penetration is especially high in North America, Europe and parts of the Asia-Pacific, with typically more than 70% of adults being users. Furthermore, smartphones are very common in Europe and North-America, but also in many parts of Asia, with typically more than half of the population owning a smartphone or a mobile device. The role of mobile and smartphones in our daily lives is ever-increasing, and that calls for a need to study how smartphone use aligns with human psychology and behavior. The aim of the current dissertation is to provide knowledge on the topic of smartphone use in relation to behavioral, psychopathological, dispositional, and educational constructs. With this work, I am aiming to improve the state of literature on these topics from conceptual as well as methodological aspects.

While originally the word *smartphone* was defined as "any of various telephones enhanced with computer technology", the more contemporary definition is "a mobile phone that performs many of the functions of a computer, typically having a touchscreen interface, Internet access, and an operating system capable of running downloaded apps" (Oxford University Press, 2018). The evolution of smartphones may be somewhat confusing, as several products have been considered to be smartphones in the past, but may not be considered smartphones by the contemporary definition. Although personal digital assistants (PDAs), also known as handheld personal computers, were available earlier, the first smartphone, IBM's Simon, was released on sale for the public in August 1994. It had several features resembling contemporary smartphones, such as a touchscreen, e-mail capability, predictive typing, and calendar, but no web browser (Aamoth, 2014). Simon was followed by the first BlackBerry mobile device BlackBerry 5810 in 2002 which, too, has been considered to be among the first smartphones (Andrew, 2018). It featured a calendar and full keyboard, one could listen to music and access the Internet. However, both Simon and BlackBerry, by contemporary definition, would not be considered smartphones, as they did not have the capability of downloading (third-party) applications – instead, the applications were pre-installed during the production. Therefore, the first smartphone by present-day definition would be the iPhone, released by Apple in 2007, that, in addition to having pre-installed applications, met all the contemporary criteria. It had a touchscreen interface, Internet access, and operating system that was capable of running third-party applications (Andrew, 2018). Since the release of the iPhone, the smartphone market has exploded. For instance, according to a report published in 2018, around two thirds of the global population own a mobile device, most typically a smartphone (We Are Social Inc, 2018).

In comparison to their predecessors, mobile and cell phones, smartphones have introduced a variety of functionalities that allow their users to browse the

Internet, watch videos and listen to music (on- and offline), use different entertainment and productivity apps, but also enhance the omnipresence of social contact. In addition to the more traditional phone call and text messaging options, smartphones also provide ubiquity through the possibility of using social networking sites like Facebook, Twitter, Instagram, SnapChat, YouTube, and others. In many countries, smartphones could also be used for banking, and in some countries, like Estonia, also for other identification and verification related services, such as e-voting (Solvak & Vassil, 2016), potentially further driving the pick-up and diffusion of e-governance (Solvak et al., 2019).

Indeed, smartphones may be helpful in increasing one's productivity in comparison to predecessing cell phones, potentially because of the availability and ubiquity of access to e-mail, Web browsing and calendar/task management services (Kalkbrenner & McCampbell, 2011). Yet, high engagement inducing properties of smartphones may have also introduced some potential adverse associations and effects that have resulted in calls for caution due to potentially addictive effects of this technology (Kalkbrenner & McCampbell, 2011).

1.1. The research problem and aims of the dissertation

Smartphones are a relatively new technology, and yet their penetration and diffusion rates in the planet's population are vast. Although this technology may provide increases in productivity, social connectedness, and may bring more variety to leisure, it is largely unknown how smartphone use is related to human behavior, thinking, feeling, and health. Smartphone use research has been receiving increasing attention since the release of first smartphones less than fifteen years ago, and yet there are uncharted territories regarding the interplay between these devices and human psychology. This research is highly relevant not only in academic circles, but also for informing people outside of academia. Popular media and blogs tend to sensationalize the potential negative effects of mobile and smartphone use to even being called "an epidemic" (Baker, 2017), where excessive smartphone use is typically seen as the culprit of one's daily adversities. Several designated clinics in different countries around the world have been opened aiming to treat excessive Internet use related conditions. While the French government has already banned smartphone use in classes for schoolchildren younger than 15 years (CNN, 2018), it has also been debated in Estonia whether smartphones should or should not be used during academic activities (Sibold, 2017). This clearly exemplifies the importance of this line of research, as it is discussed on a national policy level. The current dissertation aims to fill several gaps in smartphone use research. The results of this study will not only advance this line of research, but could also be useful as input for policymaking. Even though the empirical evidence in this dissertation have their own limitations, they are in many ways the first, original reports providing answers to pressing research questions, such as:

- How is smartphone use related to psychopathology or constructs directly relevant to academic achievement?
- What could explain these potential relationships?
- Could smartphone checking be an indicator of a person's anxiety or depression symptom severity?
- Can one's depressive mood predict daily smartphone use?

I believe that the results of the presented original studies, as well as previous empirical evidence and theoretical frameworks used in this work, could provide compelling answers to these questions. There is an increasing amount of information being published each year describing the associations between excessive smartphone use and outcomes of interest. The following are some of the limitations and gaps in literature that need to be met.

It has recently been found that the level of smartphone penetration in the population is associated with higher levels of intolerance of uncertainty, the tendency to react negatively to events and situations with uncertain outcomes and a core factor in several anxiety disorders (Carleton, Desgagne, Krakauer, & Hong, 2018). However, no studies have thus far investigated how excessive smartphone use is associated with this construct, believed to be a core vulnerability factor in anxiety disorders. This dispositional construct in relation to smartphone use is further investigated in STUDY IV.

Although there are reports regarding associations between self-reported smartphone use and psychopathology, there is little evidence that also contrasts these findings with objectively measured smartphone use. In other words, a lot of research relies on self-reports rather than actually recorded behavior. Furthermore, while contemporary approaches hypothesize that a person's predispositions and dysfunctional coping with negative affect may drive more excessive smartphone use (Billieux, 2012; Brand, Young, & Laier, 2014; Brand, Young, Laier, Wölfling, & Potenza, 2016; Kardefelt-Winther, 2014), there are no studies that investigate daily mood in relation to smartphone use, measured objectively and with self-reports. Finally, in general, the field of smartphone use research relies largely on observational cross-sectional datasets, adding limitations to the interpretation of the causality in results. These limitations are addressed in STUDY I.

Studies have found that excessive mobile/smartphone use is related to poorer academic outcomes (Kates, Wu, & Coryn, 2018; Lepp, Barkley, & Karpinski, 2015; Samaha & Hawi, 2016); yet, there is little research on more general constructs, such as approaches to learning and procrastination, that may be pivotal in explaining these associations. These constructs are in the focus of STUDIES II and III.

This dissertation aims to fill these gaps in the literature of problematic smartphone use (PSU), or the excessive use of smartphones associated with functional impairments and resemblance to substance use disorders (Billieux, Maurage, Lopez-Fernandez, Kuss, & Griffiths, 2015). The specific objectives of original studies presented in this dissertation are:

- To investigate if and how objectively measured smartphone use (OMSU) is associated with self-reported PSU, depression and anxiety symptom severity measures, and daily depressive mood (STUDY I);
- To investigate if cross-sectionally measured self-reported PSU is associated with self-reported anxiety and depression measures, and daily depressive mood (STUDY I);
- To investigate if PSU is associated with approaches to learning (deep and surface) and if social media use in lectures could account for these relationships (STUDY II);
- To investigate if procrastination is associated with PSU in university students and if social media use in lectures mediates the relationship (STUDY III);
- To investigate if intolerance of uncertainty (IU) is associated with PSU and if types of smartphone feature use (for social and non-social purposes) may potentially explain the relationship in repeated-measures study design (STUDY IV).

These research aims have several implications. Of theoretical contributions, this dissertation introduces both replicative and original findings into the field of PSU research, further advancing the field. While some findings are relatively well-established (e.g, the link between PSU and depression and anxiety), there is little research that correlate OMSU, PSU, and psychopathology, and transdiagnostic measures. This dissertation includes studies that are among the first in investigating the relationships between PSU, approaches to learning, procrastination, and intolerance of uncertainty. These empirical works may also be helpful in assessing how theoretical frameworks may explain the findings. Secondly, the studies in this dissertation also present some methodological approaches that are relatively novel in the field. Although individual's smartphone use has been tracked before in some studies, there is a lack in research regarding the associations between OMSU, PSU, and psychopathology measures. This dissertation also provides the first study to implement measuring daily depressive mood over a period of one week in addition to OMSU and baseline psychopathology measures. Although there are two studies that implemented SEM methods on cross-sectional data, there is also a study that provides evidence from a repeated-measures design.

All in all, the current dissertation has several theoretical and methodological contributions that may also be useful for practical implications, e.g., providing evidence to support, reject, or at least discuss national policies. In this work, I am going to provide an overview of some theoretical approaches aiming to explain engaging in (excessive) smartphone use. These theories are also exemplified by empirical findings that have used the specific frameworks to conceptualize the findings. I will also discuss some controversies regarding the construct of PSU, and present findings and research gaps from the domains of smartphone use research in relation to academic settings and psychopathology. Then, I will provide a brief overview of the original studies in terms of their methodology, results, and how these findings may advance knowledge.

2. THEORETICAL FRAMEWORKS, EMPIRICAL FINDINGS, RESEARCH GAPS

2.1. A brief overview of relevant theories

Why are concerning associations between daily life variables and higher engagement in digital technology use observed? The following is a brief overview of some theoretical explanations for not only problematic smartphone use (PSU), but also for excessive engagement in digital technology use in general.

While reading works on the topic of PSU, it is highly likely that one will find different theoretical approaches that aim to conceptualize empirical findings of virtually the same phenomenon. It may be because of two primary factors: firstly, this whole field has a relatively short research history, and, secondly, academics from different disciplines describe the phenomenon based on the practices applied in their field of study. Therefore, instead of only opting for one single theoretical framework, I instead present some highly relevant and influential explanations in studying PSU. Furthermore, as the reader could find out below, I think that there may be a theory that could provide a unified model for explaining PSU, while also encompassing the elements of other theoretical frameworks. It is worth noting that most of these theories have been originally developed to describe the adverse effects and relationships within the context of excessive Internet use. However, these theories work logically and conceptually well for explaining problematic behaviors, antecedents, and outcomes related to excessive smartphone use, too. Below, I will provide a brief overview of the following frameworks: the components model of addiction (Griffiths, 2005), the uses and gratifications theory (Blumler, 1979), cognitive-behavioral model of pathological Internet use (Davis, 2001), pathways model of problematic mobile phone use (Billieux, 2012), the compensatory internet use theory (Kardefelt-Winther, 2014), and, finally, the interaction of person-affect-cognition-execution model (Brand et al., 2016). All of these theories have found use in PSU research.

According to the **components model of addiction** (CMA; Griffiths, 2005), both substance-related and behavioral addictions could be characterized by similar addiction criteria and could also share a similar developmental pathway via biopsychosocial processes (Kuss, Shorter, van Rooij, Griffiths, & Schoenmakers, 2014). Regarding digital technology engagement research, this model was initially applied in the field of Internet addiction domain, but has also found its place in PSU studies. The typical components of CMA are tolerance, withdrawal, salience, mood modification, relapse, and conflict (Griffiths, 2005). In the context of PSU, *tolerance* would mean that in order to experience similar gratifications, one needs to increase one's engagement in smartphone use. In other words, it would mean that the smartphone user is increasing their smartphone use over time – possibly reaching the state of almost constantly being on their device. *Withdrawal* may manifest in negative psychological and physio-

logical symptoms (e.g., anger, irritability, anxiety) after the decrease or discontinuation of the behavior. When a person with high levels of PSU will (suddenly) not be able to use their smartphone, it may bring upon a state of distress. *Salience*, in essence, is cognitive, affective, and behavioral preoccupation with the behavior. The person's thinking revolves around smartphone use, there is a craving for that, and some other behaviors, e.g., social interactions may be neglected due to smartphone use (Kuss et al., 2014). *Mood modification* could be regarded as the use of one's smartphone for escaping their real life (reality) and to cope with negative affect. Smartphone use may work as a mood regulator that helps in forgetting everyday problems. The c*onflict* component reflects the extent of struggle the excessive smartphone user experiences between the user and other people around them (e.g., conflicts between partners due to spending too much time on smartphone), with other activities (e.g., instead of studying, the student is spending time on smartphone engaging in other activities), or within the person themselves (e.g., subjective feeling of loss of control). Finally, *relapse* expresses difficulties to maintain the control over excessive smartphone use (e.g., after a period of PSU and subsequent period of decreased and controlled smartphone use, one backslides into the earlier behavioral patterns). Probably the most important and common application of the CMA approach in PSU research could be found in scales measuring the levels of PSU, such as arguably the most used instrument in PSU research, the Smartphone Addiction Scale developed by Kwon, Lee, et al. (2013), and its adaptations and spin-offs (e.g., Ching et al., 2015; Demirci, Orhan, Demirdas, Akpinar, & Sert, 2014; Kwon, Kim, Cho, & Yang, 2013; Rozgonjuk, Rosenvald, Janno, & Täht, 2016).

Because smartphones also have features of mass communication media, another relevant theoretical approach that has been implemented to conceptualize PSU, is the **uses and gratifications theory** (UGT; Blumler, 1979). According to UGT, the purpose of the media is to satisfy the psychological needs of people who actively seek out for that specific media. The several need satisfactions, or gratifications, could be the core motivators of specific media selection (Rubin, 2009). They allow to gratify various needs, such as relaxation, mobility, information seeking, and social needs (different gratifications are reviewed in Sundar & Limperos, 2013). Gratifications have been broadly categorized into three typologies: the content, process, and social gratifications. While the uses of media (and smartphones, too) could be due to its *content* (e.g., information, entertainment), the motivation in digital technology use could also be due to the *process* features of the technology. The latter implies to the use of technology for the actual experience of using the medium (e.g, exploring the technology, browsing online without the focused aim of seeking for information; Cutler & Danowski, 1980). Finally, contemporary digital technologies could also gratify social needs, by allowing for communication between people (Song, LaRose, Eastin, & Lin, 2004; Stafford, Stafford, & Schkade, 2004). Therefore, different types of need gratifications could reflect in different types of media uses. As noted by Stafford et al. (2004), the older UGT studies that

typically researched the uses and gratifications of television and radio did not identify the social aspect of these media technologies, sticking to the content/process distinction. However, smartphones are universal in the sense that they have features that may address all of these three gratification categories. One may entertain themself by watching videos, listening to music and playing games on their smartphone (content use); browse the Web, social media feed, and discover different applications on their smartphone (process use); (video) call and text people, chat via social networking sites, and send e-mails (social use). Furthermore, Song et al. (2004) did not find a clear dichotomy of content-process distinction while studying Internet addiction; instead, their empirical evidence supported the two-fold distinction of social and process gratifications. While it has been found that social smartphone use is associated with habitual (but not addictive) smartphone use, process features have been found to predict both habitual and addictive smartphone use (van Deursen, Bolle, Hegner, & Kommers, 2015). It has also been found that both social and process features are associated with PSU – with more evidence indicating larger effects between process features and PSU (Elhai, Hall, Levine, & Dvorak, 2017; Elhai, Levine, Dvorak, & Hall, 2017).

Among the more influential models regarding excessive Internet use is the **cognitive-behavioral model (CBM) of pathological Internet use** (PaIU) by Davis (2001). Adding to the theoretical behavioral tenets from addiction literature, Davis (2001) introduced the role of cognitions in development of PaIU. Specifically, the author discussed the role of distal and proximal contributory causes of problematic behavior. An individual's predispositional factors, such as psychopathology and situational cues could be considered as distal, while the interplay between maladaptive cognitions, social isolation, and Internet use specificity are considered as proximal factors. In addition, Davis (2001) also distinguished between generalized PaIU (more general and multidimensional overuse of Internet) and specific PaIU (dependency on a specific function of the Internet). Generalized PaIU relates more to communicative applications of the Internet and the lack of support in real life, which may be driven by feelings of social isolation and loneliness. On the other hand, specific PaIU may develop offline and Internet could serve as a medium to fuel other addictions, like pornography, gaming, and gambling. According to the CBM approach, high engagement in Internet use may not necessarily develop into pathological behavior. The CBM approach has also largely influenced the development of the I-PACE model (see below).

Billieux (2012) has proposed a **pathways model (PM) of problematic mobile phone use** that describes various pathways that lead to dysfunctional mobile phone use. According to PM, there are at least four pathways: impulsive, relationship, extraversion, and cyber addiction pathways. The *impulsive pathway* describes those whose smartphone use is typically driven by maladapative emotion regulation and/or poor self-control. The *relationship pathway* describes individuals who tend to use their smartphone in order to gain reassurance in affective relationships; typically, these individuals are characterized

by lower self-esteem and higher levels of neuroticism. The *extraversion pathway* describes people who are using their smartphone excessively due to being more sociable and outgoing, and they may have higher need for communication with peers. Finally, the *cyber addiction pathway* describes people who have a tendency to problematically engage in the use of various digital technologies and activities that may not be necessarily bounded to smartphones. Examples include online gaming, gambling, and social networking; this pathway is somewhat similar to the generalized PIU approach described by Davis (2001). These four proposed pathways can co-occur and are not mutually exclusive. Furthermore, according to the PM, the adverse consequences associated with PSU generate a vicious circle through the perpetuation of negative affect.

The **compensatory Internet use theory** (CIUT; Kardefelt-Winther, 2014) denotes that higher engagement in digital technology use may largely be driven by negative affect. Specifically, some people may use these technologies, such as the Internet in order to cope with negative emotions (Kardefelt-Winther, 2014). It is important to note, however, that CIUT does not conceptualize conditions, such as problematic Internet use (PIU) as disorders, but views it rather as a naturally occurring, though maladaptive, coping with distress. The main thesis is that negative affect related precondition leads to more digital technology engagement – resulting in problematic technology use in some individuals. CIUT, too, has been used in several studies in conceptualizing the relations between PSU and psychopathology symptoms (Elhai, Tiamiyu, Weeks, et al., 2018; Wang, Wang, Gaskin, & Wang, 2015; Zhitomirsky-Geffet & Blau, 2016).

Probably the most comprehensive theory that aims to explain the antecedents and mechanism of problematic digital technology use is the **model for Internet addiction** (MIA) by Brand et al. (2014) and its elaboration, the **interaction of person-affect-cognition-execution** model of excessive internet communications use (I-PACE; Brand et al., 2016). The MIA is strongly influenced by CBM (Davis, 2001), and it proposes that Internet use could be functional or dysfunctional. The latter is considered as addictive behavior, and is divided into generalized Internet addiction (GIA) and specific Internet addiction (SIA), similarly as in Davis (2001). The I-PACE focuses on explaining how specific Internet use related disorders are formed and maintained. In addition to being influenced by the CBM (Davis, 2001), it is also somewhat based on the Internet gaming disorder (Dong & Potenza, 2014) and empirical evidence. The I-PACE reflects different levels of addiction (-like behavior) development and maintenance in Internet use related disorders. The I-PACE specifies that person's core characteristics, such as personality, social cognitions, biopsychological factors (genetics, stress vulnerability, early childhood experiences), and psychopathology, may influence how a certain situation is perceived and/or how the person responds to stressful situations and personal conflicts. In addition, a person's core characteristics should also influence one's coping style and digital technology use related cognitive biases (e.g., expectancies, illusions and implicit associations). These factors, in turn, influence the person's affective and

cognitive responses (e.g., craving, cue reactivity, attentional bias, and mood modification), and are conceptualized as mediators and moderators between the core characteristics and excessive digital technology engagement. This leads to the decision of using a certain Internet-based application, resulting in either adaptive gratification, or problematic behavior. As these processes reinforce, the condition results in problematic digital technology behavior, characterized by diminished control over the use of these technologies that leads to negative consequences in daily life. This condition, too, stabilizes and intensifies, influencing the person's core characteristics. The graphical depiction of the model is presented in Figure 1 (retrieved from Brand et al., 2016).

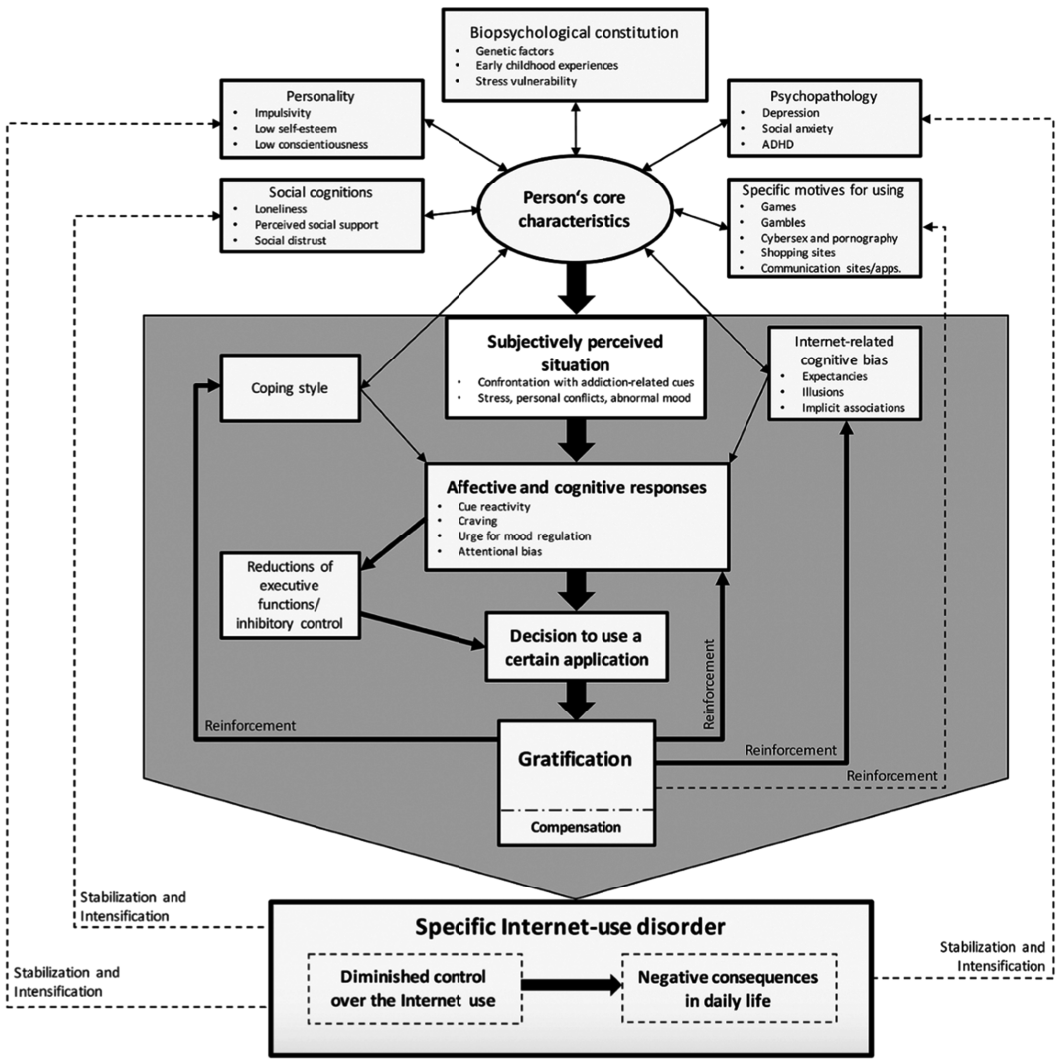

Figure 1. The Interaction of Person-Affect-Cognition-Execution model of excessive internet communications use (I-PACE; Brand et al., 2016)

The I-PACE approach is probably among the most comprehensive models to explain the antecedents, mechanism, the outcome, and interactions between these factors in problematic digital technology engagement behavior. This model specifies the complexity of the condition by introducing different direct and indirect pathways with potential feedback loops. The I-PACE could also serve as a model that joins other relevant theories mentioned above. For instance, components of the CMA (Griffiths, 2005) could be observed in different parts of the I-PACE. The I-PACE model specifies both the motivations and decision-making processes regarding specific media use, and how that leads to gratification, the central tenets of the UGT (Blumler, 1979). The I-PACE approach is also in line with the pathways model by Billieux (2012), emphasizing the role of predisposing factors in interaction with coping mechanisms and technology use, and including feedback loops that may be considered to be vicious circles described by Billieux (2012). Finally, the roles of stressful situations and coping with these situations and related (negative) emotions are also defined in the context of developing higher engagement in digital technology use – while it is also acknowledged that the outcome of these processes may in some cases lead to problematic behavior, cohering with the main theses of CIUT (Kardefelt-Winther, 2014).

Therefore, the I-PACE model could be the unifying framework that explains disordered digital technology engagement and joins relevant theories into a coherent model. The main limitation, however, could be the complexity of the I-PACE model that makes it difficult to test the relationships and processes described. Firstly, the number of potential variables mentioned in the model is very high. Secondly, many of those variables are interacted with each other. Finally, there are feedback loops on several levels that make it even harder to establish cause and effect in relations between different constructs. All in all, to test the I-PACE model empirically would mean to obtain a large number of research items from a large sample over a considerable period of time. Nevertheless, some recent studies (Lemenager et al., 2018; Montag, Sindermann, Becker, & Panksepp, 2016) have used more simplified takes on this model for conceptualizing problematic Internet use in the I-PACE framework (e.g., looking for rather linear relationships between the variables and not including potential feedback loops). In addition, specifically relevant to this dissertation, recent studies have started to embrace this theory in conceptualizing PSU (Duke & Montag, 2017; Montag et al., 2016).

To sum up, there are several theoretical approaches relevant in explaining PSU-like behaviors. While some of them take a more simplified take on PSU, probably among the more comprehensive (and also complex) models is the I-PACE approach (Brand et al., 2016). The I-PACE views the development of problematic digital technology use as an outcome of individual predisposing factors in interaction with (dysfunctional) reactions and coping with situations inducing negative affect that may lead to gratifying several negative emotion alleviation related gratifications that intensify over time. As a result, some individuals may develop PSU. These behavioral, cognitive, and affective patterns

are reinforced and further feed into predisposing factors, such as psychopathology. Because other theories explaining problematic digital technology engagement contain some elements described in the I-PACE, the I-PACE could be the approach that unifies other frameworks.

2.2. The emergence and controversies of technological addictions

Griffiths (1995) was among the first scholars to propose the concept of technological addictions. He operationalized technological addictions as "non-chemical (behavioral) addictions which involve human-machine interaction. They can be passive (e.g. watching television) or active (e.g. playing computer games) and usually contain inducing and reinforcing features which may contribute to the promotion of addictive tendencies." (Griffiths, 1995, p. 15). Griffiths (1995) drew upon an example of the "fruit machine addiction", (later) more commonly known as gambling disorder, of how the addiction components (see the components model of addiction) could be present in the human-machine interaction. A few years later, with the wider diffusion of the Internet in the population, a whole new field that focused on heavy Internet use related adversities started developing.

Among the first works looking into potentially addictive nature of the Internet were by Kimberley Young, where she presented a case study of an individual possibly addicted to Internet (Young, 1996), followed by the first seminal study including approximately 600 cases of people suffering from daily life adversities due to unability to control Internet use (Young, 1998a). Then, a paper where a measurement instrument was devised was published (Young, 1998b). Another pioneering work was by Griffiths (1996), where he discusses the nature of Internet as one of the potential technological addictions. These works could be considered landmark papers, at least in terms of scientific influence (measured in citations), that started a controversial field of Internet addiction research. It should be noted that the debates and issues in Internet addiction research are as relevant and timely in smartphone use research.

Why is the research field controversial? First, the term "Internet addiction" itself has been argued to be too broad, e.g., Griffiths (2000) argues that Internet is not what people are "addicted" to – rather, it serves as a medium to fuel other addictions (e.g., one may be addicted to gambling, therefore spending a lot of time in online casinos – this would manifest as excessive Internet use). Therefore, it would be necessary to understand if people are dependent *on* the Internet or *to* the Internet (Spada, 2014). However, as may be inferred from previously mentioned theoretical frameworks, e.g., the pathways model (Billieux, 2012), the CBM (Davis, 2001), the MIA (Brand et al., 2014), and the I-PACE (Brand et al., 2016), it could be both *to* and *on* the Internet. This may further obscure the treatment of high engagement in Internet use either as a manifestation of dysfunctionalities or being the outcome condition itself.

Second, there is confusion in how to call this phenomenon, and "addiction" terminology in this context has received much critique (Mihajlov & Vejmelka, 2017). There are different proposed terms for Internet-related problematic behavior, e.g., pathological Internet use (Morahan-Martin & Schumacher, 2000), Internet dependency (teWildt, 2011), problematic Internet use (Davis, Flett, & Besser, 2002), and Internet use disorder (Lachmann et al., 2018), to name some. Are all of these conditions reflecting the same construct? It seems that a number of studies have conceptualized these differently named conditions into an umbrella term "problematic Internet use" (PIU; Caplan, 2002; Shapira, Goldsmith, Keck Jr, Khosla, & McElroy, 2000; Widyanto & Griffiths, 2006). Beard and Wolf (2001, p. 378) have proposed that PIU is the "use of the Internet that creates psychological, social, school, and/or work difficulties in a person's life", and the most popular conceptual approach seems to be the (components model of) addiction approach (Caplan, 2002). Nevertheless, there is still no unison with regards to the name of this phenomenon. That is, some researchers have been advising moving away from addiction terminology, as "Internet addiction" has been regarded as a misnomer (Griffiths, 2018).

Third, the direction of causality is not clear. Although PIU has been shown to be related to various psychological disorders (Ho et al., 2014; Ko, Yen, Yen, Chen, & Chen, 2012), it is not clear if PIU is caused by underlying psychopathology, causes psychopathology, or is a comorbidity of accompanying psychopathology. In addition, it is not clear if PIU would be a separate diagnosis of its own accord or if it is triggered by underlying, comorbid psycho(pato)logical conditions (Mitchell, 2000). Again, the theoretical approaches mentioned earlier in this dissertation allow to infer that all of these causality directions may be valid. Internet use is nowadays so intertwined with daily functioning that it is difficult to study the cause and effect.

Fourth, there is a lack of consensus among experts regarding the construct. Some researchers have argued that PIU could be considered as an addictive behavior or an impulse-control disorder (Shapira et al., 2000), typically characterized by a set of addiction symptoms (Potenza, 2006; Widyanto & Griffiths, 2006). Additionally, it has been proposed that despite being an ill-defined construct, two features appear to be fundamental for conceptualization of PIU: the first is the excessive (or compulsive) Internet use, and the second characteristic is the myriad of various adverse consequences due to spending too much time online, e.g., neglecting social and professional activities, tasks, and one's health (Spada, 2014). Another related issue is that the construct of PIU is non-standardized and criteria of PIU make it hard to estimate and compare the prevalence of this condition (Spada, 2014).

Finally, the number of daily life operations adjusted for online environments (e.g., communication, banking, working, etc) has been on the rise and will likely be increasing in the future. Could it be that increasing time spent online is just a new reality? And if so, could it be that activities that require more time online are viewed as pathological, even though they may not necessarily be so? It could be that many daily life activities, e.g., excessive working, exercising,

eating, and others (Demetrovics & Griffiths, 2012), could lead to a genuine addiction, but it is necessary to shift the research from a mere criteria-based approach to a more integrative approach including other psychological processes (Billieux, Schimmenti, Khazaal, Maurage, & Heeren, 2015).

It should be noted that after scholarly debate that has spanned over approximately two decades, Internet addiction has not been included in the latest editions of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013), nor in the International Classification of Diseases (ICD-11; World Health Organization, 2018). Nevertheless, the relationships between various adverse daily life outcomes and PIU are relatively well-documented (Ho et al., 2014; Ko et al., 2012), suggesting that there is definitely something worrisome going on. Although not in the focus of this study, it would still be relevant to mention that of Internet use related conditions, problematic gaming behavior has been included to both DSM-5 (as Internet Gaming Disorder; IGD) under Section III (emerging measures and models/conditions for further study) and to ICD-11 (as Gaming Disorder). As a response to the inclusion of IGD as a diagnosis in section III of DSM-5 (that also fits with recent developments seen in ICD-11), several researchers have refrained from addiction terminology (e.g., Internet addiction), and have started using Internet Use Disorder (IUD) terminology, viewing IGD as a distinct form of IUD (Sindermann, Sariyska, Lachmann, Brand, & Montag, 2018).

It would also be necessary to point out the link between Internet use disorders and smartphones. The aforementioned I-PACE model (Brand et al., 2016) deals with specific Internet Use disorders and does not explicitly mention smartphones. Yet there is a large overlap between Internet Communications disorder (problematic use of communication applications) and problematic smartphone use, with the latter possibly being a *mobile* form of IUD (Montag et al., 2018; Sha, Sariyska, Riedl, Lachmann, & Montag, 2018).

2.3. Excessive mobile device use in association with health and behavior

Earlier works have reported negative associations between mobile phone use and various daily life outcomes. First studies on this topic were looking into how mobile phone use while driving influenced the drivers' attentional capacities, implying to detrimental effects of mobile phone use while behind the wheel (e.g., Johnson, Voas, Lacey, McKnight, & Lange, 2004; Violanti, 1998; White, Eiser, & Harris, 2004). A recent review paper confirms that mobile phone use (even when using a hands-free device) while driving has detrimental effects on driving (Lipovac, Đerić, Tešić, Andrić, & Marić, 2017). One of the main explanations to these results is that mobile phone use while driving impairs the driver's attention, leading to physical, visual, auditory, and/or cognitive distraction (Lipovac et al., 2017).

Although not in the focus of this study, another research area regarding the associations between health and mobile phone use has been focusing on the potential carcinogenic effects of mobile phone use (Blettner & Berg, 2009). It has been hypothesized that exposure to radiofrequency radiation may increase tumor incidence (see Moulder et al., 1999 for a review on relevant physics, technology of smartphones, and radiation research). Recent meta-analyses provide mixed results in this field, showing no statistically significant relationship between mobile phone use and brain cancers or tumors in the head (Repacholi et al., 2012), or indicating to the increased risk of intracranial tumors related to long-term (over 10 years) mobile phone use (Bortkiewicz, Gadzicka, & Szymczak, 2017).

Among the main functions of mobile devices could be generally considered the enhancement of mobility in communication and the ability to contact and be contacted by others with more flexibility regarding one's physical location. In addition to phone call and text-messaging features, mobile phones over the last two decades have typically included additional features, such as an address book and mobile games (e.g., the Snake mobile game). These attributes could increase the engagement of a mobile phone user, and in some cases this may lead to problematic usage behavior (Billieux, 2012).

Indeed, as was the case with the emergence of the Internet, excessive engagement in mobile phone use in relation to daily-life adversities started gaining research interest. The first studies were conducted in Asian cultures, such as Korea (Kim, Ho, & Man, 2007; Park, 2005) and Japan (Toda, Monden, Kubo, & Morimoto, 2004). The findings indicated to mobile phone addiction being related to loneliness, lower need for mental stimulation and using mobile phone for passing time (Park, 2005). Additionally, associations with depression, aggression, impulsivity and attention were reported (Kim et al., 2007). In the mentioned works, excessive mobile phone use was investigated from the addiction perspective, e.g., as a mobile phone addiction/dependency.

Because addiction approach to study excessive mobile phone use has been applied, measures studying the condition were inspired by previously known addiction frameworks and/or substance abuse related measures, as could be seen in an overview of some of the measures that were used to study mobile phone addiction in Billieux (2012, p. 2). It could also be observed that these instruments were either using a several-point Likert scale or a multi-item dichotomous measure. While in some cases the scales allowed for multifactorial approaches, most of the instruments could be used for a unidimensional approach (e.g., measuring problematic mobile phone use).

Similar to what has been demonstrated in Internet use related literature, relations between psychopathology and mobile phone addiction have been found in various studies, e.g., mobile phone addiction has been associated with increased levels of depression, stress, anxiety, and sleep disturbances (see De-Sola Gutierrez, Rodriguez de Fonseca, & Rubio, 2016 for a review; it should be noted that in this work, smartphones are also included as mobile devices). De-Sola Gutierrez et al. (2016) also mentioned that the emergence of mobile phone

use also marked the emergence of a potentially addictive behavior – maybe even more so, when smartphone use penetrated the population. Mobile devices allow for high portability and accessibility, and it has also been shown that although there are similarities between different problematic digital technology use conditions (e.g., problematic Internet use, problematic social media use, Internet gaming disorder), these conditions are distinct from each other in terms of phenomenology, and may be associated with different outcomes (Baggio et al., 2018; Kiraly et al., 2014).

2.4. From smartphone addiction to problematic smartphone use (PSU)

Research on the topic of mobile phone addiction has been on the rise (Carbonell, Guardiola, Beranuy, & Belles, 2009). As mentioned earlier, the emergence of smartphones may have further increased the level of potential engagement with the device, further fuelling this research area.

One of the potential issues in the field of mobile/cell/smartphone studies is the variety of terminology that potentially describe the same phenomenon. One may find literature on several mobile/smartphone-related conditions that, essentially, seem to imply to a similar – if not indistinguishable – phenomenon. Of course, the disparities may be nuanced, e.g., the difference between "mobile phone addiction" (Park, 2005) and "smartphone addiction" (Choi, Lee, & Ha, 2012) may be in the level of programmability the latter provides, introducing several features unavailable in older, pre-smartphone mobile devices. Yet, "smartphone overuse" (Hwang, Yoo, & Cho, 2012) and "excessive smartphone use" (Kim, Kim, & Jee, 2015) seem to be describing virtually the same thing. One of the reasons in the terminological disparity could also be due to translational differences, as especially in the earlier years, smartphone use research was conducted in Asian cultures, e.g., in Korea and China. The plentitude of terms already implies to one of the problems in that line of research: little consensus in a standardized description of the construct.

Using addiction terminology and considering mobile or smartphone addiction (or problematic use of these devices) as an addictive behavior has also been critiqued (Billieux, Maurage, et al., 2015; Billieux, Philippot, et al., 2015). On one hand, there is lacking evidence that either confirms or rejects the addiction model approach regarding a mobile device addiction (Billieux, Maurage, et al., 2015); on the other hand, using addiction framework in research may have limited clinical relevance, as it does not identify the etiopathological processes, and suggests targeting the symptoms instead of their causes (Billieux, Philippot, et al., 2015). In addition, the field of excessive smartphone use research shares similar controversies as mobile phone addiction and Internet addiction discussed earlier. Seemingly the same problems seen in Internet addiction debate haunt smartphone use research.

Recently, therefore, scholars in the field of excessive technology research and addictions have proposed avoiding addiction terminology. While in itself, the term "problematic use" was implemented earlier (e.g., Wang et al., 2015), also in research regarding Internet use (e.g., Shapira et al., 2000), Panova and Carbonell (2018) called upon a consensus in using the term "problematic smartphone use" for coherence and clarity in the field. PSU, therefore, would work as an umbrella term for all excessive smartphone use related conditions. Typically, the operationalization still includes some elements of the addiction approach, with PSU reflecting adversities related to smartphone use, such as withdrawal (experiencing negative emotions, typically anxiety, irritability, and anger, when being unable to use the smartphone), tolerance (failed attempts to reduce smartphone use, and possibly increase of smartphone use over time), and various daily-life disturbances, such as missing planned activities, experiencing problems in social functioning, and decreased productivity at school or/and work (Kwon, Lee, et al., 2013). It should be noted, however, that despite this, there is still no consensus regarding how to name that somewhat confusiong condition. "Problematic smartphone use" is in itself somewhat ambiguous, as it does not explicitly specify if it stands for a person being on the way from "healthy" to experiencing full-blown psychopathological symptoms, or is it the end condition in itself (Rozgonjuk, Elhai, & Hall, in press). Furthermore, newer works have also started implementing the "smartphone use disorder" terminology (e.g., Lachmann et al., 2018; Sha et al., 2018), further exemplifying the lack in consensus in the field. It is my hope that during the upcoming years a solution to this issue is found, and the suitable term is agreed upon. With that being said, I will continue using the "problematic smartphone use" terminology in this dissertation, because this has recently been explicitly proposed (Panova & Carbonell, 2018). However, I will once again emphasize and acknowledge that during the time of writing these lines, the debate regarding the terminology is still ongoing. Therefore, the following conceptualization will be used throughout this dissertation: **problematic smartphone use (PSU**) is viewed as **excessive use of smartphone that is associated with functional impairment and symptoms resembling substance use disorders, such as withdrawal and tolerance** (Billieux, Maurage, et al., 2015).

As mentioned earlier, measures of PSU are largely influenced by measures used in excessive Internet use related disorders research. Typically, those instruments have measured facets of addiction symptoms, therefore allowing for treating the scales as both multi- and unidimensional. Recently, Rozgonjuk et al. (2016) and Ellis, Davidson, Shaw, and Geyer (2018) have provided brief overviews of various instruments that have been used to measure (problematic) smartphone use related phenomena. While it is possible to retrieve the number of citations to gauge at the academic impact of different scales, these citations may not necessarily reflect the actual use of these instruments. Arguably the most cited article that includes the development of a disordered mobile device use related instrument is the Mobile Phone Problem Use Scale (MPPUS) by Bianchi and Phillips (2005) with more than 1000 citations according to Google

Scholar (accessed on 28.12.2018). However, probably the most influential smartphone-related measure is the Smartphone Addiction Scale (SAS) developed by Kwon, Lee, et al. (2013) with more than 400 citations according to Google Scholar (accessed on 28.12.2018). Interestingly, while the original SAS includes 33 items, Kwon, Kim, et al. (2013) published a shorter, 10-item SAS-SV the same year. That article has thus far received more than 250 citations (according to Google Scholar, accessed on 28.12.2018). Because either a longer, shorter, or an Estonian spin-off of the SAS has been used in publications included in this dissertation, I will provide a brief overview of the SAS.

The original SAS included 33 items measuring different facets of smartphone addiction. The responses for each item range from "strongly disagree" (1) to "strongly agree" (6) on a 6-point Likert scale, with higher scores indicating to higher level of adversity intensity. The six factors of the whole SAS are: daily-life disturbances, positive anticipation, withdrawal, cyberspace-oriented relationships, overuse, and tolerance; these factors form a higher-order factor of smartphone addiction. As may be seen, this scale is loosely based on the components model of addiction (Griffiths, 2005). Despite initially measuring "addiction", the scale (and it's shorter analogue) is *de facto* used to measure PSU across a large body of works (e.g., see Contractor, Frankfurt, Weiss, & Elhai, 2017; Elhai, Levine, Dvorak, & Hall, 2016; Wolniewicz, Tiamiyu, Weeks, & Elhai, 2018).

2.5. Objectively measured smartphone use (OMSU) in relation to PSU

One of the main limitations in PSU research is that many of the studies rely on self-report measures. Moreover, the studies typically do not gauge self-reported smartphone duration and frequency, but the main focus in PSU research are the levels of PSU symptoms' severity. This means that although people do report several adversities related to smartphone use, there is actually a lack in studies validating the self-report measures with objectively recorded smartphone use. Previous studies have demonstrated that when it comes to estimating one's smartphone use in terms of duration or frequency, subjective estimations relate poorly to objectively measured smartphone use (OMSU; Andrews, Ellis, Shaw, & Piwek, 2015; Boase & Ling, 2013; Montag et al., 2015). Furthermore, the research body regarding specifically PSU in relation to OMSU is scarce. Because PSU, by definition, should be related to excessive smartphone use behavior, using recorded behavioral measures should provide a more valid insight into psychopathology research (Andone et al., 2016; Miller, 2012; Yarkoni, 2012).

Among the more straightforward approaches to study OMSU is measuring smartphone use duration (screen time) and the frequency of smartphone checking (smartphone screen activation). While the former may be a reflection of time spent in one's smartphone by potentially engaging in more socially

passive activities, such as watching videos, scrolling news feeds, browsing websites, and playing games, the latter could be an indication of socially more active activities that may develop phone checking behavior, such as e-mail and social media notification checking, text messages, etc.

In order to measure the duration and frequency of smartphone use, researchers have typically used a third-party application to retrieve the data. Some researchers have implemented a commercial third-party app, such as Moment (Holesh, 2017) for iPhone tracking, and Funf in a Box (Aharony, Pan, Ip, Khayal, & Pentland, 2011), Menthal (Andone et al., 2016), and SystemSens (Falaki, Mahajan, & Estrin, 2011) for Android smartphones, to name some. While Moment retrieves and displays the duration and frequency of smartphone usage over time, other applications include more sensors that allow to track additional parameters. Furthermore, with announcing the iOS 12, Apple introduced the Screen Time application that allows iPhone users to track their phone usage (Apple Inc, 2018), reducing the need for researchers to burden their participants with downloading and installing a third-party application. In fact, a recent study has also suggested that only retrieving a screenshot from an iPhone user's Screen Time app could already prove to be feasible and with high validity for smartphone use research (Gower & Moreno, 2018). Nevertheless, research that implements objectively measured smartphone use data with regards to psychopathology and PSU is scarce; furthermore, the field also lacks in studies that have, in addition to objectively recording smartphone use data over time, measured the study participants' daily mood to relate it to smartphone use. The objective of STUDY I was to fill these gaps.

2.6. Smartphone use in academic settings

Students use their cell phones during class even though it may not be allowed to do so (Tindell & Bohlander, 2012). While smartphone use may be beneficial when used appropriately, e.g., by implementing gamification and using applications that engage the students, such as Kahoot (Bernal, Ares, Bernal, Nozal, & Sánchez, 2018), non-purposeful smartphone use in class has been associated with lower academic outcomes (Kuznekoff, Munz, & Titsworth, 2015). Students who engaged in non-relevant smartphone use in class also took less notes (Kuznekoff et al., 2015). Furthermore, it has been demonstrated that it may be social media use that could be detrimental to academic achievement, and it could be related with less concentration on learning tasks (Judd, 2014; Junco, 2012b).

It has been proposed that the relationship between smartphone use and productivity, be it work-related or academic, could have an inverted-U shape, with no digital technology use as well as excessive use being associated with poorer performance (Montag & Walla, 2016). In fact, this phenomenon has also been called the Goldilocks hypothesis (Przybylski & Weinstein, 2017), and there is some empirical support for it in a sample of teenagers, indicating to

adverse effects of not using or excessively using the Internet at school (Rozgonjuk & Täht, 2017). A potential explanation is that students who do not use digital technology, may miss out on (schoolwork) enhancing features, such as browsing for additional materials and school-related communication; on the other hand, excessive users may be so engaged with their devices that they may allocate their finite attentional resources to activities not related to schoolwork. In this dissertation, the focus is rather on the excessive use of smartphones in relation to educational factors, acknowledging that other studies could find it as interesting to investigate the other end of the inverted-U shape, the non-users.

Nonsurprisingly, excessive smartphone use has been shown to be associated with poorer academic outcomes (Lepp et al., 2015; Samaha & Hawi, 2016). However, there is little research that links PSU to other educational constructs that may affect academic performance. Although studies have demonstrated the prominent role of multitasking, or doing more than one thing at a time (Wood et al., 2012), in relation to learning and mobile device use (see Chen & Yan, 2016 for a review), there is still a need to understand the interplay between a person's predisposive factors, smartphone use, and academic outcomes. One of those trait-like characteristics that may be relevant in educational settings, is procrastination, or delaying relevant planned activities, resulting in subjective feeling of discomfort (Steel, 2007; Steel & Klingsieck, 2016). Based on some of the findings described above, it may be believed that trait procrastination could lead to more PSU. PSU, however, may further lead to less focused learning, more surface, and less deep approach to learning. Because social media use has been shown to be a vulnerability factor in developing PSU (Lopez-Fernandez et al., 2017), it would also be logical to investigate the role of social media use in lectures with PSU and the educational variables highlighted above. In addition, it has also been shown that more social media use is related to poorer academic outcomes (Al-Menayes, 2015; Kirschner & Karpinski, 2010; Liu, Kirschner, & Karpinski, 2017). Therefore, in STUDY II, I will demonstrate the association between PSU and approaches to learning, and how social media use in lectures may explain that relationship. In STUDY III, the potential role of trait procrastination as a predisposing factor is examined in relation to PSU, and social media use in lectures is treated as a potential driver of that relationship.

2.7. Smartphone use in association with psychopathology

That PSU is associated with psychopathology, mainly mood-related disorders, is well-documented. Among the more researched are the relations between depression, anxiety and PSU, with higher levels of PSU typically indicating to increased depression and anxiety (reviewed in Elhai, Dvorak, Levine, & Hall, 2017; Elhai, Levine, & Hall, 2018). In addition, PSU has been shown to be associated with lower psychological well-being (Herrero, Urueña, Torres, & Hidalgo, 2017), higher levels of social anxiety and loneliness (Bian & Leung, 2014; Enez Darcin et al., 2016), sleep disturbances (Demirci, Akgonul, &

Akpinar, 2015), symptoms of post-traumatic stress disorder (PTSD; Contractor, Frankfurt, et al., 2017; Contractor, Weiss, Tull, & Elhai, 2017), and attention deficit hyperactivity disorder (ADHD; Kim, 2018).

Because PSU is associated with a relatively wide range of psychopathology, researchers have recently started looking into traits that could be core vulnerabilities across several psychological disorders. These factors that overlap between several psychological disorders are called transdiagnostic, and are considered to be core vulnerability factors (Krueger & Eaton, 2015). Studying transdiagnostic factors in associations with psychopathology variables could be useful, as potential therapeutic approaches could have a deeper and more far-reaching impact on psychological treament outcomes (Farchione et al., 2012; Newby, McKinnon, Kuyken, Gilbody, & Dalgleish, 2015). It would also be necessary to study these aspects of human psychology, as contemporary theoretical frameworks seem to emphasize the role of these factors in developing digital technology engagement – in some cases, they may lead to problematic behaviors like PSU (Billieux, 2012; Brand et al., 2014; Brand et al., 2016; Davis, 2001).

With regards to smartphone use research, many important constructs have been shown to be related to both higher smartphone use engagement and mental illness symptoms. Poor emotion regulation has been associated with the duration of smartphone use (Elhai, Tiamiyu, Weeks, et al., 2018), while higher distress tolerance and more mindfulness (Elhai, Levine, O'Brien, & Armour, 2018) were associated with lower levels of PSU. Higher levels of PSU have also been shown to be related to higher proneness to boredom (Elhai, Vasquez, Lustgarten, Levine, & Hall, 2017), more ruminative thought style (Elhai, Tiamiyu, & Weeks, 2018), anger and worry (Elhai, Rozgonjuk, Yildirim, Alghraibeh, & Alafnan, 2019), and negative affectivity in general (Elhai, Levine, Alghraibeh, et al., 2018).

In the current dissertation, I am providing further evidence on the relations between PSU and transdiagnostic factors. Specifically, one of these variables is intolerance of uncertainty (IU), or the tendency to consistently negatively react to uncertain events despite the likelihood of their occurrence (Carleton, 2016). This construct is especially interesting, as IU is considered to be a core vulnerability factor in several anxiety disorders (Borkovec & Roemer, 1995; Carleton, Collimore, & Asmundson, 2010; Tolin, Abramowitz, Brigidi, & Foa, 2003), and it has been recently shown that higher smartphone penetration may be related to increased levels of IU (Carleton et al., 2018). However, it has not been researched if IU is associated with PSU; furthermore, it is unclear what type of smartphone feature use may explain that relationship. The aim of STUDY IV is to fill these research gaps.

3. AN OVERVIEW OF THE STUDIES

3.1. Data and Methods

There are many similarities and distinct characteristics in the datasets and methodology used in the original studies presented in this dissertation. General properties of study data and methodology are presented in Table 1. As one may see, the participants were college/university students in all studies with more than 70% of them being female. In each study, bivariate correlations between variables of interest are presented. All studies have implemented a structural equation modeling approach. Finally, in all studies, a similar scale for measuring PSU levels is used, as both E-SAPS18 and SAS-SV are developed from the SAS.

Some differences between the studies should also be mentioned. In STUDIES I and IV, a U.S.-based sample was used, whereas STUDIES II and III included Estonian participants. Latent growth curve modeling was used in STUDY I, whereas in STUDIES II-IV structural regression and mediation analysis were used. In STUDIES I and II, PSU was used as a predictor, whereas in other studies it was treated as the outcome variable. This approach could be justified by the I-PACE model (Brand et al., 2016) mentioned above, where PSU could be viewed both as the outcome of other predisposing factors and as the predictor of other outcomes, such as approaches to learning in STUDY II. STUDIES I and IV focused more on studying psychopathology in relation to smartphone use, whereas the context of STUDIES II and III was focused more on educational settings. Although in STUDY I we also included objectively measured smartphone use data, most of the data were collected by using self-report measures.

Table 1. A brief overview of study characteristics

	STUDY I	STUDY II	STUDY III	STUDY IV
Data collection time	2017 fall semester	2015 fall semester	2017 spring semester	2018 fall semester
Outcome variable(s)	OMSU duration and frequency	Deep and surface approach to learning	PSU	PSU
Predictor(s)	PSU; depression and anxiety severity; daily depressive mood; age; gender	PSU; social media use in lectures; age and gender as covariates for mediator	Procrastination; social media use in lectures; age; gender	IU; process and social smartphone use
Mediator(s)	NA	Social media use in lectures	Social media use in lectures	Social and process smartphone use
Analysis methods	Correlation analysis, latent growth curve modeling	Correlation analysis, structural regression, mediation analysis	Correlation analysis, structural regression, mediation analysis	Correlation analysis, structural regression, mediation analysis
PSU measure	SAS	E-SAPS18	E-SAPS18	SAS-SV
Other measures	DASS-21, daily depressive mood items, the Moment application (OMSU duration and frequency)	R-SPQ-2F, social media use in lectures score	API, social media use in lectures score	SPSUS, IUS-12
Sample	101 U.S. college students (76.2% women), M_{age} = 19.53, SD_{age} = 4.31	405 Estonian university students (79% women), M_{age} = 23.33, SD_{age} = 4.21	366 Estonian university students (76.2% women), M_{age} = 19.53, SD_{age} = 4.31	261 U.S. college students (76.9% women), M_{age} = 19.73, SD_{age} = 3.52

Notes. API = Aitken Procrastination Inventory; E-SAPS18 = Estonian Smartphone Addiction Proneness Scale; IU = intolerance of uncertainty; IUS-12 = Intolerance of Uncertainty Scale-Short version; OMSU = objectively measured smartphone use; PSU = problematic smartphone use; R-SPQ-2F = Revised Two Factor Study Process Questionnaire; SAS = Smartphone Addiction Scale; SAS-SV = Smartphone Addiction Scale Short Version; SPSUS = Social and Process Smartphone Use Scale.

I will provide a more detailed, yet brief overview of each individual study below.

3.2. STUDY I: PSU, OMSU, psychopathology, and daily depressive mood

Although knowledge on associations between smartphone use and psychopathology is expanding, the proportion of research that has also implemented objective smartphone use tracking is scarce. For instance, Elhai, Tiamiyu, Weeks, et al. (2018) found that lower depression was related to increased smartphone use duration over a week, while emotional suppression predicted more baseline smartphone use duration.

Yet, even while some studies have looked into OMSU relations with psychopathology, among that research, a small number of studies have specifically looked into the relationships between PSU (or a similar condition) and OMSU. Results in this domain have been somewhat mixed. Lin et al. (2017) found that OMSU duration and frequency predicted self-reported PSU symptoms. Furthermore, Lin et al. (2015) have found that smartphone checking frequency predicts self-reported PSU, while Wilcockson, Ellis, and Shaw (2018) did not find OMSU to predict self-reported PSU.

The aforementioned studies have typically used cross-sectional baseline measures of psychopathology variables and/or PSU to predict OMSU over a period of time. However, there is no research that implements ecological momentary assessment (EMA) to see how one's daily mood relates to the corresponding day's OMSU.

Therefore, the central research questions of STUDY I were:

1. How are OMSU duration and frequency related to
    a. self-reported PSU;
    b. self-reported depression and anxiety symptom severity;
    c. daily depressive mood?
2. How is cross-sectionally measured PSU associated with
    a. self-reported anxiety and depression severity;
    b. daily depressive mood?

The specific information regarding methodology and results of STUDY I are reported in Rozgonjuk, Levine, Hall, and Elhai (2018). We combined cross-sectional self-report measures (via a web survey) with OMSU and self-reported daily depressive mood items over a week among college students. We used the cross-sectional measures for baseline assessment of PSU (measured with the SAS), and depression and anxiety symptom severity (measured with the DASS-21). For objective recording of smartphone use behavior, we used the Moment app mentioned earlier. For daily depressive mood, we sent a text message (using the ClickSend platform) each morning for each participant, asking about the participant's daily depressive mood with two questions from the previous day. We used latent growth curve analysis in order to see if the predictors

(baseline measures and daily depressive mood items) predict OMSU duration and smartphone checking frequency. Age and gender were used as covariates predicting OMSU.

The results of correlation analyses showed that OMSU duration is correlated with PSU, but not with depression and anxiety severity nor the weekly average daily depressive mood; OMSU frequency was negatively correlated with depression and anxiety, but was not associated with PSU and weekly average daily depressive mood. Similar results were demonstrated in latent growth curve analyses, although the results held when the week's baseline, but not growth over a week, was predicted for OMSU. In addition, younger age predicted more baseline OMSU frequency. These somewhat disparate results are the more interesting, because OMSU duration and frequency were consistently correlated to each other during each measurement day, yielding Spearman correlation coefficient sizes of .262 to .398.

Self-reported PSU was positively associated with both self-reported depression and anxiety symptom severity, but also with the average daily depressive mood over a week. These results are consistent with previous findings, where depression and anxiety have been found to be related with these psychopathology variables (reviewed in Elhai, Dvorak, et al., 2017; Elhai, Levine, & Hall, 2018).

What do these results tell us? Maybe the most important takeaway point from here is that smartphone use duration and frequency, although related behavioral constructs, may indicate to different behavioral smartphone use patterns. While smartphone use duration is associated with PSU, smartphone use frequency is not. Furthermore, more frequent smartphone use (e.g., more screen unlocks) is related to decreased levels of depression and anxiety symptom severity. These findings may suggest that more frequent smartphone users could be more socially active smartphone users – it could be due to more social cues, such as phone calls, text messages, and social media notifications. It could also be that higher frequency of smartphone use could be associated with work-related activities. Furthermore, while smartphone use duration may reflect more socially passive content consumption with less active interaction (watching videos, browsing social media sites), smartphone use frequency may be associated with using more socially active smartphone features (such as texting, phone calls, receiving social media notifications, etc). Yet, this interpretation is thus far hypothetical, and needs to be further tested.

It is also interesting that smartphone use duration is correlated with PSU, while not being correlated to depression and anxiety. These results add to body of existing literature that has provided mixed results thus far. While Lin et al. (2015) have demonstrated that smartphone use frequency is associated with PSU severity, Lin et al. (2017) have found that both higher smartphone use duration and frequency are predicted by higher levels of PSU. Yet, Elhai, Tiamiyu, Weeks, et al. (2018) found that lower depression is related to increased smartphone use over a week, and Wilcockson et al. (2018) did not find PSU to be related to OMSU at all. Finally, a very recent study that

encompassed several self-report PSU measures demonstrated that there may be some variability in the relationship between PSU and OMSU due to using a specific PSU scale (Ellis et al., 2018). However, when the same scale was used in Ellis et al. (2018) which was used in STUDY I, both OMSU duration and frequency were related to PSU. One potential explanation to this mixed bag of results could be that PSU is not necessarily a measure of high engagement in smartphone use, but contains more subjective elements describing adverse associations related to smartphone use. In other words, it could be that high engagement in digital technology use may not be necessarily problematic, as has been argued by several authors (Billieux, 2012; Brand et al., 2014; Brand et al., 2016; Davis, 2001; Kardefelt-Winther, 2014). Therefore, one of the conclusions from this work, in line with other research, is that by simply looking at one's smartphone use behavior, it could not be reliably determined whether the person is suffering from depression and/or anxiety symptoms.

Essentially, the results described in this study also fall into the framework of *digital phenotyping*, or the "moment-by-moment quantification of the individual-level human phenotype *in situ* using data from smartphones and other personal digital devices" (Torous, Kiang, Lorme, & Onnela, 2016). Tracking one's smartphone use frequency and duration, as well as the use of specific features, could be linked to other information, such as medical records, and molecular and neuroimaging data (Onnela & Rauch, 2016; Sariyska, Rathner, Baumeister, & Montag, 2018). By implementing more complex analysis methods, digital phenotyping could be useful in predicting and, ultimately, understanding human psychology and behavior (Montag & Elhai, 2019). In addition to only tracking smartphone use duration and frequency, and linking these data to self-reported psychopathology symptom severity, smartphones include a variety of sensors that could be helpful in studying human behavior (Miller, 2012) as well as psychopathology. For instance, smartphones could be used to track the sleep-wake cycle patterns that are typically disturbed in depressive disorders (Dogan, Sander, Wagner, Hegerl, & Kohls, 2017). Another example: the recorded speech data retrieved with the use of a microphone in a smartphone could be used for voice as well as word sentiment analysis to detect the emotional state of the user (Cummings & Schuller, 2019). Finally, physical activity which is commonly associated with mental health (Hiles, Lamers, Milaneschi, & Penninx, 2017) could be measured with an accelerometer. In turn, these data could also be linked to the duration and frequency of smartphone use to better understand the context and potential drivers of problematic behavior and psychopathology.

3.3. STUDY II: PSU, approaches to learning, and social media use in lectures

Learning attitudes should be pivotal for better academic engagement and, therefore, achievement. One broad way to distinct approaches to learning could be

based on the "depth" of learning. A well-known categorization in that regard would be deep and surface approach (see Asikainen & Gijbels, 2017 for a more comprehensive theoretical and historical overview; Biggs, 1987; Marton & Säljö, 1976). Deep approach to learning entails more intrinsic motivation, interest in the learned materials, and a more holistic approach to study materials by trying to synthesize and connect different pieces of information (Biggs, Kember, & Leung, 2001). On the other hand, surface approach to learning could be characterized as selective, or rote, memorization of facts, primarily based on extrinsic motives, such as achieving a good grade and/or fear of failure (Vanthournout, Doche, Gijbels, & Van Petegem, 2014). Studies have demonstrated that deeper approach to learning is linked to higher educational success, while more surface, or superficial, approach is related to lower academic outcomes (Gynnild & Myrhaug, 2012; Heikkilä & Lonka, 2006; Salamonson et al., 2013). However, research on the association between problematic technology use and approaches to learning is scarce. For instance, Alt and Boniel-Nissim (2018) found that more surface approach to learning was related to higher levels of problematic Internet use. Yet, the relationship between approaches to learning and PSU has not been investigated. The aim of STUDY II was to fill this gap. Specifically, the research questions in STUDY II were:

1. Are deep and surface approach to learning associated with PSU?
2. Are deep and surface approach to learning related to social media use in lectures?
3. Does social media use in lectures mediate the relationship between PSU and approaches to learning?

The exact methodology and results can be found in Rozgonjuk, Saal, and Täht (2018). In order to find the answers to the research questions, Estonian students were surveyed with regards to their levels of PSU, social media use in lectures, and approaches to learning. Specifically, to measure PSU, we used the Estonian Smartphone Addiction Proneness Scale (E-SAPS18; Rozgonjuk et al., 2016), and we used the Estonian adaptation of the Revised Study Process Questionnaire (R-SPQ-2F; Valk & Marandi, 2005) to measure the extent of deep and surface approach to learning. Finally, social media use in lectures was measured by two items combined into a single index, adapted from Junco (2012a). Structural equation modelling (SEM) and mediation analysis were used to see if PSU predicts the levels of deep and surface approach to learning, and if social media use in lectures mediates the relationship. Age and gender were included as covariates for the mediating variable, as it has previously been shown that these demographics may impact social media engagement (Kuss & Griffiths, 2011).

The results of the study showed that PSU is negatively associated with deep and positively with surface approach to learning; however, it should be noted that the effect sizes were rather small. With correlations approaching medium effect size, social media use in lectures was similarly negatively correlated with deep and positively with surface approach to learning. PSU and social media use in lectures were moderately positively correlated. The results of SEM showed similar findings. In addition, younger age was associated with more

social media use, while gender did not play role in social media engagement. Mediation analysis showed that social media use in lectures completely mediated the relationships between both approaches to learning and PSU.

This is the first study to look into the association between PSU and approaches to learning. The results of this study may provide an insight into findings regarding academic achievement in association with problematic technology engagement. Specifically, it could be that more PSU and more social media use in lectures may lead to more surface and less deep approach to learning. This, in turn, could lead to poorer academic outcomes as found in Samaha and Hawi (2016) and Lepp et al. (2015).

3.4. STUDY III: Procrastination, social media use in lectures, and PSU

Another relevant aspect in academic achievement is how well a student is able to execute planned tasks and avoid distracting activities while engaging in studying. One of these factors is procrastination. Procrastination has been regarded as a self-control failure (Steel, 2007) that is characterized by the delay of intended and/or important activity, resulting in subjective feeling of discomfort (Steel, 2007; Steel & Klingsieck, 2016). Procrastination could be divided to strategic (or rational) and irrational delay (Klingsieck, 2013). While the former includes voluntary delay of the activity, with expectance of potential negative outcomes, the latter entails dysfunctional or irrational delay with mainly detrimental outcomes. Procrastinatinatory behavior has been generally regarded as an individual's relatively stable characteristic, suggesting it to be a trait-like feature (Reinecke et al., 2018). More procrastination has been negatively associated with learning and academic achievements (e.g., see a meta-analysis by Kim & Seo, 2015). Procrastination has also been associated with more impaired technology use (Reinecke et al., 2018), social media use (Meier, Reinecke, & Meltzer, 2016; Panek, 2013) and media use in general (Hofmann, Reinecke, & Meier, 2017). Therefore, it would be logical to assume that procrastination, PSU, and social media use could be inter-related. However, it has not been investigated how trait procrastination is related to PSU, and if social media use (in lectures) potentially explains that relationship. The aim of STUDY III was to fill the gap in scientific literature. The specific research questions are:

1. How are procrastination and PSU related?
2. How is procrastination associated with social media use in lectures?
3. What is the role of social media use in lectures in the association between procrastination and PSU?

Detailed outline of methodology and results can be found in Rozgonjuk, Kattago, and Täht (2018). Estonian students responded to the Estonian adaptation of the Aitken Procrastination Inventory (API; Aitken, 1982), the Estonian Smartphone Addiction Proneness Scale (E-SAPS18; Rozgonjuk et al., 2016), and two items regarding social media use in lectures adapted from Junco

(2012a) and also used in Rozgonjuk, Saal, et al. (2018). Structural equation modelling (SEM) and mediation analysis were used to see if trait procrastination predicts the levels of PSU, and if social media use in lectures mediates the relationship. Age and gender were included as covariates for PSU, based on previous findings that have demonstrated higher levels of PSU typically more occurring in women (Rozgonjuk et al., 2016; van Deursen et al., 2015).

Procrastination was positively correlated to PSU and social media use in lectures; however, the effect size was rather small in both instances. Furthermore, social media use in lectures completely mediated the relationship between procrastination and PSU. In addition, younger age was associated with higher levels of PSU and social media use in lectures, while a student's gender did not predict PSU. It should be noted, however, that although the link between procrastination and PSU was significant, it was relatively weak.

This is the first study to investigate the relationship between procrastination and PSU, and the role of social media use in lectures in that relationship. The findings are in line with literature from other domains of problematic technology use suggesting procrastination to be in the center of problematic digital technology use (Davis et al., 2002). Furthermore, these findings are in coherence with results demonstrating that excessive social media (e.g., WhatsApp, Facebook) use may be a significant driver of PSU (Sha et al., 2018).

Additionally, it would have been interesting to investigate fear of missing out (FoMO) in relation to key constructs of this study. FoMO is the fear of missing out on experiences that are rewarding, and is a relatively constant need to stay connected with one's social network (Przybylski, Murayama, DeHaan, & Gladwell, 2013). FoMO has been shown to be related to PSU (Elhai, Levine, Alghraibeh, et al., 2018; Gezgin, 2018; Wolniewicz et al., 2018) as well as (excessive) use of a smartphone's social features/social media (Blackwell, Leaman, Tramposch, Osborne, & Liss, 2017; Oberst, Wegmann, Stodt, Brand, & Chamarro, 2017; Sha et al., 2018). A recent study also showed that FoMO was associated with more disrupted daily activities due to smartphone pop-up notifications (Rozgonjuk, Elhai, Ryan, & Scott, 2019). Discontinuing a task at hand in order to be engaged with notifications may perhaps even be viewed here as synonymous with procrastination. However, that study did not differentiate between different sources of notifications. In other words, the role of FoMO was not directly contrasted with more specific, say, either social or non-social features of a smartphone. Future studies may aim to fill that gap.

3.5. STUDY IV: Intolerance of uncertainty, types of smartphone use, and PSU

Buhr and Dugas (2009, p. 216) have defined intolerance of uncertainty (IU) as "a dispositional characteristic that results from a set of negative beliefs about uncertainty and its implications and involves the tendency to react negatively on an emotional, cognitive, and behavioral level to uncertain situations and

events". This feature is considered to be stable and trait-like (Carleton et al., 2012; Dugas, Gagnon, Ladouceur, & Freeston, 1998), and it has been typically conceptualized as a transdiagnostic vulnerability/predisposing factor for primarily anxiety-related psychopathology, such as generalized anxiety disorder (GAD), obsessive-compulsive disorder (OCD), and social anxiety (Borkovec & Roemer, 1995; Carleton et al., 2010; Tolin et al., 2003). Higher IU has also been linked to other individual characeteristics relevant to development and maintenance of psychopathology, such as higher levels of neuroticism, lower extraversion, and lower openness to experience in the Big Five approach (Berenbaum, Bredemeier, & Thompson, 2008). Furthermore, *fear of uncertainty* (which essentially measures IU) is also a sub-domain in *harm avoidance* in Cloninger's psychobiological model of personality (Cloninger, Svrakic, & Przybeck, 1993). More harm avoidance is, similarly to IU, positively associated with neuroticism and inversely with extraversion (De Fruyt, Van De Wiele, & Van Heeringen, 2000). As these associations may suggest, people who are more prone to IU may have the expectation of the occurring event to have negative outcomes, and this is associated with perceived inability to predict such events, leading to interpreting ambiguous information as threatening (Carleton, Norton, & Asmundson, 2007). This (mis)preception is also associated with somatic stress reactions and negative affect (Greco & Roger, 2003), and disrupted problem-solving, possibly leading people with higher levels of IU to avoid ambiguous events and situations (Dugas, Freeston, & Ladouceur, 1997). Clearly, this behavior may impair one's functioning and is, therefore, of academic and clinical interest.

Research has thus far demonstrated quite consistently that PSU is associated with anxiety (reviewed in Elhai, Dvorak, et al., 2017; Elhai, Levine, & Hall, 2018), and as IU is considered to be a core vulnerability for several anxiety-related psychological disorders, it may be useful to investigate how engagement with digital technology is associated with IU. This research is the more important, because a recent meta-analysis indicated to increasing levels of IU over time and this rise in IU has been shown to be related to increased internet, mobile, and smartphone penetration (Carleton et al., 2018). Thus far IU has not been studied in relation to PSU, making STUDY IV the first original contribution to this research domain.

The research questions of STUDY IV are:

1. How are IU and PSU related?
2. How do IU and PSU relate to social and non-social (process) smartphone use?
3. Do types of smartphone use (social/non-social) mediate the association between IU and PSU?

Detailed methodology and results are presented in Rozgonjuk, Elhai, Täht, et al. (2019). American college students responded to a web survey where they filled out the Smartphone Addiction Scale Short Version (SAS-SV; Kwon, Kim, et al., 2013), the Social and Process Smartphone Use Scale (adapted from van Deursen et al., 2015), and the Intolerance of Uncertainty Scale Short version

(IUS-12; Carleton et al., 2007). After a month, the participants responded to these scales once again. Therefore, in this study, a repeated-measures study design was applied. This is important, as most studies regarding PSU have used cross-sectional study design. While we acknowledge that time lag alone does not constitute for causality, this study may still provide more reliable results, as the measurement of predictors precedes the measurement of the outcome variable (Cole & Maxwell, 2003; Gollob & Reichardt, 1987).

The research model included IU (measured on Time 1) as a predictor for PSU (Time 2), with social and non-social (process) smartphone use variables (both measured at Time 1) as mediators in that relationship. We used SEM and medition analysis.

The results showed that IU (Time 1) was positively correlated to PSU and non-social (process) smartphone use, but was not correlated to social smartphone use (all Time 1 measurements). The effect sizes for the statistically significant relationships were small, approching medium. PSU (Time 2) was significantly correlated to both types of smartphone use, yielding a medium effect with non-social (process), and small effect size with social smartphone use. These results are interesting, because the correlation of .501 between social and non-social (process) smartphone use could be considered as large effect size. Mediation analysis showed, however, that non-social (process) smartphone use (Time 1) mediated the relationship between IU (Time 1) and PSU (Time 2), while social smartphone use (Time 1) was not a significant mediator.

This is the first study to look into the association between IU and PSU, and including the types of smartphone use features provides further insights to that relationship. It is interesting that non-social, but not social smartphone use mediated the relationship between IU and PSU. One potential interpretation for these findings could be that higher levels of IU may be specifically associated with social behavior related anxiety. Social anxiety has been found to be related both with IU (Boelen & Reijntjes, 2009; Carleton et al., 2010; Carleton et al., 2012) and PSU (Wolniewicz et al., 2018). Because social anxiety has also been found to be correlated with socially avoidant behavior (Schwaber, 2006), it could be that the uncertainty accompanied with social situations may deter individuals with higher levels of IU from social interactions, opting for the use of non-social (process) features of one's smartphone. Elhai, Levine, et al. (2017) have found that increased smartphone use is more related to PSU, and personality traits associated with inhibited social behavior that are also related to IU (Berenbaum et al., 2008) further support this interpretation.

An additional explanation for the findings could be that individuals with higher levels of IU could engage in non-social smartphone use to browse for information to quell their uncertainty about things in general. The world, but also one's own life is full of uncertainties, and various websites and applications could provide answers to increase the individual's certainty in their uncertain world. This high engagement in seeking for certainty in answers and solutions could reflect in higher levels of PSU.

Finally, as was the case with STUDY III, it would also be interesting to investigate how fear of missing out (FoMO) and IU are related to each other. As in both constructs the tendency to experience anxiety is an underlying feature, it may be hypothesized that these two constructs are related; however, research on the relations of these factors is lacking. Although FoMO has been shown to be associated with the (excessive) use of social features of smartphone (Oberst et al., 2017), it may be insightful to learn if, firstly, IU and FoMO are related, and, secondly, if types of smartphone use are differently related to these variables.

4. CONCLUSIONS

4.1. Key findings

The results of studies presented in this dissertation provide new insights into (problematic) smartphone use research. Below, I am providing a short summary of conclusions regarding each original study presented as part of this dissertation.

- In STUDY I we investigated how self-reported PSU, depression and anxiety severity measures, objectively measured smartphone use (minutes of screen time and number of phone screen unlocks) and daily depressive mood measured over a week were related to each other. The study provided several interesting findings. Firstly, self-reported PSU was associated with objectively measured smartphone use duration, but not frequency. Secondly, while self-reported PSU was correlated to depression, anxiety, and a week's average daily depressive mood, objectively measured smartphone use (OMSU) duration could not be predicted from those variables. Furthermore, self-reported depression and anxiety symptom severity were negatively related to OMSU frequency. In general, the increase (nor decrease) of smartphone use over a week could not be predicted from these psychopathology measures. Finally, participant's gender nor age predicted the increase in smartphone use over a week, while OMSU frequency was associated with age.
- The aim in STUDY II was to see if higher levels of PSU could predict approaches to learning and if social media use in lectures could explain these potential associations. Indeed, the results showed that PSU was negatively associated with deep and positively with surface approach to learning. Mediation analysis showed that social media use in lectures mediated these relationships, correlating positively with PSU, negatively with deep, and positively with surface approach to learning. Participant's younger age, but not gender, was also a significant variable explaining the higher levels of social media use in lectures.
- STUDY III focused on the potential relationship between trait procrastination and PSU. Here, too, we investigated if the association could be further explained by social media use in lectures. We found that more procrastination was associated with higher levels of PSU. Furthermore, social media use in lectures completely mediated that association, positively correlating with both procrastination and PSU. Younger age, but not participant's gender, predicted higher levels of PSU and social media use in lectures.
- Intolerance of uncertainty (IU) in relation to PSU and types of smartphone (social or non-social/process) feature use was in the focus of STUDY IV. The results showed that IU and PSU are positively related, and that non-social/process, but not social smartphone use mediates that relationship.

To summarize, PSU is related to behavioral (STUDY I) psychopathological (STUDIES I and IV), and dispositional variables (STUDIES III and IV), and could as well play a role in educational settings (STUDIES II and III). I have demonstrated in the current dissertation that:

- PSU could be reflected in smartphone use duration (screen time);
- Smartphone use frequency (phone-checking/screen unlocking) may not be indicative of PSU, and it could, in fact, indicate to lower levels of psychopathology symptom severity;
- Although PSU is associated with depression and anxiety symptom severity, and weekly average depressive mood, OMSU may not be associated with weekly average depressive mood;
- PSU is associated with more surface and less deep approach to learning, more trait procrastination, and higher levels of IU;
- Social media use in lectures could explain the relations between PSU and approaches to learning, and trait procrastination;
- Non-social (process) smartphone use may be the explanatory factor in the relationship between IU and PSU.
- While the role of age and gender has been inconsistent across these studies, it could be noticed that younger age was typically more associated with higher levels of digital technology engagement.

These findings are also coherent with the theoretical frameworks described in the Introduction section of this dissertation. While STUDIES I and II were more focused on the potential outcomes of PSU, STUDIES III and IV investigated the possible role of predisposing factors of development of PSU.

As mentioned, there is evidence of major overlap between the I-PACE model and other relevant theories aiming to explain PSU and other relevant Internet use disorders. I-PACE seems to encompass all other referred theories. For instance, the components model of addiction could be regarded as an outcome condition in the process of developing PSU; one major reason for this statement is that probably most of the studies investigating PSU (as well as all studies in the current dissertation) have implemented a measure that is directly derived from a components model perspective. Secondly, the uses and gratifications theory posits that people actively seek out to gratify their needs by using specific media (Blumler, 1979); these motivations also constitute segments of the I-PACE model both as predisposing factors as well as mediator and moderator variables leading to digital technology engagement. The compensatory Internet use theory (Kardefelt-Winther, 2014) approach, similarly, fits well with the relevance of (dysfunctional) coping mechanisms observed in the I-PACE model. The pathways model of problematic mobile phone use (Billieux, 2012) is similar to the I-PACE approach, as it highlights the role of predisposing factors (e.g., personality traits) in combination with moderating and mediating variables (e.g., emotion regulation, coping styles) in the development of PSU. Finally, the cognitive-behavioral model (CBM) of pathological Internet use

(Davis, 2001) could be viewed as the direct predecessor of the I-PACE model. Therefore, the results of the studies presented in this dissertation could be conceptualized within the I-PACE theoretical framework. Importantly, it should be reminded that the I-PACE model does not explicitly mention smartphones, and it deals with specific (rather than general) Internet use disorders. However, due to a large overlap between the Internet communications disorder and PSU, the latter could be a mobile form of Internet use disorder (Montag et al., 2018; Sha et al., 2018).

While other mentioned theoretical frameworks could also be applied, the findings of STUDIES I-IV could be interpreted within the I-PACE framework, as the I-PACE approach seems to encompass other theoretical explanations. Firstly, the role of predisposing factors was identified (namely, procrastination in STUDY III and intolerance of uncertainty in STUDY IV). Secondly, it was further specified which specific usage patterns (e.g., the use of different smartphone features) were potentially relevant in developing PSU (social media use in STUDY III and non-social smartphone use in STUDY IV). It should be noted that while social media use may refer to social smartphone use, it could also indicate to using a smartphone (or, more specifically, social media) in a socially more passive manner, e.g., browsing social media, but not necessarily engaging in social activities. In fact, studies have shown that passive social media use (rather than active) is associated with more trait neuroticism and social anxiety (Gerson, Plagnol, & Corr, 2017; Rozgonjuk, Ryan, Kuljus, Täht, & Scott, 2019; Shaw, Timpano, Tran, & Joormann, 2015; Verduyn et al., 2015) – some of the variables also found to be associated with PSU (Billieux, 2012; Cho, Kim, & Park, 2017; Enez Darcin et al., 2016). Thirdly, in coherence with the I-PACE model, PSU was used as a predictor variable for potential behavioral (objectively measured smartphone use duration and frequency in STUDY I) and educational (approaches to learning in STUDY II) outcomes. While STUDY I demonstrated that PSU may manifest, behaviorally, in smartphone use duration (but not smartphone use frequency), STUDY II showed that one of the seemingly dysfunctional outcomes could be a more surface and a less deep approach to learning which, in turn, has been associated with poorer academic outcomes (Gynnild & Myrhaug, 2012; Heikkilä & Lonka, 2006; Salamonson et al., 2013). Therefore, as discussed in this text, the findings of STUDIES I-IV integrate into a larger overarching theoretical framework of the I-PACE model.

4.2. Contribution of the dissertation

There are several contributions that this dissertation makes to the field of (problematic) smartphone use research. Below, I am discussing some theoretical and methodological contributions.

The studies in this dissertation present original and novel findings in smartphone use and PSU research. Firstly, STUDIES II, III, and IV, were the first ones to present knowledge on PSU's relations with several constructs that may

have a significant impact on one's daily functioning. These constructs were approaches to learning (deep and surface), procrastination, and intolerance of uncertainty. Secondly, in STUDIES II and III, we demonstrated that a potential association between PSU and the construct of interest could be mediated by social media use (in lectures). Third, STUDY IV demonstrated that in the relationship between intolerance of uncertainty and PSU, non-social (process) smartphone use may play a critical role in development and maintenance of PSU. Fourth, in STUDY I, we showed that smartphone use duration and frequency may constitute for different usage patterns, whereas duration is related with PSU, and frequency is negatively related to depression and anxiety. Fifth, in STUDY I we also showed that daily depressive mood may not be necessarily associated with daily recorded smartphone use.

A large body of PSU studies shares limitations across different research items. More common limitations seem to be relying on self-reported measures and cross-sectional study design. While self-reported data based models were presented in three studies (STUDIES II to IV), in STUDY I, we included OMSU over a period of one week to provide more valid insights into the relationship between smartphone use and psychopathology. Although over the recent years the use of OMSU has been made more feasible thanks to various smartphone use tracking applications, there is still a need for studies that further look into the patterns of recorded smartphone use in relation to self-report PSU measures, but also other constructs.

As mentioned, another limitation that, in addition to OMSU, was met, was implementing repeated-measures design (STUDIES I and IV). While in STUDY I, we objectively measured smartphone use over a week, in STUDY IV, participants' levels of PSU were measured twice, with one month apart. Although time lag in itself may not constitute for causality, it allows to consider potential causal relationships, as the predictor was preceding the outcome variable, a necessary assumption for causality (Cole & Maxwell, 2003; Gollob & Reichardt, 1987).

STUDY I also included a novel approach in PSU research, namely, measuring daily depressive mood for seven days while also tracking participants' objective smartphone use. This experience sampling method showed that self-reported daily depressive mood, in general, was not associated with the corresponding day's smartphone use. However, interestingly, average daily depressive mood was positively correlated to self-reported PSU.

Finally, although minor addition in comparison to other methodological contributions is conducting research in two cultures. Specifically, students from United States and Estonia were studied. Although there were no cross-cultural comparisons, the findings indicate to PSU being a pan-cultural phenomenon. These findings, of course, support other studies that have, in fact, compared users from different cultural backgrounds (Lopez-Fernandez, 2017; Lopez-Fernandez et al., 2017).

4.3. Limitations and future perspectives

Although this dissertation includes studies that have aimed to meet several limitations found in PSU literature (e.g., research gaps, relying on self-reports, using cross-sectional study design), there are still some limitations that remained. One of them was using a college/university student sample which was present in all studies of this dissertation. In addition to not being representative of the entire population of smartphone users due to demographic differences in educational level, the variability of age of participants was partly limited due to this convenience sample. Previous studies have shown that engagement in smartphone use is typically associated with younger age (Rozgonjuk et al., 2016; van Deursen et al., 2015). It could be that in some studies, where age was not a statistically significant covariate of digital technology engagement, the age effects could have been present if the samples were more heterogeneous regarding age. Another sample-related issue is that the samples of studies tended to be biased towards more women taking part in our research. Previous research has found that women typically show higher levels of engagement with smartphone use, especially in PSU studies (Rozgonjuk et al., 2016; van Deursen et al., 2015). Yet in those studies there are issues with the proportion of men and women being biased towards more female participants.

In several studies, we used structural equation modelling and mediation analyses to try to model potential pathways between different constructs and PSU. In those studies, we mainly relied on cross-sectional study design that may limit causal interpretation of those pathways, theoretically allowing predictors to be the caused outcomes, and *vice cersa*. It may be evident especially in the case of STUDY II and STUDY III, where PSU was treated as the predictor (STUDY II), and the outcome variable (STUDY III). While the I-PACE model (Brand et al., 2016) allows, in theory, for both causality directions, further studies should implement longitudinal designs to validate those models.

Although this dissertation offers several new insights intro smartphone use research, there are still some issues that need to be further addressed beyond this work. Maybe the most pressing of these is clarifying the construct of PSU. It is interesting that although the discussion on excessive Internet related adverse conditions started more than 20 years before this work, there does not seem to be a consensus with regards to what that condition entails. Furthermore, although "Internet addiction" is now treated as a misnomer (Griffiths, 2018), one may still find a large body of research being published with this terminology, and there is no unison in how that phenomenon should be called – is it pathological Internet use, or problematic Internet use, or Internet use disorder, or something else? This is important contextual information, as similarly to excessive Internet use research, the same problems seem to haunt excessive smartphone use research. As mentioned earlier in the text, I am using the "problematic smartphone use" terminology, as this term has been explicitly proposed by academic community (Panova & Carbonell, 2018), and "smartphone addiction", too, is rather being treated as misnomer (Griffiths, 2018). Nevertheless,

there may be other potential candidates, such as “smartphone use disorder” (Lachmann et al., 2018; Sha et al., 2018), that could be a better terminological fit and conceptualization of this phenomenon.

In order to better understand smartphone use in relation to daily life adversities, the field would gain a lot by implementing more objectively measured data from smartphones and other life domains (the so-called digital phenotyping) (Onnela & Rauch, 2016; Sariyska et al., 2018; Torous et al., 2016). In addition to more straightforward measures, like smartphone use duration and frequency, contemporary smartphones allow to track various parameters relevant to mental and physical health, such as temperature, air pressure, and ambient light in smartphone user’s surrounding environment. Finally, more sophisticated machine learning algorithms may also be useful in analyzing larger data sets generated by smartphone use behavior.

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SUMMARY IN ESTONIAN

Problemaatiline nutitelefonikasutus: käitumuslikud, psühhopatoloogilised, seadumuslikud ning akadeemilised korrelaadid

Tehnoloogia arengul on potentsiaali parandada inimeste elu. Lisaks telefonikõnede tegemisele ning SMS-ide saatmisele võimaldavad tänapäeva nutitelefonid otsida internetist informatsiooni, kasutada erinevaid produktiivsusele kaasa aitavaid rakendusi (nt kalendrid jm aja- ja tööjuhtimisrakendused) ning lahutada meelt. Peale selle võimaldavad nutitelefonid olla pea alati kättesaadav *online*-maailmas.

Samas on viimase paari kümnendi jooksul leitud, et digitaalsete tehnoloogiate, nagu interneti, arvutite ning mobiil- ja nutitelefonide liigne kasutamine on negatiivselt seotud mitmete igapäevaelu aspektidega. Näiteks on leitud, et liigsete interneti- ja nutitelefonikasutajate vaimne tervis on tihtipeale viletsam, väljendudes erinevate psüühikahäirete sümptomite tõsiduses. Samuti on näidatud, et liigne digitehnoloogiate kasutamine on seotud viletsamate akadeemiliste tulemustega.

Juba interneti laiema levikuga hakkasid teadusmaastikule ilmuma uuringud, mis käsitlesid liigset internetikasutust seoses tervisega. Taolist liigset internetikasutust, mis oli negatiivselt seotud mitmete igapäevaelu aspektidega, nimetati internetisõltuvuseks. Pärast umbkaudu kahe kümnendi pikkust akadeemilist arutelu on jõutud järeldusele, et internetisõltuvus ei ole formaalselt psühholoogide ja psühhiaatrite poolt häireks tunnistatud (st seda ei saa diagnoosida) ning teadlaskond on pigem hakanud seda nähtust kirjeldama kui problemaatilist internetikasutust.

Eeltoodud diskussioon laienes liigse interneti kasutamiselt ka mobiiltelefonide ja nutitelefonide konteksti. Ka siin ilmnesid interneti uurimises esinenud vastuolud ja segasused. Konkreetsemalt nutitelefonide kontekstis on liigse kasutusega seotud nähtuseid käsitletud kui "liigset nutitelefonikasutust" (ingl k *excessive smartphone use*), "nutitelefoni ülekasutust" (ingl k *smartphone overuse*), "nutitelefonisõltuvust" (ingl k *smartphone addiction*), "soodumust nutitelefonisõltuvuseks" (ingl k *smartphone addiction proneness*), jmt. Eestikeelses meediaruumis on räägitud ka "nutisõltuvusest" ja "nutinarkomaaniast". Viimased uuringud on aga soovitanud kasutada terminit **problemaatiline nutitelefonikasutus (PNK; ingl k *problematic smartphone use*)**, mis aitab vältida sõltuvuse-terminoloogiat, ent samas kirjeldab ära ka nähtuse tuuma, milleks on **liigse nutitelefonikasutusega seotud vaevused ja probleemid igapäevaeluga**.

PNK põhjuseid ja tagajärgi seletavaid teooriaid on mitmeid, ent viimase aja seisukohad viitavad sellele, et teatud inimestel on eelsoodumus kogeda negatiivseid emotsioone. Koos kehva emotsioonide regulatsiooniga võib see viia olukordadeni, kus inimene ei oska ärevuse, kurbuse ja/või vihaga toime tulla ning kasutab nende emotsioonide maandamiseks oma nutitelefoni. Taoline

pigem mittefunktsionaalne emotsiooniregulatsioon ja emotsioonidega toimetulemine võibki mõningate indiviidide puhul viia PNK-ni. See aga võib omakorda tekitada enam negatiivseid emotsioone, sh psühhopatoloogia sümptomeid, tekitades nõiaringi. Sellise mõttekäigu leiab inimese-afekti-tunnetusetäidesaatmise interaktsiooni mudelist (ingl k *interaction of person-affect-cognition-execution* ehk *I-PACE model*). Ehkki käsitlen käesolevas töös põgusalt ka teisi lähenemisi, on I-PACE ilmselt kõige mitmetahulisemalt PNK-d seletada võimaldav mudel. Tegelikult võib selgelt näha, et teised teooriad ja mudelid, mida olen käesolevas töös maininud, sobituvad I-PACE mudeli osadeks.

Kuivõrd nutitelefonid on suhteliselt uus nähtus, ja empiiriliselt on näidatud, et PNK-l on võrreldes muude sarnaste nähtustega (nt problemaatiline internetikasutus, *online*-mängurlus, küberseksisõltuvus) oma unikaalsus, on tegemist suhteliselt väheuuritud valdkonnaga. Näiteks on võrdlemisi vähe uuritud, kuivõrd on PNK seotud objektiivselt mõõdetud nutitelefonikasutusega. Samuti on PNK-d vähe uuritud hariduslikus kontekstis ja akadeemiliste konstruktidega seoses. Kuivõrd I-PACE mudeli kohaselt on väga olulisel kohal inimeste seadumuslikud omadused (nt isiksuseseadumused, jmt), siis on ka oluline uurida, kuidas ja millised individuaalsed erinevused on seotud PNK-ga.

Käesolev doktoritöö põhineb neljale originaalsele uuringule, mis annavad mitmetahulise ülevaate problemaatilise nutitelefonikasutuse seostest käitumuslike, psühhopatoloogiliste, seadumuslike ning hariduslike konstruktidega. Alljärgnevalt on lühiülevaade iga uuringu põhilistest leidudest:

- **Uurimuses I** olid luubi all enesekohaste küsimustikega mõõdetud PNK seosed depressiooni ja ärevuse, objektiivselt mõõdetud nutitelefoni kasutamise (ekraaniaja minutid ning ekraaniavamiste arv) ning päevane depressiivse meeleolu tase mõõdetuna nädala aja jooksul. Selles uuringus leidsime, et enesekohaselt mõõdetud PNK oli seotud objektiivselt mõõdetud nutitelefonikasutuse kestusega (st ekraaniajaga), kuid mitte kasutamise sagedusega (st ekraani avamiste arvuga). Teiseks: depressiooni, ärevuse ning keskmise nädala jooksul mõõdetud päevase depressiivsuse skoorid ei olnud seotud objektiivselt mõõdetud nutitelefonikasutuse kestusega; seevastu objektiivselt mõõdetud nutitelefonikasutuse sagedus oli negatiivselt seotud depressiooni ja ärevuse mõõdikud. Teisisõnu, mida sagedasem oli nutitelefonikasutus, seda madalamad olid ärevuse ja depressiooni skoorid. Enesekohaste küsimustikega mõõdetud psühhopatoloogia mõõdikud ega ka sugu ja vanus üldiselt ei ennustanud objektiivselt mõõdetud nutitelefoni kasutuse kestuse ja sageduse kasu nädala jooksul. Samas, sagedasem objektiivselt mõõdetud nutitelefonikasutus oli seotud noorema vanusega.
- **Uurimuses II** oli eesmärgiks välja selgitada, kas üliõpilaste kõrgemad PNK skoorid suudavad ennustada nende õpihoiakuid. Lisaks oli eesmärgiks uurida, kas neid seoseid vahendab sotsiaalmeedia kasutamine loengutes. Uuringu tulemused näitasid, tudengid, kellel olid kõrgemad PNK skoorid, väitsid sageli ka, et kasutavad enam pindmist ja vähem

sügavat õpistiili. Sotsiaalmeedia kasutamine loengutes vahendas seda seost, olles positiivses korrelatsioonis PNK ja pindmise õpistiili ning negatiivselt seotud sügava õpistiiliga. Noorem vanus, kuid mitte vastaja sugu, ennustas kõrgemat sotsiaalmeedia kasutust loengutes.

- **Uurimuses III** oli eesmärgiks vaadata, kas üliõpilaste PNK on seotud prokrastineerimisega (tegevuste ebamõistlik edasilükkamine). Nagu ka Uurimuses 2, üritasime välja selgitada, kas sotsiaalmeedia kasutamine loengutes võib seda potentsiaalset seost vahendada. Tulemused näitasid, et PNK on seotud positiivselt prokrastineerimisega ning sotsiaalmeedia kasutamine loengutes vahendab seda seost täielikult. Teisisõnu, kõrgem prokrastineerimise tase ennustab kõrgemat sotsiaalmeedia kasutust loengutes, mis omakorda ennustab rohkem PNK-d. Uuringus osalejate noorem vanus (kuid mitte sugu) ennustas kõrgemat PNK-d ja sotsiaalmeedia kasutust loengutes.
- **Uurimuses IV** oli eesmärgiks välja selgitada, kas ebakindluse talumatus (ingl k *intolerance of uncertainty*) on seotud PNK-ga ning kas sotsiaalsete ja/või mittesotsiaalsete nutitelefoni rakenduste kasutamine vahendab seda seost. Tulemused näitasid, et ebakindluse talumatus ja PNK on omavahel positiivses korrelatsioonis. Mitte-sotsiaalne (kuid mitte sotsiaalne) nutitelefonikasutus oli seotud nii PNK kui ka ebakindluse talumatusega. Kõrgem ebakindluse talumatus on seotud kõrgema mitte-sotsiaalse nutitelefonikasutusega, mis omakorda võib viia PNK-ni.

Käesoleva doktoritöö uuringute leiud on kirjeldatavad eelmainitud I-PACE mudeli raamistikus. Uurimused III ja IV ilmestasid individuaalsete erinevuste (prokrastineerimine Uurimuses III ning ebakindluse talumatus Uurimuses IV) potentsiaalset olulisust PNK kujunemisel, aga ka spetsiifiliste nutitelefoni rakenduste kasutamise rolli selles (sotsiaalmeedia kasutamine loengutes Uurimuses III ning nutitelefoni mittesotsiaalse sisuga rakenduste kasutamine Uurimuses IV). Uurimuste I ja II põhilised leiud viitavad aga, et PNK võib potentsiaalselt ennustada käitumuslikke (objektiivselt mõõdetud nutitelefonis veedetud aeg Uurimuses I) ja hariduslikke tegureid (õpistiilid Uurimuses II). I-PACE mudeliga on need leiud kooskõlas.

Kokkuvõtteks võib öelda, et PNK on seotud käitumuslike (Uurimus I), psühhopatoloogiliste (Uurimus I ja IV), ja seadumuslike (Uurimus III ja IV) omadustega, aga võib olla oluline tegur ka akadeemilises keskkonnas (Uurimused II ja III). Käesolevas doktoritöös on näidatud, et:

- PNK-d võib peegeldada suurem nutitelefonis veedetud aeg (ekraaniaeg);
- Nutitelefonikasutuse sagedus (ekraani aktiveerimine/avamine) ei pruugi näidata seost PNK-ga, vaid võib isegi hoopis viidata madalamale psühhopatoloogia sümptomite esinemisele;

- Kuigi enesekohaste küsimustikega mõõdetud PNK on seotud nii depressiooni kui ka ärevuse sümptomite, aga ka keskmise nädala jooksul mõõdetud depressiivse meeleoluga, ei pruugi nädala jooksul mõõdetud depressiivne meeleolu olla seotud objektiivselt mõõdetud nutitelefonikasutusega.
- PNK on seotud rohkema pindmise õpihoiakuga, prokrastineerimise ning ebakindluse talumatusega, ja vähema sügava õpihoiakuga.
- Sotsiaalmeedia kasutamine loengutes võib seletada enesekohaste küsimustikega mõõdetud PNK, õpistiilide ja prokrastineerimise vaheliste seostega.
- Mitte-sotsiaalne nutitelefonikasutus võib seletada PNK ja ebakindluse talumatuse vahelist seost.
- Ehkki vanus ja soo roll on erinevates uuringutes pisut segane, võib üldiselt märgata, et noorematel inimestel on sageli kõrgemad skoorid digitaalsete tehnoloogiate kasutamisega seotud mõõdikutel.

PUBLICATIONS

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