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Addicted to my smartphone: what factors influence the task-switching cost that occurs when using a smartphone while walking?

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Résumé

Les effets négatifs de la surutilisation de téléphone intelligent et les dangers d'utiliser un téléphone intelligent en marchant, ont fait l'objet de plusieurs études ces dernières années. Cependant, la surutilisation peut-elle influencer notre attention au monde réel en présence d'un téléphone intelligent ? Ce mémoire par article étudie l'impact de la prédisposition à la dépendance au téléphone intelligent et les risques associés à l'utilisation de celui-ci en marchant. Plusieurs facteurs pouvant interagir avec la dépendance sont considérés : l'impulsivité, la perception du risque, les habitudes et les émotions.

En laboratoire, 48 participants ont réalisé quatre conditions expérimentales (conversation individuelle, conversation de groupe, jeu et contrôle) tout en marchant sur un tapis roulant. Simultanément, les participants devaient déterminer si les marcheurs, dont la présence était signalée par un stimulus auditif, allaient à droite ou à gauche.

Les résultats suggèrent que l'utilisation d'un téléphone intelligent en marchant est un distracteur dangereux. Il a été constaté qu'une prédisposition à la dépendance accrue au téléphone intelligent augmente le coût attentionnel d'utiliser celui-ci en marchant. Certaines émotions augmentent cet effet de prédisposition à la dépendance. Les habitudes, l'impulsivité et la perception du risque n'interagissent pas avec la prédisposition à la dépendance.

Les résultats aident à mieux comprendre les populations et comportements à cibler afin de réduire le nombre d'accidents piétonniers liés aux téléphones intelligents. Les résultats contribuent à la littérature existante sur la dépendance aux téléphones intelligents et sur les effets de l'utilisation de ceux-ci en marchant. Cette expérimentation est également la première à fusionner ces deux sujets de recherche.

Mots Clés : multitâche · attention divisée · dépendance · téléphone intelligent · mobilité · habitudes · émotions · expérimentation

Summary

The negative effects of smartphone overuse and the dangers of smartphone-use while walking, have been the subject of several studies in recent years. This thesis by article investigated the role of smartphone-addiction proneness, a specific pattern of smartphone overuse, on the task-switching cost of using a smartphone while walking. Other factors were also considered, such as impulsivity, risk perception, smartphone task type, habits, and emotions.

In a laboratory setting, a study was conducted with 48 participants. Participants underwent four experimental conditions (individual conversation, group conversation, gaming and control condition) while walking on a treadmill. During these conditions, participants had to simultaneously do a direction task, with a point-light walker figure, whose presence was cued by an auditory stimulus.

Our results suggest that using a smartphone while walking is a dangerous distractor, with gaming being the most distracting use measured. It was found that higher smartphone-addiction proneness increases the task-switching cost of using a smartphone while walking. Certain emotions were shown to augment this effect of smartphone-addiction proneness, on task-switching costs. Finally, participants' habits, impulsiveness and risk perception did not interact with smartphone-addiction proneness to influence task-switching costs.

Our findings help policy makers better understand the populations, and behaviors, that must be targeted to decrease the levels of smartphone related pedestrian accidents. Our results contribute to the existing literature on smartphone addiction and on the effects of using a smartphone while walking. Furthermore, this experiment was the first to merge both of these research topics together, to see how they interact.

Keywords: multitasking · task-switching · smartphone addiction · texting while walking · habits · emotions · experimentation

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Preface

This dissertation, written in the form of an article, was approved by the Administrative Direction of the Master of Science in Administration program and the co-authors' consent of the article composing the dissertation was obtained.

The approval of the HEC Montréal Research Ethics Board (CER) was received for this study in May 2018.

The article is currently being prepared for submission to the Journal of Addictive Behaviors.

The article was added to the dissertation with the signed consent of the co-authors.

Acknowledgments

I would like to start by thanking my supervisors Pierre-Majorique Léger and Sylvain Sénécal, without whom none of this would be possible. Specifically, I would like to thank them both for their patience, guidance, support and invaluable advice throughout this long and challenging project. They helped me find and develop a research topic that met my past experience as well as my future ambitions.

I would also like to thank Anne-Frances Cameron, François Bellavance, Franco Lepore and Jocelyn Faubert for taking the time to meet with me in order to give me feedback on my project and hypothesis. I am also very grateful to Eric DeCelles, who assisted me with my research project throughout the summer. I would also like to thank Élise Labonté-LeMoyne, for being available to answer my questions and for advising me throughout this process. In addition, I would like to thank Marc Fredette and Shang Lin Shen, for their help and insight into statistical analysis.

The Tech3lab has an amazing team of research assistants and a great operation's team. Thank you all for allowing me to bring my project to life! I know it was a long and stressful process, so your patience was truly appreciated. I am also grateful to my laboratory colleagues, for listening to me and supporting me throughout the ups and downs of this project.

Furthermore, I would like to express my gratitude to the Social Sciences and Humanities Research Council of Canada (SSHRC) for funding my research. I would also like to express my appreciation to every person who gave their time to participate in my research project, because without participants, research would never be possible!

Finally, I wish to thank my parents for their love, support, and encouragement throughout this journey. They taught me the value of hard work and always pushed me to surpass my limits and follow my academic ambitions.

Introduction

Texting while driving is known to be a dangerous act and laws have been put into place to prevent and penalize such behaviors. Yet, according to the National Safety Council (n.d.), there were approximately 6,000 pedestrian fatalities in 2017, in the United States, mirroring the numbers from 2016. The trend of distracted walking is a serious issue, and the familiarity with the environment does not protect from its dangers: The National Safety Council (n.d.) also states that over 50% of pedestrian injuries occur at home. With the rise in smartphone use, this problem is becoming a more prominent issue than ever before. Many efforts have been made to diminish the number of pedestrian accidents and fatalities, with different countries trying different methods. In the Netherlands, a controversial attempt was made at creating LED traffic lights on the ground specifically to get the attention of pedestrians that are on their phones (Sulleyman, 2017). In Honolulu, a law was put into effect on October 25, 2017, to give fines to individuals who use or stare at their mobile devices while crossing a street or highway (Ellis, 2017). In Ontario, a bill called the *Phones Down, Heads Up Act*, was proposed in 2017 to "*prohibit pedestrians from holding and using certain mobile devices while crossing a roadway*" (Baker, 2017). The question remains as to whether such efforts will be successful in changing this risky behavior. We must understand what makes people more at risk of hurting themselves when using a smartphone while walking, in order to decrease the occurrence of distracted walking and its associated risks.

When we see people exhibiting risky and dangerous behavior, such as using their smartphones while walking, many factors could explain such behaviors. It is possible that individuals simply do not perceive that behavior as risky, that they are too impulsive to consider the potential negative consequences, or that certain rewards have been associated with the behavior making it worth the risk. Furthermore, the development of technology has changed how and why smartphones are used. Originally used for mere communication (e.g., calls and text messages), these devices are increasingly being used for entertainment purposes, such as browsing the internet, listening to music, watching videos, and playing games. It is therefore important to consider different smartphone uses. This study aims at understanding what personal factors and task-specific characteristics may increase the dangers of such distracted walking. In particular, we seek to determine if addictive tendencies towards smartphones can increase the attentional deficits observed in people who use a smartphone while walking.

Through experimental research, we investigated the task-switching cost of smartphone use, while walking, on the perception of a real-world stimulus (i.e., the direction of a walker figure). Considering the important role of task-switching abilities in such an activity, we used a task-switching paradigm to measure participants' awareness of their surroundings while doing different tasks on a smartphone, such as texting and playing video games. We hypothesized that doing a task on a smartphone while walking would decrease performance on the direction task. We also hypothesized that doing a task on a smartphone while walking would lead to a task-switching cost, and that an increase in task-switching cost would decrease performance on the direction task. Furthermore, we attempted to determine whether excessive patterns of smartphone usage (i.e., smartphone-addiction proneness) increase the cost of using a smartphone while walking in a task-switching paradigm. We hypothesized that higher smartphone-addiction proneness would increase the task-switching cost of doing a task on a smartphone while walking. It is possible that this population has a harder time coming out of the digital environment to focus on real-world stimuli. Although the role of smartphone-addiction proneness was the focus of this research project, other factors, that could mitigate its role in the task-switching cost of using a smartphone while walking, were also investigated. Firstly, the impact of smartphone habits was measured. The assumption was that individuals very used to walking while using their smartphones, may have, over time, developed certain mechanisms to be able to do so more efficiently. Hence, we hypothesized that habits related to higher frequencies of smartphone usage, while walking, would decrease the impact of smartphone-addiction scores on the task-switching cost. Secondly, we measured participants' emotional state during the experiment to note how it might interact with smartphone addiction. Since emotions are known to impact how we see the world and how we behave, we hypothesized that the participant's state during the smartphone task would moderate the impact of addiction scores on task-switching cost. Moreover, we also measured participants impulsivity, nomophobia, and risk perception. Nomophobia was used as a manipulation check for smartphone-addiction proneness. In the case of risk perception, it was hypothesized that the perception of risk would moderate the impact of smartphone-addiction proneness on task-switching cost. Finally, in the case of impulsivity, it was hypothesized that higher impulsivity would increase the impact of smartphone-addiction proneness on task-switching cost.

The article contained in this thesis is being submitted to the Addictive Behaviors - Elsevier Journal. Unfortunately, impulsivity, nomophobia and risk perception were not discussed in the article contained in chapter 2 of this thesis, due to the journal's word-count restrictions of 3,500 words. Nonetheless, they are examined in the third chapter of this dissertation.

In summary, this thesis attempts to answer the following main research questions:

Does smartphone-addiction proneness augment the task-switching cost of using a smartphone while walking?

Do habits, emotions, impulsivity, and risk perception moderate the impact of smartphone-addiction proneness on this task-switching cost?

To better understand my contribution to the research project, the table below shows my contributions to each step of the process. The percentage of work I have done is included at each stage.

Steps	Contribution and tasks performed
Definition of requirements	Definition of the research question and the problem - 80% • Due to my previous research experience with drug addiction, my supervisors proposed the possibility of looking at the impact of

<table>
<tr><td></td><td>smartphone or gaming addiction on the phenomenon of texting while walking.
Through a review of the literature, I determined in what way such addictions may impact this phenomenon and justified the need for such a study.
My supervisors and the other researchers contributed to the definition of the research questions and the approach to adopt.</td></tr>
<tr><td>Literature Review</td><td>Performed a literature review to determine which constructs to test and which self-reported measurements to use - 100%

Definition of the measurement tools to use to test the constructs - 80%
My supervisors and the research team gave me feedback on my choices of constructs and ensured that the selected measurement tools were able to test the chosen constructs.</td></tr>
<tr><td>Stimuli</td><td>N/A: I was restricted in the stimuli used in the experiment because the results of a previous study had to be comparable to the results of this research project.</td></tr>
<tr><td>Creation of the experimental design</td><td>Conception of the necessary forms for the application to the CER - 100%

Creation of the experimental protocol – 90%
It was based on the protocol from the previous experiments, but I was responsible for adjusting it to fit the specific requirement of this research project and to modify it following the feedback from the pretests.
Preparation of the experiment room - 70%
The room set up was designed and refined by myself with the feedback</td></tr>
</table>

	from my supervisors. I was responsible for the set-up of the room and was aided by the research assistants. In order to ensure that noise was minimized we set up foam in the gaps in the wall and to ensure the participant's safety we put foam on the door directly behind them and created a protective structure for the treadmill. ● Due to safety restriction, all material that needed to be constructed in this study was built by laboratory personnel. Creation of the risk perception questionnaire – 80% ● My research assistant aided me in the determination of the scenarios to use when creating the questionnaire. ● My supervisors guided me through the whole process and gave me feedback on the scenarios chosen and the measurement scale used.
Participant recruitment	Development of the recruitment form - 100% Solicitation and recruitment of participants - 100% ● Due to the difficulty recruiting participants with high smartphone-addiction proneness, laboratory assistants helped me with street interviews. Ensuring that participants met the smartphone-addiction proneness requirements - 100% Experiment schedule management 100 % ● I contacted the participants to inform them of the conditions of participation, and to schedule and

	confirm their appointments. The laboratory team ensured that I had research assistants available for those schedules.
Pretests and data collection	Responsible for pretests - 100% Responsible for data collection - 100% ● I conducted all the experiments with the help of 2 research assistants.
Data extraction and transformation	Extraction and cleaning of the data from questionnaires - 100% Calculation of the scores associated with the questionnaires - 100%
Data Analysis	Statistical analysis of the dissertation - 80% ● I determined the hypotheses and the statistical relationships to be measured, based on the existing literature. ● The laboratory statistician aided me in the actual running of the statistics. ● I interpreted the results of the statistical analysis. ● My supervisors gave vital feedback throughout the whole process.
Writing	Contribution in writing the article - 100% ● My supervisors gave me constructive comments throughout the writing to improve the quality of the article and to ensure all the relevant concepts were discussed.

Table 1: Contributions to the responsibilities of the research project.

Chapter 1 : Literature review

Smartphone use while walking

Smartphone penetration rates are at an all-time high and with this increase in smartphone use, the negative consequences of excessive patterns of usage have begun to emerge, impacting mental health, sleep patterns and overall productivity (Demirci, Akgönül, & Akpinar, 2015; Lanaj, Johnson, & Barnes, 2014). In recent years, several research papers have focussed their attention on the dangers of being distracted by smartphone use while walking (Byington & Schwebel, 2013; Haga et al., 2015; Hatfield & Murphy, 2007; Oh & LaPointe, 2017; Stavrinos, Byington, & Schwebel, 2011). This peaking interest is partly due to the increased occurrence of this phenomenon and to the potentially life-threatening consequences associated with it. In one study, smartphone-use while walking was found to negatively impact walking speed and gait, with the results warning against reading and texting while walking (Oh & LaPointe, 2017). Another study's results showed increased reaction times, to both auditory and visual targets, in conditions where participants used a smartphone while walking, as compared to the control condition, suggesting a heightened risk of accidents due to smartphone use (Haga et al., 2015). A study by Banducci and colleagues (2016) found that participants, that were more engaged while texting, were more likely to be involved in a collision during a simulated crossing task, when walking on a treadmill in a virtual environment. In another study, participants had to search for information on a smartphone's internet browser, while crossing a virtual pedestrian street (Byington & Schwebel, 2013). Participants displayed riskier behavior when using a smartphone than in the control condition, including looking away from the road more often and being more likely to be hit by an oncoming vehicle (Byington & Schwebel, 2013). These findings suggest that using a smartphone while walking can be highly distracting. It influences not only how we walk, but how much attention we give to our external environment and our risk of injury. Although many studies have provided evidence of the dangers of using a smartphone while walking, the question remains as to what makes such behaviors more or less dangerous.

Learning and Reward

It is not groundbreaking to say that people do things because they are somehow rewarding and that, over time, such rewards cause a reinforcement of the behavior that can turn it into a habit. As such, when studying the acquisition and maintenance of a certain behavior, the mechanisms underlying learning and reinforcement become relevant. In operant conditioning, when the consequence of a behavior is a reward, referred to as a positive reinforcement, the behavior is strengthened and more likely to be repeated in the future (Skinner, 2012). In the case of what is referred to as negative reinforcement, it is the removal of something unpleasant, which can be seen as a reward, that causes the strengthening of a particular behavior (Skinner, 2012). It is important to note that the initial behavior is not triggered by the reinforcement, but that it is the outcome that immediately follows the behavior that is relevant and reinforcing (Skinner, 2012). In the words of B. F. Skinner "*The consequences of behavior may "feedback" into the organism. When they do so, they may change the probability that the behavior which produced them will occur again.*" (Skinner, 2012). In operant conditioning, behaviors that are reinforced are more likely to happen again and when the behavior is no longer reinforced, its frequency will eventually decrease and even extinguish (Skinner, 2012). Nonetheless, some types of reinforcement have been shown to be quite robust, making them much harder to extinguish (Skinner, 2012).

In the face of negative consequences, such as collisions and accidents, we would hope to see a behavior diminish. Unfortunately, some habits are hard to extinguish and using a smartphone while walking seems to be a particularly dangerous behavior because it tends to persist despite negative consequences. This is exemplified by the accident rates described in Kim, Min, Kim, and Min (2017) where participants reported several instances of accidents or bodily harm due to texting while walking. From an evolutionary psychology perspective, we might assume that our environment, with the accumulated importance attributed to it due to its wide array of available threats and rewards, should have developed saliency superior to that of a relatively new object (e.g., a smartphone), especially when moving about. One way to reconcile this discrepancy is to admit that smartphones have developed a high degree of importance and saliency in our environment in a relatively short amount of time.

When something is considered important to an individual, it is usually more salient in their environment. This is what occurs in the case of attentional biases, where what is perceived in the environment is shaped by an involuntary attention, or a difficulty turning attention away from, a stimulus that has become particularly salient (Field & Cox, 2008; Keyser-Marcus et al., 2016). These types of biases have been found in both drug addiction and clinical anxiety (Anderson, 2016; Asmundson & Stein, 1994). In the case of addiction, strong attentional biases have been found in response to drug-related cues, which can increase drug-seeking behavior and lead to relapse (Anderson, 2016). In clinical anxiety and phobias, research has found that individuals are more likely to focus on, and pay attention to, threat-related information (Asmundson & Stein, 1994). It seems that stimuli that have previously been paired with both rewards and threats are associated with an augmented attention-grabbing effect in our environment. When looking at the reward associated with smartphone use, smartphone-addiction proneness will be used. Smartphone Addiction is a form of behavioral addiction where patterns of excessive smartphone use lead to tolerance, withdrawal, and dependence towards smartphones (Kwon et al., 2013). In the case of threat, nomophobia is a particularly relevant disorder to consider, since smartphones are used in part for communication purposes. Nomophobia is defined as a social phobia where people are afraid of not being able to use their phones (Tams, Legoux, & Léger, 2018). In their study, Tams, Legoux, and Léger (2018) found that nomophobia caused stress via social threat when uncertainty or lack of control was present. Based on this, it is possible that both smartphone-addiction proneness and nomophobia would make it more difficult for individuals to focus their attention away from a smartphone and towards their environment. It is possible that people would focus more of their attention on their smartphone, while walking, because they are afraid of the social consequences of not always being available in such an interconnected world. Another possibility is that the rewards of this digital world are just too good to resist. Nonetheless, since withdrawal is an important diagnostic criterion for addiction, it seems probable that nomophobia would be intrinsically linked to smartphone-addiction proneness. Due to this fact, nomophobia is only considered here as a manipulation check for smartphone-addiction proneness.

Relevant smartphone uses

In the context of our study, it is possible that smartphones are simply devices that allow individuals to satisfy a desire or need, with its use being reinforced by the associated reward. It could be argued that the smartphone serves the function of a cue, associated with the rewarding effect of using the device. Yet different types of rewards can be gained with the modern smartphone, depending on the specific use. For example, text messages might give social rewards, while games might be associated with entertainment-related rewards. As argued by Billieux (2012), researchers that have studied smartphone addiction often use this diagnosis as an umbrella term, not distinguishing between the different types of smartphone uses. This paper proposes a pathway model for problematic smartphone use that emphasizes the fact that dysfunctional uses, although seemingly similar at first glance, are actually developed for different reasons and through different mechanisms (Billieux, 2012). In other words, people might overuse smartphones for different reasons and although the compulsive behaviors may seem similar on the surface, they might actually be ontologically different. This would likely imply that different uses have different related risk factors. We argue that this is in fact the case and that the smartphone in and of itself is not the reinforcement, but instead is the vehicle which allows the individual to gain the reward they are craving. This led us to believe that a focus on the impact of different smartphone tasks on attention would be more appropriate. For this reason, in our study, we observed distinct smartphone uses, to determine the particular level of risk associated with those tasks.

Several smartphone applications could have been chosen for the purpose of this research. Nonetheless, smartphone addiction is not yet a recognized disorder, while Gaming Disorder is soon to be recognized as a disease, making gaming behavior an interesting use to observe. The World Health Organization will be including Gaming Disorder as a clinical syndrome in the ICD-11. They define a Gaming Disorder as a behavioral disorder where a particular pattern of gaming behavior is found, which is characterized by impaired control over gaming and gaming behavior gaining priority over other daily activities, to the extent that it results in impaired functioning or distress (Poznyak, 2018). Importantly, this behavior continues in spite of negative consequences and starts to consume the whole life of the individual (Poznyak, 2018). Interestingly, this diagnosis shares the behavioral pattern described in the definition of substance abuse and addiction (see O'Brien, 2011). It is also similar to that described for smartphone addiction (see Kim, Lee, Lee, Nam, & Chung, 2014). Since games have the capacity to elicit such strong habits, as to merit being termed a disorder, looking at the impact of playing a game on a smartphone while walking, seems important. For the experimental manipulation of our study, we used a time-sensitive smartphone game (i.e., Tetris®). Another very relevant use to observe is communication, which was the original purpose of mobile phones. To this day it is still one of the main uses of these devices, although the form has gone from voice to text messages. For these reasons, it seems unavoidable to study the impact of texting on a smartphone while walking, on people's attention. Nonetheless, a conversation with one individual and a group conversation may not entail the same cognitive demands, social norms, social pressures or social desirability. For this reason, we chose to look at both individual and group conversations.

If, in fact, disordered patterns of smartphone use cause attentional biases towards the associated cue (i.e., the smartphone), regardless of the smartphone task, we are likely to be able to capture this effect through our experimental manipulation.

Reward, motivation, and addiction in the brain

With rewards being so relevant to our research question, certain neurological aspects need to be considered because repetitive reward patterns can affect the brain, as it has been shown in the case of drug addiction (Volkow & Morales, 2015). The Mesocorticolimbic Dopaminergic Pathway in the brain has long been associated with reward (Arias-Carrión, Stamelou, Murillo-Rodríguez, Menéndez-González & Pöppel, 2010). Here, dopamine neurons are essential for reward-related processing (Volkow & Morales, 2015). The dopamine cell bodies of this pathway originate in the ventral tegmental area (VTA) and project to the nucleus accumbens (NAc), to the prefrontal cortex (PFC), amongst other areas (Arias-Carrión et al., 2010; Koob, 1992; McBride, Murphy & Ikemoto, 1999; Pierce and Kumaresan, 2006; Wise, 1996). Dopamine is a neurotransmitter that plays an essential role in learning and in the brain's reward system (Arias-Carrión et al., 2010). The dopamine activity is thought to increase in the presence of a stimulus that, through learning and reinforcement, is perceived as predicting rewards, while dopamine activity decreases in cases where the stimulus has been previously associated with predicting a negative outcome (Arias-Carrión et al., 2010; Volkow, & Morales, 2015).

A relevant area to discuss when studying a behavioral addiction, such as smartphone-addiction proneness, would be the NAc, since its activation plays a big role in reward-seeking and approach behaviors. Through repetition, stimuli that occur when increased dopamine activation in the NAc is present, are believed to lead to conditioning that later associates those stimuli with rewards (Volkow & Morales, 2015). After this associative learning occurs, increased activation in this area has been found to occur in the presence of those stimuli that were previously paired with rewards and, in the case of drug addiction, this is believed to trigger cravings (Volkow & Morales, 2015). Another area to consider is the prefrontal cortex (PFC) which is known to mediate the effects of rewards and conditioned responses on approach behavior, making it important for self-control (Lewis, 2017; Volkow & Morales, 2015). This regulatory role is so strong that research has found that stimulating the PFC activity can even prevent relapse in rodents (Volkow & Morales, 2015). According to the United States' National Institute on Drug Abuse (n.d.), brain-imaging studies show physical changes in the areas of the brain involved in decision-making, learning, memory, and behavioral control, in drug addicted individuals. With addiction, the PFC, responsible for cognitive control, becomes somewhat disconnected from the striatum, which plays a big role in reward-seeking and approach behaviors (Lewis, 2017). The NAc, an important area of the striatum, is a sort of motivational system, that motivates people to go towards things. It is thanks to the dorso-lateral prefrontal cortex's (dlPFC) influence on the striatum that we are able to delay our need for immediate reward or pleasure (Volkow & Morales, 2015). In essence, the dlPFC usually regulates the NAc's activation, but we see an under-regulation of this brain area in addicts (Lewis, 2017). This implies that in the brain of people suffering from addiction, the executive functions regulate less the seeking of the addictive substance, when cues trigger these cravings (Volkow & Morales, 2015). This could be responsible for the compulsive behavior that people suffering from addiction exhibit (Volkow & Morales, 2015). Interestingly, this partial disconnection with the striatum is also seen in cases of eating disorders, suggesting that it does not only occur with drug addiction (Lewis, 2017).

Although, in the literature, it's been believed for quite some time that it is the drugs in themselves that cause the addiction to develop and the brain areas to change, some authors have proposed that these changes that occur with addiction may be due to something else (Grant, Potenza, Weinstein, & Gorelick, 2010; Lewis, 2017). Lewis (2017) is one author that takes a strong stance against the disease model of addiction. He believes that the brain changes we see in addicted individuals are the same as "*those (changes) generally observed when recurrent, highly motivated goal seeking results in the development of deep habits, Pavlovian learning, and prefrontal disengagement*" (Lewis, 2017). He states that neural development and change are due to synaptic activation patterns that result from experiences with the world, thanks to neuroplasticity (Lewis, 2017). New experiences change the brain, and, with repetition and time, patterns can establish themselves and this can consolidate into knowledge or habits (Lewis, 2017). He states that addiction, like habits, can cause brain tissue to first change and then stabilize. Lewis believes that strong habits that have high motivational value could cause these changes and goes as far as saying that addiction itself is "*a habit that grows and self-perpetuates relatively quickly, when we repeatedly pursue the same highly attractive goal. Or, in a phrase, motivated repetition that gives rise to deep learning"* (Lewis, 2017). This theory, that drugs in and of themselves are not solely responsible for the changes in brain chemistry, seems to be supported by the existence of behavioral addictions, such as pathological gambling. These behavioral addictions can be quite similar in terms of cognitive features and neurobiological processes and can have consequences that are just as severe as drug addiction (Grant et al., 2010).

The task-switching paradigm and addiction

In the scientific literature, there seems to be a consensus that there is a cost to task-switching in the general population, implying that such an activity is demanding for most people (Monsell, 2003; Schmitz & Voss, 2012; Stoet & Snyder, 2007; Yeung & Monsell, 2003). It would therefore not be surprising to see a task-switching cost in the context of walking while using a smartphone. Nevertheless, the reduction of cross-talk between the PFC and the striatum, seen in addicted populations, could further impact one's ability to task-switch. This hypothesis stems from the fact that patients, with left frontal lobe damage, have been shown to have more pronounced deficits in task-switching abilities (Aron, Monsell, Sahakian, & Robbins, 2004; Shallice, Stuss, Picton, Alexander, & Gillingham, 2007). In fact, in studies done with patients suffering from brain lesions, it was found that patients with left frontal lobe lesions suffered larger switch costs and had an increased error rate, as compared to control groups (Aron et al., 2004; Shallice et al., 2007). Nonetheless, these effects seem to be mediated by the degree of practice, with the differences between the groups diminishing over time (Shallice et al., 2007).

Changes in PFC activation have also been shown to influence risky behaviors. It has been found that damage to certain areas of the prefrontal cortex influence the evaluation of risk and lead to individuals exhibiting more risk-taking behaviors (Floden, Alexander, Kubu, Katz, & Stuss, 2008). A serious cause for concern was that these participants exhibited less behavioral reactions to the negative outcomes, meaning that they were less likely, than the control group, to change their behavior following negative feedback (Floden et al., 2008). The authors believed that this was due to an impairment in reward-related processing (Floden et al., 2008). Considering that using a smartphone while walking is a risky behavior, changes in this brain area's activation could potentially influence the likelihood of perpetuating this behavior even after negative consequences. Furthermore, it might increase the risks taken, and hence the dangers involved, in such a behavior.

The simple fact that smartphone use has become so excessive that people are claiming (controversially) that smartphone addiction is in fact a disease, tells us that the habit of excessive use is deviant enough from “normal” behavior to possibly entail changes in the brain. These changes could then influence the motivational and decision-making areas in the brain in a similar way as what is seen in the case of drug addiction, due to strong habit formation. Although Lewis’ (2017) perspective is still being debated, the neuroplasticity of our brains leaves open the possibility for an impact of smartphone overuse on the reward and motivational system, including a “silencing” of the dlPFC. If this is the case, the population that would score higher on smartphone-addiction proneness could be more at risk of collisions and accidents while using their smartphones while walking.

The role of impulsivity, risk perception and habits

Using a smartphone while walking is a risky behavior; when focusing our attention on a smartphone, we could easily miss the presence of danger in our immediate environment. Through changes in brain wiring, addiction influences our attention to specific cues that have been previously paired with rewards (Field & Cox, 2008), which could in turn increase risk-taking behaviors and negative outcomes. Nonetheless, other factors can also play a role and these interactions should be considered. Many factors can impact someone’s propensity to partake in risky behaviors and the potential outcomes associated with it. A study conducted with trauma center patients, with intact cognition, found that impulsivity was correlated with the incidence of risky behaviors (Ryb, Dischinger, Kufera, & Read, 2006). Furthermore, impulsivity and addiction have been found to coexist (Moeller, Barratt, Dougherty, Schmitz & Swann, 2001). In their review, Moeller et al., (2001) state that, although impulsivity is not only found in disordered populations, a high level of impulsivity has been linked to substance abuse and dependence, although the causal nature of this relationship is still unclear. There is still no consensus on how to define impulsivity and many perspectives exist (Bakhshani, 2014). In the Barratt Impulsiveness Scale (BIS), impulsivity is defined mainly by increased motor activity, lowered attention, or decreased planning (Moeller et al., 2001). As such, impulsivity could potentially impact a multitasking behavior, such as using a smartphone while walking. Although we could not find any studies specifically looking at the impact of impulsivity on task-switching cost, task-switching requires a shift in attention, and lowered attention could be believed to increase task-switching cost. This hypothesis is supported by a study looking at low-level auditory processing which found that, when attentional switching was required, participants that were considered highly impulsive, as measured by the BIS, did significantly worse than low impulsive participants (Leshem, 2016). This suggests that impulsivity might increase the impact of smartphone-addiction proneness on task-switching cost in this study, by influencing the participant's capacity to switch their attention from the smartphone task to the external stimulus.

The study conducted with trauma center patients also found that low-risk perception was correlated with the incidence of risky behaviors (Ryb et al., 2006). Risk perception is relevant to this study because it is possible that the perceived riskiness of using a smartphone while walking could influence the likelihood of doing this behavior as well as its outcomes. In their study on adolescent risk-taking, Reniers, Murphy, Lin, Bartolomé, and Wood (2016) found that increased risk perception reduced self-reported risk-taking behaviors. Now, the perception of risk might also alter the outcome by influencing the person's state during the risky behaviors. This is especially true when being forced to do so in a laboratory setting since it might not be a behavior that they would be willing to do in real life. For example, high-risk perception might cause the participant to feel anxious while doing the task. High state anxiety has been found to lead to poor performance, especially in more complex tasks (Elsey et al., 2016). It is also possible that an individual that does not believe something is risky (low-risk perception) might pay less attention to their environment because they do not see the potential dangers associated with their behavior. Nonetheless, it is hard to predict what state might be caused by such scenarios. It could cause a wide variety of emotions depending on the particular individual, and different emotions have been found to influence multitasking performance and attention differently (Morgan & D'Mello, 2013; Storbeck & Clore, 2008). We hope to determine if the perception of risk correlates with the outcome of using a smartphone while walking although, due to the design of our study, we will not be able to go into the mechanisms by which this might occur. It is important to note that the participant’s emotional state can vary regardless of risk perception and, as such, it was measured separately in this study.

Addiction, as a repeated pattern of reward-seeking, clearly impacts our habits. When it comes to motor behaviors, such as using a smartphone while walking, we can vary in the amount of cognitive effort needed and this can be influenced by the amount of practice we have performing that task (Anderson, 1983). It has been theorized that when acquiring a skill, we first develop declarative knowledge, which is an explicit knowledge on how to perform the task (Anderson, 1983). After repetition and practice, we cease to need the declarative knowledge, and the skill becomes what is called procedural knowledge, with the individual being able to perform the task with little or no conscious awareness of the steps involved (Anderson, 1983). This suggests that people who frequently use their smartphones while walking might develop procedural knowledge, which would involve less conscious cognitive engagement while doing this task. The importance of taking habits into consideration is further reinforced by the knowledge that the larger switch costs and error rates, seen in patients with left frontal lobe lesions, were mediated by the degree of practice (Shallice et al., 2007). This implies that a task-switching experiment, looking at a potentially mundane task, could be influenced by the amount of practice people already have with that task. Because of the potential impact of habits, we decided to obtain self-reported measures of participants’ habits of using their smartphone while walking, in order to account for potential differences in attentional effects due to varying levels of cognitive load in our study.

The findings described above suggest that impulsivity, risk perception, and smartphone usage habits could influence the task-switching cost in our experiment and could impede us from noticing the extent of the relationship between smartphone-addiction proneness and task-switching cost. It would, therefore, be relevant to analyze if these factors interact with smartphone-addiction proneness and modulate its impact on task-switching cost.

Conclusion and relevance

In conclusion, the tendency to repeatedly pursue a specific goal can become an addiction, leading neuroplasticity to somewhat rewire the brain (Lewis, 2017). Throughout evolution, human brains became wired to seek pleasure, by motivating the repetition of pleasurable experiences, and to avoid pain, with defenses motivating the handling of potential threat (Saah, 2005). This is why we will be looking at individuals seeking a highly salient reward (higher smartphone-addiction proneness) and comparing them to individuals for whom that reward is less relevant (lower smartphone-addiction proneness). We do not argue here that smartphone addiction is a clinical disorder, this is outside the scope of our study. Instead, we try to capture how smartphone overuse, and the rewarding effects of smartphone use, might influence the likelihood of getting hurt when using a smartphone while walking.

Our research will attempt to discover if particular types of smartphone users (i.e., higher smartphone-addiction proneness) perform worse at task-switching in the context of mobile multitasking. As previously mentioned, a study by Banducci and colleagues (2015) found that participants that were more engaged while texting were more likely to be involved in a collision while doing a simulated crossing task. We expect that participants, who have a higher smartphone-addiction proneness, might show attentional biases that make them more engaged with their smartphones and less likely to notice the environmental cues because of a high importance associated with the device. We also predict that all participants will have an impaired detection of external real-world stimuli while both playing games and texting on a smartphone while walking, as compared to the control condition. As noted previously, it is possible that participants who have a higher tendency of using a smartphone while walking may show less attentional impairment because of the development of compensatory mechanisms resulting from practice. The participant's emotional state could also moderate the impact of using a smartphone while walking. Finally, we predict that high impulsivity and risk perception could increase the dangers of using a smartphone while walking.

This study is important because, if we hope to deploy efforts to lower the probability of distracted walking and its associated consequences, we must first understand the population that is more at risk and the different factors that may make the behavior more or less dangerous. This research project will add to the literature by experimentally studying distracted walking, due to smartphone use, in a population that meets the criteria for high smartphone-addiction proneness. This will allow us to observe the possible relationships between excessive smartphone usage and the potential consequences of using a smartphone while walking. In order to properly consider the effects of using a smartphone while walking on task-switching abilities, it is important to question whether what we are seeing is actually an augmented reaction to task-switching, that is in part influenced by smartphones taking up a bigger part of our lives. As a society, we must be aware of how technology can influence our minds, as well as our culture, in order to responsibly indulge in it. Furthermore, this research might help to determine which populations are more at risk of this type of behavior so that policies and campaigns can be targeted accordingly.

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Chapter 2: Research Article for Addictive Behaviors

Using a smartphone while walking: the cost of smartphone-addiction proneness.

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Abstract

Distracted walking is an ever-increasing problem. Studies have already shown that using a smartphone while walking impairs attention and increases the risk of accidents. This study seeks to determine if smartphone-addiction proneness magnifies the risks of using a smartphone while walking. In an experimental design, participants, while walking on a treadmill and engaged in a smartphone task, were required to switch tasks by responding to an external stimulus i.e. determining the direction of movement of a point-light walker. Participants were chosen to cover a range of smartphone-addiction proneness. Four smartphone-use conditions were simulated: a control condition, an individual conversation condition, a gaming condition, and a group conversation condition. Our results show that participants with a higher smartphone-addiction proneness were also prone to higher task-switching costs; these lead to lower performance in the direction determination task. This effect was magnified by certain emotional states that participants reported having felt during the task (i.e., lower valence and higher dominance). Furthermore, of all the smartphone tasks, the gaming condition was found to be the most distracting.

Keywords: smartphone addiction · task-switching · multitasking · texting while walking· emotions · habits

1. Introduction

Even though multitasking is now the norm rather than an exception, the consensus is that task switching comes with a cost (see Monsell, 2003). It’s therefore not surprising to observe a task-switching cost when using a smartphone while walking. Using a smartphone while walking negatively impacts walking speed and gait (Oh & LaPointe, 2017), and also increases reaction times, to auditory and visual targets (Haga et al., 2015). Furthermore, higher engagement in smartphone tasks increased the risk of collisions during a simulated crossing task in a virtual environment (Banducci et al., 2016). In another study, using a smartphone’s internet browser while crossing a virtual street increased the time spent looking away from the road and the frequency of vehicular collisions (Byington & Schwebel, 2013). These findings suggest that smartphone use while walking influences how we walk, how much attention we give to our environment, and our risk of injury. Furthermore, Nasar and Troyer (2013) found that, although pedestrian injury rates have decreased over the years, the percentage of phone-related injuries was actually increasing. Although research demonstrates the dangers of smartphone use while walking, the question remains as to what moderates this danger.

With smartphone use on the rise, research suggests negative effects of smartphone overuse on mental health (Demirci, Akgönül, & Akpinar, 2015) and productivity (Duke & Montag, 2017). Researchers have even proposed the existence of smartphone addiction (Kwon et al., 2013). Furthermore, smartphone use is extremely reinforcing: O’Donnell and Epstein (2019), found that after abstaining from food and smartphones, students chose to use their smartphones rather than eat. While smartphone addiction is still controversial, in one study university students scoring higher on the smartphone addiction proneness scale reported higher accident rates when using a smartphone while walking than people with lower scores (Kim, Min, Kim, & Min, 2017). The question remains as to how excessive patterns of smartphone use could influence the dangers of using them while walking.

Repetitive reward patterns affect the brain, as shown with drug addiction. A relevant area affected by these changes is the Prefrontal Cortex (PFC), an important area for executive control (Volkow & Morales, 2015). The PFC's regulatory role in the brain's reward-pathway allows people to delay gratification and coordinate their actions; in drug dependent populations, however, this regulatory role is impaired (Volkow & Morales, 2015). Similarly, participants with damage to certain PFC areas exhibited more risk-taking behaviors and were less likely, than the control group, to change their behavior following negative feedback (Floden, Alexander, Kubu, Katz, & Stuss, 2008). Although smartphone and drug addiction are different phenomena, they share similarities in their diagnosis: tolerance, withdrawal and dependence (Kwon et al., 2013; O'Brien, 2011). Lewis (2017) suggests that brain changes, observed in drug dependence, are due to patterns of highly motivated goal seeking. Interestingly, some of these neurological changes are also seen in behavioral addictions (Grant, Potenza, Weinstein, & Gorelick, 2010), suggesting that they not only occur with drug exposure. Furthermore, in drug addiction, strong attentional biases exist towards drug-related cues, which can increase drug seeking (Anderson, 2016). Hence, stimuli paired with rewards can develop an augmented attention-grabbing effect. In light of this, we propose that higher smartphone-addiction proneness causes higher task-switching costs, by modifying attentional and regulatory mechanisms.

Situational factors, such as emotions, and habits can impact how well we perform. Firstly, people vary in how often they use their smartphones while walking. The risks of using a smartphone while walking are linked to the cognitive demands required by the tasks (Oh & LaPointe, 2017; Stavrinos, Byington, & Schwebel, 2011) and research shows that familiar tasks done repeatedly require lower cognitive load then those practiced less often (Haith & Krakauer, 2018). Patients with left frontal-lobe lesions suffered greater switch costs and increased error rates compared to control groups; yet these effects were mediated by the degree of practice, with group differences diminishing over time (Shallice, Stuss, Picton, Alexander, & Gillingham, 2007). Thus, habits may lower the costs of using a smartphone while walking, even assuming that high smartphone-addiction proneness impairs PFC functioning. Secondly, emotions can impact attention. Positive emotions broaden the scope of attention while negative emotions narrow it (Fredrickson & Branigan, 2005), and participants feeling positive emotions show superior multitasking performance than those feeling negative emotions (Morgan & D'Mello, 2013). Storbeck and Clore (2008) state that emotional arousal can impact time perception and narrow the focus of attention. Emotions also magnify reward-seeking in addiction. Sinha et al. (2009) found that stress increased alcohol cravings in alcohol-dependent participants. Thus, emotional states could increase the costs of smartphone use while walking, by modulating cravings, attention, and perception.

This study attempts to discover what personal and task-specific factors increase the dangers of smartphone use while walking. This was measured by observing the cost associated with switching from a smartphone task to an external stimulus task. Specifically, we investigated the perception of a point-light walker's direction while simply walking on a treadmill, as compared to also using a smartphone. We believe that smartphone use will increase task-switching cost and lower performance in the direction task. We also hypothesize that high smartphone-addiction proneness will augment this task-switching cost. We predict that a higher frequency of smartphone use while walking will decrease the impact of smartphone-addiction proneness on task-switching costs. Finally, we hypothesize that certain emotional states will increase the effect of smartphone-addiction proneness on task-switching costs.

2. Research Method

Participants

Forty-eight participants (ages 18-46, M=25.5, SD=5.5) were recruited through an online panel, social media, and street interviews. The sample, 20 males and 28 females, consisted mostly of university students (73%). Participants had normal or corrected-to-normal vision and were excluded if they reported being diagnosed with a physical, psychiatric, or neurological disorder. To be selected for the experiment, participants had to fill out the Smartphone Addiction Proneness Scale (SAPS) (Kim, Lee, Lee, Nam, & Chung, 2014). Participants were chosen based on smartphone overuse, being considered "normal smartphone users" (n=30) or "smartphone over-users" (n=18). Smartphone over-users had high smartphone-addiction proneness (total score $\geq$42). This threshold was based on the scores used by Kim et al. (2017).

Participants provided written consent before the experiment and received a $50 compensation upon completion. This study was approved by our institution’s Ethics Research Committee (Certificate #2019-3115).

Stimuli and apparatus

Visual Stimuli. To simulate a human being’s presence and motion, Johansson's point-light walker stimulus was chosen, because divided attention influences the performance on the point-light walker direction task (Thornton, Rensink, & Shiffrar, 2002). Fifteen black dots representing a walking human form on a white background, walked either towards the left or right, with a 3.0° (or -3.0°) deviation angle. The walker was displayed for 1000 milliseconds (ms) using a projector (Epson, Japan). It was 1.08 meters in height and displayed 2.44 meters away from the treadmill, giving a 25º visual angle.

Auditory Stimuli. Two speakers (Logitech, Switzerland) located in front of participants, displayed a 1000ms auditory cue, 500ms before the visual stimuli’s presentation.

Smartphone. Participants used a white iPhone 6s (Apple, USA) and were required to have owned and used an iPhone for at least 6 months over the last 5 years.

Treadmill. The treadmill used was the iMovR's ThermoTread GT (iMovR, USA) which operates quietly with a 42.7 dB noise level.

Procedure

Prior to the first experimental manipulation, participants underwent practice trials to get acquainted with the direction task and ensure that they understood the differences between the walker’s 2 directions. Then, participants underwent four experimental conditions (described below) while walking on a treadmill at 0.8 miles per hour. Participants were given 5-minute resting periods between conditions; the participants could sit while answering a short questionnaire. To conclude, participants answered a final questionnaire. To avoid bias, the presentation order of the conditions was randomized across participants.

In each condition, participants first walked on a treadmill while performing the relevant task for 17 seconds, at which point an auditory cue was presented, followed by the walker's appearance. The participants were instructed to verbally state the walker's direction (i.e., left/right). Each stimulus appearance was a trial and each condition had 40 trials. A trial was successful if the walker was seen and the correct direction, stated. A trial was unsuccessful if the walker was not seen or the wrong direction, given. Trials where participants did not see the walker were coded as *missed trials*. The experiment was composed of 4 blocks, one for each condition (4 x 40 trials). Each block lasted 16.5 minutes. The experiment was recorded with several cameras (Logitech, Switzerland).

Experimental conditions. In *task CC*, participants simply walked on the treadmill. In *task ICC*, participants had a texting conversation with one individual. In *task GC*, participants played a game on the smartphone. Tetris® was chosen because of its inherent time pressures. Finally, in *task GCC*, participants had a texting conversation with 2 individuals. Both conversation tasks were conducted with research assistants, via the Facebook Messenger application.

Table 1

Experimental Conditions Legend

Abbreviation	Explanation
Task CC	Control Condition
Task ICC	Individual Conversation Condition
Task GC	Gaming Condition
Task GCC	Group Conversation Condition

Questionnaires

Smartphone Addiction Proneness Scale (SAPS). This scale, developed by Kim et al. (2014), was used as a recruitment questionnaire and measures smartphone-addiction risk. It has 15 items rated on a 4-point Likert scale (1= strongly disagree; 4= strongly agree).

SAM SCALE. To determine their emotional state, participants filled out the SAM scale (Bradley & Lang, 1994) after each condition. This scale measures pleasure, arousal, and dominance. We added a question about self-perceived performance, measured on a 5-point Likert scale (1= low; 5= high).

Participants Profile Questionnaire. Participants answered a short questionnaire to determine their demographic characteristics.

Usage Habits. To determine a habit's potential impact, participants reported the frequency of texting and of playing games on a smartphone while walking. This was measured on a 6-point Likert scale (1= Never; 6= Several times a day).

Behavioral measures

Task-Switching Cost. We calculated the number of missed stimuli on the direction task, per condition. A stimulus was "missed" if, after the auditory cue, the participant did not lift their head before the stimulus disappeared. Higher scores represent lower awareness of the surroundings, hence a higher switch cost. Since an auditory cue preceded the presentation of the walker, the task-switching cost represents an inability to switch attention from the smartphone to the walker stimulus in under 2 seconds (i.e., the delay between the sound and disappearance of the stimulus).

Performance. Overall performance represents the participants' ability to notice an obstacle in their surroundings. This was calculated with the accuracy score on the direction task (i.e., the successful response percentage). The control condition represents this task's baseline accuracy.

Statistical Analyses

Due to our repeated measures design, we conducted linear regressions with mixed models. When the data was not normally distributed, we conducted Poisson regressions with mixed models. To test if performing a task on a smartphone decreased performance in the direction task, we performed a linear mixed effects analysis of the relationship between accuracy and the experimental condition. To determine if doing a task on a smartphone leads to a task-switching cost, we performed a linear mixed effects analysis of the relationship between the condition and the number of missed stimuli. Since we hypothesized lower performance and a higher task-switching cost when compared to *task CC*, these specific comparisons were analyzed with one tailed p-values. To establish if higher smartphone-addiction proneness increased the task-switching cost of performing a task on a smartphone while walking, we performed a Poisson mixed effects regression of the relationship between smartphone-addiction scores and the number of missed stimuli. To test if an increase in task-switching cost decreased performance, we performed a linear mixed effects analysis of the relationship between the number of missed stimuli and the accuracy scores adjusted from the baseline (*task CC* accuracy). This was done in order to account for differences in the participants' capacity to perform this task overall. To evaluate if the participant's state during a smartphone task moderated the impact of addiction scores on task-switching cost, we performed a Poisson mixed effects regression of the relationship between the smartphone-addiction scores, the scores on the items of the SAM scale, and the number of missed stimuli. To determine if smartphone-use habits decreased the impact of addiction scores on task-switching cost, we performed a Poisson mixed effects regression of the relationship between smartphone-addiction scores, the smartphone usage habit scores, and the number of missed stimuli.

3. Results

Task ICC (*M*=0.86, *SD*=0.12), *GC* (*M*=0.81, *SD*=0.12) and *GCC* (*M*=0.84, *SD*=0.14) generated lower accuracy than the control condition, i.e., *task CC* (*M*=0.89, *SD*=0.10). *Task GC* had the lowest accuracy percentage.

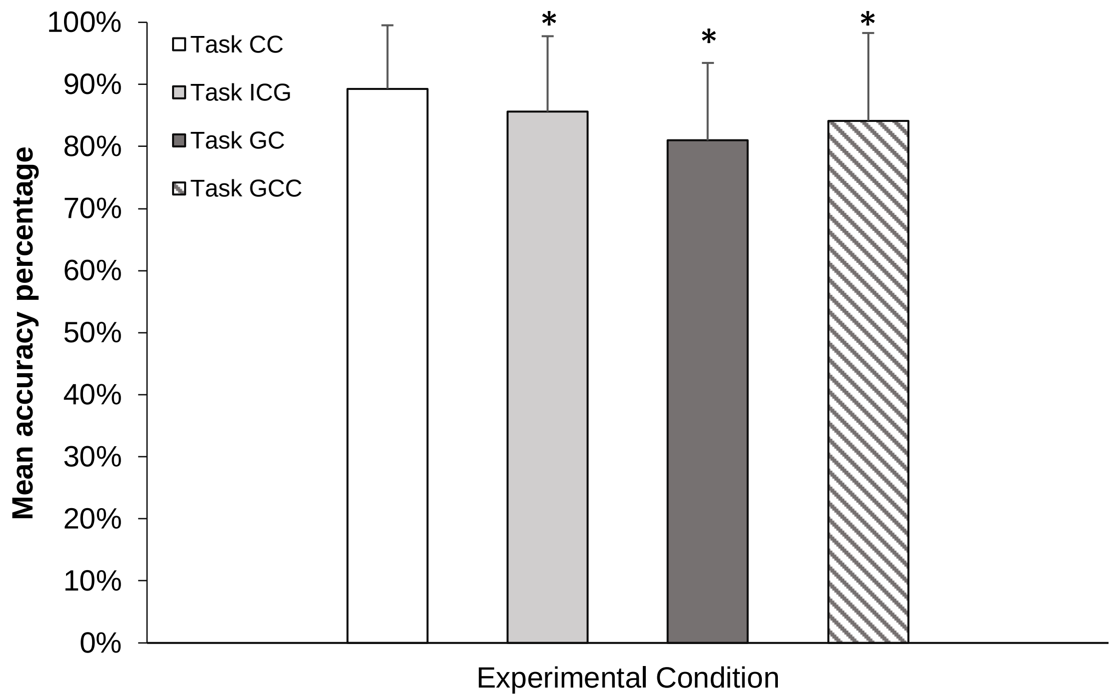

Figure 1. Performance on the direction task in the different experimental conditions. Data are mean accuracy percentage per experimental condition. Error bars represent standard deviation from the mean. * $p < 0.05$ of the difference between the least squared means as compared to the control condition (Task CC).

When comparing accuracy scores, *task CC* showed a statistically significant higher accuracy than *task ICC*, $t(140)=2.26$, $p=.037$ (one-tailed), than *task GC*, $t(140)=5.10$, $p<.001$ (one-tailed), and than *task GCC* $t(140)=3.15$, $p=.001$ (one-tailed). *Task ICC* had a statistically higher accuracy than *task GC*, $t(140)=2.84$, $p=.005$. *Task ICC* and *GCC*'s accuracies did not differ statistically, $t(140)=0.89$, $p=.37$, nor did the accuracies of *task GCC* and *GC*, $t(140)=-1.94$, $p=.105$. (see table 2 for LS-mean differences).

Table 2

Least square mean differences in accuracy scores

	Task CC	Task ICC	Task GC	Task GCC
Task CC		0.04*	0.08***	0.05***
Task ICC	0.04*		0.05	0.01
Task GC	0.08***	0.05		-0.03
Task GCC	0.05***	0.01	-0.03	

Note. Accuracy scores are measured in percentages. **p<.05, **p<.01, ***p<.001*

A higher task-switching cost preceded the lower accuracy in smartphone-use conditions. *Task ICC* (*M*=1.40, *SD*=2.97), *GC* (*M*=2.42, *SD*=2.65) and *GCC* (*M*=1.67, *SD*=2.76) generated more missed than *task CC* (*M*=0.04, *SD*=0.29). *Task GC* had the most missed stimuli.

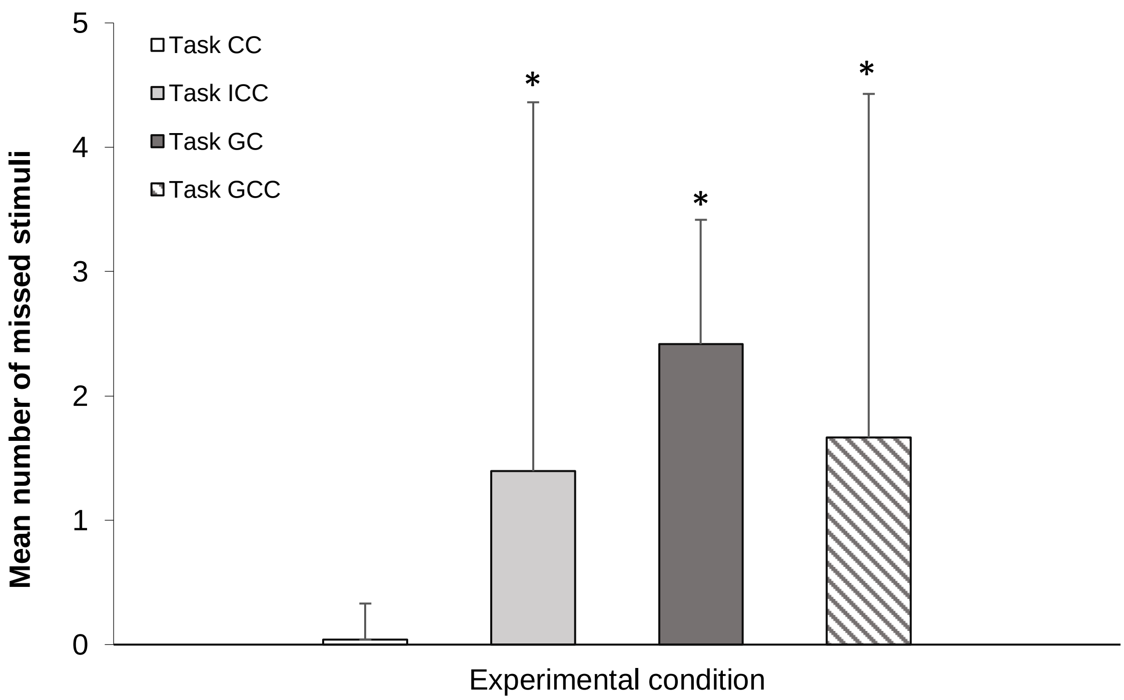

Figure 2. The task-switching cost of the different experimental conditions. Data are mean number of missed stimuli per experimental condition. Error bars represent standard deviation from the mean. * $p < 0.05$ of the difference between the least squared means as compared to the control condition (Task CC).

When comparing the number of missed stimuli, *task CC* statistically showed less missed stimuli than *task ICC*, $t(140)=-4.79$, $p<.001$ (one-tailed), than *task GC*, $t(140)=-5.70$, $p<.001$ (one-tailed), and, than *task GCC*, $t(140)=-5.07$, $p<.001$ (one-tailed). *Task ICC* statistically showed less missed stimuli than *task GC*, $t(140)=-4$, $p<.001$. *Task ICC* and *GCC*, did not differ statistically, $t(140)=-1.14$, $p=.26$. Task *GCC* statistically showed less missed stimuli than *task GC*, $t(140)=2.94$, $p=.0076$ (see table 3 for LS-mean differences).

Table 3

Least square mean differences in the number of missed stimuli

	Task CC	Task ICC	Task GC	Task GCC
Task CC		-3.44***	-4.07***	-3.63***
Task ICC	-3.44***		-0.63***	-0.19
Task GC	-4.07***	-0.63***		0.44**
Task GCC	-3.63***	-0.19	0.44**	

*Note. *p<.05, **p<.01, ***p<.001*

Our results showed that across all tasks, a higher score on the smartphone addiction scale was related to more missed stimuli in the direction task, $b=.04$, $t(144)=2.16$, $p=.03$. Moreover, the number of missed stimuli statistically predicted the accuracy, adjusted from baseline, on *tasks ICC, GC* and *GCC*. We found that a higher number of missed stimuli correlated with a sharper accuracy decrease, $b=.026$, $t(95)=9.09$, $p<.001$.

When considering task-specific states, lower valence increased the impact of addiction scores on the number of missed stimuli, $b=-.024$, $t(142)=-1.99$, $p=.048$., as did higher dominance, $b=.026$, $t(142)=2.62$, $p=.0098$. The interaction between addiction scores and arousal was not statistically significant, $b=-.002$, $t(142)=-0.24$, $p=.81$. The interaction between addiction scores and self-reported performance was not statistically significant, $b=-.008$, $t(142)=-0.7$, $p=.49$.

When looking at the impact of smartphone-use habits, the frequency of texting while walking did not interact with addiction scores to influence the number of missed stimuli in *tasks ICC* and *GCC*, b=.36, $t(48)$=0.30, p=.77. Game playing frequency, while walking, did not interact with addiction scores to influence the number of missed stimuli in *task GC*, b=-.019, $t(44)$=-0.83, p=.41. The participant's smartphone brand did not modify addiction scores' effect on the number of missed stimuli, b=-.023, $t(143)$=0.41, p=.68.

4. Discussion and Conclusion

This study investigated factors that could affect the risk of injury from using a smartphone while walking. As predicted, in smartphone-use conditions, task-switching costs increased and performance on the direction task decreased, as compared to the control condition. The gaming condition was the most distracting, being associated with the most missed stimuli and the lowest accuracy scores. Our results showed that an increase in task-switching cost was related to a sharper decrease in accuracy percentages in all smartphone-use conditions. Moreover, higher smartphone-addiction scores augmented task-switching costs; this effect was moderated by the participant's state during the experimental conditions, with low valence and high dominance augmenting the addiction score's effect. Finally, contrary to what was posited, smartphone-use habits did not moderate the smartphone addiction's effect.

In our study, we determined an application-level risk. The gaming condition was the most distracting, and hence the most dangerous task performed. Similarly, Haga et al. (2015) found that their gaming condition decreased performance the most. The game they used was similar to Tetris® (i.e., Drop Block), both possibly more distracting due to their inherent time pressures. Future studies should examine games that do not involve time pressures to determine if this factor is responsible for the heightened distracting effect found. Also, when looking at accuracy and task-switching cost, we saw no statistical difference between group and individual conversations. This suggests that a stronger "social component", inferred from the number of participants in the conversation, had no impact on how distracting texting was.

This study's main finding was that higher smartphone-addiction proneness participants suffered higher task-switching costs, insinuating that they had a harder time focusing their attention away from the smartphone. This is consistent with findings that drug addiction increases attention towards addiction-related cues (Anderson, 2016). In light of our findings, the heightened rate of injuries found by Kim et al. (2017) in participants highly prone to smartphone-addiction was likely due to attentional consequences developed through patterns of smartphone overuse, and not simply because they put themselves at risk more frequently.

In this study, the participant's state represented a situational variable's impact on a more stable trait: addiction. In particular, we found that feeling lower valence and/or higher levels of dominance, led to a stronger relationship between smartphone-addiction scores and task-switching costs. Surprisingly, arousal didn't interact with addiction scores to influence task-switching costs. Participants reported their state at the end of the condition and might have felt worse because they missed more stimuli. Nonetheless, participants' self-perceived performance had no impact in our analysis, suggesting that participants were not proficient at judging their performance. Future studies should test these claims by attempting to replicate our finding while inducing emotional states in participants.

Past behavior did not impact our results. It was predicted that habits related to the task being done might serve as protective factors since cognitive load is lower when performing familiar tasks (Haith & Krakauer, 2018). Nonetheless, the frequency of smartphone use while walking did not interact with smartphone-addiction proneness. This is consistent with the findings by Stoet and Snyder (2007) that even extensive practice performing a task does not abolish task-switching costs. Importantly, habits were self-reported, and these can be hard to recall and report accurately. In fact, smartphone users were shown to be unable to correctly assess the time spent on their phones (Montag et al., 2015). Future research studying the impact of habit on task-switching cost should determine habits with longitudinal psychoinformatic measures.

Our results have practical implications for policy makers. Using a smartphone while walking is dangerous, and these dangers are only augmented by patterns of smartphone overuse. This suggests that those more likely to use a smartphone while walking, are also those more prone to physical harm. Campaigns need to target these over-users, discouraging excessive smartphone use, since the subsequent learned reward patterns may cause individuals to be even more distracted by smartphone use. Campaigns should also warn against gaming while walking, since our data shows that games are even more distracting than text messaging. It is also important to highlight the fact that repeated multitasking of this type does not make one more proficient at it and does not protect from harm. Regarding the workforce, we recommend that companies prohibit smartphone use on warehouse floors, construction sites, and places where potentially harmful materials and machinery are present.

Certain limitations need to be considered. Task-switching costs are usually observed as the time difference between doing 2 tasks simultaneously compared to doing them successively. In this study we used missed stimuli to measure task-switching costs. Since the walker's presentation was always preceded by an auditory cue, a missed stimulus represents a literal inability to switch tasks in under 2 seconds; this makes it hard to compare our results with other studies. Finally, this study was constrained to an unrealistic pedestrian environment. In the real world there are many stimuli in the environment. Due to this, the attentional impact of being focused on one's smartphone might be greater in reality, because of higher cognitive demands. Nonetheless, participants might have felt safer in the experimental environment and been less likely to pay attention to the stimulus, because no real danger existed. Nonetheless, observational studies show that pedestrians do cross the street while looking at their phones (Hatfield & Murphy, 2007). Future research should attempt to better understand the influence of risk perception on these behaviors, in both laboratory and real-world environments.

In conclusion, our data suggests that a higher smartphone-addiction proneness increases risks of an accident when using a smartphone while walking. Further research is required to better understand the underlying mechanisms. The gaming condition was found to be the most disruptive task, possibly due to the time constraints involved. The degree of experience using a smartphone while walking did not decrease the dangers involved. Furthermore, feeling lower emotional valence or higher dominance increased risk. With smartphone use on the rise, it is important to regulate how we as a society use these devices to avoid becoming victims of the technology we create. Our data suggests that smartphone use on the go can be highly distracting due to the importance and attachment attributed to them; and with smartphone-related pedestrian accidents still increasing, changes in how we interact with this technology need to be reconsidered and enforced through public policy.

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Chapter 3: Post-hoc Analysis

2.1 Introduction

In order to get a better grasp of the factors that could influence the impact of smartphone-addiction proneness on task-switching cost, we conducted an exploratory analysis. As mentioned previously, impulsivity has long been linked to addiction, although the relationship between the two is still unclear (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). Furthermore, impulsivity impacts attention (Moeller et al., 2001) and was found to negatively impact performance in tasks that required attentional switching (Leshem, 2016). Due to this we believed impulsivity would increase the impact of smartphone-addiction proneness on task-switching cost. In the literature review, we also mentioned the potential mediating role of risk perception. We believe risk perception might influence participants' emotions as well as the amount of attention given to their environment. As such, risk perception might interact with smartphone-addiction proneness to influence task-switching cost. Finally, we also wanted to ensure that our measure of smartphone-addiction proneness allowed us to obtain a population that varied in their amount smartphone usage and cravings. Nomophobia, a social phobia where people are afraid of not being able to use their phones (Tams, Legoux, & Léger, 2018) was used for these purposes. In order to do this, we measured nomophobia scores for all the participants, to ensure that higher smartphone-addiction proneness participants truly varied from lower smartphone-addiction proneness participants.

2.2 Measurements

Nomophobia Questionnaire. In order to measure participants' level of nomophobia, we used the NMP-Q questionnaire developed by Yildirim and Correia (2015). This scale consists of 20 questions scored on a 7-point Likert scale. This questionnaire was used as a manipulation check for smartphone-addiction proneness. We assumed people scoring high on nomophobia would also score high on smartphone-addiction proneness, showing that the SAPS scale reflects the participant's tendency and desire to overuse a smartphone.

Barratt Impulsiveness Scale. In order to determine the influence of impulsiveness on the consequences of using a smartphone while walking, we measured impulsivity with the Barratt Impulsiveness Scale (Patton, Stanford & Barratt, 1995). This scale consists of 30 items scored on a 4-point scale (1= Rarely/Never to 4= Almost Always/Always). It measures 3 main factors: Attentional factor, Motor factor and Non-planning factor.

Risk Perception Questionnaire. In order to better understand the role of risk perception on the effects of using a smartphone while walking, we measured participants' self-reported risk perception of different events. This was done to determine how risky participants perceive certain behaviors to be. This questionnaire was developed for the purposes of this study and measures participants' perception of the risk associated with several events, by measuring the perceived probability of the scenario's occurrence and the perceived severity of the consequences of that scenario. For each scenario 2 types of risk perceptions were measured: the participant's perception of the risk for themselves personally and their perception of the risk for someone in the general population. The original intention of this questionnaire was to gain insight into the participants overall perception of risk as compared to the actual risk rates associated with each event. Nonetheless due to the complexity of determining how to score this questionnaire as a whole, we have yet been able to reach a consensus on the scoring and interpretation of the scale at the moment of the writing of this dissertation. For the purposes of this study, the statistical analysis focused solely on the risk perception of scenarios directly related to the smartphone tasks done in the experiment. The probability of the scenario was measured as a written percentage (0 to 100%) and the severity was measured on a scale ranging from 0 to 10. Participant's risk perception scores for each scenario were calculated by multiplying the probability percentage with the severity rating. The questionnaire was based on Peter and Ryan's model (1976) where overall risk is equal to the probability of negative consequences occurring multiplied by the importance of the negative consequences. We felt that it was important to look at both personal risk and the risk pertaining to the general population, because of potential discrepancies that can occur when asked to estimate personal risk as compared to the risk for others. There was a total of 16 scenarios (see appendix). In our analysis we only looked at the risk perception of the following scenarios: getting into an accident when texting while walking and getting into an accident when playing a game on your smartphone while walking.

2.3 Statistical Analysis

In order to do our manipulation check, to ensure that smartphone-addiction proneness related to a tendency and craving to overuse smartphones, we ran a two-tailed spearman correlation to determine whether the smartphone-addiction scores were correlated with the nomophobia scores. In order to establish if higher impulsivity increased the impact of smartphone-addiction proneness on task-switching cost, we performed a Poisson mixed effects regression of the relationship between addiction scores and scores on the Barratt impulsiveness scale, on the number of missed stimuli. Finally, in order to determine if risk perception moderated the impact of smartphone-addiction proneness on task-switching cost, we ran several Poisson mixed effects regressions of the relationship between smartphone-addiction scores and the risk perception scores of certain smartphone uses while walking, on the number of missed stimuli.

2.4 Results

Smartphone-addiction scores were found to be correlated with nomophobia scores. We found a statistically significant positive correlation, where an increase in smartphone-addiction scores correlated with an increase in nomophobia scores, $r(46) = .745$, $p < .001$.

We found no interaction of smartphone-addiction scores and impulsivity scores on the number of missed stimuli, $b = -.004$, $t(143) = -1.16$, $p = .25$. A two-tailed spearman correlation was run in order to determine whether the smartphone-addiction scores were correlated to the impulsivity scores. No statistically significant correlation was found, $r(46) = .008$, $p = .957$.

We found no interaction of smartphone-addiction scores and the scores regarding participants' perception of the risk of texting while walking for themselves, on the number of missed stimuli, $b = -.0002$, $t(138) = 1.17$, $p = .24$. We found no interaction of smartphone-addiction scores and the participant's perception of the risk of texting while walking to the general population, on the number of missed stimuli, $b = -.000001$, $t(143) = -0.02$, $p = .99$. We found a statistically significant interaction of smartphone-addiction scores and the participant's perception of the risk of playing a game while walking for themselves, on the number of missed stimuli, where the effect of the smartphone-addiction trait, on the number of missed stimuli, was more positive when the perception of risk was higher, $b = -.0003$, $t(137) = 2.23$, $p = .027$. Finally, the smartphone-addiction score's interaction with the participant's personal perception of the risk of playing a game while walking to the general population, on the number of missed stimuli, was not statistically significant, $b = -.0001$, $t(144) = 1.45$, $p = .15$.

2.5 Discussion

Considering that risk perception and impulsivity have been linked to the rates of exhibiting risky behavior (Ryb, Dischinger, Kufera, & Read, 2006), we felt it appropriate to determine if they played a mediating role in the augmented task-switching cost of using a smartphone while walking, that is caused by smartphone-addiction proneness. Our results did not support our study's hypothesis that impulsivity increased smartphone-addiction proneness's influence on task-switching cost. Furthermore, in our sample, smartphone-addiction scores were not statistically correlated with impulsivity scores. Our hypothesis that risk perception would moderate smartphone-addiction proneness's influence on task-switching cost was also not supported by our findings. Finally, Nomophobia scores were positively correlated with smartphone-addiction scores, suggesting that our manipulation was successful.

Impulsivity and addiction have long been studied together and it was once believed that addiction was either caused by impulsivity or led to more impulsive behavior (Moeller et al., 2001; Sher, Bartholow & Wood, 2000; Winstanley, Olausson, Taylor & Jentsch, 2010). The fact that no relationship between these scores was found is rather unexpected, especially considering that addiction and impulsivity have been found to coexist (Moeller et al., 2001). Nonetheless, the relationship between impulsivity and drug abuse and dependence has long been debated (Moeller et al., 2001) and our results suggest that the excessive pattern of reward-seeking, in the case of smartphone-addiction proneness, is probably not caused by an individual's impulsivity nor leads to more impulsive traits. Furthermore, our results suggest that the augmented distracting effect of using a smartphone while walking, that was found with higher smartphone-addiction proneness, is unrelated to impulsiveness. Smartphone-addiction scores were not statistically correlated with impulsivity scores, and no interaction was found between smartphone addiction and impulsivity. This is rather surprising, since high impulsivity has been shown to increase error rates when doing tasks where attention switching is involved (Leshem, 2016). This further reinforces our belief that it is in fact changes in the attentional mechanisms, due to excessive smartphone use, that make it more dangerous, and not an incapacity to delay gratification due to impulsiveness.

Although impulsiveness and risk perception have been linked to the probability of partaking in risky behaviors (Ryb et al., 2006), research has not specifically looked at how risk perception influences the consequences of risky behaviors. Our findings do not suggest a mediating role of risk perception on smartphone-addiction proneness's effect on task-switching cost. The only statistically significant finding, in the case of risk perception, was that the effect of smartphone-addiction proneness on task-switching cost was more pronounced for participants who believed that playing a game, while walking, was riskier for themselves personally. Nonetheless, this effect was quite small and was potentially an artefact of our study's design. Participants answered this questionnaire at the end of the study, and since the gaming condition was found to be the most distracting task, it is possible that participants reported a higher perceived risk because their experience during the experiment led them to conclude that it was in fact quite distracting and dangerous. We originally believed that having lower levels of risk perception might make people pay less attention to their environment when using a smartphone while walking, because they wouldn't consider the behavior as dangerous. We also hypothesized that higher risk perception might have caused negative emotions while doing a risky behavior, such as anxiety or stress, which might increase task-switching cost. Our results suggest that this is likely not the case. Nonetheless, the risk perception questionnaire used was created for the purposes of this study and it is possible that it might not have accurately represented the construct of risk perception or that participant's responses might have been subject to a desirability bias, if our questions were not subtle enough.

In conclusion, the results of our post-hoc analysis suggest that impulsivity and risk perception do not play a role in smartphone-addiction proneness's impact on task-switching cost. Furthermore, our manipulation check was successful, showing that higher smartphone-addiction proneness was related to higher nomophobia scores, and hence a higher need for smartphone use.

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Chapter 4 : Conclusion

The current study investigated factors that could make people more or less at risk of hurting themselves when using a smartphone while walking. Our data revealed many interesting insights. First, as predicted, using a smartphone while walking increased the task-switching cost in this study and decreased the performance on the direction task. Our results suggest that the simple act of using a smartphone while walking, whether it be texting or playing a game, puts individuals at risk of missing stimuli that are present in their environment. The gaming condition was the most distracting, suggesting that this use should be avoided at all cost. The game used in this study was Tetris®, which has inherent time constraints. This also leads us to caution against any smartphone use, while walking, that may have a time-sensitive component (e.g., time pressures), since we cannot rule out that the differences between our conditions were due to this factor. Secondly, as theorized, we found that higher smartphone-addiction scores were statistically related to a higher task-switching cost, represented by a higher number of missed stimuli in the direction task. These results imply that higher smartphone-addiction proneness makes smartphone use more distracting and reduces the awareness of, or the attention given to, the external environment. This is a cause for great concern because it suggests that those more likely to use a smartphone while walking (because of dependence and cravings) are also those more at risk of hurting themselves. This also suggests that although smartphone addiction is a controversial disorder, it does share some commonalities with drug addiction, in this case, a heightened attention towards addiction-related cues. Thirdly, as anticipated, the results also showed a statistical relationship between the number of missed stimuli (as compared to the baseline) and the accuracy on the direction task, showing that an increase in task-switching cost was related to a sharper decrease in accuracy percentages, in all the conditions involving a smartphone task. This suggests that an increase in task-switching cost decreases the performance on the external stimuli task. Therefore, when using a smartphone while walking, a greater task-switching cost leads to individuals focussing less on the environment and more on the smartphone. Fourthly, as predicted, the participant's self-reported state during the experimental conditions moderated the impact of smartphone-addiction proneness on task-switching cost. Specifically, we found that when participant felt lower emotional valence or higher levels of dominance, this was related to the addiction score increase being associated with a higher number of missed stimuli (i.e., a higher switching cost). This means that the effect of smartphone-addiction proneness can be amplified by situation-specific emotions, such as negative emotions and feelings of dominance. We then urge people to avoid using smartphones while walking when they are feeling low valence emotions and not to underestimate the cognitive demands of using a smartphone while walking by feeling overly confident, because this makes them more at risk of being distracted and potentially getting hurt. Fifthly, contrary to what was posited, the results did not show that smartphone usage habits moderated the impact of smartphone-addiction proneness on task-switching cost. These results suggest that practice doing this type of behavior does not increase the competence to do this task and does not protect from the negative consequences. Furthermore, considering the effects of dominance discussed previously, believing that you are more proficient at this type of multitasking, because of extensive experience using a smartphone while walking, might increase the riskiness of this behavior. Sixthly, our results did not support the hypothesis that impulsivity would increase the influence of smartphone-addiction proneness on task-switching cost. Moreover, smartphone-addiction scores weren’t correlated with impulsivity scores. This suggests that the effects of smartphone-addiction proneness are not related to impulsiveness. We propose that the effect of smartphone-addiction proneness, on task-switching cost, is potentially related to attentional biases, developed after repeated patterns of overuse. Finally, the results did not support the hypothesis that risk perception would moderate the influence of smartphone-addiction proneness on task-switching cost. The perception of risk, associated with smartphone use while walking, did not interact with the smartphone-addiction scores to influence task-switching cost. This means that whether people believed that using a smartphone while walking was more or less risky did not play a role in how distracted they were by smartphone use. Nonetheless, since this questionnaire was created for the purposes of this study and has not yet been validated, this should be interpreted with caution.

Certain considerations that impact the interpretation of the results must be discussed. Due to the fact that we did not have a great number of participants (n=48) it is possible that we did not have enough statistical power to determine certain fine differences that may interact with smartphone-addiction proneness. Our sample also consisted mostly of university students, so the generalizability of these results can be questioned. Nonetheless, the younger generations might be the target of campaigns because technology seems to be even more ingrained in their everyday lives since they grew up surrounded by it. Furthermore, in the experimental procedure, participants were told to give an answer after each stimulus but were not forced to respond when no answer was given, because this would cause an extra distraction that could not be replicated across all participants. Although forcing a response is common practice in this type of research, since the goal of this study was to determine how distracting a smartphone can be while walking, adding a verbal distractor may have invalidated our results. When they did answer after missing the stimulus, we did not consider that answer as correct, because it’s a 50-50 guessing chance and this could have altered the accuracy of our data. In this study, participants differed in their capacity to do the direction task. We, therefore, chose to analyze the relationship between task-switching cost and accuracy by using the accuracy adjusted from the baseline, in order to remove the potential impact of the participants’ overall ability to perform on the direction task. The baseline was the participant’s ability to do the direction task when no distracting smartphone tasks were simultaneously being performed (i.e., control condition). In this way, this accuracy demonstrates how participants’ performance during the smartphone task conditions varied from the control condition, due to the task-switching costs associated with each condition. It is important to note that since a trial where a stimulus was missed was considered as an incorrect response, therefore lowering the accuracy percentage, it could be assumed that these two factors should be statistically related because they are an inherently connected. Nonetheless, when looking at the data across all the participants, we found that out of the 7681 trials conducted, only 264 trials involved missed stimuli, suggesting that, although a missed stimulus does decrease accuracy scores, the analysis conducted is likely to be measuring an effect that goes beyond a decrease in performance simply due to the number of missed stimuli.

Importantly, a missed stimulus in a real-world environment is quite severe (e.g., that's all it takes to be hit by a vehicle). Our data shows that regardless of smartphone-addiction proneness, doing tasks on a smartphone while walking can be very dangerous. Nevertheless, high smartphone-addiction proneness worsens the attentional consequences of this behavior.

This study has many practical implications for both the workforce and public policy. We recommend that smartphone use, while walking, be prohibited in all dangerous environments, such as pedestrian crosswalks, staircases, warehouses, construction sites, laboratories with hazardous materials, etc. Moreover, with Gaming Disorder soon to be recognized as a clinical syndrome by the World Health Organization, and our data showing that games have the potential of being even more distracting than text messages, pedestrians should be urged to refrain from playing games while walking at all costs. Although risk perception did not seem to influence task-switching costs, awareness of the dangers of using a smartphone while walking still need to be promoted. Campaigns aiming at changing this behavior need to focus on certain topics. People may have a tendency to believe that if they do something all the time, they do it well. It is important to make it clear that this is not the case and that believing this might actually increase the risk of distraction. Campaigns should also warn against using a smartphone while walking when people are feeling negative emotions (e.g., feeling sad or angry) because they are even more predisposed to being distracted by smartphone use under these conditions. Campaigns should also be done to encourage people to spend less time on their smartphones and to disconnect from technology more often because our results suggest that patterns of smartphone overuse could make them more at risk of missing relevant information in their environment, when using a smartphone while walking.

Human behavior is extremely complex and can be influenced by many elements, and there are certainly factors that might be at play that were not considered in our study. Nonetheless, our results allow us to get a glimpse of the potential dangers of smartphone-addiction proneness in the context of using a smartphone while walking. In conclusion, our study suggests that, while using a smartphone while walking should always be avoided, high smartphone-addiction proneness could augment the risk of accidents and injuries associated with this behavior. Although further research is needed to understand the underlying mechanisms, the substance abuse and dependence literature hints that this may be partly due to attentional biases developed following repeated patterns of reward. The gaming condition was found to be the most disruptive, yet other entertainment purposes need to be studied by future research, such as watching videos and browsing social media, amongst other uses. Habits of smartphone use while walking did not protect against the increased task-switching cost related to higher smartphone-addiction proneness, and negative emotional states as well as feelings of dominance while doing this type of behavior only increased the task-switching costs. It might be comforting to think that the people at risk of suffering the consequences of smartphone use while walking are impulsive, can't delay gratification or do not think things through. Our results suggest that impulsivity plays little or no role in the negative consequences of using a smartphone while walking and that everyone should be cautious of this type of behavior. As stated in the article, with the rise of smartphone use, it is important to regulate how we as a society use these devices to avoid becoming victims of the technology we created. Smartphone use, while walking, can be highly distracting, and this is only worsened by the importance and attachment we attribute to it. Pedestrians accidents due to smartphone use are on the rise, and we need to reconsider how we interact with this technology as a society.

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Appendix

DIRECTIVES ACCOMPAGNANT UN QUESTIONNAIRE ANONYME

L'effet multitâche d'un téléphone sur l'absorption cognitive et le déficit d'attention en marchant.

Vous trouverez dans les prochaines pages un questionnaire anonyme auquel nous vous invitons à répondre. Ce questionnaire a été développé dans le cadre d'un mémoire à HEC Montréal.

Répondez sans hésitation aux questions incluses dans ce questionnaire, car ce sont vos premières impressions qui reflètent généralement le mieux votre pensée. Il n'y a pas de limite de temps pour répondre au questionnaire, bien que nous ayons estimé que cela devrait vous prendre environ 15 minutes.

Les renseignements recueillis sont anonymes et resteront strictement confidentiels ; ils ne seront utilisés que pour l'avancement des connaissances et la diffusion des résultats globaux dans des forums savants ou professionnels.

Le fournisseur de collecte de données en ligne s'engage à ne révéler aucune information personnelle (ou toute autre information relative aux participants de cette étude) à d'autres utilisateurs ou à tout autre tiers, à moins que le répondant consente expressément à une telle divulgation ou que celle-ci soit exigée par la loi.

Vous êtes complètement libre de refuser de participer à ce projet et vous pouvez décider en tout temps d'arrêter de répondre aux questions. Le fait de remplir ce questionnaire sera considéré comme votre consentement à participer à notre recherche et à l'utilisation des données recueillies dans ce questionnaire pour d'éventuelles recherches. Puisque le questionnaire et anonyme, une fois votre participation complétée, il vous sera impossible de vous retirer du projet de recherche, car il sera impossible de déterminer quelles réponses sont les vôtres.

Si vous avez des questions concernant cette recherche, vous pouvez contacter le chercheur principal, Gabrielle Mourra, au numéro de téléphone ou à l'adresse de courriel indiqués ci-dessous.

Le comité d'éthique de la recherche de HEC Montréal a statué que la collecte de données liée à la présente étude satisfait aux normes éthiques en recherche auprès des êtres humains. Pour toute question en matière d'éthique, vous pouvez communiquer avec le secrétariat de ce comité au (514) 340-6051 ou par courriel à cer@hec.ca.

Merci de votre précieuse collaboration !

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Smartphone Addiction Proneness Scale (SAPS)

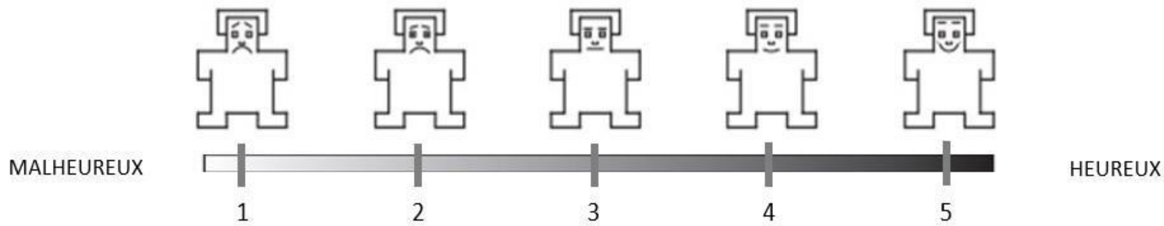
Ce questionnaire nous permettra de déterminer si vous êtes admissible à participer à cette étude. Le fait d'y répondre ne vous permettra pas de participer à l'étude et de recevoir la compensation, mais servira simplement à évaluer votre admissibilité selon des critères de sélection prédéterminés. Dans le cas où vous répondez à ces critères, vous serez recontacté. Pour obtenir la compensation, vous devrez être sélectionné et participer à l'étude.

Pour chacun des énoncés suivants, indiquez votre degré d'accord sur une échelle de 1 à 4, où 1 signifie « complètement en désaccord », 2 signifie « en désaccord », 3 signifie « en accord » et 4 signifie « complètement en accord ».

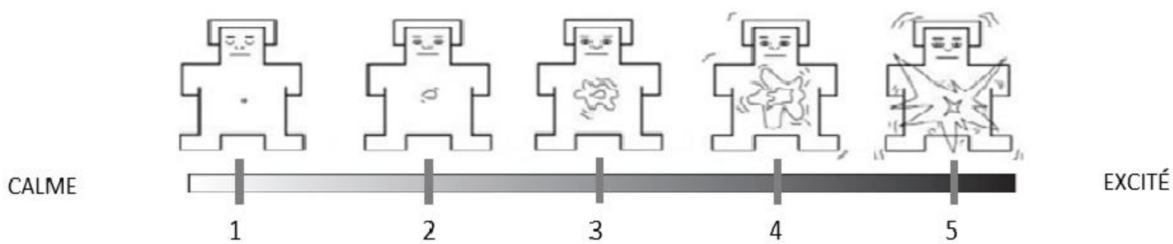
1. Mes résultats scolaires ont baissé à cause de l'utilisation excessive de téléphone intelligent.
2. J'ai de la difficulté à faire ce que j'ai prévu (travailler, étudier, faire mes devoirs, aller à des cours de rattrapage) à cause de l'utilisation excessive de téléphone intelligent.
3. Les gens me font souvent des commentaires sur mon utilisation excessive de téléphone intelligent.
4. Ma famille et mes ami(e)s se plaignent souvent que j'utilise trop mon téléphone intelligent.
5. Mon téléphone intelligent ne me distrait pas de mes études.
6. Utiliser un téléphone intelligent est plus agréable que de passer du temps avec ma famille et mes ami(e)s.
7. Quand je ne peux pas utiliser un téléphone intelligent, je me sens comme si j'avais perdu le monde entier.
8. Ce serait douloureux si on m'interdisait d'utiliser un téléphone intelligent.
9. Je deviens agité et nerveux lorsque je suis sans un téléphone intelligent.
10. Je ne suis pas anxieux même lorsque je suis sans un téléphone intelligent.
11. Je panique lorsque je ne peux pas utiliser mon téléphone intelligent.
12. J'essaie de réduire mon utilisation de téléphone intelligent, mais j'échoue.
13. Je peux contrôler mon temps d'utilisation de téléphone intelligent.
14. Même quand je crois devoir arrêter, je continue de trop utiliser mon téléphone intelligent.
15. Passer beaucoup de temps sur mon téléphone intelligent est devenu une habitude.

SAM Scale

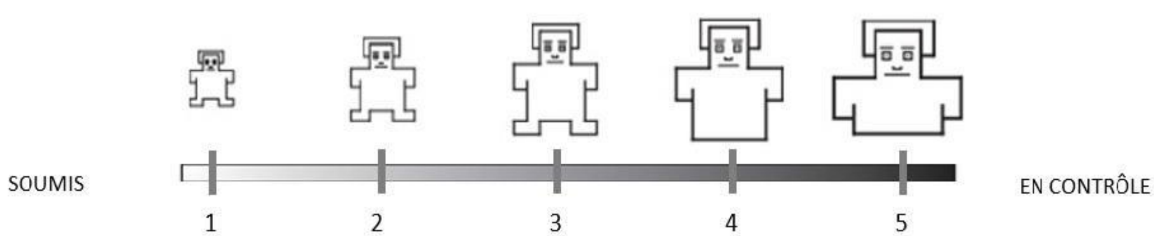
En utilisant l'échelle suivante, cochez le chiffre qui correspond le mieux à ce que vous avez ressenti par rapport à l'expérience que vous venez de vivre.



En utilisant l'échelle suivante, cochez le chiffre qui correspond le mieux à ce que vous avez ressenti par rapport à l'expérience que vous venez de vivre.



En utilisant l'échelle suivante, cochez le chiffre qui correspond le mieux à ce que vous avez ressenti par rapport à l'expérience que vous venez de vivre.



Comment évaluez-vous votre performance dans la tâche que vous venez d'effectuer (discriminer la direction du marcheur) ?

Faible	.	.	.	Élevée
○	○	○	○	○

Nomophobia Questionnaire (NMP-Q questionnaire)

Pour chacun des énoncés suivants, indiquez votre degré d'accord sur une échelle de 1 à 7, où 1 signifie « complètement en désaccord », 2 signifie « moyennement en désaccord », 3 signifie « faiblement en désaccord », 4 signifie « neutre », 5 signifie « faiblement en accord », 6 signifie « moyennement en accord » et 7 signifie « complètement en accord ».

1. Je me sens inconfortable sans un accès continu à de l'information avec mon téléphone intelligent.
2. Je suis agacé lorsque je ne peux pas rechercher de l'information sur mon téléphone intelligent quand je le veux.
3. Ne pas être en mesure de lire les nouvelles (météos, actualité, etc) sur mon téléphone intelligent me rend nerveux.
4. Je suis agacé lorsque je ne peux pas utiliser mon téléphone intelligent et/ou ses fonctionnalités quand je le veux.
5. Je suis effrayé à l'idée de manquer de batterie avec mon téléphone intelligent
6. Je panique lorsque je dépasse ma limite de mon forfait de données.
7. Lorsque je n'ai pas de signal réseau ou de Wifi, je regarde constamment mon téléphone pour revérifier la force du signal ou bien je cherche un autre réseau.
8. Je suis effrayé de rester pris quelque part lorsque je ne peux pas utiliser mon téléphone intelligent.
9. Lorsque je ne peux pas regarder mon téléphone intelligent pendant un moment, je sens le désir de le regarder.

Lorsque je n'ai pas mon téléphone intelligent avec moi,

10. Je me sens anxieux parce que je ne peux pas communiquer instantanément ma famille et/ou mes amis.
11. Je suis inquiet parce que ma famille et/ou mes amis ne peuvent pas me rejoindre.
12. Je me sens nerveux lorsque je ne suis pas en mesure de recevoir des messages textes et des appels.
13. Je suis anxieux lorsque je ne peux pas rester en contact avec ma famille et/ou mes amis.
14. Je suis nerveux lorsque je ne peux pas savoir si quelqu'un a tente me rejoindre.

15. Je suis anxieux lorsque la connexion constante avec ma famille et mes amis serait rompue.
16. Je me sens nerveux lorsque je suis déconnecté de ma vie virtuelle.
17. Je me sens inconfortable lorsque je ne peux pas rester à jour avec les réseaux sociaux.
18. Je me sens inconfortable lorsque je ne peux pas regarder mes notifications de mises à jour de mes connaissances sur les réseaux sociaux.
19. Je me sens anxieux lorsque je ne peux pas regarder mes courriels.
20. Je me sens inconfortable lorsque je ne sais pas quoi faire.

Barratt Impulsiveness Scale

Pour chacun des énoncés suivants, indiquez à quelle fréquence ils s'appliquent à vous. (1=Rarement, 2= Occasionnellement, 3= Souvent, 4= Presque toujours)

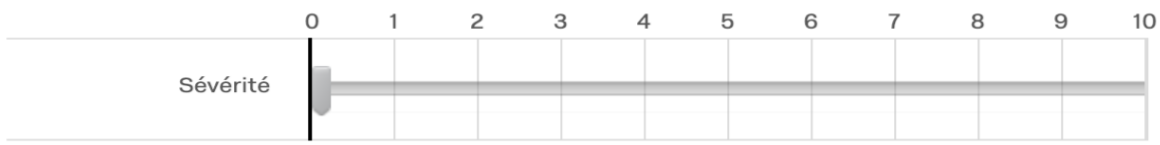
1. Je prépare soigneusement les tâches à accomplir.
2. Je fais les choses sans réfléchir.
3. Je me décide rapidement.
4. Je suis insouciant.
5. Je ne fais pas attention.
6. Mes pensées défilent très vite.
7. Je programme mes voyages longtemps à l'avance.
8. Je suis maître de moi.
9. Je me concentre facilement.
10. Je mets de l'argent de côté raisonnablement.
11. Je ne tiens pas en place aux spectacles ou aux conférences.
12. Je réfléchis soigneusement.
13. Je veille à ma sécurité d'emploi.
14. Je dis les choses sans réfléchir.
15. J'aime réfléchir à des problèmes complexes.
16. Je change d'emploi.
17. J'agis sur un "coup de tête".
18. Réfléchir sur un problème m'ennuie vite.
19. J'agis selon l'inspiration du moment.
20. Je réfléchis posément.
21. Je change de logement.
22. J'achète les choses sur un "coup de tête".
23. Je ne peux penser qu'à un problème à la fois.
24. Je change de loisir.
25. Je dépense ou paye à crédit plus que je ne gagne.
26. Lorsque je réfléchis d'autres pensées me viennent à l'esprit.
27. Je m'intéresse plus au présent qu'à l'avenir.
28. Je m'impatiente lors de conférences ou de discussions.
29. J'aime les "casse-têtes".
30. Je fais des projets pour l'avenir.

Risk Perception Questionnaire

1. *Pour chacun des énoncés qui apparaîtront sur la page suivante, indiquez la probabilité que les événements se produisent****. Considérez que les énoncés s'appliquent à n'importe qui.*** *Inscrivez une probabilité sous forme de pourcentage (entre 0 et 100).*
De plus, veuillez indiquer, pour chacun des énoncés, comment vous percevez la sévérité des conséquences potentielles de chaque situation. Choisissez un niveau de sévérité avec un score allant de 0 à 10, où 0 signifie « pas du tout sévère » (ex. quelques égratignures seulement), et 10 signifie « extrêmement sévère » (ex. mort).

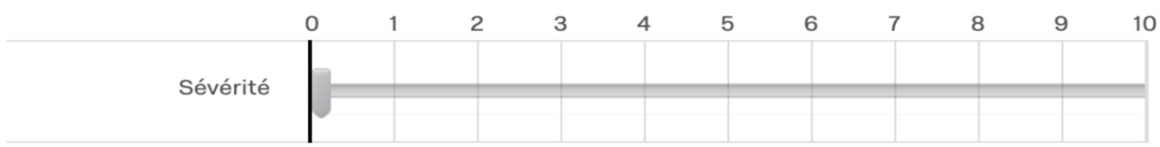
1. **Se faire frapper par la foudre**

   Probabilité : __/100



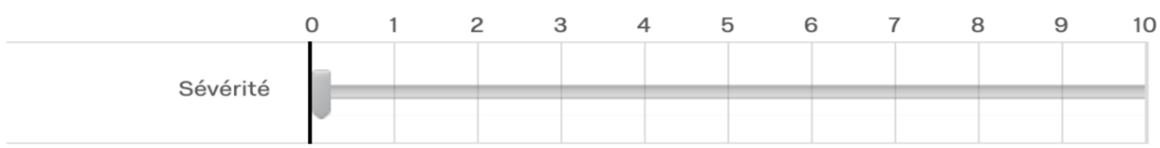
2. **Subir un accident d'avion**

   Probabilité : __/100



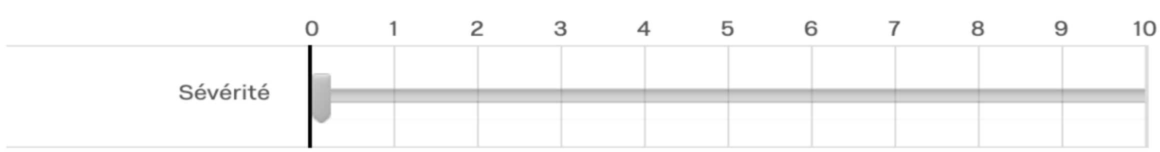
3. **Subir un accident de voiture**

   Probabilité : __/100



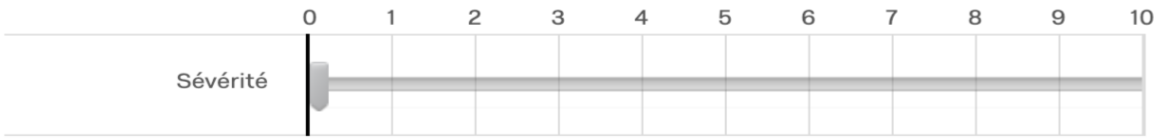
4. **Être atteint d'un cancer**

   Probabilité : __/100



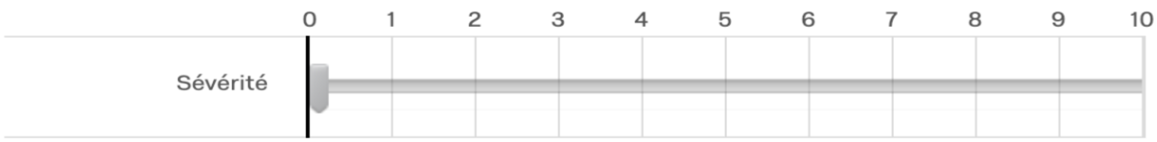
5. Subir un accident causé par la rédaction d'un message texte en conduisant

Probabilité : __/100



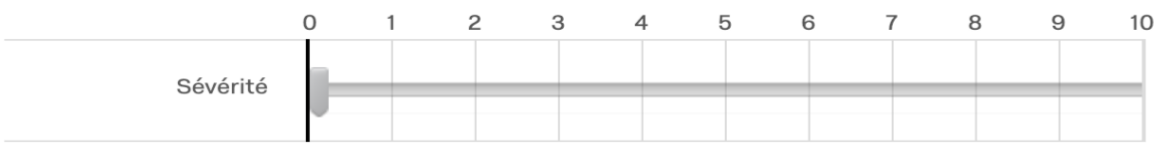
6. Subir un accident causé par la rédaction d'un message texte en marchant

Probabilité : __/100



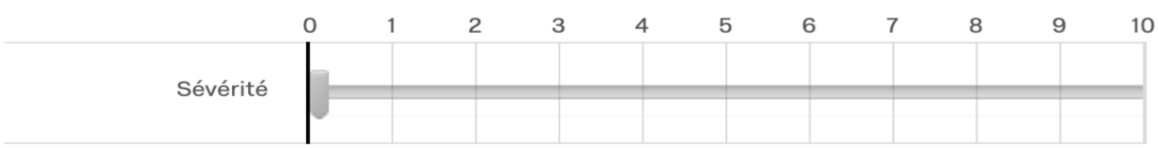
7. Subir un accident pendant une conversation téléphonique en marchant

Probabilité : __/100



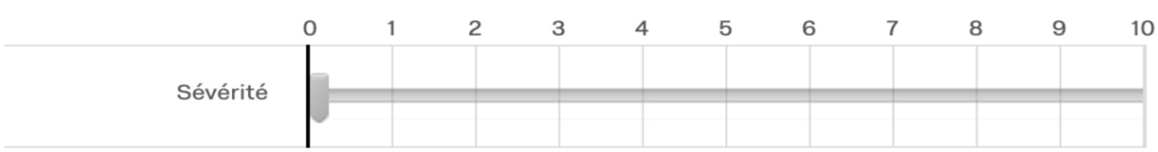
8. Subir un accident pendant une conversation téléphonique en conduisant

Probabilité : __/100



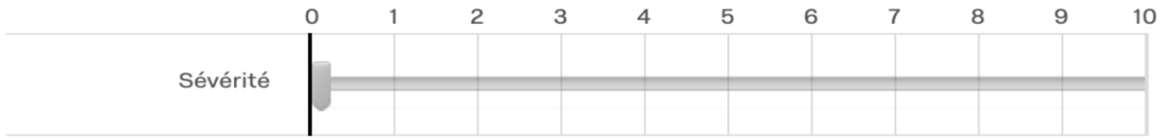
9. Subir un accident en jouant à un jeu mobile en marchant

Probabilité : __/100



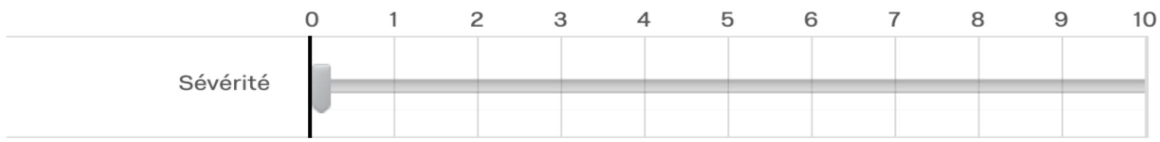
10. Subir un accident en jouant à un jeu mobile en conduisant

Probabilité : __/100



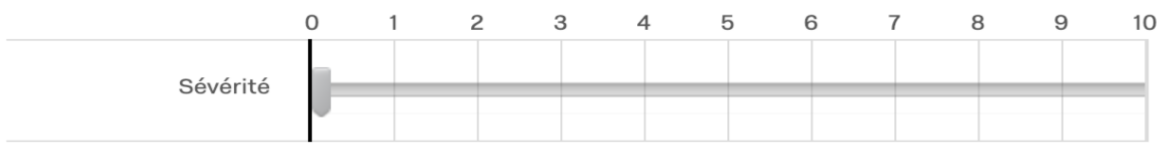
11. Subir un empoisonnement alimentaire

Probabilité : __/100



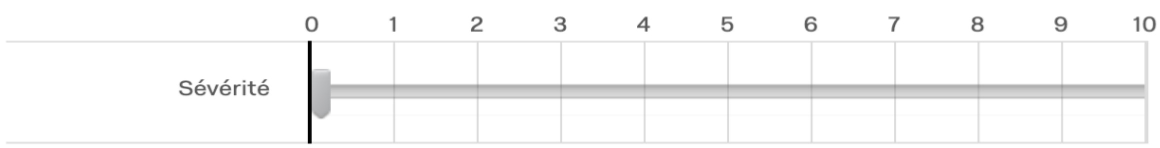
12. Subir un accident en traversant la rue alors que la lumière est rouge

Probabilité : __/100



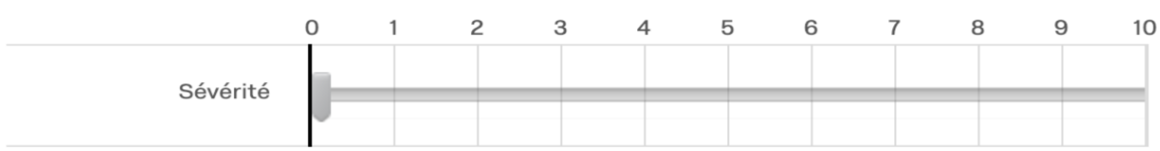
13. Être victime d’une attaque terroriste

Probabilité : __/100



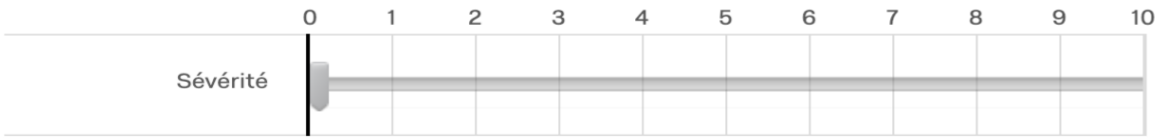
14. Être victime d’une attaque par balle (se faire tirer dessus)

Probabilité : __/100



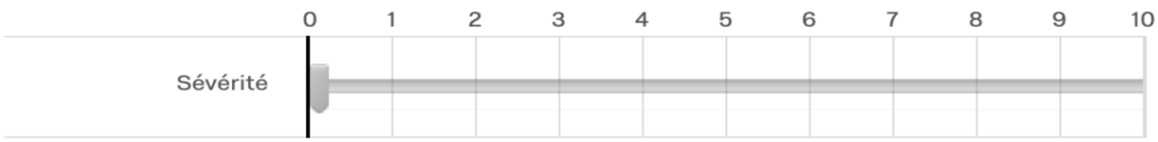
15. Subir un tremblement de terre

Probabilité : __/100



16. Subir une crise cardiaque

Probabilité : __/100

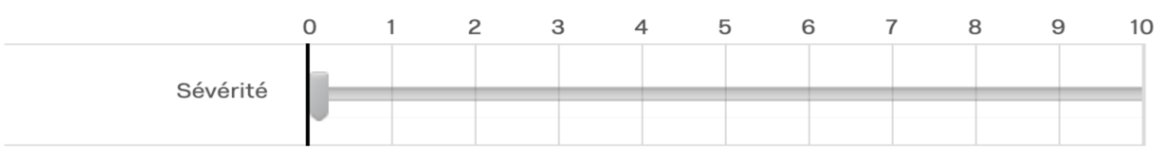


2. *Pour chacun des énoncés qui apparaîtront sur la page suivante, indiquez la probabilité que vous fassiez l'expérience de l'événement présenté.* ***Considérez que les énoncés s'appliquent à vous spécifiquement.*** *Inscrivez une probabilité sous forme de pourcentage (entre 0 et 100).*

De plus, veuillez indiquer, pour chacun des énoncés, comment vous percevez la sévérité des conséquences potentielles de chaque situation. Choisissez un niveau de sévérité avec un score allant de 0 à 10, où 0 signifie « pas du tout sévère » (ex. quelques égratignures seulement), et 10 signifie « extrêmement sévère » (ex. mort).

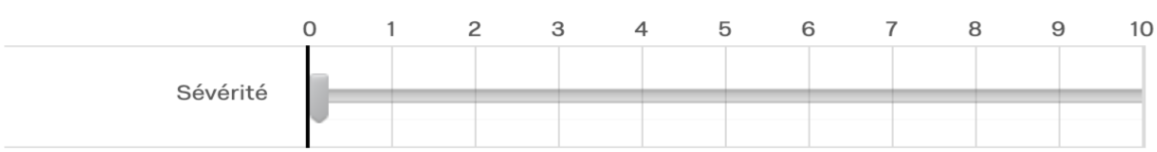
1. Se faire frapper par la foudre

Probabilité : __/100



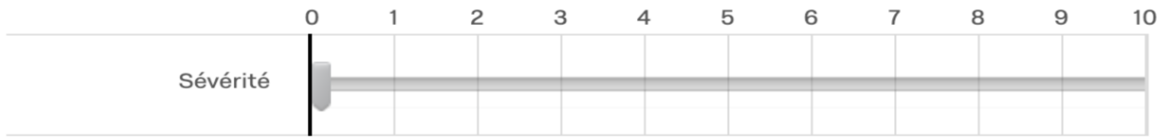
2. Subir un accident d'avion

Probabilité : __/100



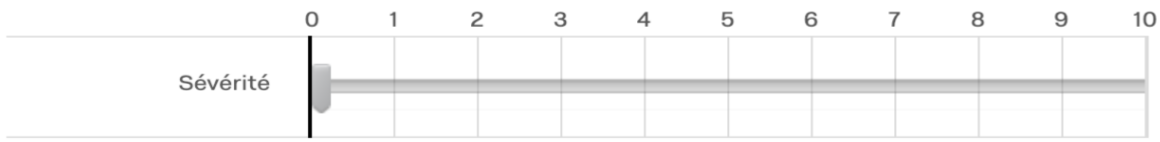
3. **Subir un accident de voiture**

   Probabilité : __/100



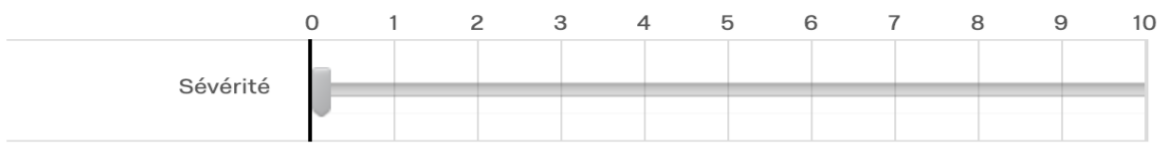
4. **Être atteint d’un cancer**

   Probabilité : __/100



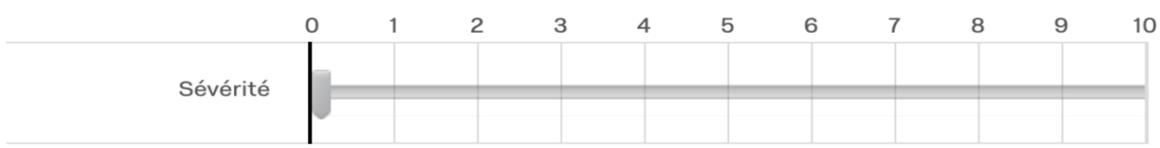
5. **Subir un accident causé par la rédaction d’un message texte en conduisant**

   Probabilité : __/100



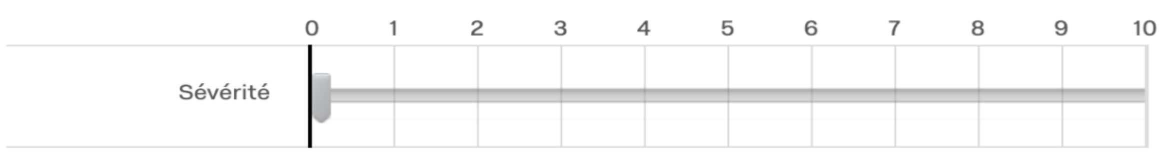
6. **Subir un accident causé par la rédaction d’un message texte en marchant**

   Probabilité : __/100



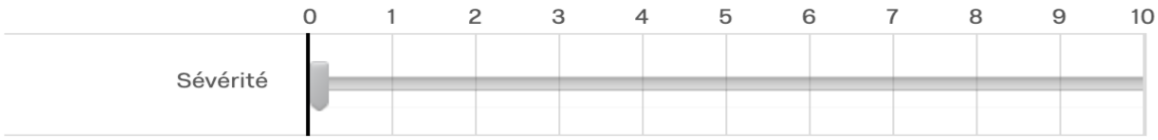
7. **Subir un accident pendant une conversation téléphonique en marchant**

   Probabilité : __/100



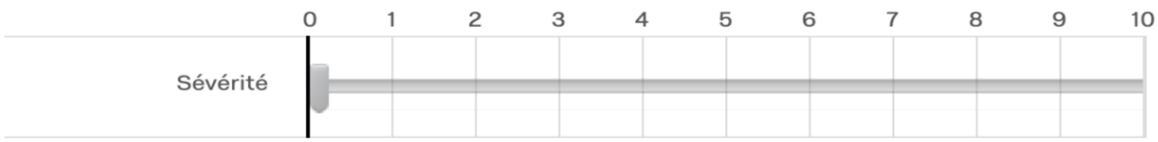
8. **Subir un accident pendant une conversation téléphonique en conduisant**

Probabilité : __/100



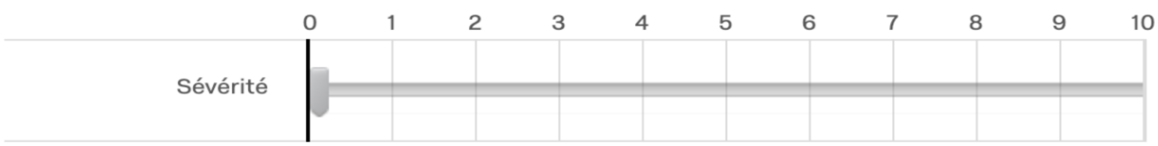
9. **Subir un accident en jouant à un jeu mobile en marchant**

Probabilité : __/100



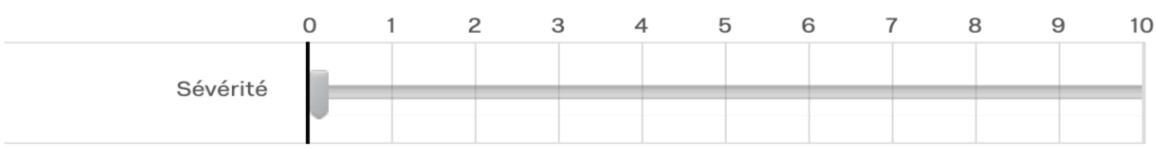
10. **Subir un accident en jouant à un jeu mobile en conduisant**

Probabilité : __/100



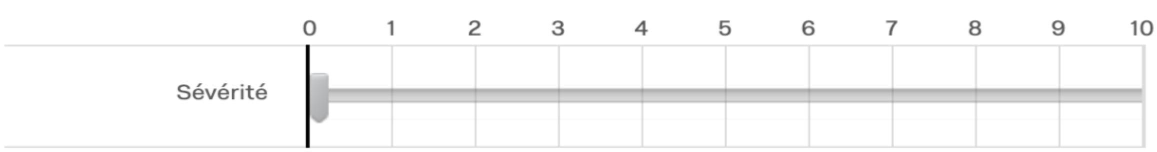
11. **Subir un empoisonnement alimentaire**

Probabilité : __/100



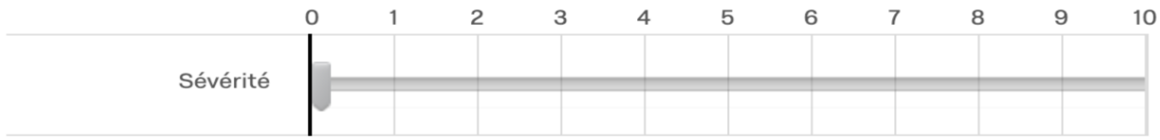
12. **Subir un accident en traversant la rue alors que la lumière est rouge**

Probabilité : __/100



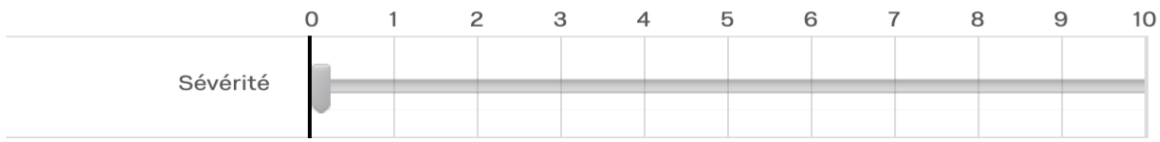
13. Être victime d’une attaque terroriste

Probabilité : __/100



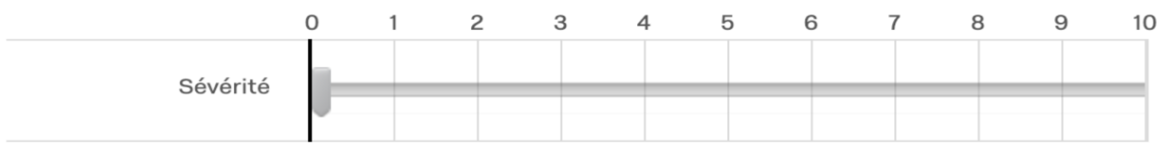
14. Être victime d’une attaque par balle (se faire tirer dessus)

Probabilité : __/100



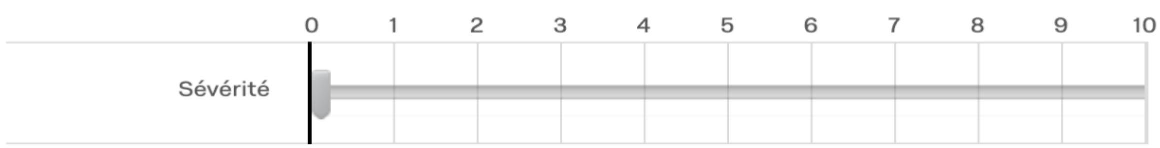
15. Subir un tremblement de terre

Probabilité : __/100



16. Subir une crise cardiaque

Probabilité : __/100



Participants Profile Questionnaire

Choisissez une réponse pour chacun des énoncés suivants :

1) Sexe :
- ☐ Homme
- ☐ Femme
- ☐ Autre

2) Âge : __

3) État civil :
- ☐ Célibataire
- ☐ En couple
- ☐ Marié
- ☐ Divorcé
- ☐ Veuf/ve
- ☐ Autre

4) Avez-vous des enfants ?
- ☐ Oui
- ☐ Non

5) Plus haut niveau d'éducation complété :
- ☐ Secondaire
- ☐ Collégial/Cégep
- ☐ Baccalauréat
- ☐ Maîtrise
- ☐ Doctorat
- ☐ Post-Doctorat

6) Fréquence à laquelle vous écrivez des messages textes en marchant :
- ☐ Plusieurs fois par jour
- ☐ Plusieurs fois par semaine
- ☐ Plusieurs fois par mois
- ☐ Plusieurs fois par année
- ☐ Quelques fois au total
- ☐ Jamais

7) Fréquence à laquelle vous parlez au téléphone en marchant :
- ☐ Plusieurs fois par jour
- ☐ Plusieurs fois par semaine
- ☐ Plusieurs fois par mois
- ☐ Plusieurs fois par année
- ☐ Quelques fois au total
- ☐ Jamais

8) Fréquence à laquelle vous jouez à un jeu sur votre téléphone en marchant :
- ☐ Plusieurs fois par jour
- ☐ Plusieurs fois par semaine
- ☐ Plusieurs fois par mois
- ☐ Plusieurs fois par année
- ☐ Quelques fois au total
- ☐ Jamais

9) Fréquence à laquelle vous naviguez sur des médias sociaux (Instragram, Facebook, etc.) sur votre téléphone en marchant :
- ☐ Plusieurs fois par jour
- ☐ Plusieurs fois par semaine
- ☐ Plusieurs fois par mois
- ☐ Plusieurs fois par année
- ☐ Quelques fois au total
- ☐ Jamais

10) Fréquence à laquelle vous utilisez votre téléphone intelligent :
- ☐ Plusieurs fois par jour
- ☐ Plusieurs fois par semaine
- ☐ Plusieurs fois par mois
- ☐ Plusieurs fois par année
- ☐ Quelques fois au total
- ☐ Jamais

Pour chacun des énoncés suivants, choisissez toutes les réponses qui s'appliquent.

11) Situation professionnelle actuelle :
- ☐ Étudiant/en formation
- ☐ Employé à temps partiel
- ☐ Employé à temps plein
- ☐ Sans emploi
  - ☐ Homme/Femme au foyer
  - ☐ En incapacité de travail
  - ☐ Chômeur/Chômeuse
  - ☐ Pensionné(e)
  - ☐ Autre

12) Utilisations principales de votre téléphone intelligent (maximum 3 réponses) :
- ☐ Navigation internet
- ☐ En relation avec l'école et/ou le travail
- ☐ Divertissement (musique, vidéos, etc.)
- ☐ Jeu(x) vidéo(s)
- ☐ Médias sociaux (Instagram, Facebook, etc.)
- ☐ Communication (SMS, Messenger, appels téléphoniques, etc.)
- ☐ Autre (pornographie, magasinage en ligne, GPS, services bancaires)